UFC 3-400-02
20 September 2018
Change 2, 20 September 2024

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: ENGINEERING WEATHER DATA

UFC 3-400-02
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DESIGN: ENGINEERING WEATHER DATA

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	09 Jan 2024	Updated ASHRAE 90.1 reference in paragraph 1-1; paragraph 2-10.1.3; and Appendix A References.
2	20 Sep 2024	Updated ASCE/SEI 7 reference in paragraph 2-2.6.4.3 and Appendix A References.

This UFC supersedes UFC 3-400-02, dated February 2003.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source: Whole Building Design Guide website http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-400-02, *DESIGN: ENGINEERING WEATHER DATA*

Superseding: UFC 3-400-02, dated 28 February 2003

Description: The purpose of this document is to provide an overview of and instructions for access to climate data available for use by engineers designing government structures. Final selection of sites was based upon availability of climate data. Most are located at military installations supporting airfield operations, or at local airports/airfields. This UFC is applicable to all service elements and contractors involved in the planning, design and construction of DoD facilities worldwide.

Reasons for Document:

- To update document to include new procedures for accessing weather data, new selection sites, new design values and new format.

Impact:

- There are no impacts.

Unification Issues

None.

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FIGURES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

The purpose of this document is to provide an overview of and instructions for access to climate data available for use by engineers designing government structures.

The 14th Weather Squadron (14 WS), formerly AFCCC, compiled Engineering Weather Data (EWD) at the request of the Air Force Civil Engineering Center (AFCEC). Sites were identified by AFCEC, US Army Corps of Engineers (USACE), and the Naval Facilities Engineering Command (NAVFAC). Final selection of sites was based upon availability of climate data. Most are located at military installations supporting airfield operations, or at local airports/airfields. Non-DoD requests may be satisfied from a private consulting meteorologist or from NOAA's National Centers for Environmental Information (NCEI, formally the National Climatic Data Center). Each site's EWD is presented as a PDF. To comply with **1**\ ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (Refer to UFC 1-200-02, for applicable publication date) /**1**/, the 14 WS has added a separate comma separated values file containing all cooling degree-day data based on 50°F for all sites. Paragraph in Chapter 2 entitled "Alternate Cooling Degree-Days Calculation" covers the use of this file in more detail. Bin Temperature Data .csv files are suitable for importing into Microsoft® Excel.

1-2 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design and construction of DoD facilities worldwide.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

1-5 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

1-6 ACCESSING EWD.

1-6.1 Retrieving data for .mil domain users.

1. Access https://www.climate.af.mil/.
2. A Common Access Card (CAC) is required to access the 14th Weather Squadron's web site. If you do not have one, call 828-271-4291 to request an EWD or send an email request to 14WS_SAR@us.af.mil.
3. A CAC user can also electronically submit a Support Assistance Request by clicking on the "Request Support" tab at the top of the 14 WS website.

1-6.2 Retrieving Data for Non-DoD (non CAC) Users.

Non-DoD users (e.g., contractors) may access data from the 14 WS if they are working on a DoD contract. If so, follow these instructions:

1. Fill out the Sample SAR Form in Appendix D, and send an email requesting support to 14WS_SAR@us.af.mil. This email inbox is monitored Monday –Friday 0730-1630 with the exception of holidays.
2. Pay particular attention to the fields requesting a complete description of the information being requested (e.g., site location and coordinates), a suspense date, a statement about how the data applies to the mission and the contract number.
3. The 14 WS must be able to verify that the contractor is working on a valid DoD contract before providing the information. The 14 WS will then e-mail the appropriate PDF file for the site requested. Non-DoD contractors and vendors must contact the National Centers for Environmental Information (NCEI, formally NCDC) to purchase the Engineering Weather Data (EWD).
4. Retrieving data for unlisted sites. If a station is not in the EWD list, fill out the 14 WS Support Assistance Request (SAR) form (example in Appendix D) and pay particular attention to the fields requesting a complete description of the information being requested (e.g., site location and coordinates), a suspense date, a statement about how the data applies to the mission, and the contract number.

CHAPTER 2 DATA DESCRIPTION AND APPLICATIONS

2-1 INTRODUCTION.

This chapter summarizes each page in a typical site data set and provides guidance for using the data.

2-2 DATA SET PAGE 1: CLIMATE SUMMARY.

Figure 2-1 is a sample of Data Set Page 1, which summarizes the site's climate.

2-2.1 Location Information.

This section of Data Set Page 1 contains a summary table that includes site name, location, elevation (above mean sea level), period of record (POR), and average (atmospheric) pressure not corrected to sea level (higher elevations result in lower pressures). The POR is the time frame over which the data used to compute the statistics in this document were compiled.

2-2.2 Design Values.

2-2.2.1 Explanation of Design Values.

Design values are provided for dry bulb temperature, wet bulb temperature, and humidity ratio at specific percentile frequencies of occurrence. The design values of 0.4%, 1%, and 2% are based on the entire year. The winter design values of 99.6%, 99%, and 97.5% are also based on the entire year. In other words, the design values are annual values, not seasonal values. These design values were instituted for several reasons. At some locations, the warmest or coldest months of the year do not fall into the months listed above. It is easier to compare locations that are in tropical or marine climates where there is less seasonal variability. It is also more straightforward to compare southern hemisphere locations.

Figure 2-1 Sample Data Set Page 1

SCOTT AFB MIDAMERIC	
Latitude = 38.55 N	Station ID = ICAO_KBLV
Longitude = 89.84 W	Elevation = 459 Feet
Period of Record = 1985 To 2014	Average Pressure = 29.55 inches Hg

		Mean Coincident (Average) Values			
Dry Bulb Temperature (T)	**Design Value (°F)**	**Wet Bulb Temperature (°F)**	**Humidity Ratio (gr/lb)**	**Wind Speed (mph)**	**Prevailing Direction (NSEW)**
Median of Extreme Highs	100	77	105	7.8	VRB
0.4% Occurrence	95	78	118	7.7	S
1.0% Occurrence	93	77	116	8	S
2.0% Occurrence	90	76	112	8.1	S
Mean Daily Range	20	-	-	-	NW
97.5% Occurrence	18	17	10	8.5	NW
99.0% Occurrence	11	10	7	7.9	NW
99.6% Occurrence	7	6	5	8.3	N
Median of Extreme Lows	0	-1	4	7.6	NNW

Wet Bulb Temperature (T_{wb})	Design Value (°F)	Dry Bulb Temperature (°F)	Humidity Ratio (gr/lb)	Wind Speed (mph)	Prevailing Direction (NSEW)
Median of Extreme Highs	83	92	153	7.4	S
0.4% Occurrence	81	91	143	7.2	S
1.0% Occurrence	79	88	134	7	S
2.0% Occurrence	78	87	130	7	S

Humidity Ratio (HR)	Design Value (gr/lb)	Dry Bulb Temperature (°F)	Vapor Pressure (in. Hg)	Wind Speed (mph)	Prevailing Direction (NSEW)
Median of Extreme Highs	161	87	1.05	6.3	S
0.4% Occurrence	144	85	0.94	6.8	S
1.0% Occurrence	141	83	0.93	4.9	VRB
2.0% Occurrence	134	84	0.88	6.1	S

Air Conditioning/ Humid Area Criteria	Threshold	T ≥ 93°F	T ≥ 80°F	Twb ≥ 73°F	Twb ≥ 67°F
	# of Hours	99	1053	896	2050

Other Site Data

Weather Region	Rain Rate 100 Year Recurrence (in./hr)	Basic Wind Speed 3 sec gust @ 33 ft 50 Year Recurrence (mph)	Ventilation Cooling Load Index (Ton-hr/cfm/yr) Base 75°F-RH 60% Latent + Sensible
7	3.3	90	3.7 + 1.1
Ground Water Temperature (°F) 50 Foot Depth*	**Frost Depth 50 Year Recurrence (in)**	**Ground Snow Load 50 Year Recurrence (lb/ft²)**	**Average Annual Freeze-Thaw Cycles (#)**
58.6	38	20	55

*Note: Temperatures at greater depths can be estimated by adding 1.5 °F per 100 feet additional depth.

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2-2.2.2 Dry Bulb Temperature.

2-2.2.2.1 Median of Extreme Highs (or Lows).

The dry bulb temperature extreme high (or low) is determined for each calendar year of the POR along with the coincident values for wet bulb temperature, humidity ratio, wind speed, and prevailing wind direction. Median values are determined from the distribution of extreme highs (or lows).

2-2.2.2.2 0.4%, 1.0%, 2.0%, 97.5%, 99.0%, and 99.6% Dry Bulb Design Values.

Listed is the dry bulb temperature corresponding to a given annual cumulative frequency of occurrence and its respective mean coincident values for wet bulb temperature, humidity ratio, wind speed, and prevailing wind direction. The dry bulb temperature listed represents the value that was exceeded for the respective percent of time over the entire POR. For example, the 1.0% occurrence design value temperature (92 °F) has been exceeded only 1 percent of the time during the entire POR. All the observations occurring within one degree of the design value are grouped, and the Mean Coincident (Average) Values for Wet Bulb Temperature, Humidity Ratio, and Wind Speed are calculated. The prevailing wind direction (the “mode” of the wind direction distribution) is also calculated.

2-2.2.2.3 Mean Daily Range.

The mean daily range (difference between daily maximum and daily minimum temperatures) is the average of all daily dry bulb temperature ranges for the POR.

2-2.3 Wet Bulb Temperature.

2-2.3.1 Median of Extreme Highs.

The Median of Extreme Highs value for wet bulb temperature is the highest annual extreme wet bulb temperature averaged over the POR. The corresponding Mean Coincident (Average) Values are determined the same way as for the respective values for dry bulb temperature.

2-2.3.2 0.4%, 1.0 %, 2.0% Wet Bulb Temperature Design Values.

The design values listed and the corresponding Mean Coincident (Average) Values are determined the same way as for dry bulb temperature, described in 2-2.2.2.2.

2-2.4 Humidity Ratio.

2-2.4.1 Median of Extreme Highs.

The value for humidity ratio is the highest annual extreme averaged over the POR. The corresponding Mean Coincident (Average) Values are determined the same way as described in 2-2.2.2.2.

2-2.4.2 0.4%, 1.0%, and 2.0% Humidity Ratio Design Values.

Design values are provided for humidity ratio and the corresponding Mean Coincident (Average) Values for dry bulb temperature, vapor pressure, wind speed, and wind prevailing direction.

2-2.5 Air Conditioning/Humid Area Criteria.

These are the number of hours, on average, that dry bulb temperatures of 34 °C (93 °F) and 27 °C (80 °F) and wet bulb temperatures of 23 °C (73 °F) and 19 °C (67 °F) are equaled or exceeded during the year.

2-2.6 Other Site Data.

This information is provided **for general reference only, and should not be used as the basis for design**. There are some locations for which this data is not available. In these cases, that portion of the table will be left blank.

2-2.6.1 Weather Region.

Eleven weather regions have been developed by the Department of Energy. They are defined by the range of cooling-degree days and heating-degree days based on 65 °F. ASHRAE/IESNA Standard 90.1 of 2001 uses annual HDD65 (Heating Degree Days based on 65 °F) and CDD50 (Cooling Degree Days based on 50 °F) to select the appropriate Building Envelope Requirements table for energy conservation design. Refer to paragraph 2-10 for further explanation of this data.

2-2.6.2 Ventilation Cooling Load Index.

The Ventilation Cooling Load Index (VCLI) is a two-part index that defines the total annual cooling load for ventilation air by calculating sensible heat load separately from the latent heat load (moisture). The results are expressed in ton-hours per cubic feet per minute per year of latent and sensible load. Values for sensible heat load are calculated by comparing the outdoor temperature to indoor conditions (75 °F and 60% relative humidity [RH]), and calculating how much energy is required to bring the outdoor air to the indoor temperature. The latent load is calculated similarly. Separate calculations are made for each hour of the year and then summed to form the annual VCLI.

2-2.6.3 Average Annual Freeze-Thaw Cycles.

This value is the average number of times per year that the air temperature first drops below freezing and then rises above freezing, regardless of the duration of either the freezing or thawing. The number of cycles is summed per year and averaged over the entire POR. Days with high temperatures or low temperatures at 0 °C (32 °F) are not counted for a freeze- thaw cycle. A cycle is counted only when the temperature drops below freezing (-0.5 °C [31 °F] or colder) or goes above freezing (0.5 °C [33 °F] or warmer).

2-2.6.4 Other Values.

The following values are derived from sources other than the 14 WS. Engineers and architects should review the publications listed below and contact the organizations for current values, including background information and complete guidelines for use of these data elements.

2-2.6.4.1 Groundwater.

National Ground Water Research and Educational Foundation
601 Dempsey Road
Westerville OH 43081-8978
(800) 551-7379
http://www.ngwa.org/

NOTE: Average groundwater temperature parallels long-term average air temperature, because soil at a depth of 15 meters (50 feet) does not undergo significant temperature change over the course of a year. Soil temperature at 15 meters stays slightly warmer than average annual air temperature by approximately 1.4 °C (2.5 °F).

2-2.6.4.2 Rain Rate.

International Plumbing Code
International Code Council
4051 West Flossmoor Road
Country Club Hills IL 60478
(888) 422-7233
http://www.iccsafe.org/

2-2.6.4.3 Frost Depth, Basic Wind Speed, Ground Snow Loads.

2\ ASCE/SEI 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* /***2***/
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191
(800) 548-2723
http://www.asce.org/

NOTE: Use UFC 3-301-01, *Structural Engineering*, for reference on some frost depth and ground snow load values.

2-2.7 Suggestions for Use.

The dry bulb, wet bulb, and humidity ratio values in Figure 2-1 are peak load conditions and are used for sizing mechanical equipment. Design guidance determines the frequency of occurrence design is to be based upon.

2-2.7.1 Dry Bulb Temperature.

The 0.4% dry bulb temperature value is seldom used for sizing conventional comfort control systems but is sometimes appropriate for mission-critical systems where equipment failure due to high heat would be unacceptable. Using the 0.4% value for equipment sizing requires that the engineer consider its operation at less-than-peak design conditions. In the past, oversized cooling equipment has been incapable of modulating during the more common range of operating conditions, yielding comfort control problems. Also, over-sized equipment cycles on and off more frequently, increasing maintenance costs and failing to remove enough moisture to maintain humidity control.

2-2.7.1.1 Design for Extreme Conditions.

Similar special considerations apply to the extreme low dry bulb temperature. Heating equipment designed for extreme conditions must be evaluated carefully to ensure that it will modulate properly to maintain comfort at less extreme outdoor temperatures that occur in 99.6% of the hours during the year.

2-2.7.1.2 Design of Humidity Control Systems.

The mean coincident value for humidity at the 0.4% peak dry bulb temperature is not the highest moisture value and must not be used for design of humidity control systems. The mean coincident value is the arithmetic average of all the moisture levels that occur when the dry bulb temperature is high; however, the highest moisture values typically occur when the dry bulb temperatures are lower.

2-2.7.2 Wet Bulb Temperature.

High wet bulb temperature is used for sizing cooling towers and other evaporative equipment.

2-2.7.3 Peak Humidity Ratio.

Peak humidity ratio is used for sizing dehumidification systems. Peak moisture condition usually represents a higher enthalpy (total heat) than peak dry bulb condition. Consequently, engineers use the peak moisture condition to cross-check operation of a system that may be primarily intended to control temperature.

2-2.7.4 Coincident Wind Speed.

Coincident wind speed allows the engineer to accurately estimate latent loads due to infiltration of humid air in the summer and of dry air in the winter.

NOTE: The same precautions that apply to heating and cooling equipment also apply to dehumidification and humidification systems. Oversized equipment may not control properly under typical operating conditions without special attention from the engineer.

2-3 DATA SET PAGE 2: AVERAGE ANNUAL CLIMATE.

Figure 2-2 is an example of Data Set Page 2, a graph summarizing the site’s average annual climate.

2-3.1 Explanation of Graph.

The graph on Data Set Page 2 shows the site’s monthly mean temperature, dew point, and precipitation. The bar graph representing precipitation uses the scale on the right side of the chart (inches or centimeters). Lines of temperature and dew point use the scale on the left side of the chart (degrees Fahrenheit or Celsius). These charts have fixed maximum and minimum values on their axes for easy comparison between different sites. The precipitation chart is capped at a maximum of 45 centimeters (15 inches) per month. A few sites may exceed this value, but to keep the graph readable, a fixed maximum value was used. For a number of sites, no accurate precipitation data was available. In those cases, no bars appear on the chart.

2-3.2 Suggestions for Use.

2-3.2.1 Comparisons.

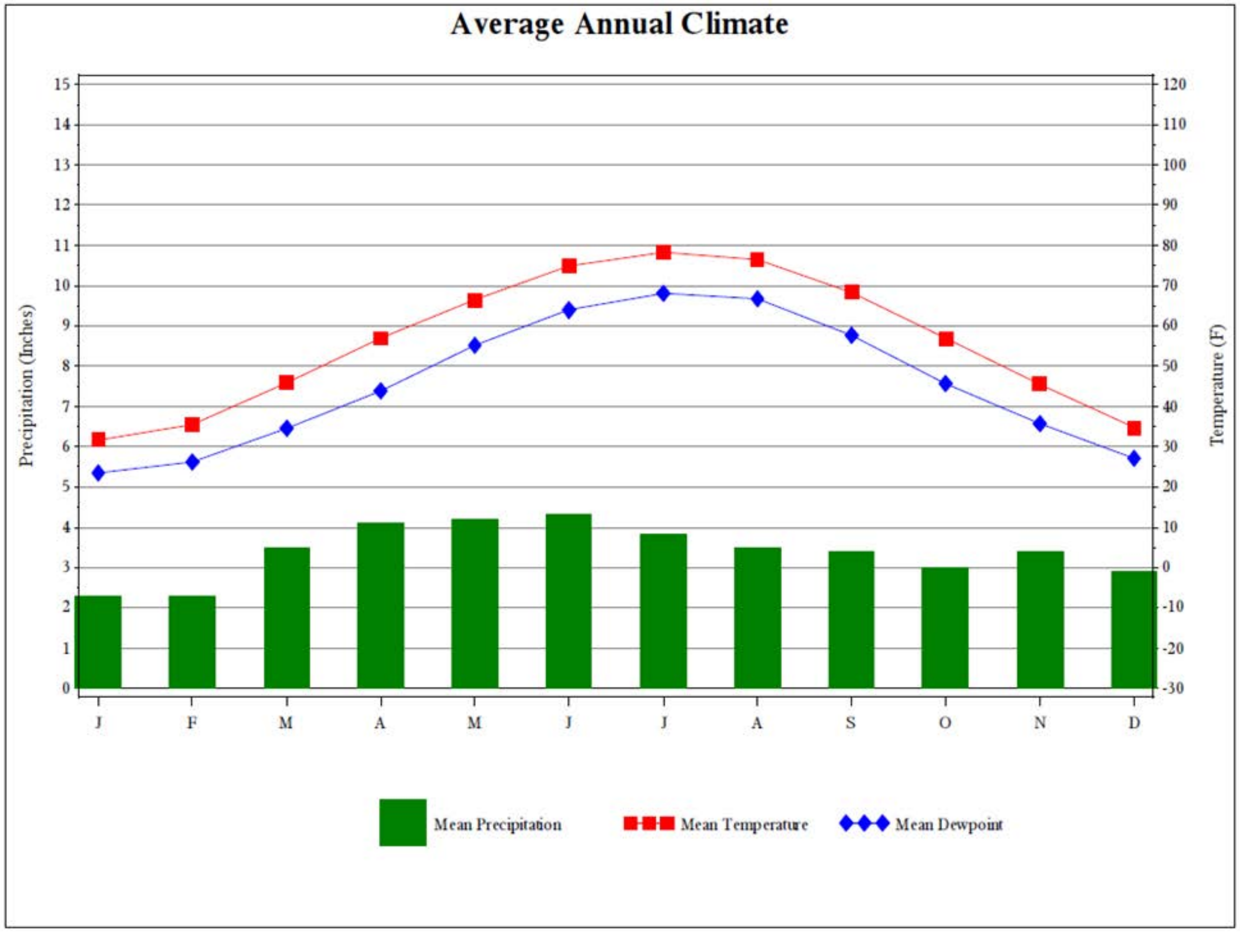
The Data Set Page 2 graph displays the average behavior of weather over a single year. An architect can compare rainfall patterns at one station with another and also the relative importance of water resistance for the exterior envelope. An engineer can compare the temperature and moisture patterns to understand the relative importance of sensible heat loads rather than latent loads at this location.

2-3.2.2 Seasonal Variations.

With averages displayed by month, it is relatively easy to comprehend seasonal variation of each variable, and also to understand which specific months are likely to be hot or cold, humid or dry, or have high precipitation. This can be helpful for mission planning, as well as for planning construction and building operation.

NOTE: This graph displays averages, not design or extreme values. Data shown should not be used to determine equipment capacities or thermal characteristics of building envelopes.

Figure 2-2 Sample Data Set Page 2



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2-4 DATA SET PAGE 3: 30-YEAR PSYCHROMETRIC SUMMARY.

Figure 2-3 is an example of Data Set Page 3, a graph summarizing the site's psychrometric data.

2-4.1 Explanation of Graph.

2-4.1.1 Joint-Frequency Table.

The graph displays the joint cumulative percent frequency of temperature and humidity ratio. Hourly observations are grouped into bins of 5 Fahrenheit degrees and 10 grains per pound (gr/lb) (or 3 Celsius degrees and 1.5 grams per kilogram [g/kg]), centered on each value of temperature or humidity ratio. For example, the 70 °F temperature bin collects all observations between 67.5 °F and 72.5 °F. The bin is depicted as a gridline on the chart; the vertical lines represent the temperature bins and the horizontal lines represent the humidity ratio bins. The intersection of temperature and humidity ratio lines represent a further subdivision of the observations into groups meeting both temperature and humidity ratio criteria. For example, the intersection of the 70 °F bin line and the 40 gr/lb bin line represent the observations when temperature was between 67.5 °F and 72.4 °F and the humidity ratio was between 35 gr/lb and 44 gr/lb. Thus, a joint-frequency table is created for all temperature and humidity ratio bin combinations.

NOTE: The psychrometric graph is intended as a visual tool only. Its purpose is to allow a quick visual comparison between climates at different locations. Extrapolation of data directly from the graph is not advised due to the approximate plotting routine used to generate the graph from the binned data. This is evident where values of humidity appear past their saturation point. This discrepancy between the actual data and the graph is the result of the plotting routine used to generate the graph and not from errors in the original hourly data used to create the binned summary.

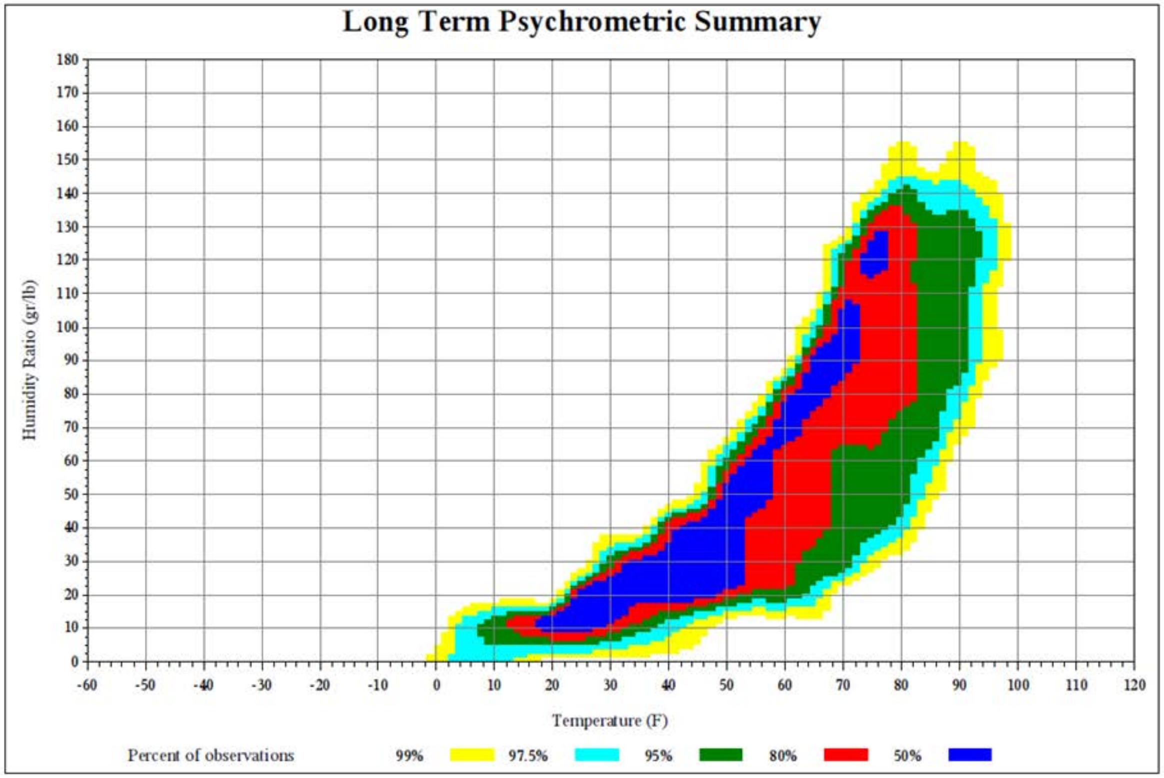
2-4.1.2 Contours.

The contours on this chart represent the areas containing 99%, 97.5%, 95%, 80%, and 50% of all observations (cumulative percent frequency or percentiles). The contours are centered on the most frequently occurring bins (50% contour), spreading outward until almost all observations (99%) are grouped. Contours are defined by calculating a percent frequency for each bin (relative to the others), and then accumulating these percent frequencies (from most frequent to least frequent) until the 50% value is passed, and thus the first set of bins is grouped. The accumulating continues until the 80% value is passed, and the second group of bins is grouped. This process continues until the 95%, 97.5%, and 99% values are passed.

2-4.1.3 Least Frequent (Most Extreme) Bins.

Consequently, the least frequent (most extreme) bins, which when accumulated amount to less than 1 percent of the total observations, are outside of the 99% contour. Any bins outside the 99% contour thus have either not occurred, or have occurred so infrequently that they should not be taken into consideration for sizing equipment.

Figure 2-3 Sample Data Set Page 3



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2-4.2 Suggestions for Use.

2-4.2.1 Most Common Temperature and Moisture Conditions.

The Data Set Page 3 graph displays the long-term history of temperature and moisture at each station (a total of 262,800 hourly observations if the POR is 30 years and if the data is complete over that period). The engineer can use this graph to ascertain the most common temperature and moisture conditions that will be encountered over the operating life of the mechanical equipment.

2-4.2.2 Ensure Modulation and Control Capability.

It is often useful to calculate the behavior of the proposed system at “most common” conditions and assess these calculations in addition to the traditional peak design calculations. This will help ensure that the selected equipment and controls are capable of modulation and control at all points of operation rather than simply at extreme conditions.

2-5 DATA SET PAGE 4: PSYCHROMETRIC DISPLAY OF DESIGN VALUES.

Figure 2-4 is an example of Data Set Page 4, a psychometric display of the site’s design values.

2-5.1 Saturation Curve.

Similar to Data Set Page 3, this chart depicts the saturation curve (when RH = 100%) along with peak design values. The design values are calculated as in the table on Data Set Page 1 (Figure 2-1), but this chart shows their relationships graphically, depicting their position relative to each other and relative to the saturation curve.

2-5.2 Observations.

Above and to the left of the saturation curve, RH would be greater than 100% (not possible). The area below and to the right of the curve (including the points on the curve itself) represent the area where RH is less than or equal to 100%, and thus where all observations occur. Note that since the humidity ratio is a function of pressure, and pressure varies with elevation, different sites will have different saturation curves.

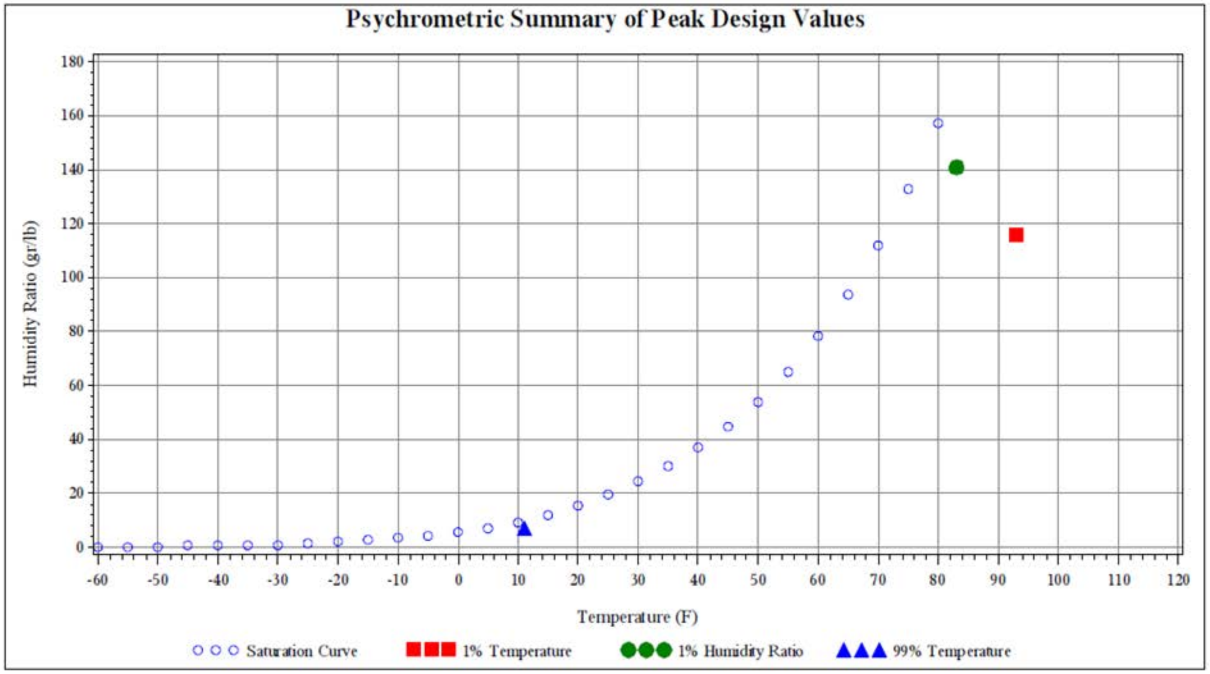
2-5.3 Scatter Plot.

The dry bulb temperature is the horizontal coordinate on this scatter plot, and the humidity ratio is the vertical coordinate. Peak design values are depicted by the red square (1.0% Temperature [dry bulb]), the green circle (1.0% Humidity Ratio), and the blue diamond (99% Temperature [dry bulb]).

2-5.4 Table.

The table below the chart shows the exact values of 99% dry bulb temperature, 1.0% humidity ratio, and 1.0% dry bulb temperature, along with calculated values of enthalpy, mean coincident wet bulb temperature, and humidity ratio (as applicable). The value of enthalpy coincident to each temperature/humidity ratio is created using the psychrometric functions provided by the Linric Company, Bedford, New Hampshire. The dry bulb temperature and humidity ratio are used to calculate enthalpy using the Linric algorithms.

Figure 2-4 Sample Data Set Page 4



	(°F) / (gr/lb)	MCDB (°F)	MCWB (°F)	MCDP (°F)	MCHR (gr/lb)	Enthalpy (btu/lb)
1.0% Dry Bulb	93.0		77		116.0	40.6
99.0% Dry Bulb	11.0				7.0	3.6
1.0% Humidity Ratio	141.0	83.0	78.5	76.7		42.1

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2-6 DATA SET PAGES 5 THROUGH 9: TEMPERATURE BIN DATA.

Figures 2-5 through 2-9 are examples of Data Set Pages 5 through 9, respectively. These tables show the number of hours that temperatures occur in 5 Fahrenheit degree (3 Celsius degree) bins of specific 8-hour daily periods during a given month. The 8-hour periods are based upon a 24-hour clock and displayed in Local Standard Time (LST). For each month, the number of observations for each temperature bin during each of the specific 8-hour periods of the day appear in a column under the specific Hour Group (LST). The total number of observations (hours) in each temperature bin is displayed in the “Total Obs” column for the month. The mean coincident wet bulb temperature is the mean value of all those wet bulb temperatures that occur coincidentally with the dry bulb temperatures in the particular 5° temperature bin. At the upper, or warmer, end of the mean coincident wet bulb distribution, the values occasionally reverse their trend because the highest wet bulb temperatures do not necessarily occur with the highest dry bulb temperatures. There are 13 such tables, one for each month and one representing the overall annual summary (Data Set Page 9).

2-6.1 Suggestions for Use.

Binned summaries are used by many different technical disciplines for different purposes. They are useful in making informal estimates of energy consumption by cooling and heating equipment, and for gaining a general understanding of patterns of temperature and moisture at different times of the day, month, and year.

NOTE: Do not use these binned summaries to calculate design moisture loads.

2-6.2 Comments.

These particular binned summaries are based on the dry bulb temperature. After each observation has been placed into a dry bulb bin, the average humidity ratio is calculated for all observations in each bin. Consequently, dry bulb bins underestimate the magnitude of dehumidification and humidification loads because the averaging calculation “flattens” the peaks and valleys of humidity ratios. The amount of the underestimation varies according to the intended humidity control level.

Figure 2-5 Sample Data Set Page 5

Dry-Bulb Temperature Hours For An Average Year

	January					February					March				
Temperature Range (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)
105/109															
100/104															
95/ 99															
90/ 94															
85/ 89												0	0	0	63.6
80/ 84							0		0	57.3		3	0	3	64.5
75/ 79							0	0	0	60.4		9	2	11	63
70/ 74		1		1	58.8		1	0	1	59.3	1	15	7	23	60.4
65/ 69	0	3	0	3	58.8	0	4	1	5	55.9	3	14	13	30	57.3
60/ 64	2	6	3	11	55.5	2	10	5	17	54.1	11	22	18	51	54.4
55/ 59	4	10	6	20	51.8	4	14	9	27	50.2	16	31	24	71	50.2
50/ 54	7	13	10	30	47	7	21	13	41	45.6	19	36	33	88	45.8
45/ 49	7	22	13	42	41.7	14	28	22	64	41.9	36	39	43	118	42
40/ 44	15	28	23	66	38.2	19	28	27	74	38	34	29	33	96	38.1
35/ 39	37	43	43	123	34.1	35	40	42	117	34	47	26	35	108	34.2
30/ 34	49	45	51	145	29.8	48	33	46	127	29.6	40	16	23	79	29.5
25/ 29	42	31	38	111	24.7	43	20	28	91	24.9	25	6	12	43	24.9
20/ 24	27	16	20	63	20.2	20	11	12	43	20.1	10	2	3	15	20.5
15/ 19	24	15	19	58	15.8	15	7	9	31	15.7	5	1	1	7	16.4
10/ 14	17	9	11	37	10.8	9	4	6	19	10.7	1	0	1	2	11.1
5/ 9	11	4	5	20	6.1	6	2	2	10	6	1	0	0	1	6.2
0/ 4	5	1	2	8	1.1	2	0	1	3	0.8	0			0	3
-5/ -1	1	0	1	2	-3	0	0	0	0	-3.3					
-10/ -6	0	0	0	0	-7.4	1	0	0	1	-7.4					
-15/-11	0	0		0	-13.3	0			0	-12					
-20/-16	0			0	-15.5										

Caution: This summary reflects the typical distribtion of temperature in a typical year. It does not reflect the typical mositure distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

Figure 2-6 Sample Data Set Page 6

Dry-Bulb Temperature Hours For An Average Year

	April					May					June				
Temperature Range (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)
105/109												0	0	0	71.3
100/104												1	0	1	75.1
95/ 99							0		0	73		5	1	6	75.5
90/ 94		1	0	1	70.4		6	1	7	72.9	0	34	9	43	75.1
85/ 89		4	1	5	68.6		19	5	24	71.6	1	47	19	67	73.3
80/ 84		14	4	18	66.1	1	39	15	55	69.3	8	61	38	107	71.3
75/ 79	0	25	11	36	63.7	7	49	33	89	66.6	34	48	57	139	69.6
70/ 74	6	32	23	61	60.7	26	47	46	119	64.4	72	26	58	156	67.6
65/ 69	12	31	25	68	58.2	44	33	45	122	61.6	56	11	33	100	63.9
60/ 64	28	40	39	107	55.3	57	33	44	134	57.7	43	5	18	66	59.7
55/ 59	39	36	41	116	51.2	45	15	33	93	53	20	2	5	27	55.2
50/ 54	44	27	40	111	47.1	39	6	18	63	49	6	0	1	7	50.4
45/ 49	44	18	28	90	42.7	20	1	7	28	44.5	1			1	46.5
40/ 44	28	9	16	53	38.3	7	0	1	8	40.3					
35/ 39	23	3	10	36	34.5	2		0	2	36.8					
30/ 34	12	1	3	16	29.9										
25/ 29	3	0	0	3	24.7										
20/ 24	0			0	21										
15/ 19															
10/ 14															
5/ 9															
0/ 4															
-5/ -1															
-10/ -6															
-15/-11															
-20/-16															

Caution: This summary reflects the typical distribtion of temperature in a typical year. It does not reflect the typical mositure distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

Figure 2-7 Sample Data Set Page 7

Dry-Bulb Temperature Hours For An Average Year

	July					August					September				
Temperature Range (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)
105/109															
100/104		2	0	2	76.6		1	0	1	77.1		0		0	77.8
95/ 99		18	3	21	78.5		14	2	16	78.2		3	0	3	74.6
90/ 94	0	51	16	67	77.3		41	10	51	77		16	2	18	73.8
85/ 89	2	59	26	87	75.1	1	56	19	76	74.5	0	26	5	31	71.4
80/ 84	18	63	56	137	73.2	8	67	45	120	72.6	1	46	15	62	69.2
75/ 79	65	36	68	169	71.8	45	45	68	158	71.3	10	52	35	97	67.6
70/ 74	85	15	52	152	68.9	87	18	62	167	68.8	36	45	50	131	65.5
65/ 69	43	3	19	65	64.7	52	4	27	83	64.5	38	24	41	103	62.5
60/ 64	27	1	8	36	60.7	38	1	12	51	60.5	53	18	42	113	58.7
55/ 59	7		1	8	56.6	14		3	17	55.8	46	8	30	84	54.2
50/ 54	0			0	53	3		0	3	51.1	34	2	14	50	50
45/ 49						0			0	45.1	14	1	4	19	45.4
40/ 44											5		1	6	40.5
35/ 39											2		0	2	36.9
30/ 34											0			0	31
25/ 29															
20/ 24															
15/ 19															
10/ 14															
5/ 9															
0/ 4															
-5/ -1															
-10/ -6															
-15/-11															
-20/-16															

Caution: This summary reflects the typical distribtion of temperature in a typical year. It does not reflect the typical mositure distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

Figure 2-8 Sample Data Set Page 8

Dry-Bulb Temperature Hours For An Average Year

Temperature Range (°F)	October					November					December				
	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)
105/109															
100/104															
95/ 99															
90/ 94		1		1	71.9										
85/ 89		5	0	5	69.3										
80/ 84		16	1	17	66.1		1		1	63.5					
75/ 79	1	28	7	36	64.1		4	0	4	61.9					
70/ 74	5	36	19	60	61.7	0	12	2	14	60.8		1		1	62.2
65/ 69	13	34	24	71	59.4	2	14	7	23	58.8	0	2	0	2	59.9
60/ 64	28	45	39	112	56	11	25	18	54	55.9	2	7	4	13	57.2
55/ 59	36	37	46	119	51.8	17	33	24	74	51	5	13	7	25	52
50/ 54	47	29	45	121	47.8	23	34	32	89	47	8	20	12	40	47.2
45/ 49	49	15	35	99	43.5	33	42	41	116	42.6	15	32	22	69	42.8
40/ 44	33	3	18	54	39.2	36	31	35	102	38.5	22	33	31	86	38.5
35/ 39	26	1	11	38	35.3	43	25	38	106	34.2	38	50	49	137	34.4
30/ 34	11		2	13	31.1	40	13	28	81	29.7	53	38	49	140	30
25/ 29	1		0	1	26.8	21	4	10	35	25.1	43	25	34	102	25
20/ 24						8	1	4	13	20.5	23	10	18	51	20.4
15/ 19						4	0	2	6	16.4	18	10	12	40	16.1
10/ 14						1		0	1	11.1	10	5	7	22	11.1
5/ 9						0			0	7.2	5	1	3	9	6.4
0/ 4											2	1	1	4	1.5
-5/ -1											1	1	0	2	-3.5
-10/ -6											1	0	1	2	-7.8
-15/-11											0	0	0	0	-12.4
-20/-16															

Caution: This summary reflects the typical distribtion of temperature in a typical year. It does not reflect the typical mositure distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

Figure 2-9 Sample Data Set Page 9

Dry-Bulb Temperature Hours For An Average Year

	Annual				
Temperature Range (°F)	01 To 08 LST	09 To 16 LST	17 to 00 LST	Total Obs	MCWB (°F)
105/109		0	0	0	71.3
100/104		5	1	6	76.5
95/99		40	6	46	77.7
90/94	0	150	37	187	76.2
85/89	4	216	75	295	73.7
80/84	36	309	174	519	71.2
75/79	162	297	280	739	69.2
70/74	317	248	319	884	66.1
65/69	263	176	236	675	61.8
60/64	302	213	250	765	57.3
55/59	254	197	229	680	52.1
50/54	236	188	218	642	47.4
45/49	233	197	216	646	42.7
40/44	198	162	186	546	38.4
35/39	253	189	228	670	34.3
30/34	254	146	202	602	29.8
25/29	178	86	123	387	24.9
20/24	88	40	57	185	20.3
15/19	66	33	43	142	15.9
10/14	38	18	25	81	10.8
5/9	22	7	10	39	6.1
0/4	9	2	3	14	1.2
-5/-1	2	1	1	4	-3.2
-10/-6	2	0	1	3	-7.6
-15/-11	1	0	0	1	-12.6
-20/-16	0			0	-15.5

Caution: This summary reflects the typical distribtion of temperature in a typical year. It does not reflect the typical mositure distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

2-7 DATA SET PAGE 10: ANNUAL TEMPERATURE SUMMARY.

Figure 2-10 is an example of Data Set Page 10. This chart shows a week-by-week summary of dry bulb temperatures for the given site. The observations are grouped into 7-day periods (approximate calendar weeks). For example, observations from January 1 through 7 from all years are grouped, observations from January 8 through 14 from all years are grouped, and so on, overlapping the end of one month and beginning of the next month where necessary. The following statistics are shown for each of the 7-day periods:

- *1% Dry Bulb Temp* is the dry bulb temperature that is exceeded 1% of the time during that calendar week.
- *MCWB (1% Dry Bulb)* is the mean of wet bulb temperatures coincident with 1% dry bulb temperatures during the same week.
- *Mean Max Temp* is the daily maximum dry bulb temperature, averaged by week over the POR.
- *Mean Min Temp* is the daily minimum dry bulb temperature, averaged by week over the POR.
- *99% Min Dry Bulb Temp* is the daily dry bulb temperature that is at or above this value 99% of the time, or below this value 1% of the time.

NOTE: The information in this chart is calculated on a weekly basis; information on a climate summary (Data Set Page 1) is calculated on an annual basis.

2-7.1 Suggestions for Use.

The weekly 1% and 99% temperatures are useful for understanding the probable temperature extremes that can occur during a given week of the year. The weekly dry bulb temperatures are useful for understanding the change of seasons at a given location. The display is helpful for mission planning and construction project planning.

2-7.2 Special Considerations.

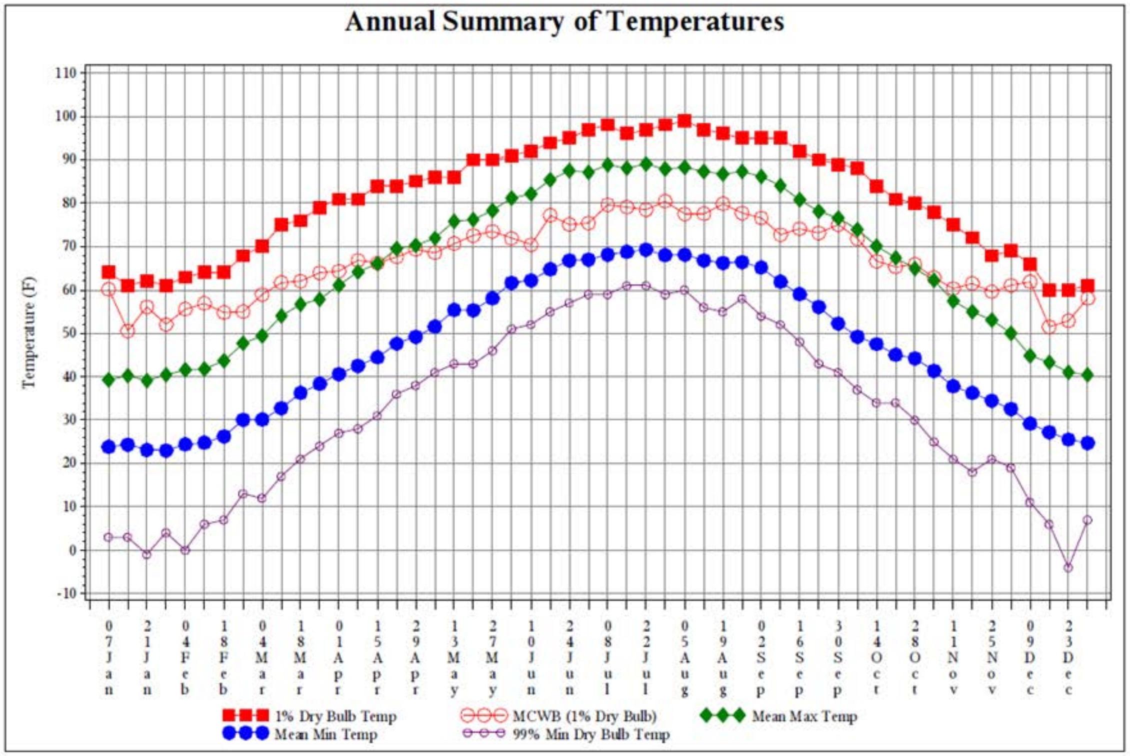
2-7.2.1 Designers.

The values displayed here are based on the 30-year record. It is important that designers **not** base equipment selection on the “highest” or “lowest” recorded temperature at the station. That error would result in selecting equipment extremely costly to install, which would operate inefficiently for all but the very hottest or coldest single hour in 30 years. See the Design Criteria Data section on Sample Data Set Page 1 (see Figure 2-1) in this document for appropriate maximum and minimum temperatures for sizing equipment.

2-7.2.2 Construction and Operation Planners.

The mean maximum and minimum temperatures shown for each week seldom occur in the same year. Keep in mind that these are mean values that are useful for understanding the **typical** range of temperatures in a given week. The difference does **not** represent the **actual** day-night temperature swing in a given week.

Figure 2-10 Sample Data Set Page 10



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2-8 DATA SET PAGE 11: ANNUAL HUMIDITY SUMMARY.

Figure 2-11 is an example of Data Set Page 11. Similar to the annual temperature summary (see Sample Data Set Page 10, Figure 2-10), this chart depicts mean maximum and minimum values of humidity ratio, plus the 1% maximum humidity ratio, along with its mean coincident dry bulb temperature, summarized by calendar week. The chart uses two vertical axes: on the left are the humidity ratio values and on the right is a temperature scale for the mean coincident dry bulb temperature.

2-8.1 Suggestions for Use.

Weekly humidity ratios are useful for understanding the change of seasons at a given location and the probable high and low moisture levels during a given week of the year. The display is helpful for planning humidity- controlled storage projects and for understanding factors contributing to atmospheric corrosion. Humidity also affects the deterioration rate of building materials and the weathering of military equipment and structures exposed to the elements.

2-8.2 Special Considerations.

2-8.2.1 Designers.

The values displayed here are based on the 30-year record. It is important that designers **not** base equipment selection on the “highest” or “lowest” recorded humidity at the station. That error would result in selecting oversized equipment, which would increase costs and might result in control problems at other than extreme conditions. Use design values on Data Set Page 1 (Figure 2-1) for equipment sizing.

2-8.2.2 Construction and Operation Planners.

The high and low humidity ratios shown for each week seldom occur in the same year. Keep in mind that these are mean values that are useful for understanding the typical range of humidity ratio in a given week. The difference does **not** represent the **actual** day-night humidity ratio swing in a given week.

2-9 DATA SET PAGE 12: ANNUAL DRY BULB TEMPERATURE AND HUMIDITY SUMMARY TABLES.

Figure 2-12 is an example of Data Set Page 12. Data Set Page 12 consists of tables containing the values used to plot the charts on Data Set Page 10 and Data Set Page 11. The left half of the table uses Data Set Page 10 and the right half uses Data Set Page 11.

Figure 2-11 Sample Data Set Page 11

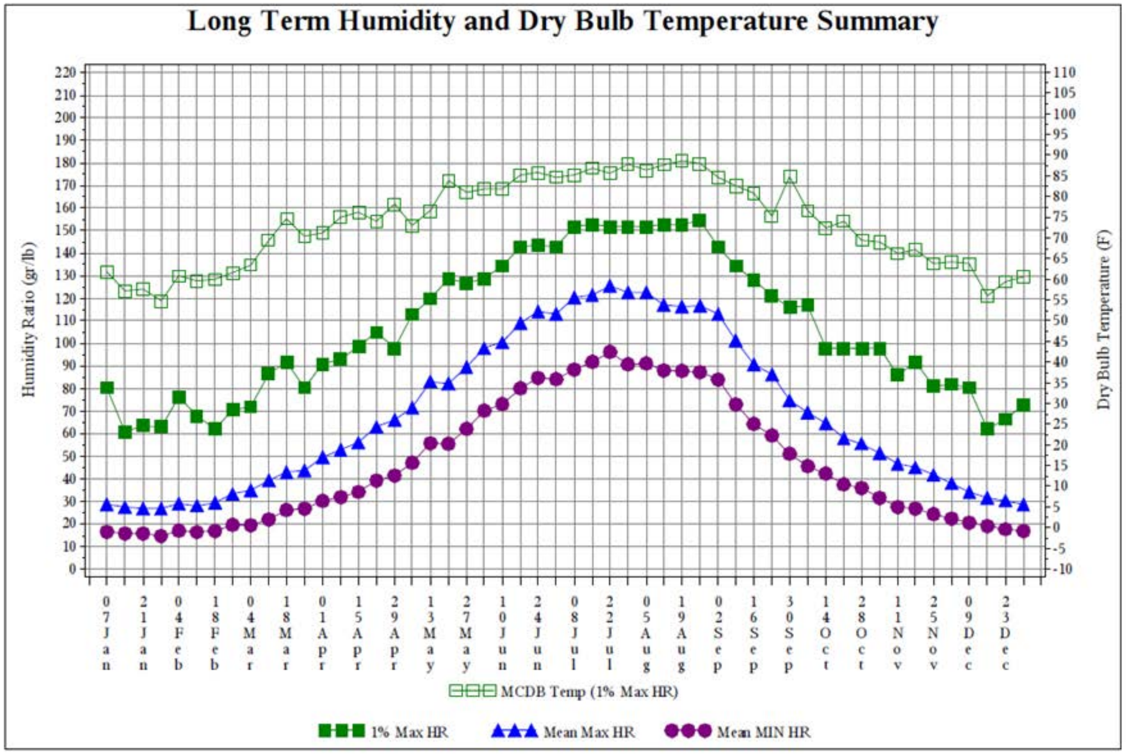

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Figure 2-12 Sample Data Set Page 12

Long Term Humidity and Dry Bulb Temperature Summary

Week Ending	1.0% Temp (°F)	MCWB@ 1% Temp (°F)	Mean Max Temp (°F)	Mean Min Temp (°F)	99% Temp (°F)	1.0% HR (gr/lb)	MCDB@ 1% HR (°F)	Mean Max HR (gr/lb)	Mean Min HR (gr/lb)
7-Jan	64	60.2	39.2	23.8	3	80.5	61.8	28.9	16.6
14-Jan	61	50.5	40.2	24.3	3	60.9	57.2	27.5	15.8
21-Jan	62	56.1	39	23.1	-1	63.7	57.6	26.9	15.8
28-Jan	61	52	40.5	23	4	63	54.8	27	14.8
4-Feb	63	55.6	41.6	24.4	0	76.3	60.9	29.1	17.2
11-Feb	64	56.9	41.7	24.8	6	67.9	59.6	28.2	16.5
18-Feb	64	54.8	43.6	26.2	7	62.3	60.1	29.5	17
25-Feb	68	55	47.7	30	13	70.7	61.6	33.4	19.7
4-Mar	70	58.9	49.5	30.1	12	72.1	63.5	35	19.5
11-Mar	75	61.7	54	32.7	17	86.8	69.5	39.3	22.1
18-Mar	76	62	56.7	36.3	21	91.7	74.7	43.1	26.3
25-Mar	79	63.9	57.9	38.4	24	80.5	70.5	43.7	26.9
1-Apr	81	64.3	61.1	40.6	27	91	71.3	49.7	30.3
8-Apr	81	66.8	64.2	42.5	28	93.1	75.1	52.9	32
15-Apr	84	66.2	66.1	44.5	31	98.7	76.2	56.1	34.3
22-Apr	84	67.6	69.6	47.6	36	105	74	63.1	39.3
29-Apr	85	69.4	70.3	49.2	38	98	78.2	66.1	41.5
6-May	86	68.6	71.9	51.6	41	112.7	73	71.7	47.2
13-May	86	70.7	75.9	55.4	43	119.7	76.6	83.2	55.9
20-May	90	72.5	76.2	55.3	43	128.8	83.8	82.3	55.6
27-May	90	73.5	78.3	58.1	46	126.7	81.1	89.7	62.3
4-Jun	91	71.9	81.1	61.6	51	128.8	81.9	97.9	70.3
10-Jun	92	70.4	82.2	62.2	52	134.4	81.9	100.5	73.3
17-Jun	94	77.2	85.3	64.8	55	142.8	85.2	109.1	80.2
24-Jun	95	75.1	87.5	66.8	57	143.5	85.8	114.1	84.8
1-Jul	97	75.4	87.2	67	59	142.8	84.7	113.1	84.3
8-Jul	98	79.6	88.9	68.1	59	151.9	85.2	120.3	88.4
15-Jul	96	79.1	88	68.8	61	152.6	86.9	121.6	91.9
22-Jul	97	78.5	89.1	69.3	61	151.9	85.7	125.5	96.3
29-Jul	98	80.5	87.8	68	59	151.9	87.8	122.5	90.9
5-Aug	99	77.5	88.3	68.1	60	151.9	86.4	122.5	91.2
12-Aug	97	77.6	87.3	66.8	56	152.6	87.7	117	88.1
19-Aug	96	79.9	86.8	66.2	55	152.6	88.7	116.3	87.9
26-Aug	95	77.7	87.3	66.4	58	154.7	88	116.8	87.3
2-Sep	95	76.6	86.2	65.2	54	142.8	84.6	113.1	84.1
9-Sep	95	72.7	84	61.9	52	134.4	82.6	101.4	73.1
16-Sep	92	74.1	80.8	59	48	128.1	80.8	90.8	64.5
23-Sep	90	73.1	78.1	56.1	43	121.1	75.3	86.4	59.3
30-Sep	89	75	76.5	52.2	41	116.2	84.8	74.8	51.2
7-Oct	88	71.8	74	49.2	37	116.9	76.7	69.6	45.8

14-Oct	84	66.6	70	47.5	34	98	72.4	64.7	42.4
21-Oct	81	65.3	67.4	45.1	34	97.7	74.1	58.2	37.7
28-Oct	80	65.9	65	44.2	30	98	69.5	55.7	36.1
4-Nov	78	62.9	62.2	41.3	25	98	69	51.4	31.7
11-Nov	75	60.3	57.4	37.8	21	86.1	66.3	46.7	27.6
18-Nov	72	61.5	54.9	36.3	18	91.7	67.2	45.1	26.8
25-Nov	68	59.6	53.1	34.4	21	81.2	63.9	41.8	24.5
2-Dec	69	61	50	32.5	19	81.9	64.2	38.1	22.4
9-Dec	66	61.9	44.8	29.2	11	80.5	63.8	34.2	20.7
16-Dec	60	51.5	43.2	27.2	6	62.3	56	31.7	19.1
23-Dec	60	52.9	41	25.5	-4	66.5	59.5	30.4	17.8
31-Dec	61	58.1	40.4	24.7	7	72.8	60.7	28.9	17

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2-10 DATA SET PAGE 13: BUILDING ENVELOPE LOADS.

Figure 2-13 is an example of Data Set Page 13. Data Set Page 13 consists of charts summarizing a site's mean heating and cooling degree days.

2-10.1 Explanation of Charts.

2-10.1.1 Calculation of Cooling Degree-Days.

Cooling degree-days are derived by multiplying the number of hours that the outdoor temperature is above the base temperature of 65 °F (18 °C) times the number of degrees of that temperature difference. For example, if 1 hour was observed at a temperature of 78 °F, that observation adds 13 degree-hours to the annual total. The sum of the degree-hours is divided by 24 to yield degree-days.

2-10.1.2 Calculation of Heating Degree-Days.

Heating degree-days are calculated similarly, against the base temperature of 65 °F, so a 1-hour outside temperature observation of 62 °F adds 3 degree-hours to the annual total. Heating degree-days are summed separately from the cooling degree-days. Heating and Cooling degree-hours do not cancel each other out, since both heating and cooling conditions may occur over the course of a given day.

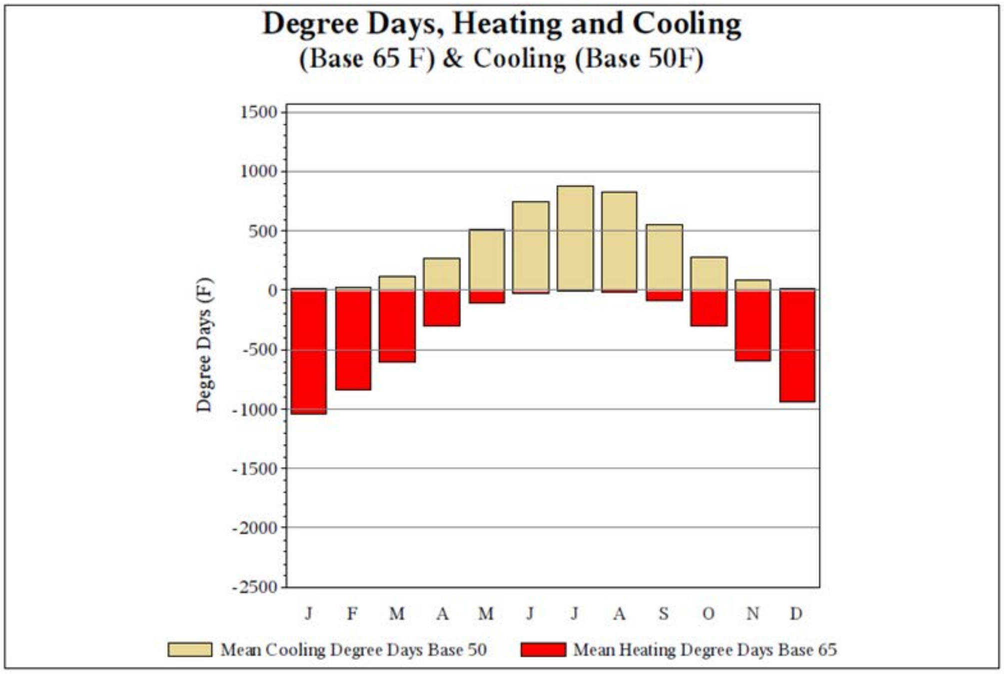
2-10.1.3 Alternate Cooling Degree-Days Calculation.

A separate file has been added to the 14 WS Web site to include the cooling degree-days based upon a base temperature of 50 °F. This file is located on the Engineering Weather Data page under the Standard EWD Package file. This data is intended to allow selection of the proper Building Envelope Requirements table from within **1**\ ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (Refer to UFC 1-200-02, for applicable publication date) /**1**/ for energy conservation design. The cooling degree-days based on 65 °F tabulated and graphed here are historically used to estimate loads as suggested in paragraph 2-10.2 below.

2-10.2 Suggestions for Use.

Degree-days are used to estimate the sensible heat and sensible cooling loads on the building envelope. Degree-day loads can be used to estimate the annual energy consumption of a building, provided that the loads from ventilation and infiltration air are also considered (see paragraph 2-11).

Figure 2-13 Sample Data Set Page 13



Month	Mean Cooling Degree Days (°F) Base 50	Mean Cooling Degree Days (°F) Base 65	Mean Heating Degree Days (°F) Base 65
JAN	16.6	0.4	1032.6
FEB	25	1.1	832.7
MAR	111.8	16.6	605.6
APR	271.4	56.8	298
MAY	516.1	154	110.3
JUN	747.3	316.5	19.2
JUL	875.4	415.9	5.6
AUG	819.6	366.6	12
SEP	556	188.9	88
OCT	275.9	56.4	306.5
NOV	90.3	8.3	592.6
DEC	18.7	0.4	940.5
ANN	4324.1	1581.9	4843.6

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2-11 DATA SET PAGE 14: VENTILATION AND INFILTRATION LOADS.

Figure 2-14 is an example of Data Set Page 14. Data Set Page 14 consists of a graph and table that display the independent loads imposed by heating, cooling, humidifying, and dehumidifying outside air as it is brought into a building. The calculation assumes that air inside the building is maintained at conditions between 68 °F (20 °C)/30% RH and 75 °F (24 °C)/60% RH. For the purposes of these calculations, when the outside air is within that range of temperature and moisture, any incoming air is assumed not to impose any load.

These values are calculated with the methodology used to calculate the annual VCLI on Data Set Page One, except that values on this page are computed by month and the result is displayed as British thermal units per cubic foot per minute (Btu/cfm) rather than as ton-hours per CFM per year. The heating and humidifying loads are shown as negative values. Cooling and dehumidifying loads are displayed as positive values.

2-11.1 Suggestions for Use.

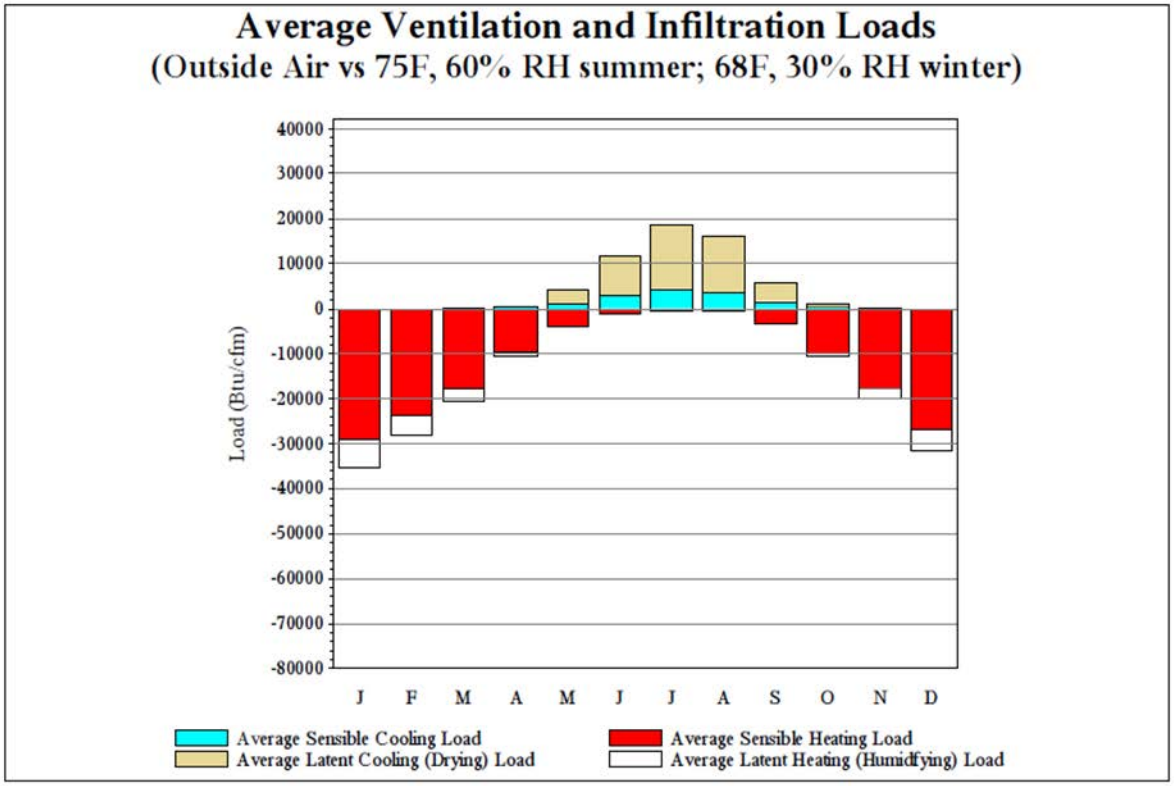
Bringing fresh ventilation air into a building or allowing air to infiltrate into buildings through cracks imposes heating, cooling, dehumidification, and humidification loads on the mechanical system. The information on this data set page helps the architect, engineers, and operating personnel understand the nature and magnitude of those loads on an annual basis. It also shows how the loads vary from month to month throughout the year.

2-11.2 Comments.

These calculations are based on the load created when 1 cubic foot of outside air is brought into the building each minute. The results of the calculation include the moisture load or deficit, and the sensible heat load or deficit created by that cubic foot of air during each month of the year. Note that most months have both a load and a deficit for temperature and moisture. The monthly deficit and load do not “cancel” from the perspective of the mechanical system, because temperature and moisture loads will often occur at different times of the day.

NOTE: The values displayed here assume that the inside air is maintained between 68 °F/30% RH and 75 °F/ 60% RH. If the inside conditions are held in a different range of temperature or moisture, the loads will be different. For example, in calculating loads for humidity-controlled but unheated storage, the loads vary according to the change in both temperature and humidity, since the inside temperature varies but the inside humidity is held constant. For estimating loads in that or similar applications, the engineer may obtain better results by using the average maximum weekly humidity data shown on Data Set Pages 11 and 12 (Figures 2-11 and 2-12).

Figure 2-14 Sample Data Set Page 14



Month	Average Sensible Cooling Load (Btu/cfm)	Average Sensible Heating Load (Btu/cfm)	Average Latent Cooling Load (Btu/cfm)	Average Latent Heating Load (Btu/cfm)
JAN	0	-29169	7	-5929
FEB	1	-23761	6	-4543
MAR	47	-17927	101	-2731
APR	267	-9536	420	-867
MAY	998	-4073	3315	-67
JUN	2894	-926	8717	-1
JUL	4255	-345	14237	0
AUG	3511	-629	12438	0
SEP	1434	-3287	4223	-21
OCT	266	-9831	745	-576
NOV	13	-17587	100	-2359
DEC	0	-26781	8	-4742
ANN	13686	-143852	44317	-21836

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2-12 DATA SET PAGES 15 AND 16: SOLAR RADIATION DATA.

Figures 2-15 and 2-16 are samples of Data Set Page 15 and Data Set Page 16, respectively.

2-12.1 Explanation of Charts.

2-12.1.1 Data Source.

This data is reproduced courtesy of the National Renewable Energy Laboratory (NREL). The data were first published in the NREL's *Solar Radiation Data Manual for Buildings* (1995). The user should refer to that publication for a complete description of how to use this data. The manual can be accessed online at http://www.osti.gov/bridge by searching for "NREL/TP--463-7904."

2-12.1.2 Site Location.

The site used in each station record is the nearest NREL-published site available within a 1.5° latitude radius from the requested location. Consequently, some sites may be several miles away, and in some cases, the NREL location may be in a neighboring state. Use caution when the nearest site available is not in the same city as the requested location, since significant differences in cloud climatology can exist over short distances.

2-12.1.3 Site Availability.

When this document was prepared, the only sites available from NREL were Puerto Rico, Guam, and the 50 states. For locations where solar radiation data is not available, Data Set Pages 15 and 16 are blank. For these locations, users may wish to contact NREL directly to obtain advice concerning data not published in the NREL solar radiation data manual.

2-12.2 Suggestions for Use.

The solar data presented here can be used for calculating solar radiation cooling loads on building envelopes, and also for estimating the value of solar illumination for daylighting calculations. Again, the user should refer to the *Solar Radiation Data Manual for Buildings* for a complete description of how to use this data.

NOTE: The data source for the NREL reports comes from the National Solar Radiation Database—not the data set used to calculate peak design values and other monthly temperature and moisture data in this document. The two data sets will differ for many reasons, including different POR, measurement locations, sampling methodology and frequency, and differences in calculation methodology. Consequently, the user should expect differences in degree-days, minimum and maximum temperatures, and humidity values between this data and that calculated by the 14 WS. For design criteria, use the temperature and moisture values presented on the Design Criteria Data section of Data Set Page 1 (see Figure 2-1) of this document. These were calculated more recently and used a longer POR. Also, they are taken from records at DoD locations rather than from civilian locations near—but not always identical to—the military data collection points.

Figure 2-15 Sample Data Set Page 15

Average Annual Solar Radiation - Nearest Available Site
Source: National Renewable Energy Laboratory, Golden CO, 1995

Station Information		Shading Geometry in Dimensionless Units	
City, State, WBAN	ST.LOUIS, MO 13994	Window:	1.000
Lat, Lon, Elev	38.75N 90.38W 564ft	Overhang:	0.498
Press, Stn_Type	14.5psia Secondary	Vert Gap:	0.314

AVERAGE INCIDENT SOLAR RADIATION (Btu/sq.ft./day) Percentage Uncertainty = 9

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
HORIZ.	Global	690	930	1230	1590	1860	2030	2020	1800	1460	1100	720	580	1340
	Std.Dev.	56	69	98	135	138	114	120	110	112	98	69	57	42
	Minimum	550	800	1060	1370	1550	1830	1750	1570	1190	870	590	490	1280
	Maximum	780	1070	1430	1930	2180	2350	2240	1960	1690	1250	870	710	1480
	Diffuse	340	460	590	710	810	840	810	730	600	430	350	300	580
Clear Day	Global	950	1300	1760	2230	2520	2630	2550	2290	1870	1400	1000	840	1780
NORTH	Global	210	280	360	440	550	630	600	490	380	290	220	190	390
	Diffuse	210	280	360	430	500	530	520	460	380	290	220	190	370
Clear Day	Global	190	250	330	430	580	680	630	470	360	270	200	170	380
EAST	Global	460	590	750	920	1060	1140	1130	1050	880	710	470	390	800
	Diffuse	260	340	440	530	600	640	620	570	470	360	270	230	440
Clear Day	Global	710	910	1150	1340	1440	1460	1430	1340	1170	940	730	640	1110
SOUTH	Global	1080	1110	1060	970	830	780	820	950	1110	1220	1020	940	990
	Diffuse	370	440	500	540	560	570	570	560	520	440	360	330	480
Clear Day	Global	1930	1970	1770	1380	1040	890	950	1210	1580	1840	1870	1860	1520
WEST	Global	470	600	740	920	1040	1110	1120	1030	880	700	480	390	790
	Diffuse	260	340	440	530	610	650	630	580	480	360	270	230	450
Clear Day	Global	710	910	1150	1340	1440	1460	1430	1340	1170	940	730	640	1110

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Figure 2-16 Sample Data Set Page 16

Average Annual Solar Radiation - Nearest Available Site
Source: National Renewable Energy Laboratory, Golden CO, 1995

AVERAGE TRANSMITTED SOLAR RADIATION (Btu/sq.ft./day) FOR DOUBLE GLAZING Percentage Uncertainty = 9														
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
HORIZ.	Unshaded	450	640	870	1150	1350	1480	1470	1300	1040	770	480	370	950
NORTH	Unshaded	150	190	250	300	370	410	390	330	260	200	150	130	260
	Shaded	130	170	220	270	330	370	350	300	240	180	140	110	230
EAST	Unshaded	320	410	530	660	750	810	810	750	620	500	320	270	560
	Shaded	290	370	470	570	650	700	700	650	550	450	290	240	490
SOUTH	Unshaded	810	810	740	630	510	470	490	600	750	870	760	700	680
	Shaded	790	750	590	420	350	360	360	390	550	770	730	680	560
WEST	Unshaded	320	420	520	650	740	790	800	740	620	490	330	270	560
	Shaded	290	370	460	570	640	680	690	640	550	440	300	240	490

AVERAGE INCIDENT ILLUMINANCE (klux-hr) FOR MOSTLY CLEAR AND MOSTLY CLOUDY CONDITIONS Percentage Uncertainty = 9											
				March					June		
		9am	11am	1pm	3pm	5pm	9am	11am	1pm	3pm	5pm
HORIZ.	M.Clear	40	73	82	64	26	48	84	101	96	67
	M.Cloudy	23	45	52	40	16	32	61	76	71	49
NORTH	M.Clear	10	14	15	13	8	19	16	17	17	15
	M.Cloudy	9	16	17	14	7	15	18	19	19	16
EAST	M.Clear	75	56	15	13	8	78	72	31	17	15
	M.Cloudy	25	30	17	14	7	40	49	27	19	16
SOUTH	M.Clear	40	73	82	64	26	12	31	45	41	19
	M.Cloudy	17	36	43	32	12	12	26	37	33	18
WEST	M.Clear	10	14	24	67	64	12	16	17	53	78
	M.Cloudy	9	16	21	33	22	12	18	19	41	50
M.Clear	(% hrs)	32	28	27	28	29	43	39	32	29	34

				Sept					Dec		
		9am	11am	1pm	3pm	5pm	9am	11am	1pm	3pm	5pm
HORIZ.	M.Clear	29	68	86	78	47	16	42	48	30	2
	M.Cloudy	17	42	58	53	31	9	25	28	17	2
NORTH	M.Clear	9	14	16	15	12	6	10	11	8	1
	M.Cloudy	7	15	18	17	12	4	10	11	7	1
EAST	M.Clear	65	70	28	15	12	42	39	11	8	1
	M.Cloudy	23	36	23	17	12	11	18	11	7	1
SOUTH	M.Clear	21	57	75	67	37	39	82	88	63	6
	M.Cloudy	11	31	45	41	21	10	29	32	20	2
WEST	M.Clear	9	14	16	54	74	6	10	22	50	9
	M.Cloudy	7	15	18	35	35	4	10	14	17	2
M.Clear	(% hrs)	47	47	41	41	43	31	30	30	30	32

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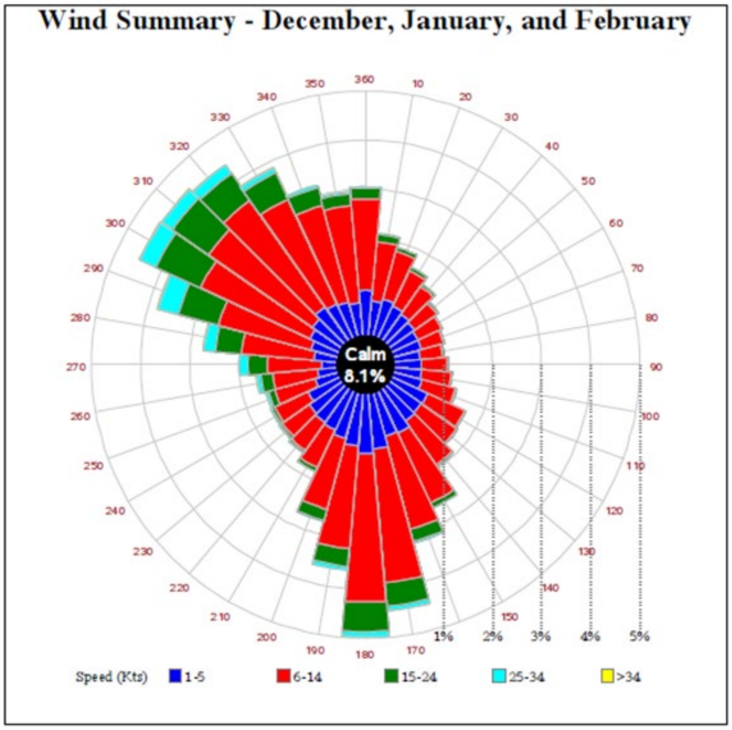
Figure 2-17 Sample Data Set Page 17



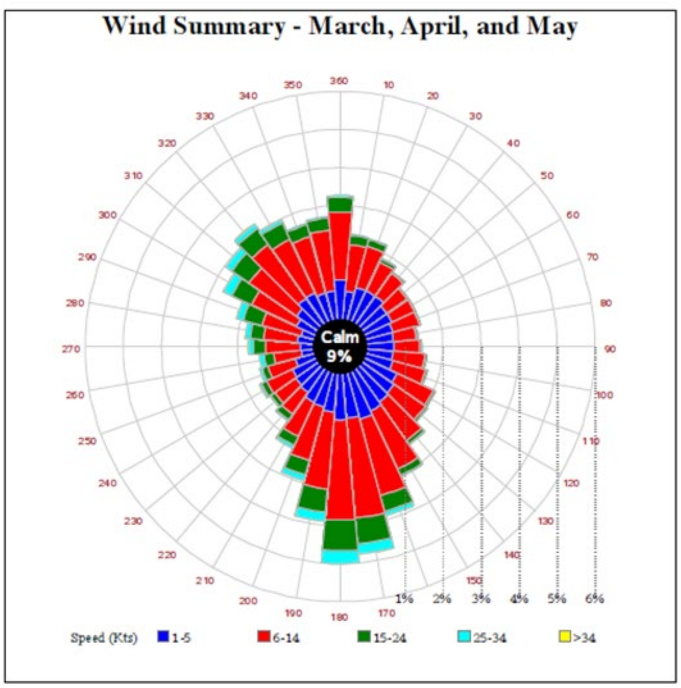


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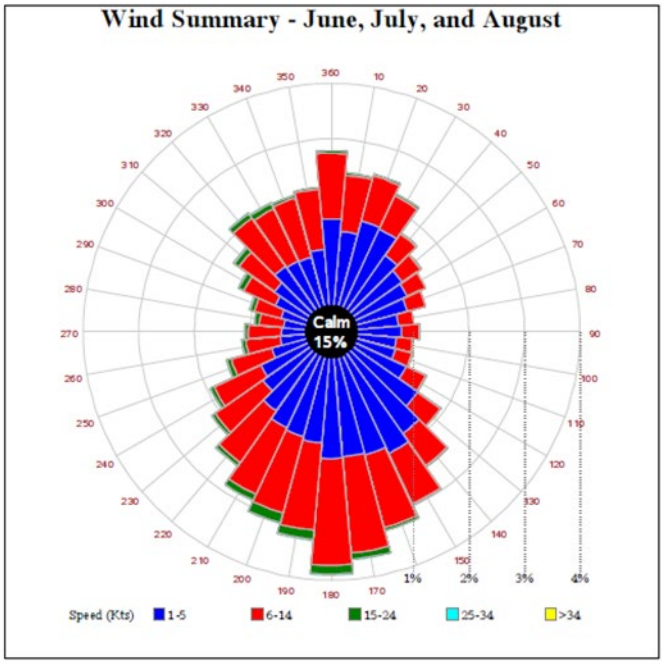
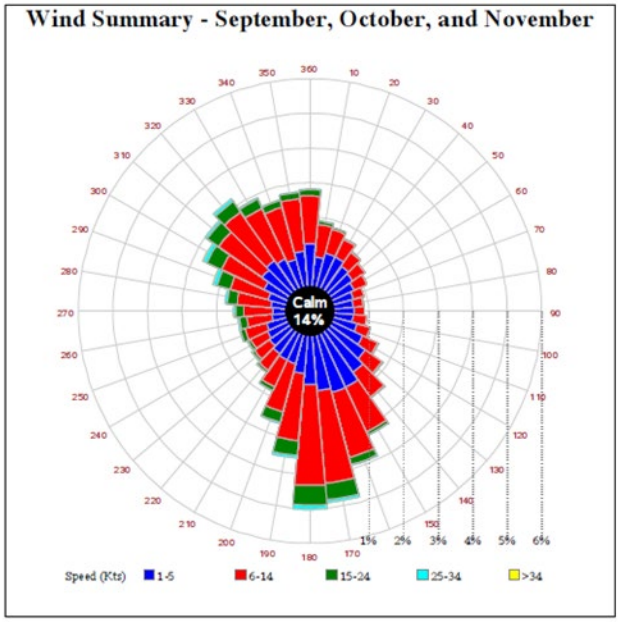
Figure 2-18 Sample Data Set Page 18





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2-13 DATA SET PAGES 17 AND 18: WIND SUMMARY.

Figures 2-17 and 2-18 are samples of Data Set Page 17 and Data Set Page 18, respectively.

2-13.1 Explanation of Charts.

2-13.1.1 Depiction.

These charts depict the frequency of different wind direction and wind speed combinations. The observations are binned into 36 compass directions and 5 speed categories (1 to 5 knots, 6 to 14 knots, 15 to 24 knots, 25 to 34 knots, and greater than 34 knots). The frequency of direction and the tick marks indicate that values lie along each “spoke” of the wind chart. The wind speed bins for each direction are color coded by the legend at the bottom of the chart.

2-13.1.2 Percent Frequency.

To determine the percent frequency of a particular wind direction, look for the tick mark bounding the outer edge of a colored (wind speed) area. In the case of the first wind speed bin (1 to 5 knots), the percent frequency is simply the value of the tick mark on the outer edge of the 1 to 5 knot region. For the higher speed bins (6 to 14 knots or greater), subtract the earlier spoke values from the value shown to get the frequency for the speed bin in question.

2-13.1.3 Total Percent Frequency.

The values for percent frequency have been summed by direction, so to determine the total percent frequency for all speeds from a particular direction, look up the tick mark (or interpolated value) bounding the outermost colored area along that spoke. That tick mark represents the total percent frequency of wind from that direction.

2-13.1.4 Calm Conditions.

Since the calm condition has no direction, the percent occurrence of calm conditions is displayed at the center of the chart.

2-13.2 Wind Summary Chart Example.

The wind summary charts are prepared by 3-month seasons, over all hours (e.g., December, January, February for northern hemisphere winter or southern hemisphere summer; March, April, May for northern hemisphere spring or southern hemisphere fall). See the December through February sample wind summary chart in Figure 2-17 for an example of determining percent frequencies.

2-13.2.1 December through February.

From the December through February sample wind summary chart, the percent frequency of wind between 1 to 5 knots and from the north (N) is about 1%. The percent frequency of wind between 6 to 14 knots and from the south (S) is about 3% (~4.25% minus ~1.25%). The percent frequency of all wind speeds from the south (S) is about 5%. The percent frequency of all wind directions from the west through north (270° - 360°) is about 35% (2% + 2.75% + 3.875% + 4.5% + 4.5% + 4.25% + 3.875% + 3.25% + 3% + 3%, respectively – all values approximated). It is easy to determine that wind speeds greater than 34 knots almost never occur (or are such a small frequency from any direction) because the colored area (yellow) is not shown or is indistinguishable because it is extremely small.

2-13.2.2 Calm Wind.

The percent of time the wind is calm is indicated in the center of the chart—in this case, 8.1%. When the outermost value from each of the 36 directions are summed and added to the percent calm, the result is 100% (allowing for rounding). Occurrences of variable wind direction are omitted from the sample before computing percent frequency by direction.

2-13.3 Suggestions for Use.

Knowing the probable wind speed and direction in a particular month can be helpful in construction and mission planning as well as in designing structures that experience severe wind-driven rain or drifting snow. Engineers designing outside air intake and building exhaust vents for heating and air conditioning systems can use these data to minimize the potential for cross-contamination between supply and exhaust air streams. Also, when drifting snow accumulation on roofs is likely, the information on these data set pages can be helpful for locating inlet and exhaust ducts so they are less likely to be obstructed by snowdrifts.

NOTE: The wind currents around any building are strongly affected by the geometry of the building and the topography of the site as well as those of any surrounding buildings. The wind data used for these wind summaries are typical of flat and open airfields where there are no obstructions near the observation point.

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APPENDIX A REFERENCES

AMERICAN SOCIETY OF CIVIL ENGINEERS

http://www.asce.org/

2\ ASCE/SEI 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* /**2**/

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

http://www.ashrae.org/

1\ ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (Refer to UFC 1-200-02, for applicable publication date) /**1**/

INTERNATIONAL CODE COUNCIL

http://www.iccsafe.org/

International Plumbing Code, 2012

NATIONAL GROUND WATER RESEARCH AND EDUCATIONAL FOUNDATION

http://www.ngwa.org/

NATIONAL RENEWABLE ENERGY LABORATORY

http://www.osti.gov/bridge

Solar Radiation Data Manual for Buildings, 1995

UNITED STATES DEPARTMENT OF DEFENSE

http://www.dtic.mil/whs/directives/

DoD Directive 4715.21, *Climate Change Adaptation and Resilience*, 14 January 2016

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *DoD Building Code (General Building Requirements)*

UFC 3-301-01, *Structural Engineering*

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APPENDIX B BEST PRACTICES

B-1 BEST PRACTICES.

No best practices are documented at this time.

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APPENDIX C GLOSSARY

C-1 ACRONYMS

AAF	Army Air Field
AB	Air Base
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
AFM	Air Force Manual
AFS	Air Force Station
ANGB	Air National Guard Base
ANGS	Air National Guard Station
ANSI	American National Standards Institute
ARB	Air Reserve Base
ARS	Air Reserve Station
ASHRAE/IESNA	American Society of Heating, Refrigerating, and Air Conditioning Engineers/Illuminating Engineering Society of North America
Btu	British thermal units
Btu/cfm	British thermal units per cubic foot per minute
Btu/lb	British thermal units per pound of air (enthalpy)
Btu/sq. ft./day	British thermal units per square foot per day (solar radiation)
C	Celsius
Cfm	Cubic foot per minute
DoD	Department of Defense
EWD	Engineering Weather Data
F	Fahrenheit
gr/lb	Grains per pound (humidity ratio, grains of water vapor per pound of air)

g/kg	Grams per kilogram (humidity ratio, grams of water vapor per kilogram of air)
in. Hg	Inches of mercury (atmospheric pressure)
in.	Inches (frost depth)
in./hr	Inches per hour (rain rate)
klux-hr	Thousands of lux-hours (average incident illuminance)
lb/ft2	pounds per square foot (snow load)
LST	Local Standard Time
MCAS	Marine Corps air station
MCB	Marine Corps base
MC Dewpt	Mean Coincident Dewpoint
MCDB	Mean of dry bulb temperatures
MCHR	Mean Coincident Humidity Ratio
MCWB	Mean of wet bulb temperatures
mph	Miles per hour (wind speed)
NAS	Naval Air Station
NAF	Naval Air Facility
NAVFAC	Naval Facilities Engineering Command
NCDC	National Climatic Data Center
NRC	Naval Reserve Center
NREL	National Renewable Energy Laboratory
NS	Naval Station
NSA	Naval Support Activity
POR	Period of record
RH	Relative humidity
ton-hr/cfm/yr	Ton-hours of load per cubic foot per minute per year (Btu÷12,000)

USACE	US Army Corps of Engineers
VCLI	Ventilation Cooling Load Index
WBAN No	Weather Bureau Army Navy number, an identification number for solar radiation data stations in NREL's *Solar Radiation Data Manual for Buildings*
WS	Weather Squadron
BIA	Bilateral Infrastructure Agreement
DoD	Department of Defense
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria
U.S.	United States

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APPENDIX D SAMPLE 14 WS SUPPORT ASSISTANCE REQUEST (SAR) FORM

14WS SUPPORT ASSISTANCE REQUEST (SAR)

SUBJECT

CONTACT INFORMATION

RANK/TITLE | FULL NAME

TELEPHONE NUMBER | E-MAIL

ORGANIZATION	STATION
ORGANIZATION TYPE:	LOCATION
Are you Meteorological or Oceanographic Personnel?	
Are you a part of the Air Force Weather community?	

REQUEST

When do you need your data?

Describe what you need, include specific locations, if applicable and all pertinent details:

Who will receive the information? What it will be used for? Include any tangible benefits or expected impacts. If classified, contact via classified email.

IF DOD CONTRACTOR
MILITARY POINT OF CONTACT

RANK/TITLE | FULL NAME

CONTACT TELEPHONE | CONTRACT NUMBER

14 WS FORM 1, DEC 12 ***(EF-V2)*** PREVIOUS EDITIONS MAY BE USED. PAGE 1 OF 1 PAGES

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APPENDIX E LIST OF AVAILABLE EWD SITES

E-1 REGULARLY UPDATED SITES.

Table E-1 is a list that consists of the Site Name, 4-letter Station ID, Latitude/Longitude, and Country for each Engineering Weather Data (EWD) site available at the 14th Weather Squadron. Note that the sites are regularly updated and the latest list should be retrieved at https://www.climate.af.mil.

Table E-1 List of Available EWD Sites

Site Name	Station ID	Lat	Lon	Country
BAGRAM	KQSA	34.94	69.26	AFGHANISTAN
BASTION AIRFIELD/SHORABACK	OAZI	31.85	64.22	AFGHANISTAN
HERAT	OAHR	34.21	62.23	AFGHANISTAN
JALALABAD	KQL5	34.4	70.48	AFGHANISTAN
KABUL INTL	OAKB	34.57	69.21	AFGHANISTAN
KALAT	OAKT	32.12	66.9	AFGHANISTAN
KANDAHAR AIRPORT	40990	31.5	65.85	AFGHANISTAN
KUNDUZ	40913	36.67	68.92	AFGHANISTAN
MAZAR I SHARIF	OAMS	36.71	67.21	AFGHANISTAN
EL GOLEA	DAUE	30.57	2.86	ALGERIA
HOUARI BOUMEDIENE	DAAG	36.69	3.22	ALGERIA
TAMANRASSET	DAAT	22.81	5.45	ALGERIA
TINDOUF	DAOF	27.7	-8.17	ALGERIA
BASE MARAMBIO (CENTRO MET. ANTARTICO)	89055	-64.23	-56.72	ANTARCTICA
V C BIRD INTL	TAPA	17.14	-61.79	ANTIGUA AND BARBUDA
MINISTRO PISTARINI	SAEZ	-34.82	-58.54	ARGENTINA
POSADAS	SARP	-27.39	-55.97	ARGENTINA
RESISTENCIA	SARE	-27.45	-59.06	ARGENTINA
RIO GALLEGOS	SAWG	-51.61	-69.31	ARGENTINA
ROSARIO	SAAR	-32.9	-60.78	ARGENTINA
REINA BEATRIX INTL	TNCA	12.5	-70.02	ARUBA
ADELAIDE INTL	YPAD	-34.94	138.53	AUSTRALIA
ALICE SPRINGS	YBAS	-23.81	133.9	AUSTRALIA
BRISBANE AIRPORT	YBBN	-27.42	153.07	AUSTRALIA
CANBERRA	YSCB	-35.31	149.2	AUSTRALIA
DARWIN INTL	YPDN	-12.41	130.88	AUSTRALIA
LEARMONTH	YPLM	-22.24	114.09	AUSTRALIA
MELBOURNE INTL	YMML	-37.67	144.84	AUSTRALIA

Site Name	Station ID	Lat	Lon	Country
PERTH INTL	YPPH	-31.94	115.97	AUSTRALIA
SYDNEY INTL	YSSY	-33.95	151.18	AUSTRALIA
TOWNSVILLE	YBTL	-19.25	146.77	AUSTRALIA
SALZBURG	LOWS	47.79	13	AUSTRIA
NASSAU INTL	MYNN	25.04	-77.47	BAHAMAS
BAHRAIN INTL	OBBI	26.27	50.63	BAHRAIN
HAZRAT SHAHJALAL INTL	VGHS	23.84	90.4	BANGLADESH
ZHITCKOVICHI	33027	52.22	27.87	BELARUS
BRUSSELS NATL	EBBR	50.9	4.48	BELGIUM
CHIEVRES AB	EBCV	50.58	3.83	BELGIUM
FLORENNES	EBFS	50.24	4.65	BELGIUM
CADJEHOUN	DBBB	6.36	2.38	BENIN
BERMUDA INTL	TXKF	32.36	-64.68	BERMUDA
EL ALTO INTL	SLLP	-16.51	-68.19	BOLIVIA
TTE AV JORGE HENRICH ARAUZ	SLTR	-14.82	-64.92	BOLIVIA
VIRU VIRU INTL	SLVR	-17.64	-63.14	BOLIVIA
CONGONHAS	SBSP	-23.63	-46.66	BRAZIL
DEPUTADO LUIS EDUARDO MAGALHAES	SBSV	-12.91	-38.33	BRAZIL
EDUARDO GOMES INTL	SBEG	-3.04	-60.05	BRAZIL
GALEAO ANTONIO CARLOS JOBIM	SBGL	-22.81	-43.24	BRAZIL
GUARARAPES GILBERTO FREYRE INTL	SBRF	-8.13	-34.92	BRAZIL
PINTO MARTINS INTL	SBFZ	-3.78	-38.53	BRAZIL
PRESIDENTE JUSCELINO KUBITSCHEK	SBBR	-15.86	-47.91	BRAZIL
SALGADO FILHO	SBPA	-29.99	-51.17	BRAZIL
SANTOS DUMONT	SBRJ	-22.91	-43.16	BRAZIL
VAL DE CANS INTL	SBBE	-1.38	-48.48	BRAZIL
DIEGO GARCIA NSF	FJDG	-7.31	72.41	BRITISH INDIAN OCEAN TERRITORY
BURGAS	LBBG	42.57	27.52	BULGARIA
SOFIA	LBSF	42.7	23.41	BULGARIA
VARNA	LBWN	43.23	27.83	BULGARIA
OUAGADOUGOU	DFFD	12.35	-1.51	BURKINA FASO
MINGALADON	48096	16.9	96.18	BURMA
ARGENTIA (AUT)	71807	47.3	-53.98	CANADA
ARMSTRONG (AUT) ONT	71841	50.28	-88.9	CANADA
CALGARY INTL	CYYC	51.11	-114.02	CANADA
CAMBRIDGE BAY	CYCB	69.11	-105.14	CANADA
CAPE DYER	CWFD	66.65	-61.38	CANADA
CAPE PARRY A	CZCP	70.17	-124.72	CANADA
CHAPAIS	CYMT	49.77	-74.53	CANADA

Site Name	Station ID	Lat	Lon	Country
CHARLO AUTO NB	71315	47.98	-66.33	CANADA
CHURCHILL A UA MAN	71913	58.73	-94.07	CANADA
CHURCHILL FALLS	CZUM	53.57	-64.1	CANADA
COLD LAKE	CYOD	54.4	-110.28	CANADA
COMOX	CYQQ	49.71	-124.89	CANADA
EDMONTON/NAMAO(MIL)	CYED	53.67	-113.47	CANADA
ESTEVAN A	CYEN	49.22	-102.97	CANADA
FORT NELSON	CYYE	58.83	-122.6	CANADA
FORT SMITH	CYSM	60.02	-111.96	CANADA
FREDERICTON	CYFC	45.87	-66.53	CANADA
GANDER INTL	CYQX	48.94	-54.57	CANADA
GOOSE BAY	CYYR	53.32	-60.42	CANADA
GRANDE PRAIRIE	CYQU	55.18	-118.88	CANADA
HALIFAX INTL	CYHZ	44.88	-63.51	CANADA
HALL BEACH	CYUX	68.78	-81.24	CANADA
HOPEDALE (AUT) NFLD	71900	55.45	-60.22	CANADA
INUVIK MIKE ZUBKO	CYEV	68.3	-133.48	CANADA
IQALUIT	CYFB	63.76	-68.56	CANADA
KAMLOOPS	CYKA	50.7	-120.44	CANADA
KAPUSKASING	CYYU	49.41	-82.47	CANADA
KUGLUKTUK	CYCO	67.82	-115.14	CANADA
LESTER B PEARSON INTL	CYYZ	43.68	-79.63	CANADA
LYNN LAKE	CYYL	56.86	-101.08	CANADA
NORMAN WELLS	CYVQ	65.28	-126.8	CANADA
NORTH BAY	CYYB	46.36	-79.42	CANADA
OTTAWA MACDONALD CARTIER INTL	CYOW	45.32	-75.67	CANADA
PIERRE ELLIOTT TRUDEAU INTL	CYUL	45.47	-73.73	CANADA
POND INLET	CYIO	72.68	-77.97	CANADA
PORT HARDY	CYZT	50.68	-127.37	CANADA
PRINCE GEORGE	CYXS	53.89	-122.68	CANADA
RANKIN INLET	CYRT	62.81	-92.12	CANADA
RESOLUTE BAY	CYRB	74.72	-94.97	CANADA
SANDSPIT	CYZP	53.25	-131.81	CANADA
SASKATOON J G DIEFENBAKER INTL	CYXE	52.17	-106.7	CANADA
SEPT ILES	CYZV	50.22	-66.27	CANADA
SHEPHERD BAY A	CYUS	68.82	-93.43	CANADA
SHERBROOKE	CYSC	45.44	-71.69	CANADA
SIOUX LOOKOUT AIRPORT	CYXL	50.12	-91.9	CANADA
ST JOHNS INTL	CYYT	47.62	-52.75	CANADA
STEPHENVILLE A	CYJT	48.53	-58.55	CANADA

Site Name	Station ID	Lat	Lon	Country
SUDBURY	CYSB	46.63	-80.8	CANADA
SYDNEY A	CYQY	46.17	-60.05	CANADA
TERRACE	CYXT	54.47	-128.58	CANADA
THE PAS AIRPORT	CYQD	53.97	-101.1	CANADA
THUNDER BAY A	CYQT	48.37	-89.33	CANADA
TIMMINS VICTOR POWER A	CYTS	48.57	-81.38	CANADA
VANCOUVER INTL	CYVR	49.19	-123.18	CANADA
WHITEHORSE INTL	CYXY	60.71	-135.07	CANADA
WINNIPEG INTL	CYWG	49.91	-97.24	CANADA
YARMOUTH	CYQI	43.83	-66.09	CANADA
YELLOWKNIFE	CYZF	62.46	-114.44	CANADA
AMILCAR CABRAL INTL	GVAC	16.74	-22.95	CAPE VERDE
BANGUI M POKO	FEFF	4.4	18.52	CENTRAL AFRICAN REPUBLIC
NDJAMENA HASSAN DJAMOUS	FTTJ	12.13	15.03	CHAD
ARTURO MERINO BENITEZ INTL	SCEL	-33.39	-70.79	CHILE
CARRIEL SUR INTL	SCIE	-36.77	-73.06	CHILE
CERRO MORENO INTL	SCFA	-23.44	-70.45	CHILE
ANQING	58424	30.62	116.97	CHINA
ARXAN	50727	47.17	119.93	CHINA
BAITA	ZBHH	40.85	111.82	CHINA
BAYTIK SHAN	51288	45.37	90.53	CHINA
BEIJING - CAPITAL INTERNATIONAL AIRPORT	ZBAA	40.08	116.58	CHINA
BENGBU	58221	32.85	117.3	CHINA
BOXIAN	58102	33.78	115.73	CHINA
CHANGLE	ZSFZ	25.94	119.66	CHINA
DA-QAIDAM	52713	37.85	95.37	CHINA
EJIN QI	52267	41.95	101.07	CHINA
FUJIN	50788	47.23	131.98	CHINA
GAOPING	57411	30.75	106.13	CHINA
GARZE	56146	31.62	100	CHINA
HAIKOU	59758	20	110.25	CHINA
HAILAR	50527	49.25	119.7	CHINA
HALIUT	53336	41.57	108.52	CHINA
HARBIN	50953	45.93	126.57	CHINA
HECHI	59023	24.7	108.05	CHINA
HEZUO	56080	35	102.9	CHINA
HONGQIAO INTL	ZSSS	31.2	121.34	CHINA
HOTAN	51828	37.13	79.93	CHINA
HUADE	53391	41.9	114	CHINA

Site Name	Station ID	Lat	Lon	Country
HUOSHAN	58314	31.4	116.33	CHINA
JI'AN	57799	27.12	114.97	CHINA
KASHI	ZWSH	39.54	76.02	CHINA
KUQA	51644	41.72	82.95	CHINA
LANZHOU	52889	36.05	103.88	CHINA
LAOHEKOU	57265	32.43	111.73	CHINA
LIANGJIANG	ZGKL	25.22	110.04	CHINA
LIJING	56651	26.83	100.47	CHINA
LINDONG	54027	43.98	119.4	CHINA
LIUTING	ZSQD	36.27	120.37	CHINA
OTOG QI	53529	39.1	107.98	CHINA
RUOQIANG	51777	39.03	88.17	CHINA
SANJIAZI	ZYQQ	47.24	123.92	CHINA
SHENYANG	54342	41.73	123.52	CHINA
SHUANGLIU	ZUUU	30.58	103.95	CHINA
WUJIABA	ZPPP	24.99	102.74	CHINA
WUSU	ZBYN	37.75	112.63	CHINA
XIN BARAG YOUQI	50603	48.68	116.82	CHINA
YANCHI	53723	37.8	107.38	CHINA
YICHANG	57461	30.73	111.37	CHINA
ZHOUSHUIZI	ZYTL	38.97	121.54	CHINA
ALFONSO BONILLA ARAGON INTL	SKCL	3.54	-76.38	COLOMBIA
ELDORADO INTL	SKBO	4.7	-74.15	COLOMBIA
ERNESTO CORTISSOZ	SKBQ	10.89	-74.78	COLOMBIA
NDJILI INTL	FZAA	-4.39	15.44	CONGO, DEMOCRATIC REPUBLIC OF
JUAN SANTAMARIA INTL	MROC	9.99	-84.21	COSTA RICA
ABIDJAN FELIX HOUPHOUET BOIGNY INTL	DIAP	5.26	-3.93	COTE D'IVOIRE
GUANTANAMO BAY NS	MUGM	19.91	-75.21	CUBA
JOSE MARTI INTL	MUHA	22.99	-82.41	CUBA
LARNACA	LCLK	34.88	33.62	CYPRUS
PAFOS INTL	LCPH	34.72	32.49	CYPRUS
RUZYNE	LKPR	50.1	14.26	CZECH REPUBLIC
FLYVESTATION AALBORG	EKYT	57.09	9.85	DENMARK
KASTRUP	EKCH	55.62	12.66	DENMARK
CAMP LEMONNIER	KQRH	11.55	43.16	DJIBOUTI
DJIBOUTI AMBOULI	HDAM	11.55	43.16	DJIBOUTI
LAS AMERICAS INTL	MDSD	18.43	-69.67	DOMINICAN REPUBLIC
MARISCAL SUCRE INTL	SEQU	-0.14	-78.49	ECUADOR

Site Name	Station ID	Lat	Lon	Country
SIMON BOLIVAR INTL	SEGU	-2.16	-79.88	ECUADOR
ALEXANDRIA INTL	HEAX	31.18	29.95	EGYPT
CAIRO INTL	HECA	30.12	31.41	EGYPT
LUXOR INTL	HELX	25.67	32.71	EGYPT
ILOPANGO INTL	MSSS	13.7	-89.12	EL SALVADOR
CHUUK INTL	PTKK	7.46	151.84	FEDERATED STATES OF MICRONESIA
POHNPEI INTL	PTPN	6.99	158.21	FEDERATED STATES OF MICRONESIA
YAP INTL	PTYA	9.5	138.08	FEDERATED STATES OF MICRONESIA
NADI INTL	NFFN	-17.76	177.44	FIJI
HELSINKI VANTAA	EFHK	60.32	24.96	FINLAND
KAJAANI	EFKI	64.29	27.69	FINLAND
ARNAGE	LFRM	47.95	0.2	FRANCE
BRON	LFLY	45.73	4.94	FRANCE
CHATEAUBERNARD	LFBG	45.66	-0.32	FRANCE
COTE D AZUR	LFMN	43.66	7.22	FRANCE
LE TUBE	LFMI	43.52	4.92	FRANCE
MONT DE MARSAN	LFBM	43.91	-0.51	FRANCE
ORLY	LFPO	48.73	2.36	FRANCE
PROVENCE	LFML	43.44	5.21	FRANCE
ROCHAMBEAU	SOCA	4.82	-52.36	FRENCH GUIANA
TAHITI FAAA	NTAA	-17.55	-149.61	FRENCH POLYNESIA
LEON M BA	FOOL	0.46	9.41	GABON
BANJUL INTL	GBYD	13.34	-16.65	GAMBIA
TBILISI / LOCHINI AIRPORT	UGGG	41.75	44.77	GEORGIA
YEREVAN/YEREVAN-ARABKIR	37789	40.13	44.47	GEORGIA
ANSBACH AHP	ETEB	49.31	10.64	GERMANY
AUGSBURG	EDMA	48.43	10.93	GERMANY
BAD KREUZNACH AAF	ETEH	49.85	7.88	GERMANY
BAMBERG	10675	49.88	10.92	GERMANY
BREMEN	EDDW	53.05	8.79	GERMANY
BREMERHAVEN	10129	53.53	8.58	GERMANY
BUCHEL	ETSB	50.17	7.06	GERMANY
ERDING	ETSE	48.32	11.95	GERMANY
FRANKFURT HAHN	EDFH	49.95	7.26	GERMANY
FRANKFURT MAIN	EDDF	50.03	8.54	GERMANY
GARMISCH-PARTENKIRCHEN	10963	47.48	11.07	GERMANY
GEILENKIRCHEN	ETNG	50.96	6.04	GERMANY
GIESSEN-WETTENBERG	10532	50.6	8.65	GERMANY

Site Name	Station ID	Lat	Lon	Country
GRAFENWOHR AAF	ETIC	49.7	11.94	GERMANY
HANAU AAF	ETID	50.17	8.96	GERMANY
HANNOVER	EDDV	52.46	9.69	GERMANY
HEIDELBERG AHP	ETIE	49.39	8.65	GERMANY
IDAR-OBERSTEIN(MIL)	ETGI	49.7	7.33	GERMANY
KARLSRUHE	10727	49.03	8.37	GERMANY
KASSEL	10438	51.3	9.45	GERMANY
KITZINGEN AAF	ETIN	49.74	10.2	GERMANY
KITZINGEN(US ARMY)	10659	49.75	10.2	GERMANY
LAUTERTAL-OBERLAUTER	10671	50.3	10.97	GERMANY
LEUCHTTURM KIEL	10044	54.5	10.27	GERMANY
MANNHEIM CITY	EDFM	49.47	8.51	GERMANY
MUNCHEN	EDDM	48.35	11.79	GERMANY
NURNBERG	EDDN	49.5	11.08	GERMANY
OLDENBURG	10215	53.18	8.17	GERMANY
RAMSTEIN AB	ETAR	49.44	7.6	GERMANY
SEMBACH (USAFB)	ETAS	49.5	7.87	GERMANY
SPANGDAHLEM AB	ETAD	49.97	6.69	GERMANY
STOETTEN	10836	48.67	9.87	GERMANY
STUTTGART	EDDS	48.69	9.22	GERMANY
TEMPELHOF	EDDI	52.47	13.4	GERMANY
ULM	10838	48.38	9.95	GERMANY
WENDELSTEIN	10980	47.7	12.02	GERMANY
WIESBADEN AAF	ETOU	50.05	8.33	GERMANY
WUERZBURG	10655	49.77	9.95	GERMANY
ZWEIBRUCKEN	EDRZ	49.21	7.4	GERMANY
KOTOKA INTL	DGAA	5.61	-0.17	GHANA
AKTIO	LGPZ	38.93	20.77	GREECE
ANDRAVIDA	LGAD	37.92	21.29	GREECE
ATHINAI	LGAT	37.88	23.73	GREECE
DIAGORAS	LGRP	36.41	28.09	GREECE
ELEFSIS	LGEL	38.06	23.56	GREECE
IOANNIS KAPODISTRIAS INTL	LGKR	39.6	19.91	GREECE
LARISA	LGLR	39.65	22.47	GREECE
MAKEDONIA	LGTS	40.52	22.97	GREECE
NIKOS KAZANTZAKIS	LGIR	35.34	25.18	GREECE
SOUDA	LGSA	35.53	24.15	GREECE
SOUDA BAY (NEMOD)	EQYG	35.53	24.15	GREECE
NUUK (GODTHAAB)	4250	64.17	-51.75	GREENLAND
SONDRE STROMFJORD	BGSF	67.02	-50.69	GREENLAND

Site Name	Station ID	Lat	Lon	Country
TASIILAQ	BGAM	65.6	-37.63	GREENLAND
THULE AIR BASE	BGTL	76.53	-68.7	GREENLAND
ANDERSEN AFB	PGUA	13.58	144.93	GUAM
GUAM INTL	PGUM	13.48	144.8	GUAM
LA AURORA	MGGT	14.58	-90.53	GUATEMALA
TOUSSAINT LOUVERTURE INTL	MTPP	18.58	-72.29	HAITI
SOTO CANO AB	MHSC	14.38	-87.62	HONDURAS
TONCONTIN INTL	MHTG	14.06	-87.22	HONDURAS
HONG KONG INTL	VHHH	22.31	113.91	HONG KONG
FERIHEGY	LHBP	47.44	19.26	HUNGARY
KEFLAVIK NAS	BIKF	63.99	-22.61	ICELAND
REYKJAVIK	BIRK	64.13	-21.94	ICELAND
BEGUMPET AIRPORT	VOHY	17.45	78.46	INDIA
CHENNAI INTL	VOMM	12.99	80.18	INDIA
CHHATRAPATI SHIVAJI INTL	VABB	19.09	72.87	INDIA
NETAJI SUBHASH CHANDRA BOSE INTL	VECC	22.65	88.45	INDIA
SAFDARJUNG	VIDD	28.58	77.21	INDIA
DENPASAR NGURAH RAI	WRRR	-8.75	115.17	INDONESIA
MEHRABAD INTL	OIII	35.69	51.31	IRAN
BAGHDAD	KQTZ	33.25	44.23	IRAQ
BASRAH INTL	ORMM	30.55	47.66	IRAQ
DIWANIYA	40672	31.95	44.95	IRAQ
KIRKUK AB	ORKK	35.47	44.35	IRAQ
KUT-AL-HAI	40665	32.13	46.03	IRAQ
MOSUL	ORBM	36.31	43.15	IRAQ
NASIRIYA	40676	31.02	46.23	IRAQ
RUTBAH	40642	33.03	40.28	IRAQ
DUBLIN	EIDW	53.42	-6.27	IRELAND
SHANNON	EINN	52.7	-8.92	IRELAND
OVDA	LLOV	29.94	34.94	ISRAEL
RAMAT DAVID	LLRD	32.67	35.18	ISRAEL
SDE DOV	LLSD	32.11	34.78	ISRAEL
AVIANO AB	LIPA	46.03	12.6	ITALY
CAPODICHINO	LIRN	40.89	14.29	ITALY
CASALE	LIBR	40.66	17.95	ITALY
CIAMPINO	LIRA	41.8	12.59	ITALY
CIMONE MOUNTAIN	LIVC	44.2	10.7	ITALY
DECIMOMANNU	LIED	39.35	8.97	ITALY
ELMAS	LIEE	39.25	9.05	ITALY
GHEDI	LIPL	45.43	10.27	ITALY

Site Name	Station ID	Lat	Lon	Country
GRAZZANISE	LIRM	41.06	14.08	ITALY
LINATE	LIML	45.45	9.28	ITALY
PISA	LIRP	43.68	10.39	ITALY
RIMINI	LIPR	44.02	12.61	ITALY
SIGONELLA	LICZ	37.4	14.92	ITALY
SIGONELLA (NEMOD)	EQYS	37.4	14.9	ITALY
VENEZIA TESSERA	LIPZ	45.51	12.35	ITALY
VICENZA	LIPT	45.57	11.53	ITALY
VILLAFRANCA	LIPX	45.4	10.89	ITALY
NORMAN MANLEY INTL	MKJP	17.94	-76.79	JAMAICA
ASHIYA	RJFA	33.88	130.65	JAPAN
ATSUGI NAF	RJTA	35.45	139.45	JAPAN
FUKUOKA	47807	33.58	130.38	JAPAN
FUKUOKA	RJFF	33.59	130.45	JAPAN
FUTENMA MCAS	ROTM	26.27	127.76	JAPAN
IRUMA	RJTJ	35.84	139.41	JAPAN
IWAKUNI MCAS	RJOI	34.14	132.24	JAPAN
KADENA AB	RODN	26.36	127.77	JAPAN
MISAWA AB	RJSM	40.7	141.37	JAPAN
MORIOKA	47584	39.7	141.17	JAPAN
NAGASAKI	47817	32.73	129.87	JAPAN
NAGASAKI	RJFU	32.92	129.91	JAPAN
NAGOYA	RJNA	35.26	136.92	JAPAN
NAHA	ROAH	26.2	127.65	JAPAN
NARITA INTL	RJAA	35.76	140.39	JAPAN
NEW CHITOSE	RJCC	42.78	141.69	JAPAN
OSAKA INTL	RJOO	34.79	135.44	JAPAN
SAPPORO	47412	43.07	141.33	JAPAN
SAPPORO	RJCO	43.12	141.38	JAPAN
SASEBO	47812	33.17	129.73	JAPAN
TOKYO	RJTD	35.68	139.77	JAPAN
TOKYO INTL	RJTT	35.55	139.78	JAPAN
YOKOSUKA (NPMOF)	RJTX	35.28	139.67	JAPAN
YOKOTA AB	RJTY	35.75	139.35	JAPAN
JOHNSTON ATOLL	PJON	16.73	-169.53	JOHNSTON ATOLL
H4	OJHR	32.54	38.19	JORDAN
JERUSALEM AIRPORT	40290	31.87	35.22	JORDAN
MARKA INTL	OJAM	31.97	35.99	JORDAN
AKKUDUK	38232	42.97	54.12	KAZAKHSTAN
AKTAU	UATE	43.86	51.09	KAZAKHSTAN

Site Name	Station ID	Lat	Lon	Country
AKTYUBINSK	UATT	50.25	57.21	KAZAKHSTAN
BALHASH	35796	46.8	75.08	KAZAKHSTAN
CIRIK-RABAT	38049	44.07	62.9	KAZAKHSTAN
KOKSHETAY	28879	53.28	69.38	KAZAKHSTAN
KZYL-ORDA	UAOO	44.77	65.53	KAZAKHSTAN
NOVYJ USHTOGAN	34691	47.9	48.8	KAZAKHSTAN
SAM	35925	45.4	56.12	KAZAKHSTAN
SEMIPALATINSK	36177	50.42	80.3	KAZAKHSTAN
TAIPAK	35406	49.05	51.87	KAZAKHSTAN
TASTY	380810	44.8	69.12	KAZAKHSTAN
URALSK	UARR	51.15	51.54	KAZAKHSTAN
GARISSA	HKGA	-0.46	39.65	KENYA
MANDERA	HKMA	3.93	41.87	KENYA
MOMBASA MOI INTL	HKMO	-4.03	39.59	KENYA
NAIROBI JKIA	HKJK	-1.32	36.93	KENYA
CHONGJIN	47008	41.78	129.82	KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
KANGGYE	47020	40.97	126.6	KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
PYONGYANG INTL	ZKPY	39.22	125.67	KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
SENBONG	47003	42.32	130.4	KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
SINUIJU	47035	40.1	124.38	KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
WONSAN	47055	39.18	127.43	KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
A 511/PYEONGTAEK	RKSG	36.97	127.03	KOREA, REPUBLIC OF
ANMYEONDO	47132	36.52	126.32	KOREA, REPUBLIC OF
BAENGNYEONGDO	47102	37.97	124.63	KOREA, REPUBLIC OF
BUSAN	47159	35.1	129.03	KOREA, REPUBLIC OF
CAMP REDCLOUD/UIJD	RKSB	37.75	127.03	KOREA, REPUBLIC OF
CAMP STANLEY TMQ-53P	KQFA	37.72	127.1	KOREA, REPUBLIC OF
CHEONGJU INTL	RKTU	36.72	127.5	KOREA, REPUBLIC OF
CHUNCHEON	47101	37.9	127.73	KOREA, REPUBLIC OF
CHUPUNGNYEONG	47135	36.22	127.98	KOREA, REPUBLIC OF
DAEGU AB	RKTN	35.89	128.66	KOREA, REPUBLIC OF
GANGNEUNG	RKNN	37.75	128.94	KOREA, REPUBLIC OF

Site Name	Station ID	Lat	Lon	Country
GIMHAE INTL	RKPK	35.18	128.94	KOREA, REPUBLIC OF
GIMPO	RKSS	37.56	126.79	KOREA, REPUBLIC OF
GWANGJU	RKJJ	35.13	126.81	KOREA, REPUBLIC OF
INCHEON	47112	37.47	126.63	KOREA, REPUBLIC OF
KAESONG	47070	37.97	126.57	KOREA, REPUBLIC OF
KOREAN AF HQ	RKSF	37.5	126.92	KOREA, REPUBLIC OF
KUNSAN AB	RKJK	35.9	126.62	KOREA, REPUBLIC OF
MANGILSAN	47126	36.93	126.45	KOREA, REPUBLIC OF
MOSULPO (KOR-AFB)	RKPM	33.2	126.27	KOREA, REPUBLIC OF
OSAN AB	RKSO	37.09	127.03	KOREA, REPUBLIC OF
POHANG	RKTH	35.99	129.42	KOREA, REPUBLIC OF
SACHEON AB	RKPS	35.09	128.07	KOREA, REPUBLIC OF
SEOUL AB	RKSM	37.45	127.11	KOREA, REPUBLIC OF
SUWON	RKSW	37.24	127.01	KOREA, REPUBLIC OF
YECHEON	RKTY	36.63	128.35	KOREA, REPUBLIC OF
ALI AL SALEM	KQGV	29.33	47.52	KUWAIT
KUWAIT INTL	OKBK	29.23	47.97	KUWAIT
BISHKEK	38353	42.85	74.53	KYRGYZSTAN
GULBENE	26348	57.13	26.72	LATVIA
LIEPAJA INTL	EVLA	56.52	21.1	LATVIA
RAFIC HARIRI INTL	OLBA	33.82	35.49	LEBANON
BENINA AIRPORT	HLLB	32.1	20.27	LIBYA
TRIPOLI INTL	HLLT	32.66	13.16	LIBYA
VILNIUS INTL	EYVI	54.63	25.29	LITHUANIA
KOTA KINABALU INTL	WBKK	5.94	116.05	MALAYSIA
KUCHING INTL	WBGG	1.48	110.35	MALAYSIA
PENANG INTL	WMKP	5.3	100.28	MALAYSIA
SULTAN ABDUL AZIZ SHAH INTL	WMSA	3.13	101.55	MALAYSIA
BUCHOLZ AAF	PKWA	8.72	167.73	MARSHALL ISLAND
MARSHALL ISLANDS INTL	PKMJ	7.06	171.27	MARSHALL ISLAND
LE LAMENTIN	TFFF	14.59	-61	MARTINIQUE
NOUAKCHOTT	GQNN	18.1	-15.95	MAURITANIA
DZAOUDZI PAMANDZI	FMCZ	-12.8	45.28	MAYOTTE
LICENCIADO BENITO JUAREZ INTL	MMMX	19.44	-99.07	MEXICO
MIDWAY ATOLL	PMDY	28.2	-177.38	MIDWAY ISLANDS
CHISINAU	33815	47.02	28.98	MOLDOVA
DALANZADGAD	44373	43.58	104.42	MONGOLIA
MANDALGOBI	44341	45.77	106.28	MONGOLIA
TSETSERLEG	44282	47.45	101.47	MONGOLIA
UNDERKHAAN	44304	47.32	110.63	MONGOLIA

Site Name	Station ID	Lat	Lon	Country
PODGORICA / GOLUBOVCI	LYTI	42.37	19.25	MONTENEGRO
TIVAT	LYTV	42.4	18.72	MONTENEGRO
IBN BATOUTA	GMTT	35.73	-5.92	MOROCCO
MOHAMMED V	GMMN	33.37	-7.59	MOROCCO
SALE	GMME	34.05	-6.75	MOROCCO
MAPUTO	FQMA	-25.92	32.57	MOZAMBIQUE
HOEK VAN HOLLAND	6330	51.98	4.1	NETHERLANDS
LEEUWARDEN	EHLW	53.23	5.76	NETHERLANDS
SCHIPHOL	EHAM	52.31	4.76	NETHERLANDS
SOESTERBERG	EHSB	52.13	5.28	NETHERLANDS
VOLKEL	EHVK	51.66	5.71	NETHERLANDS
HATO	TNCC	12.19	-68.96	NETHERLANDS ANTILLES
CHRISTCHURCH INTL	NZCH	-43.49	172.53	NEW ZEALAND
WELLINGTON INTL	NZWN	-41.33	174.81	NEW ZEALAND
MANAGUA INTL	MNMG	12.14	-86.17	NICARAGUA
DIORI HAMANI	DRRN	13.48	2.18	NIGER
FRANCISCO C ADA SAIPAN INTL	PGSN	15.12	145.73	NORTHERN MARIANA ISLANDS
ANDOYA	ENAN	69.29	16.14	NORWAY
BANAK	ENNA	70.07	24.97	NORWAY
BODO	ENBO	67.27	14.37	NORWAY
FLESLAND	ENBR	60.29	5.22	NORWAY
HOYBUKTMOEN	ENKR	69.73	29.89	NORWAY
JAN MAYEN(NOR-NAVY)	ENJA	70.93	-8.67	NORWAY
ORLAND	ENOL	63.7	9.6	NORWAY
OSLO/FORNEBU	14882	59.9	10.62	NORWAY
SOLA	ENZV	58.88	5.64	NORWAY
MASIRAH	OOMA	20.68	58.89	OMAN
SEEB INTL	OOMS	23.59	58.28	OMAN
THUMRAIT	OOTH	17.67	54.02	OMAN
CHAKLALA	OPRN	33.62	73.1	PAKISTAN
JINNAH INTL	OPKC	24.91	67.16	PAKISTAN
PESHAWAR INTL	OPPS	33.99	71.51	PAKISTAN
PANAMA PACIFICO	MPPA	8.92	-79.6	PANAMA
TOCUMEN INTL	MPTO	9.07	-79.38	PANAMA
SILVIO PETTIROSSI INTL	SGAS	-25.24	-57.52	PARAGUAY
CAP FAP DAVID ABENZUR RENGIFO INTL	SPCL	-8.38	-74.57	PERU
CAPITAN MONTES	SPYL	-4.58	-81.25	PERU
CAPT JOSE A QUINONES GONZALES INTL	SPHI	-6.79	-79.83	PERU

Site Name	Station ID	Lat	Lon	Country
CORONEL FRANCISCO SECADA VIGNETTA INTL	SPQT	-3.78	-73.31	PERU
JORGE CHAVEZ INTL	SPJC	-12.02	-77.11	PERU
BAGUIO	RPUB	16.38	120.62	PHILIPPINES
CLARK INTL	RPLC	15.19	120.56	PHILIPPINES
MACTAN CEBU INTL	RPVM	10.31	123.98	PHILIPPINES
NINOY AQUINO INTL	RPLL	14.51	121.02	PHILIPPINES
SUBIC BAY INTL	RPLB	14.79	120.27	PHILIPPINES
LASK	EPLK	51.55	19.18	POLAND
OKECIE	EPWA	52.17	20.97	POLAND
LAJES	LPLA	38.76	-27.09	PORTUGAL
LISBOA	LPPT	38.78	-9.14	PORTUGAL
LUIS MUNOZ MARIN INTL	TJSJ	18.44	-66	PUERTO RICO
RAFAEL HERNANDEZ	TJBQ	18.49	-67.13	PUERTO RICO
ROOSEVELT ROADS NS	TJNR	18.25	-65.64	PUERTO RICO
AL UDEID	KQIR	25.12	51.32	QATAR
DOHA INTL	OTBD	25.26	51.57	QATAR
ST DENIS GILLOT	FMEE	-20.89	55.51	REUNION
AUREL VLAICU	LRBS	44.5	26.1	ROMANIA
CARANSEBES	LRCS	45.42	22.25	ROMANIA
CRAIOVA	LRCV	44.32	23.89	ROMANIA
DROBETA TURNU SEVERIN	15410	44.63	22.63	ROMANIA
FAGARAS	15235	45.83	24.93	ROMANIA
MIHAIL KOGALNICEANU	LRCK	44.36	28.49	ROMANIA
SATU MARE	LRSM	47.7	22.89	ROMANIA
APUKA	25956	60.43	169.67	RUSSIA
ARHARA	31594	49.42	130.08	RUSSIA
BOLSHOYE SAVINO	USPP	57.91	56.02	RUSSIA
BORZYA	30965	50.4	116.52	RUSSIA
CAPE VASILEVA	32217	50	155.38	RUSSIA
CHERNISHEVSKIJ	24724	63.03	112.48	RUSSIA
CHERTOVITSKOYE	UUOO	51.81	39.23	RUSSIA
CHOKURDAH	21946	70.62	147.88	RUSSIA
DARPIR	24598	64.17	148.03	RUSSIA
ERBOGACEN	24817	61.27	108.02	RUSSIA
GMO IM.E.K. FEDOROVA	20292	77.72	104.3	RUSSIA
HATANGA	20891	71.98	102.47	RUSSIA
ICA	32411	55.58	155.58	RUSSIA
ILYINSKIY	32121	47.98	142.2	RUSSIA
IRKUTSK	UIII	52.27	104.39	RUSSIA

Site Name	Station ID	Lat	Lon	Country
ISIT'	24951	60.82	125.32	RUSSIA
JAKUTSK	24959	62.02	129.72	RUSSIA
JUR'EVEC	27355	57.33	43.12	RUSSIA
JUZHNO-KURIL'SK	32165	44.02	145.87	RUSSIA
KALAC	34247	50.42	41.05	RUSSIA
KAMYSIN	34363	50.07	45.37	RUSSIA
KANIN NOS	22165	68.65	43.3	RUSSIA
KARASUK	29814	53.73	78.02	RUSSIA
KAZAN	UWKD	55.61	49.28	RUSSIA
KHANTY MANSIYSK	USHH	61.03	69.09	RUSSIA
KHOMUTOVO	UHSS	46.89	142.72	RUSSIA
KINGISEPP	26059	59.37	28.6	RUSSIA
KIRENSK	UIKK	57.77	108.07	RUSSIA
KLJUCHI	32389	56.32	160.83	RUSSIA
KOJNAS	22583	64.75	47.65	RUSSIA
KOLTSOVO	USSS	56.74	60.8	RUSSIA
KOTLAS	ULKK	61.23	46.72	RUSSIA
KRASNOSCEL'E	22235	67.35	37.05	RUSSIA
KYRA	30949	49.57	111.97	RUSSIA
LENSK	24923	60.72	114.88	RUSSIA
MAHACHKALA	37472	43	47.5	RUSSIA
MALYE KARMAKULY	20744	72.37	52.7	RUSSIA
MARIINSK	29551	56.18	87.68	RUSSIA
MEDVEZEGORSK	22721	62.92	34.43	RUSSIA
MUKHINO	UIUU	51.81	107.44	RUSSIA
MURMANSK	ULMM	68.78	32.75	RUSSIA
NIKOLAEVSK-ON-AMUR	UHNN	53.15	140.7	RUSSIA
NIZNE-UDINSK	UINN	54.88	99.03	RUSSIA
NJANDOMA	22854	61.67	40.18	RUSSIA
NJURBA	24639	63.28	118.33	RUSSIA
NOVY	UHHH	48.53	135.19	RUSSIA
OHOTSK	31088	59.37	143.2	RUSSIA
OLEKMINSK	24944	60.37	120.42	RUSSIA
OMSK	UNOO	54.97	73.31	RUSSIA
OSTROV DIKSON	20674	73.5	80.4	RUSSIA
PASHKOVSKIY	URKK	45.03	39.17	RUSSIA
PECHORA	23418	65.13	57.13	RUSSIA
POLARGMO IM. E.T. KRENKELJA	20046	80.62	58.05	RUSSIA
PORONAJSK	32098	49.22	143.1	RUSSIA
REMONTNOE	34759	46.57	43.67	RUSSIA

Site Name	Station ID	Lat	Lon	Country
RJAZAN'	27731	54.62	39.72	RUSSIA
SHEREMETYEVO	UUEE	55.97	37.41	RUSSIA
SKOVORODINO	30692	54	123.97	RUSSIA
SOCHI	URSS	43.45	39.96	RUSSIA
SOKOL	UHMM	59.91	150.72	RUSSIA
TAMBOV	27947	52.8	41.33	RUSSIA
TIHVIN	26094	59.65	33.55	RUSSIA
TOLMACHEVO	UNNT	55.01	82.65	RUSSIA
TROICKO-PECHERSKOE	23711	62.7	56.2	RUSSIA
TURUHANSK	23472	65.78	87.93	RUSSIA
UGOLNY	UHMA	64.73	177.74	RUSSIA
UST'-KAMCHATSK	32408	56.22	162.72	RUSSIA
VANZIL'-KYNAK	23966	60.35	84.08	RUSSIA
VERHNEE PENZINO	25538	64.22	164.23	RUSSIA
VERHOJANSK	24266	67.57	133.4	RUSSIA
VILJUJSK	24641	63.77	121.62	RUSSIA
VITIM	30054	59.45	112.58	RUSSIA
VLADIKAVKAZ	37228	43.03	44.68	RUSSIA
VLADIVOSTOK	31960	43.12	131.93	RUSSIA
ZEJA	31300	53.7	127.3	RUSSIA
ZHIGANSK	24343	66.77	123.4	RUSSIA
AL JOUF	OESK	29.79	40.1	SAUDI ARABIA
ARAR	OERR	30.91	41.14	SAUDI ARABIA
GASSIM	OEGS	26.3	43.77	SAUDI ARABIA
HAIL	OEHL	27.44	41.69	SAUDI ARABIA
KING ABDULAZIZ AB	OEDR	26.27	50.15	SAUDI ARABIA
KING ABDULAZIZ INTL	OEJN	21.68	39.16	SAUDI ARABIA
KING KHALED AB	OEKM	18.3	42.8	SAUDI ARABIA
KING KHALED INTL	OERK	24.96	46.7	SAUDI ARABIA
QAISUMAH	OEPA	28.34	46.13	SAUDI ARABIA
RAFHA	OERF	29.63	43.49	SAUDI ARABIA
RIYADH AB	OERY	24.71	46.73	SAUDI ARABIA
TABUK	OETB	28.37	36.62	SAUDI ARABIA
TURAIF	OETR	31.69	38.73	SAUDI ARABIA
WEJH	OEWJ	26.2	36.48	SAUDI ARABIA
YENBO	OEYN	24.14	38.06	SAUDI ARABIA
LEOPOLD SEDAR SENGHOR INTL	GOOY	14.74	-17.49	SENEGAL
BEOGRAD	LYBE	44.82	20.31	SERBIA
SEYCHELLES INTL	FSIA	-4.67	55.52	SEYCHELLES
PAYA LEBAR	WSAP	1.36	103.91	SINGAPORE

Site Name	Station ID	Lat	Lon	Country
BLOEMFONTEIN INTL	FABL	-29.09	26.3	SOUTH AFRICA
DURBAN INTL	FADN	-29.97	30.95	SOUTH AFRICA
JOHANNESBURG INTL	FAJS	-26.14	28.25	SOUTH AFRICA
UPINGTON	FAUP	-28.4	21.26	SOUTH AFRICA
ALICANTE	LEAL	38.28	-0.56	SPAIN
BARAJAS	LEMD	40.49	-3.57	SPAIN
BARCELONA	LEBL	41.3	2.08	SPAIN
CORDOBA	LEBA	37.84	-4.85	SPAIN
MALAGA	LEMG	36.67	-4.5	SPAIN
MENORCA	LEMH	39.86	4.22	SPAIN
MORON AB	LEMO	37.17	-5.62	SPAIN
ROTA NS	LERT	36.65	-6.35	SPAIN
SEVILLA	LEZL	37.42	-5.89	SPAIN
TORREJON	LETO	40.5	-3.45	SPAIN
VALENCIA	LEVC	39.49	-0.48	SPAIN
ZARAGOZA AB	LEZG	41.67	-1.04	SPAIN
ASCENSION AUX AF	FHAW	-7.97	-14.39	ST. HELENA
JOHAN A PENGEL INTL	SMJP	5.45	-55.19	SURINAME
ARLANDA	ESSA	59.65	17.92	SWEDEN
BROMMA	ESSB	59.35	17.94	SWEDEN
UMEA	ESNU	63.79	20.28	SWEDEN
GENEVA COINTRIN	LSGG	46.24	6.11	SWITZERLAND
ZURICH	LSZH	47.46	8.55	SWITZERLAND
ABUKMAL	40072	34.42	40.92	SYRIA
ALEPPO INTL	OSAP	36.18	37.22	SYRIA
DAMASCUS INTL	OSDI	33.41	36.52	SYRIA
CHIAYI	RCKU	23.46	120.39	TAIWAN
CHING CHUAN KANG AB	RCMQ	24.26	120.62	TAIWAN
SUNGSHAN	RCSS	25.07	121.55	TAIWAN
TAICHUNG	RCLG	24.19	120.65	TAIWAN
TAINAN	RCNN	22.95	120.21	TAIWAN
DUSHANBE	UTDD	38.54	68.83	TAJIKISTAN
KHUDJANT	38599	40.22	69.73	TAJIKISTAN
MWALIMU JULIUS K NYERERE INTL	HTDA	-6.88	39.2	TANZANIA
BANGKOK INTL	VTBD	13.91	100.61	THAILAND
CHIANG MAI INTL	VTCC	18.77	98.96	THAILAND
KHORAT	VTUN	14.93	102.08	THAILAND
NAKHON PHANOM	48357	17.42	104.78	THAILAND
UBON RATCHATHANI	VTUU	15.25	104.87	THAILAND
UDON THANI	VTUD	17.39	102.79	THAILAND

Site Name	Station ID	Lat	Lon	Country
SKOPJE	LWSK	41.96	21.62	The Former Yugoslav Republic of Macedonia
PIARCO	TTPP	10.6	-61.34	TRINIDAD AND TOBAGO
BABELTHUAP / KOROR AIRPORT	PTRO	7.37	134.54	TRUST TERRITORY OF THE PACIFIC ISLANDS (PALAU)
CARTHAGE	DTTA	36.85	10.23	TUNISIA
ANTALYA	LTAI	36.9	30.8	TURKEY
ATATURK	LTBA	40.98	28.82	TURKEY
BALIKESIR	LTBF	39.62	27.93	TURKEY
CIGLI	LTBL	38.51	27.01	TURKEY
DIYARBAKIR	LTCC	37.89	40.2	TURKEY
ERHAC	LTAT	38.44	38.09	TURKEY
ESENBOGA	LTAC	40.13	33	TURKEY
ESKISEHIR	LTBI	39.78	30.58	TURKEY
GOLCUK/DUMLUPINAR	17067	40.67	29.83	TURKEY
INCIRLIK AB	LTAG	37	35.43	TURKEY
KONYA	LTAN	37.98	32.56	TURKEY
SAMSUN	17030	41.28	36.3	TURKEY
SINOP	17026	42.03	35.17	TURKEY
TRABZON	LTCG	41	39.79	TURKEY
VAN	LTCI	38.47	43.33	TURKEY
ASHGABAT	UTAA	37.99	58.36	TURKMENISTAN
BAJRAMALY	38895	37.6	62.18	TURKMENISTAN
CHARDZHEV	38687	39.08	63.6	TURKMENISTAN
DARGANATA	38545	40.47	62.28	TURKMENISTAN
DASHKHOVUZ	38392	41.83	59.98	TURKMENISTAN
EKEZHE	38388	41.03	57.77	TURKMENISTAN
ESENGULY	38750	37.47	53.97	TURKMENISTAN
GYSHGY	38987	35.28	62.35	TURKMENISTAN
KERKI	38911	37.83	65.2	TURKMENISTAN
TURKMENBASHI	38507	40.03	52.98	TURKMENISTAN
IZIUM	34415	49.18	37.3	UKRAINE
KONOTOP	33261	51.23	33.2	UKRAINE
KRYVYI RIH	33791	48.03	33.22	UKRAINE
ODESA INTL	UKOO	46.43	30.68	UKRAINE
YALTA	33990	44.48	34.17	UKRAINE
ZHULIANY INTL	UKKK	50.4	30.45	UKRAINE
ABU DHABI INTL	OMAA	24.43	54.65	UNITED ARAB EMIRATES

Site Name	Station ID	Lat	Lon	Country
DUBAI INTL	OMDB	25.25	55.36	UNITED ARAB EMIRATES
BENSON	EGUB	51.62	-1.1	UNITED KINGDOM
BENTWATERS RAF	EGVJ	52.13	1.43	UNITED KINGDOM
BRIZE NORTON	EGVN	51.75	-1.58	UNITED KINGDOM
CHURCH LAWFORD	3544	52.37	-1.33	UNITED KINGDOM
DYCE	EGPD	57.2	-2.2	UNITED KINGDOM
EDINBURGH	EGPH	55.95	-3.37	UNITED KINGDOM
FAIRFORD	EGVA	51.68	-1.79	UNITED KINGDOM
FYLINGDALES	3281	54.37	-0.67	UNITED KINGDOM
GATWICK	EGKK	51.15	-0.19	UNITED KINGDOM
HEATHROW	EGLL	51.48	-0.46	UNITED KINGDOM
LAKENHEATH	EGUL	52.41	0.56	UNITED KINGDOM
LEUCHARS	EGQL	56.37	-2.87	UNITED KINGDOM
MILDENHALL	EGUN	52.36	0.49	UNITED KINGDOM
NORTHOLT	EGWU	51.55	-0.42	UNITED KINGDOM
PRESTWICK	EGPK	55.51	-4.59	UNITED KINGDOM
WOODBRIDGE RAF	EGVG	52.08	1.4	UNITED KINGDOM
ALAMEDA/NAS CA.	74506	37.78	-122.32	UNITED STATES
BRAINERD BRAINERD-CROW WING COU	KBRD	46.4	-94.13	UNITED STATES
CAPE HATTERAS NC.	72304	35.27	-75.55	UNITED STATES
FT. RICHARDSON/BRYANT AHP AK	70270	61.27	-149.65	UNITED STATES
GOODLAND/RENNER FIELD/GOODLAND/MUN. KS.	72465	39.37	-101.68	UNITED STATES
RUMFORD ME.	72618	44.53	-70.53	UNITED STATES
SAN CLEMENTE NAVAL AUXILIARY LA	KNUC	33.02	-118.58	UNITED STATES
ADAK	PADK	51.88	-176.65	UNITED STATES - AK
ALLEN AAF	PABI	63.99	-145.72	UNITED STATES - AK
ANIAK	PANI	61.58	-159.54	UNITED STATES - AK
ANNETTE ISLAND	PANT	55.04	-131.57	UNITED STATES - AK
BARTER ISLAND LRRS	PABA	70.13	-143.58	UNITED STATES - AK
BETHEL	PABE	60.78	-161.84	UNITED STATES - AK
BETTLES	PABT	66.91	-151.53	UNITED STATES - AK
CAPE LISBURNE LRRS	PALU	68.88	-166.11	UNITED STATES - AK
CAPE NEWENHAM LRRS	PAEH	58.65	-162.06	UNITED STATES - AK
CAPE ROMANZOF LRRS	PACZ	61.78	-166.04	UNITED STATES - AK
COLD BAY	PACD	55.21	-162.72	UNITED STATES - AK
DEADHORSE	PASC	70.19	-148.47	UNITED STATES - AK
EARECKSON AS	PASY	52.71	174.11	UNITED STATES - AK
EDWARD G PITKA SR	PAGA	64.74	-156.94	UNITED STATES - AK
EIELSON AFB	PAEI	64.67	-147.1	UNITED STATES - AK

Site Name	Station ID	Lat	Lon	Country
ELMENDORF AFB	PAED	61.25	-149.81	UNITED STATES - AK
FAIRBANKS INTL	PAFA	64.82	-147.86	UNITED STATES - AK
FORT YUKON	PFYU	66.57	-145.25	UNITED STATES - AK
GULKANA	PAGK	62.15	-145.46	UNITED STATES - AK
HOMER	PAHO	59.65	-151.48	UNITED STATES - AK
ILIAMNA	PAIL	59.75	-154.91	UNITED STATES - AK
INDIAN MOUNTAIN LRRS	PAIM	65.99	-153.7	UNITED STATES - AK
JUNEAU INTL	PAJN	58.35	-134.58	UNITED STATES - AK
KENAI MUNI	PAEN	60.57	-151.24	UNITED STATES - AK
KING SALMON	PAKN	58.68	-156.65	UNITED STATES - AK
KODIAK	PADQ	57.75	-152.49	UNITED STATES - AK
MCGRATH	PAMC	62.97	-155.62	UNITED STATES - AK
MERLE K MUDHOLE SMITH	PACV	60.49	-145.48	UNITED STATES - AK
MERRILL FLD	PAMR	61.21	-149.84	UNITED STATES - AK
MIDDLETON ISLAND	PAMD	59.45	-146.31	UNITED STATES - AK
NENANA MUNI	PANN	64.55	-149.07	UNITED STATES - AK
NOME	PAOM	64.51	-165.45	UNITED STATES - AK
NORTHWAY	PAOR	62.96	-141.93	UNITED STATES - AK
PORT HEIDEN	PAPH	56.96	-158.63	UNITED STATES - AK
RALPH WIEN MEM	PAOT	66.88	-162.6	UNITED STATES - AK
SITKA ROCKY GUTIERREZ	PASI	57.05	-135.36	UNITED STATES - AK
SPARREVOHN LRRS	PASV	61.1	-155.57	UNITED STATES - AK
ST PAUL ISLAND	PASN	57.17	-170.22	UNITED STATES - AK
TATALINA LRRS	PATL	62.89	-155.98	UNITED STATES - AK
TED STEVENS ANCHORAGE INTL	PANC	61.17	-150	UNITED STATES - AK
TIN CITY LRRS	PATC	65.56	-167.92	UNITED STATES - AK
UNALAKLEET	PAUN	63.89	-160.8	UNITED STATES - AK
UNALASKA	PADU	53.9	-166.54	UNITED STATES - AK
WAINWRIGHT AAF	PAFB	64.83	-147.62	UNITED STATES - AK
WHITTIER	PAWR	60.77	-148.68	UNITED STATES - AK
WILEY POST WILL ROGERS MEM	PABR	71.29	-156.77	UNITED STATES - AK
YAKUTAT	PAYA	59.5	-139.65	UNITED STATES - AK
ANNISTON METRO	KANB	33.59	-85.86	UNITED STATES - AL
BIRMINGHAM INTL	KBHM	33.56	-86.75	UNITED STATES - AL
CAIRNS AAF	KOZR	31.28	-85.71	UNITED STATES - AL
DOTHAN RGNL	KDHN	31.32	-85.45	UNITED STATES - AL
HUNTSVILLE INTL CARL T JONES FLD	KHSV	34.64	-86.78	UNITED STATES - AL
MAXWELL AFB	KMXF	32.38	-86.37	UNITED STATES - AL
MOBILE DOWNTOWN	KBFM	30.63	-88.07	UNITED STATES - AL
MOBILE RGNL	KMOB	30.69	-88.24	UNITED STATES - AL

Site Name	Station ID	Lat	Lon	Country
MONTGOMERY RGNL	KMGM	32.3	-86.39	UNITED STATES - AL
NORTHWEST ALABAMA RGNL	KMSL	34.75	-87.61	UNITED STATES - AL
TUSCALOOSA RGNL	KTCL	33.22	-87.61	UNITED STATES - AL
ARKANSAS INTL	KBYH	35.96	-89.94	UNITED STATES - AR
BOONE CO	KHRO	36.26	-93.15	UNITED STATES - AR
DRAKE FLD	KFYV	36.01	-94.17	UNITED STATES - AR
FORT SMITH RGNL	KFSM	35.34	-94.37	UNITED STATES - AR
GRIDER FLD	KPBF	34.17	-91.94	UNITED STATES - AR
LITTLE ROCK AFB	KLRF	34.92	-92.15	UNITED STATES - AR
MEMORIAL FLD	KHOT	34.48	-93.1	UNITED STATES - AR
SOUTH ARKANSAS RGNL AT GOODWIN FLD	KELD	33.22	-92.81	UNITED STATES - AR
TEXARKANA RGNL WEBB FLD	KTXK	33.45	-93.99	UNITED STATES - AR
DAVIS MONTHAN AFB	KDMA	32.17	-110.88	UNITED STATES - AZ
FLAGSTAFF PULLIAM	KFLG	35.14	-111.67	UNITED STATES - AZ
LUKE AFB	KLUF	33.53	-112.38	UNITED STATES - AZ
PHOENIX SKY HARBOR INTL	KPHX	33.43	-112.01	UNITED STATES - AZ
SIERRA VISTA MUNI LIBBY AAF / FT HUACHUCA	KFHU	31.58	-110.35	UNITED STATES - AZ
TUCSON INTL	KTUS	32.12	-110.94	UNITED STATES - AZ
WINSLOW LINDBERGH RGNL	KINW	35.02	-110.72	UNITED STATES - AZ
YUMA MCAS YUMA INTL	KYUM	32.66	-114.61	UNITED STATES - AZ
ARCATA	KACV	40.98	-124.11	UNITED STATES - CA
BARSTOW DAGGETT	KDAG	34.85	-116.79	UNITED STATES - CA
BEALE AFB	KBAB	39.14	-121.44	UNITED STATES - CA
BLUE CANYON NYACK	KBLU	39.27	-120.71	UNITED STATES - CA
CAMP PENDLETON MCAS	KNFG	33.3	-117.36	UNITED STATES - CA
CASTLE	KMER	37.38	-120.57	UNITED STATES - CA
CHINA LAKE NAWS	KNID	35.69	-117.69	UNITED STATES - CA
EDWARDS AFB	KEDW	34.92	-117.87	UNITED STATES - CA
EL TORO MCAS	KNZJ	33.67	-117.73	UNITED STATES - CA
FRESNO YOSEMITE INTL	KFAT	36.78	-119.72	UNITED STATES - CA
HAYWARD HAYWARD AIR TERMINAL	KHWD	37.66	-122.12	UNITED STATES - CA
IMPERIAL CO	KIPL	32.83	-115.58	UNITED STATES - CA
JACK MC NAMARA FLD	KCEC	41.78	-124.24	UNITED STATES - CA
JOHN WAYNE ARPT ORANGE CO	KSNA	33.68	-117.87	UNITED STATES - CA
LAKE TAHOE	KTVL	38.9	-120	UNITED STATES - CA
LEMOORE NAS	KNLC	36.33	-119.95	UNITED STATES - CA
LONG BEACH	KLGB	33.82	-118.15	UNITED STATES - CA
LOS ANGELES INTL	KLAX	33.94	-118.41	UNITED STATES - CA

Site Name	Station ID	Lat	Lon	Country
MARCH ARB	KRIV	33.88	-117.26	UNITED STATES - CA
MARINA MUNI	KOAR	36.68	-121.76	UNITED STATES - CA
MCCLELLAN AFLD	KMCC	38.67	-121.4	UNITED STATES - CA
MEADOWS FLD	KBFL	35.43	-119.06	UNITED STATES - CA
METROPOLITAN OAKLAND INTL	KOAK	37.72	-122.22	UNITED STATES - CA
MOFFETT FEDERAL AFLD	KNUQ	37.42	-122.05	UNITED STATES - CA
MONTEREY PENINSULA	KMRY	36.59	-121.84	UNITED STATES - CA
NORMAN Y MINETA SAN JOSE INTL	KSJC	37.36	-121.93	UNITED STATES - CA
NORTH ISLAND NAS	KNZY	32.7	-117.22	UNITED STATES - CA
ONTARIO INTL	KONT	34.06	-117.6	UNITED STATES - CA
OXNARD AIRPORT	KOXR	34.2	-119.21	UNITED STATES - CA
PASO ROBLES MUNI	KPRB	35.67	-120.63	UNITED STATES - CA
POINT MUGU NAS	KNTD	34.12	-119.12	UNITED STATES - CA
POINT PIEDRAS BLANCA	K87Q	35.67	-121.28	UNITED STATES - CA
RED BLUFF MUNI	KRBL	40.15	-122.25	UNITED STATES - CA
SACRAMENTO EXECUTIVE	KSAC	38.51	-121.49	UNITED STATES - CA
SACRAMENTO MATHER AIRPORT	KMHR	38.56	-121.3	UNITED STATES - CA
SAN BERNARDINO INTL	KSBD	34.1	-117.23	UNITED STATES - CA
SAN DIEGO INTL	KSAN	32.73	-117.19	UNITED STATES - CA
SAN DIEGO/MIRAMAR NAS CA.	72293	32.83	-117.12	UNITED STATES - CA
SAN FRANCISCO INTL	KSFO	37.62	-122.37	UNITED STATES - CA
SANDBERG	KSDB	34.74	-118.72	UNITED STATES - CA
SANTA BARBARA MUNI	KSBA	34.43	-119.84	UNITED STATES - CA
SISKIYOU CO	KSIY	41.78	-122.47	UNITED STATES - CA
SOUTHERN CALIFORNIA LOGISTICS	KVCV	34.6	-117.38	UNITED STATES - CA
STOCKTON METROPOLITAN	KSCK	37.89	-121.24	UNITED STATES - CA
TRAVIS AFB	KSUU	38.26	-121.93	UNITED STATES - CA
TUSTIN MCAS	KNTK	33.7	-117.83	UNITED STATES - CA
TWENTYNINE PALMS EAF	KNXP	34.3	-116.16	UNITED STATES - CA
USMC MTN WARFARE TRAINING CENTER	KBAN	38.35	-119.52	UNITED STATES - CA
VANDENBERG AFB	KVBG	34.74	-120.58	UNITED STATES - CA
BUCKLEY AFB	KBKF	39.7	-104.75	UNITED STATES - CO
BUTTS AAF	KFCS	38.68	-104.76	UNITED STATES - CO
CITY OF COLORADO SPRINGS MUNI	KCOS	38.81	-104.7	UNITED STATES - CO
DENVER/STAPLETON INT	72469	39.75	-104.87	UNITED STATES - CO
LA JUNTA MUNI	KLHX	38.05	-103.51	UNITED STATES - CO
PERRY STOKES	KTAD	37.26	-104.34	UNITED STATES - CO
PUEBLO MEM	KPUB	38.29	-104.5	UNITED STATES - CO
WALKER FLD	KGJT	39.12	-108.53	UNITED STATES - CO
BRADLEY INTL	KBDL	41.94	-72.68	UNITED STATES - CT

Site Name	Station ID	Lat	Lon	Country
GROTON NEW LONDON	KGON	41.33	-72.05	UNITED STATES - CT
HARTFORD BRAINARD	KHFD	41.74	-72.65	UNITED STATES - CT
IGOR I SIKORSKY MEM	KBDR	41.16	-73.13	UNITED STATES - CT
RONALD REAGAN WASHINGTON NATL	KDCA	38.85	-77.04	UNITED STATES - DC
WASHINGTON DULLES INTL	KIAD	38.94	-77.46	UNITED STATES - DC
DOVER AFB	KDOV	39.13	-75.47	UNITED STATES - DE
NEW CASTLE	KILG	39.68	-75.61	UNITED STATES - DE
APALACHICOLA MUNI	KAAF	29.73	-85.03	UNITED STATES - FL
CAPE CANAVERAL AFS SKID STRIP	KXMR	28.47	-80.57	UNITED STATES - FL
CRAIG MUNI	KCRG	30.34	-81.51	UNITED STATES - FL
DAYTONA BEACH INTL	KDAB	29.18	-81.06	UNITED STATES - FL
EGLIN AFB	KVPS	30.48	-86.53	UNITED STATES - FL
FORT LAUDERDALE HOLLYWOOD INTL	KFLL	26.07	-80.15	UNITED STATES - FL
GAINESVILLE RGNL	KGNV	29.69	-82.27	UNITED STATES - FL
HOMESTEAD ARB	KHST	25.49	-80.38	UNITED STATES - FL
HURLBURT FLD	KHRT	30.43	-86.69	UNITED STATES - FL
JACKSONVILLE CECIL FIELD AIRPORT	KVQQ	30.22	-81.88	UNITED STATES - FL
JACKSONVILLE INTL	KJAX	30.49	-81.69	UNITED STATES - FL
JACKSONVILLE NAS	KNIP	30.24	-81.68	UNITED STATES - FL
KENDALL TAMIAMI EXECUTIVE	KTMB	25.65	-80.43	UNITED STATES - FL
KEY WEST INTL	KEYW	24.56	-81.76	UNITED STATES - FL
KEY WEST NAS	KNQX	24.58	-81.69	UNITED STATES - FL
MACDILL AFB	KMCF	27.85	-82.52	UNITED STATES - FL
MAYPORT NS	KNRB	30.39	-81.42	UNITED STATES - FL
MELBOURNE INTL	KMLB	28.1	-80.65	UNITED STATES - FL
MIAMI INTL	KMIA	25.79	-80.29	UNITED STATES - FL
NASA SHUTTLE LANDING FACILITY	KTTS	28.61	-80.69	UNITED STATES - FL
ORLANDO INTL	KMCO	28.43	-81.31	UNITED STATES - FL
PAGE FLD	KFMY	26.59	-81.86	UNITED STATES - FL
PALM BEACH INTL	KPBI	26.68	-80.1	UNITED STATES - FL
PATRICK AFB	KCOF	28.25	-80.62	UNITED STATES - FL
PENSACOLA NAS	KNPA	30.35	-87.32	UNITED STATES - FL
PENSACOLA RGNL	KPNS	30.47	-87.19	UNITED STATES - FL
ST PETERSBURG CLEARWATER INTL	KPIE	27.91	-82.69	UNITED STATES - FL
TALLAHASSEE RGNL	KTLH	30.4	-84.35	UNITED STATES - FL
TAMPA INTL	KTPA	27.98	-82.53	UNITED STATES - FL
TYNDALL AFB	KPAM	30.07	-85.58	UNITED STATES - FL
VERO BEACH MUNI	KVRB	27.66	-80.42	UNITED STATES - FL
WHITING FLD NAS NORTH	KNSE	30.72	-87.02	UNITED STATES - FL
AUGUSTA RGNL AT BUSH FLD	KAGS	33.37	-81.96	UNITED STATES - GA

Site Name	Station ID	Lat	Lon	Country
COLUMBUS METROPOLITAN	KCSG	32.52	-84.94	UNITED STATES - GA
DOBBINS ARB	KMGE	33.92	-84.52	UNITED STATES - GA
HARTSFIELD JACKSON ATLANTA INTL	KATL	33.64	-84.43	UNITED STATES - GA
HUNTER AAF	KSVN	32.01	-81.15	UNITED STATES - GA
LAWSON AAF	KLSF	32.34	-84.99	UNITED STATES - GA
MALCOLM MCKINNON	KSSI	31.15	-81.39	UNITED STATES - GA
MIDDLE GEORGIA RGNL	KMCN	32.69	-83.65	UNITED STATES - GA
MOODY AFB	KVAD	30.97	-83.19	UNITED STATES - GA
RICHARD B RUSSELL	KRMG	34.35	-85.16	UNITED STATES - GA
ROBINS AFB	KWRB	32.64	-83.59	UNITED STATES - GA
SAVANNAH HILTON HEAD INTL	KSAV	32.13	-81.2	UNITED STATES - GA
SOUTHWEST GEORGIA RGNL	KABY	31.54	-84.19	UNITED STATES - GA
WRIGHT AAF	KLHW	31.89	-81.56	UNITED STATES - GA
HILO INTL	PHTO	19.72	-155.05	UNITED STATES - HI
HONOLULU INTL	PHNL	21.32	-157.92	UNITED STATES - HI
KAHULUI	PHOG	20.9	-156.43	UNITED STATES - HI
KALAELOA	PHJR	21.31	-158.07	UNITED STATES - HI
KANEOHE BAY MCAF	PHNG	21.45	-157.77	UNITED STATES - HI
LIHUE	PHLI	21.98	-159.34	UNITED STATES - HI
WHEELER AAF	PHHI	21.48	-158.04	UNITED STATES - HI
DES MOINES INTL	KDSM	41.53	-93.66	UNITED STATES - IA
FORT DODGE RGNL	KFOD	42.55	-94.19	UNITED STATES - IA
MASON CITY MUNI	KMCW	43.16	-93.33	UNITED STATES - IA
SIOUX GATEWAY COL BUD DAY FLD	KSUX	42.4	-96.38	UNITED STATES - IA
SOUTHEAST IOWA RGNL	KBRL	40.78	-91.13	UNITED STATES - IA
THE EASTERN IOWA	KCID	41.88	-91.71	UNITED STATES - IA
WATERLOO RGNL	KALO	42.56	-92.4	UNITED STATES - IA
BOISE AIR TERMINAL	KBOI	43.56	-116.22	UNITED STATES - ID
COEUR D ALENE AIR TERMINAL	KCOE	47.77	-116.82	UNITED STATES - ID
IDAHO FALLS RGNL	KIDA	43.51	-112.07	UNITED STATES - ID
LEWISTON NEX PERCE CO	KLWS	46.37	-117.02	UNITED STATES - ID
MOUNTAIN HOME AFB	KMUO	43.04	-115.87	UNITED STATES - ID
POCATELLO RGNL	KPIH	42.91	-112.6	UNITED STATES - ID
ABRAHAM LINCOLN CAPITAL	KSPI	39.84	-89.68	UNITED STATES - IL
CHICAGO MIDWAY INTL	KMDW	41.79	-87.75	UNITED STATES - IL
CHICAGO OHARE INTL	KORD	41.98	-87.9	UNITED STATES - IL
DECATUR	KDEC	39.83	-88.87	UNITED STATES - IL
DUPAGE	KDPA	41.91	-88.25	UNITED STATES - IL
GLENVIEW NAS	KNBU	42.08	-87.82	UNITED STATES - IL
GREATER PEORIA RGNL	KPIA	40.66	-89.69	UNITED STATES - IL

Site Name	Station ID	Lat	Lon	Country
QUAD CITY INTL	KMLI	41.45	-90.51	UNITED STATES - IL
SCOTT AFB MIDAMERICA	KBLV	38.55	-89.84	UNITED STATES - IL
UNIV OF ILLINOIS WILLARD	KCMI	40.04	-88.28	UNITED STATES - IL
EVANSVILLE RGNL	KEVV	38.04	-87.53	UNITED STATES - IN
FORT WAYNE INTL	KFWA	40.98	-85.2	UNITED STATES - IN
GRISSOM ARB	KGUS	40.65	-86.15	UNITED STATES - IN
INDIANAPOLIS INTL	KIND	39.72	-86.29	UNITED STATES - IN
SOUTH BEND RGNL	KSBN	41.71	-86.32	UNITED STATES - IN
TERRE HAUTE INTL HULMAN FLD	KHUF	39.45	-87.31	UNITED STATES - IN
CHANUTE MARTIN JOHNSON	KCNU	37.67	-95.49	UNITED STATES - KS
DODGE CITY RGNL	KDDC	37.76	-99.97	UNITED STATES - KS
FORBES FLD	KFOE	38.95	-95.66	UNITED STATES - KS
HUTCHINSON MUNI	KHUT	38.07	-97.86	UNITED STATES - KS
MARSHALL AAF	KFRI	39.06	-96.76	UNITED STATES - KS
MCCONNELL AFB	KIAB	37.62	-97.27	UNITED STATES - KS
PHILIP BILLARD MUNI	KTOP	39.07	-95.62	UNITED STATES - KS
SALINA MUNI	KSLN	38.79	-97.65	UNITED STATES - KS
WICHITA MID CONTINENT	KICT	37.65	-97.43	UNITED STATES - KS
BLUE GRASS	KLEX	38.04	-84.61	UNITED STATES - KY
CAMPBELL AAF	KHOP	36.67	-87.5	UNITED STATES - KY
CINCINNATI NORTHERN KENTUCKY INTL	KCVG	39.05	-84.67	UNITED STATES - KY
GODMAN AAF	KFTK	37.91	-85.97	UNITED STATES - KY
LOUISVILLE INTL STANDIFORD FLD	KSDF	38.17	-85.74	UNITED STATES - KY
ALEXANDRIA INTL	KAEX	31.33	-92.55	UNITED STATES - LA
BARKSDALE AFB	KBAD	32.5	-93.66	UNITED STATES - LA
BATON ROUGE METRO RYAN FLD	KBTR	30.53	-91.15	UNITED STATES - LA
ESLER RGNL	KESF	31.39	-92.3	UNITED STATES - LA
LAFAYETTE RGNL	KLFT	30.21	-91.99	UNITED STATES - LA
LAKE CHARLES RGNL	KLCH	30.13	-93.22	UNITED STATES - LA
LAKEFRONT	KNEW	30.04	-90.03	UNITED STATES - LA
LOUIS ARMSTRONG NEW ORLEANS INTL	KMSY	29.99	-90.26	UNITED STATES - LA
MONROE RGNL	KMLU	32.51	-92.04	UNITED STATES - LA
NEW ORLEANS NAS JRB	KNBG	29.83	-90.03	UNITED STATES - LA
POLK AAF	KPOE	31.04	-93.19	UNITED STATES - LA
SHREVEPORT RGNL	KSHV	32.45	-93.83	UNITED STATES - LA
BARNES MUNI	KBAF	42.16	-72.72	UNITED STATES - MA
GENERAL EDWARD LAWRENCE LOGAN INTL	KBOS	42.36	-71.01	UNITED STATES - MA
LAURENCE G HANSCOM FLD	KBED	42.47	-71.29	UNITED STATES - MA
NANTUCKET MEM	KACK	41.25	-70.06	UNITED STATES - MA

Site Name	Station ID	Lat	Lon	Country
OTIS AIR NATIONAL GUARD BASE	KFMH	41.65	-70.52	UNITED STATES - MA
SOUTH WEYMOUTH NAS	KNZW	42.15	-70.93	UNITED STATES - MA
WESTOVER ARB METROPOLITAN	KCEF	42.19	-72.53	UNITED STATES - MA
WORCESTER RGNL	KORH	42.27	-71.88	UNITED STATES - MA
ANDREWS AFB	KADW	38.81	-76.87	UNITED STATES - MD
BALTIMORE WASHINGTON INTL	KBWI	39.18	-76.67	UNITED STATES - MD
HAGERSTOWN RGNL RICHARD A HENSON FLD	KHGR	39.71	-77.73	UNITED STATES - MD
PATUXENT RIVER NAS	KNHK	38.29	-76.41	UNITED STATES - MD
AUGUSTA STATE	KAUG	44.32	-69.8	UNITED STATES - ME
BANGOR INTL	KBGR	44.81	-68.83	UNITED STATES - ME
BRUNSWICK NAS	KNHZ	43.89	-69.94	UNITED STATES - ME
LORING INTL	ME16	46.95	-67.89	UNITED STATES - ME
PORTLAND INTL JETPORT	KPWM	43.65	-70.31	UNITED STATES - ME
ALPENA CO RGNL	KAPN	45.08	-83.56	UNITED STATES - MI
BISHOP INTL	KFNT	42.97	-83.74	UNITED STATES - MI
CAPITAL CITY	KLAN	42.78	-84.59	UNITED STATES - MI
CHERRY CAPITAL	KTVC	44.74	-85.58	UNITED STATES - MI
COLEMAN A YOUNG MUNI	KDET	42.41	-83.01	UNITED STATES - MI
GERALD R FORD INTL	KGRR	42.88	-85.52	UNITED STATES - MI
HOUGHTON CO MEM	KCMX	47.17	-88.49	UNITED STATES - MI
JACKSON CO REYNOLDS FLD	KJXN	42.26	-84.46	UNITED STATES - MI
MARQUETTE CO. ARPT	KMQT	46.53	-87.55	UNITED STATES - MI
MUSKEGON CO	KMKG	43.17	-86.24	UNITED STATES - MI
OSCODA WURTSMITH	KOSC	44.45	-83.39	UNITED STATES - MI
PELLSTON RGNL ARPT OF EMMET CO	KPLN	45.57	-84.8	UNITED STATES - MI
ROSCOMMON CO	KHTL	44.36	-84.67	UNITED STATES - MI
SAULT STE MARIE MUNI SANDERSON FLD	KANJ	46.48	-84.37	UNITED STATES - MI
SAWYER INTL	KSAW	46.35	-87.4	UNITED STATES - MI
SELFRIDGE ANGB	KMTC	42.61	-82.83	UNITED STATES - MI
W K KELLOGG	KBTL	42.31	-85.25	UNITED STATES - MI
BEMIDJI RGNL	KBJI	47.51	-94.93	UNITED STATES - MN
DULUTH INTL	KDLH	46.84	-92.19	UNITED STATES - MN
FALLS INTL	KINL	48.57	-93.4	UNITED STATES - MN
MINNEAPOLIS ST PAUL INTL	KMSP	44.88	-93.22	UNITED STATES - MN
ROCHESTER INTL	KRST	43.91	-92.5	UNITED STATES - MN
COLUMBIA RGNL	KCOU	38.82	-92.22	UNITED STATES - MO
JEFFERSON CITY MEM	KJEF	38.59	-92.16	UNITED STATES - MO
JOPLIN RGNL	KJLN	37.15	-94.5	UNITED STATES - MO
KANSAS CITY INTL	KMCI	39.3	-94.71	UNITED STATES - MO

Site Name	Station ID	Lat	Lon	Country
LAMBERT ST LOUIS INTL	KSTL	38.75	-90.36	UNITED STATES - MO
RICHARDS-GEBAUR AP	KGVW	38.85	-94.55	UNITED STATES - MO
ROSECRANS MEM	KSTJ	39.77	-94.91	UNITED STATES - MO
SPIRIT OF ST LOUIS	KSUS	38.66	-90.65	UNITED STATES - MO
SPRINGFIELD BRANSON RGNL	KSGF	37.25	-93.39	UNITED STATES - MO
WAYNESVILLE RGNL ARPT AT FORNEY FLD	KTBN	37.74	-92.14	UNITED STATES - MO
WHITEMAN AFB	KSZL	38.73	-93.55	UNITED STATES - MO
COLUMBUS AFB	KCBM	33.65	-88.45	UNITED STATES - MS
GULFPORT BILOXI INTL	KGPT	30.41	-89.07	UNITED STATES - MS
HATTIESBURG LAUREL RGNL	KPIB	31.47	-89.34	UNITED STATES - MS
JACKSON EVERS INTL	KJAN	32.31	-90.08	UNITED STATES - MS
KEESLER AFB	KBIX	30.41	-88.92	UNITED STATES - MS
KEY FLD	KMEI	32.33	-88.75	UNITED STATES - MS
MCCOMB PIKE CO JOHN E LEWIS FLD	KMCB	31.18	-90.47	UNITED STATES - MS
MERIDIAN NAS	KNMM	32.55	-88.56	UNITED STATES - MS
TUPELO RGNL	KTUP	34.27	-88.77	UNITED STATES - MS
BERT MOONEY	KBTM	45.95	-112.5	UNITED STATES - MT
BILLINGS LOGAN INTL	KBIL	45.81	-108.54	UNITED STATES - MT
CUT BANK MUNI	KCTB	48.61	-112.38	UNITED STATES - MT
FRANK WILEY FLD	KMLS	46.43	-105.89	UNITED STATES - MT
GLACIER PARK INTL	KGPI	48.31	-114.26	UNITED STATES - MT
GREAT FALLS INTL	KGTF	47.48	-111.37	UNITED STATES - MT
HAVRE CITY CO	KHVR	48.54	-109.76	UNITED STATES - MT
HELENA RGNL	KHLN	46.61	-111.98	UNITED STATES - MT
LEWISTOWN MUNI	KLWT	47.05	-109.47	UNITED STATES - MT
MALMSTROM AFHP	KGFA	47.5	-111.19	UNITED STATES - MT
MISSOULA INTL	KMSO	46.92	-114.09	UNITED STATES - MT
WOKAL FLD GLASGOW INTL	KGGW	48.21	-106.61	UNITED STATES - MT
ALBERT J ELLIS	KOAJ	34.83	-77.61	UNITED STATES - NC
ASHEVILLE RGNL	KAVL	35.44	-82.54	UNITED STATES - NC
CHARLOTTE DOUGLAS INTL	KCLT	35.21	-80.94	UNITED STATES - NC
CHERRY POINT MCAS	KNKT	34.9	-76.88	UNITED STATES - NC
MACKALL AAF	KHFF	35.04	-79.5	UNITED STATES - NC
NEW RIVER MCAS	KNCA	34.71	-77.44	UNITED STATES - NC
PIEDMONT TRIAD INTL	KGSO	36.1	-79.94	UNITED STATES - NC
POPE FIELD	KPOB	35.17	-79.01	UNITED STATES - NC
RALEIGH DURHAM INTL	KRDU	35.88	-78.79	UNITED STATES - NC
SEYMOUR JOHNSON AFB	KGSB	35.34	-77.96	UNITED STATES - NC
SIMMONS AAF	KFBG	35.13	-78.94	UNITED STATES - NC
BISMARCK MUNI	KBIS	46.77	-100.75	UNITED STATES - ND

Site Name	Station ID	Lat	Lon	Country
DICKINSON THEODORE ROOSEVELT RGNL	KDIK	46.8	-102.8	UNITED STATES - ND
GRAND FORKS AFB	KRDR	47.96	-97.4	UNITED STATES - ND
HECTOR INTL	KFAR	46.92	-96.82	UNITED STATES - ND
MINOT AFB	KMIB	48.42	-101.36	UNITED STATES - ND
CENTRAL NEBRASKA RGNL	KGRI	40.97	-98.31	UNITED STATES - NE
EPPLEY AFLD	KOMA	41.3	-95.89	UNITED STATES - NE
LINCOLN	KLNK	40.85	-96.76	UNITED STATES - NE
NORTH PLATTE RGNL ARPT LEE BIRD FLD	KLBF	41.13	-100.68	UNITED STATES - NE
OFFUTT AFB	KOFF	41.12	-95.91	UNITED STATES - NE
WESTERN NEB RGNL WILLIAM B HEILIG FLD	KBFF	41.87	-103.6	UNITED STATES - NE
CONCORD MUNI	KCON	43.2	-71.5	UNITED STATES - NH
LEBANON MUNI	KLEB	43.63	-72.3	UNITED STATES - NH
MANCHESTER	KMHT	42.93	-71.44	UNITED STATES - NH
MOUNT WASHINGTON	KMWN	44.27	-71.3	UNITED STATES - NH
PEASE INTL TRADEPORT	KPSM	43.08	-70.82	UNITED STATES - NH
ATLANTIC CITY INTL	KACY	39.46	-74.58	UNITED STATES - NJ
LAKEHURST NAES	KNEL	40.03	-74.35	UNITED STATES - NJ
MCGUIRE AFB	KWRI	40.02	-74.59	UNITED STATES - NJ
NEWARK LIBERTY INTL	KEWR	40.69	-74.17	UNITED STATES - NJ
TETERBORO	KTEB	40.85	-74.06	UNITED STATES - NJ
TRENTON MERCER	KTTN	40.28	-74.81	UNITED STATES - NJ
ALBUQUERQUE INTL	KABQ	35.04	-106.61	UNITED STATES - NM
CANNON AFB	KCVS	34.39	-103.31	UNITED STATES - NM
CAVERN CITY AIR TERMINAL	KCNM	32.34	-104.26	UNITED STATES - NM
FOUR CORNERS RGNL	KFMN	36.74	-108.23	UNITED STATES - NM
GALLUP MUNI	KGUP	35.51	-108.79	UNITED STATES - NM
HOLLOMAN AFB	KHMN	32.85	-106.11	UNITED STATES - NM
ROSWELL INTL AIR CENTER	KROW	33.3	-104.53	UNITED STATES - NM
TUCUMCARI MUNI	KTCC	35.18	-103.6	UNITED STATES - NM
WHITE SANDS NM.	72269	32.38	-106.48	UNITED STATES - NM
DESERT ROCK	KDRA	36.62	-116.03	UNITED STATES - NV
ELKO RGNL	KEKO	40.82	-115.79	UNITED STATES - NV
ELY ARPT YELLAND FLD	KELY	39.3	-114.84	UNITED STATES - NV
MCCARRAN INTL	KLAS	36.08	-115.15	UNITED STATES - NV
NELLIS AFB	KLSV	36.24	-115.03	UNITED STATES - NV
RENO TAHOE INTL	KRNO	39.5	-119.77	UNITED STATES - NV
TONOPAH	KTPH	38.06	-117.09	UNITED STATES - NV
WINNEMUCCA MUNI	KWMC	40.9	-117.81	UNITED STATES - NV
ALBANY INTL	KALB	42.75	-73.8	UNITED STATES - NY

Site Name	Station ID	Lat	Lon	Country
BUFFALO NIAGARA INTL	KBUF	42.94	-78.73	UNITED STATES - NY
CHAUTAUQUA CO JAMESTOWN	KJHW	42.15	-79.26	UNITED STATES - NY
DUTCHESS CO	KPOU	41.63	-73.88	UNITED STATES - NY
FLOYD BENNETT MEM	KGFL	43.34	-73.61	UNITED STATES - NY
GREATER BINGHAMTON EDWIN A LINK FLD	KBGM	42.21	-75.98	UNITED STATES - NY
GREATER ROCHESTER INTL	KROC	43.12	-77.67	UNITED STATES - NY
GRIFFISS AFB/ROME	KRME	43.23	-75.41	UNITED STATES - NY
JOHN F KENNEDY INTL	KJFK	40.64	-73.78	UNITED STATES - NY
LA GUARDIA	KLGA	40.78	-73.87	UNITED STATES - NY
LONG ISLAND MAC ARTHUR	KISP	40.8	-73.1	UNITED STATES - NY
NIAGARA FALLS INTL	KIAG	43.11	-78.95	UNITED STATES - NY
ONEIDA CO	KUCA	43.15	-75.38	UNITED STATES - NY
PLATTSBURGH AFB	KPBG	44.65	-73.47	UNITED STATES - NY
STEWART INTL	KSWF	41.5	-74.1	UNITED STATES - NY
SYRACUSE HANCOCK INTL	KSYR	43.11	-76.11	UNITED STATES - NY
WATERTOWN INTL	KART	43.98	-76.02	UNITED STATES - NY
WESTCHESTER CO	KHPN	41.07	-73.71	UNITED STATES - NY
WHEELER SACK AAF	KGTB	44.06	-75.72	UNITED STATES - NY
AKRON CANTON RGNL	KCAK	40.92	-81.44	UNITED STATES - OH
CINCINNATI MUNI LUNKEN FLD	KLUK	39.1	-84.42	UNITED STATES - OH
CLEVELAND HOPKINS INTL	KCLE	41.41	-81.85	UNITED STATES - OH
JAMES M COX DAYTON INTL	KDAY	39.9	-84.22	UNITED STATES - OH
MANSFIELD LAHM RGNL	KMFD	40.82	-82.52	UNITED STATES - OH
PORT COLUMBUS INTL	KCMH	40	-82.89	UNITED STATES - OH
RICKENBACKER INTL	KLCK	39.81	-82.93	UNITED STATES - OH
TOLEDO EXPRESS	KTOL	41.59	-83.81	UNITED STATES - OH
WRIGHT PATTERSON AFB	KFFO	39.83	-84.05	UNITED STATES - OH
YOUNGSTOWN WARREN RGNL	KYNG	41.26	-80.68	UNITED STATES - OH
ZANESVILLE MUNI	KZZV	39.94	-81.89	UNITED STATES - OH
ALTUS AFB	KLTS	34.67	-99.27	UNITED STATES - OK
HENRY POST AAF	KFSI	34.65	-98.4	UNITED STATES - OK
MCALESTER RGNL	KMLC	34.88	-95.78	UNITED STATES - OK
TINKER AFB	KTIK	35.41	-97.39	UNITED STATES - OK
TULSA INTL	KTUL	36.2	-95.89	UNITED STATES - OK
VANCE AFB	KEND	36.34	-97.92	UNITED STATES - OK
WILL ROGERS WORLD	KOKC	35.39	-97.6	UNITED STATES - OK
ASTORIA RGNL	KAST	46.16	-123.88	UNITED STATES - OR
BURNS MUNI	KBNO	43.59	-118.96	UNITED STATES - OR
EASTERN OREGON RGNL AT PENDLETON	KPDT	45.7	-118.84	UNITED STATES - OR

Site Name	Station ID	Lat	Lon	Country
KLAMATH FALLS	KLMT	42.16	-121.73	UNITED STATES - OR
MAHLON SWEET FLD	KEUG	44.12	-123.21	UNITED STATES - OR
MCNARY FLD	KSLE	44.91	-123	UNITED STATES - OR
NORTH BEND MUNI	KOTH	43.42	-124.25	UNITED STATES - OR
PORTLAND INTL	KPDX	45.59	-122.6	UNITED STATES - OR
ROBERTS FLD AIRPORT	KRDM	44.25	-121.15	UNITED STATES - OR
ROGUE VALLEY INTL MEDFORD	KMFR	42.37	-122.87	UNITED STATES - OR
SEXTON SUMMIT	KSXT	42.6	-123.36	UNITED STATES - OR
ALTOONA BLAIR CO	KAOO	40.3	-78.32	UNITED STATES - PA
DU BOIS JEFFERSON CO	KDUJ	41.18	-78.9	UNITED STATES - PA
HARRISBURG INTL	KMDT	40.19	-76.76	UNITED STATES - PA
JOHN MURTHA JOHNSTOWN CAMBRIA CO	KJST	40.32	-78.83	UNITED STATES - PA
LEHIGH VALLEY INTL	KABE	40.65	-75.44	UNITED STATES - PA
NORTHEAST PHILADELPHIA	KPNE	40.08	-75.01	UNITED STATES - PA
PHILADELPHIA INTL	KPHL	39.87	-75.24	UNITED STATES - PA
PITTSBURGH INTL	KPIT	40.49	-80.23	UNITED STATES - PA
WILKES BARRE SCRANTON INTL	KAVP	41.34	-75.72	UNITED STATES - PA
WILLIAMSPORT RGNL	KIPT	41.24	-76.92	UNITED STATES - PA
WILLOW GROVE NAS JRB	KNXX	40.2	-75.15	UNITED STATES - PA
QUONSET STATE	KOQU	41.6	-71.41	UNITED STATES - RI
THEODORE FRANCIS GREEN STATE	KPVD	41.73	-71.42	UNITED STATES - RI
BEAUFORT MCAS	KNBC	32.48	-80.72	UNITED STATES - SC
CHARLESTON AFB INTL	KCHS	32.9	-80.04	UNITED STATES - SC
COLUMBIA METROPOLITAN	KCAE	33.94	-81.12	UNITED STATES - SC
FLORENCE RGNL	KFLO	34.19	-79.72	UNITED STATES - SC
GREENVILLE SPARTANBURG INTL	KGSP	34.9	-82.22	UNITED STATES - SC
MCENTIRE JNGB	KMMT	33.92	-80.8	UNITED STATES - SC
MYRTLE BEACH INTL	KMYR	33.68	-78.93	UNITED STATES - SC
ORANGEBURG MUNI	KOGB	33.46	-80.86	UNITED STATES - SC
SHAW AFB	KSSC	33.97	-80.47	UNITED STATES - SC
ABERDEEN RGNL	KABR	45.45	-98.42	UNITED STATES - SD
ELLSWORTH AFB	KRCA	44.15	-103.1	UNITED STATES - SD
HURON RGNL	KHON	44.39	-98.23	UNITED STATES - SD
JOE FOSS FLD	KFSD	43.58	-96.74	UNITED STATES - SD
PIERRE RGNL	KPIR	44.38	-100.29	UNITED STATES - SD
RAPID CITY RGNL	KRAP	44.05	-103.06	UNITED STATES - SD
LOVELL FLD	KCHA	35.04	-85.2	UNITED STATES - TN
MCGHEE TYSON	KTYS	35.81	-83.99	UNITED STATES - TN
MCKELLAR SIPES RGNL	KMKL	35.6	-88.92	UNITED STATES - TN

Site Name	Station ID	Lat	Lon	Country
MEMPHIS INTL	KMEM	35.04	-89.98	UNITED STATES - TN
MEMPHIS NAS	723345	35.35	-89.87	UNITED STATES - TN
NASHVILLE INTL	KBNA	36.12	-86.68	UNITED STATES - TN
TRI CITIES RGNL TN VA	KTRI	36.48	-82.41	UNITED STATES - TN
ABILENE RGNL	KABI	32.41	-99.68	UNITED STATES - TX
ANGELINA CO	KLFK	31.23	-94.75	UNITED STATES - TX
AUSTIN BERGSTROM INTL	KAUS	30.19	-97.67	UNITED STATES - TX
BERGSTROM AFB/AUSTI	KBSM	30.2	-97.68	UNITED STATES - TX
BROWNSVILLE SOUTH PADRE ISLAND INTL	KBRO	25.91	-97.43	UNITED STATES - TX
CHASE NAS/BEEVILLE	KNIR	28.37	-97.67	UNITED STATES - TX
CORPUS CHRISTI INTL	KCRP	27.77	-97.5	UNITED STATES - TX
CORPUS CHRISTI NAS	KNGP	27.69	-97.29	UNITED STATES - TX
DALLAS (NAS)	KNBE	32.73	-96.97	UNITED STATES - TX
DALLAS FORT WORTH INTL	KDFW	32.9	-97.04	UNITED STATES - TX
DALLAS LOVE FLD	KDAL	32.85	-96.85	UNITED STATES - TX
DEL RIO INTL	KDRT	29.37	-100.93	UNITED STATES - TX
DYESS AFB	KDYS	32.42	-99.85	UNITED STATES - TX
EL PASO INTL	KELP	31.81	-106.38	UNITED STATES - TX
ELLINGTON FLD	KEFD	29.61	-95.16	UNITED STATES - TX
FORT WORTH NAS JRB	KNFW	32.77	-97.44	UNITED STATES - TX
GEORGE BUSH INTCNTL HOUSTON	KIAH	29.98	-95.34	UNITED STATES - TX
HOOD AAF	KHLR	31.15	-97.72	UNITED STATES - TX
KINGSVILLE NAS	KNQI	27.51	-97.81	UNITED STATES - TX
LACKLAND AFB KELLY FLD ANNEX	KSKF	29.38	-98.58	UNITED STATES - TX
LAUGHLIN AFB	KDLF	29.36	-100.78	UNITED STATES - TX
LUBBOCK PRESTON SMITH INTL	KLBB	33.66	-101.82	UNITED STATES - TX
MIDLAND INTL	KMAF	31.94	-102.2	UNITED STATES - TX
RANDOLPH AFB	KRND	29.53	-98.28	UNITED STATES - TX
REESE AFB/LUBBOCK	KREE	33.6	-102.05	UNITED STATES - TX
RICK HUSBAND AMARILLO INTL	KAMA	35.22	-101.71	UNITED STATES - TX
ROBERT GRAY AAF	KGRK	31.07	-97.83	UNITED STATES - TX
SAN ANGELO RGNL MATHIS FLD	KSJT	31.36	-100.5	UNITED STATES - TX
SAN ANTONIO INTL	KSAT	29.53	-98.47	UNITED STATES - TX
SCHOLES INTL AT GALVESTON	KGLS	29.27	-94.86	UNITED STATES - TX
SHEPPARD AFB WICHITA FALLS MUNI	KSPS	33.99	-98.49	UNITED STATES - TX
SOUTHEAST TEXAS RGNL	KBPT	29.95	-94.02	UNITED STATES - TX
TYLER POUNDS RGNL	KTYR	32.35	-95.4	UNITED STATES - TX
WACO RGNL	KACT	31.61	-97.23	UNITED STATES - TX
CEDAR CITY RGNL	KCDC	37.7	-113.1	UNITED STATES - UT
HILL AFB	KHIF	41.12	-111.97	UNITED STATES - UT

Site Name	Station ID	Lat	Lon	Country
PROVO MUNI	KPVU	40.22	-111.72	UNITED STATES - UT
SALT LAKE CITY INTL	KSLC	40.79	-111.98	UNITED STATES - UT
WENDOVER	KENV	40.72	-114.03	UNITED STATES - UT
CHARLOTTESVILLE ALBEMARLE	KCHO	38.14	-78.45	UNITED STATES - VA
DANVILLE RGNL	KDAN	36.57	-79.34	UNITED STATES - VA
DAVISON AAF	KDAA	38.72	-77.18	UNITED STATES - VA
FELKER AAF	KFAF	37.13	-76.61	UNITED STATES - VA
LANGLEY AFB	KLFI	37.08	-76.36	UNITED STATES - VA
NEWPORT NEWS WILLIAMSBURG INTL	KPHF	37.13	-76.49	UNITED STATES - VA
NORFOLK INTL	KORF	36.89	-76.2	UNITED STATES - VA
NORFOLK NS	KNGU	36.94	-76.29	UNITED STATES - VA
OCEANA NAS	KNTU	36.82	-76.03	UNITED STATES - VA
QUANTICO MCAF	KNYG	38.5	-77.31	UNITED STATES - VA
RICHMOND INTL	KRIC	37.51	-77.32	UNITED STATES - VA
ROANOKE RGNL WOODRUM FLD	KROA	37.33	-79.98	UNITED STATES - VA
WALLOPS FLIGHT FACILITY	KWAL	37.94	-75.47	UNITED STATES - VA
BURLINGTON INTL	KBTV	44.47	-73.15	UNITED STATES - VT
BELLINGHAM INTL	KBLI	48.79	-122.54	UNITED STATES - WA
BOEING FLD KING CO INTL	KBFI	47.53	-122.3	UNITED STATES - WA
BREMERTON NATIONAL	KPWT	47.49	-122.76	UNITED STATES - WA
FAIRCHILD AFB	KSKA	47.62	-117.66	UNITED STATES - WA
FELTS FLD	KSFF	47.68	-117.32	UNITED STATES - WA
GRAY AAF	KGRF	47.08	-122.58	UNITED STATES - WA
HANFORD	KHMS	46.57	-119.6	UNITED STATES - WA
KELSO LONGVIEW	KKLS	46.12	-122.9	UNITED STATES - WA
MCCHORD FIELD	KTCM	47.13	-122.48	UNITED STATES - WA
OLYMPIA	KOLM	46.97	-122.9	UNITED STATES - WA
PANGBORN MEM	KEAT	47.4	-120.21	UNITED STATES - WA
QUILLAYUTE	KUIL	47.94	-124.56	UNITED STATES - WA
SEATTLE TACOMA INTL	KSEA	47.45	-122.31	UNITED STATES - WA
SNOHOMISH CO	KPAE	47.91	-122.28	UNITED STATES - WA
SPOKANE INTL	KGEG	47.62	-117.53	UNITED STATES - WA
WALLA WALLA RGNL	KALW	46.09	-118.29	UNITED STATES - WA
WHIDBEY ISLAND NAS	KNUW	48.35	-122.66	UNITED STATES - WA
WILLIAM R FAIRCHILD INTL	KCLM	48.12	-123.5	UNITED STATES - WA
YAKIMA AIR TERMINAL MC ALLISTER FLD	KYKM	46.57	-120.54	UNITED STATES - WA
AUSTIN STRAUBEL INTL	KGRB	44.49	-88.13	UNITED STATES - WI
CHIPPEWA VALLEY RGNL	KEAU	44.87	-91.48	UNITED STATES - WI
DANE CO RGNL TRUAX FLD	KMSN	43.14	-89.34	UNITED STATES - WI
GENERAL MITCHELL INTL	KMKE	42.95	-87.9	UNITED STATES - WI

Site Name	Station ID	Lat	Lon	Country
LA CROSSE MUNI	KLSE	43.88	-91.26	UNITED STATES - WI
EASTERN WV RGNL SHEPHERD FLD	KMRB	39.4	-77.98	UNITED STATES - WV
HARRISON MARION RGNL	KCKB	39.3	-80.23	UNITED STATES - WV
MERCER CO	KBLF	37.3	-81.21	UNITED STATES - WV
MID OHIO VALLEY RGNL	KPKB	39.35	-81.44	UNITED STATES - WV
MORGANTOWN MUNI WALTER L BILL HART FLD	KMGW	39.64	-79.92	UNITED STATES - WV
RALEIGH CO MEM	KBKW	37.79	-81.12	UNITED STATES - WV
TRI STATE MILTON J FERGUSON FLD	KHTS	38.37	-82.56	UNITED STATES - WV
WHEELING OHIO CO	KHLG	40.17	-80.65	UNITED STATES - WV
YEAGER	KCRW	38.37	-81.59	UNITED STATES - WV
CHEYENNE RGNL JERRY OLSON FLD	KCYS	41.16	-104.81	UNITED STATES - WY
EVANSTON UINTA CO BURNS FLD	KEVW	41.27	-111.03	UNITED STATES - WY
HUNT FLD	KLND	42.82	-108.73	UNITED STATES - WY
NATRONA CO INTL	KCPR	42.91	-106.46	UNITED STATES - WY
ROCK SPRINGS SWEETWATER CO	KRKS	41.59	-109.07	UNITED STATES - WY
SHERIDAN CO	KSHR	44.77	-106.98	UNITED STATES - WY
CARRASCO INTL	SUMU	-34.84	-56.03	URUGUAY
KARSHI	38812	38.8	65.72	UZBEKISTAN
SAMARKAND	UTSS	39.7	66.98	UZBEKISTAN
TERMEZ	UTST	37.29	67.31	UZBEKISTAN
YUZHNY	UTTT	41.26	69.28	UZBEKISTAN
ALBERTO CARNEVALLI	SVMD	8.58	-71.16	VENEZUELA
BARQUISIMETO INTL	SVBM	10.04	-69.36	VENEZUELA
GENERAL JOSE ANTONIO ANZOATEGUI INTL	SVBC	10.11	-64.69	VENEZUELA
SAN ANTONIO DEL TACHIRA	SVSA	7.84	-72.44	VENEZUELA
SIMON BOLIVAR INTL	SVMI	10.6	-66.99	VENEZUELA
DANANG INTL	VVDN	16.04	108.2	VIETNAM
NOIBAI INTL	VVNB	21.22	105.81	VIETNAM
TANSONNHAT INTL	VVTS	10.82	106.65	VIETNAM
WAKE ISLAND AFLD	PWAK	19.28	166.64	WAKE ISLAND
HARARE INTL	FVHA	-17.93	31.09	ZIMBABWE

UFC 3-401-01
1 July 2013
Change 1, October 2015

UNIFIED FACILITIES CRITERIA (UFC)

MECHANICAL ENGINEERING

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

MECHANICAL ENGINEERING

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location
1	October 2015	Changes to Chapters 1, 2 and Appendix A in response to Criteria Change Requests (CCRs) and Tri-Service reviews.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force \2\ Civil Engineer Center (AFCEC) /2/ are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 3-401-01, *Mechanical Engineering*

Superseding: None

Description: This UFC is the core document for the mechanical discipline. It is intended as a reference for all mechanical work. It is organized to provide the top-level minimum mandatory mechanical design and analysis requirements and refers to other criteria as appropriate.

Reasons for Document:

- This new UFC provides a central point reference for all mechanical design criteria.
- Establishes minimum design analysis and drawing requirements in support of design activities
- Helps direct designers to the appropriate mechanical discipline criteria document.

Impact:

- There are negligible cost impacts. Creation of a single-source reference for mechanical design discipline helps clarify requirements for the design of DoD facilities.

Unification Issues:

- The Navy uses MO-230, *Petroleum Fuel Facilities* for maintenance of petroleum fuel systems while the Air Force and Army use UFC 3-460-03, *O&M: Maintenance of Petroleum Systems*. There is a project pending by the tri-service Fuel Facility Engineering Panel to unify these documents.
- The Navy uses UFC 3-430-08N, *Central Heating Plants* for design of central heating plants while the Army and Air Force use 3-430-02FA, *Central Steam Boiler Plants*. There is an ongoing Army project to update and unify these documents.

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TABLES

CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facility Criteria (UFC) provides requirements and guidance for mechanical systems designed and constructed for the Department of Defense (DoD) together with criteria for selecting mechanical system materials and equipment. This information must be used by mechanical engineers to develop design calculations, specifications, plans, and design-build Requests for Proposal (RFPs) and must serve as the minimum mechanical design requirements.

This UFC is provided to ensure quality and consistency in design of mechanical systems with minimum life cycle costs which satisfy the functional and operational requirements of DoD facilities and which provide a healthy and safe environment for facility occupants. This UFC is intended as a reference for all mechanical work. Figure 1-1 shows the relationship of this UFC to other related mechanical UFCs.

1-2 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design and construction of Department of Defense (DoD) facilities worldwide.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, General Building Requirements. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance, sustainability, and safety. Use this UFC in addition to UFC 1-200-01 and the government criteria referenced therein.

1-4 REFERENCES.

Appendix A contains a list of references used in this document.

1-5 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

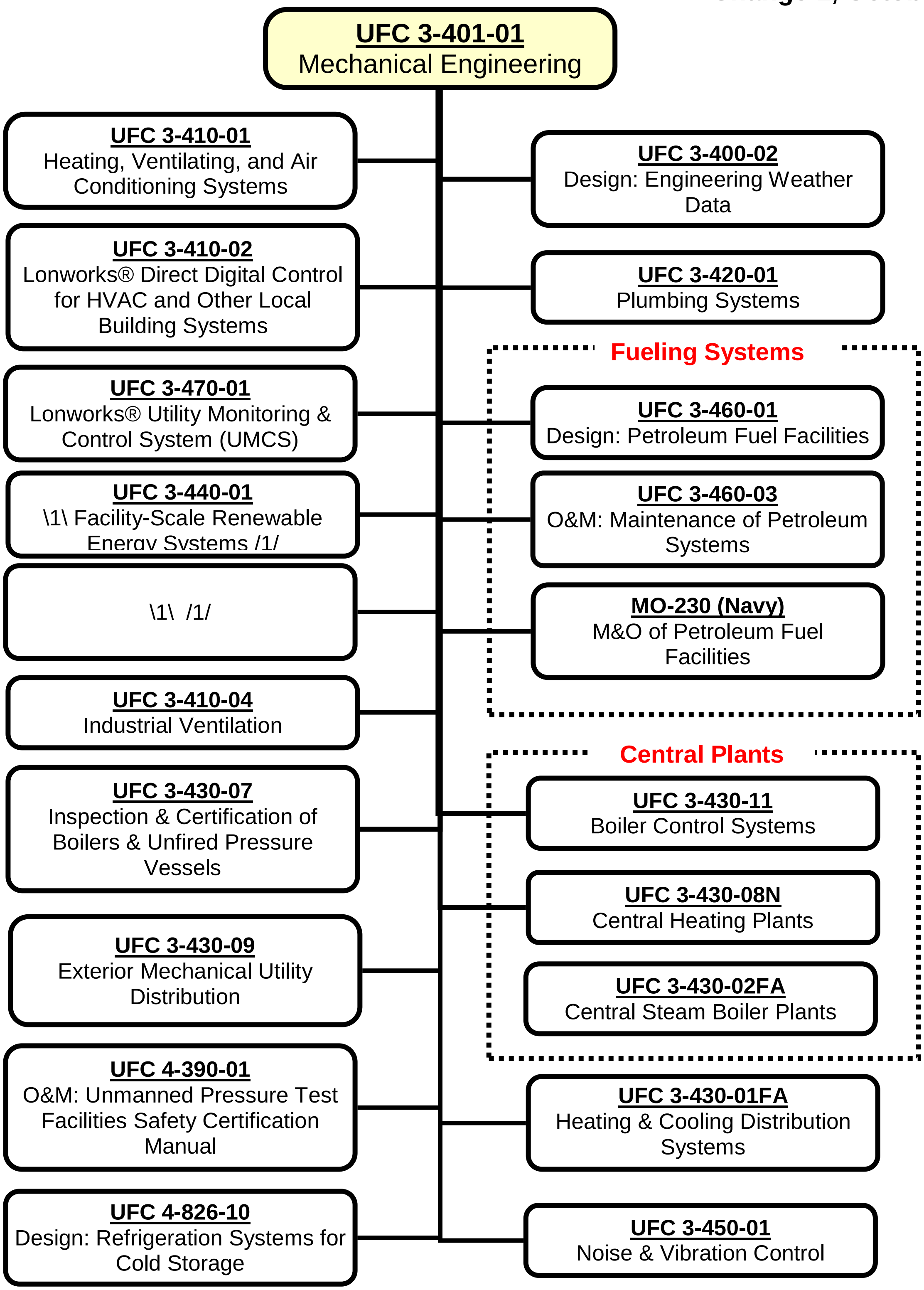

Figure 1-1 Mechanical UFC Delineation

CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 BASIC PRINCIPLES.

2-1.1 Life Cycle Considerations.

Energy and water-efficient and sustainable design attributes for military construction must be based on the cost-benefit analysis, return on investment, total ownership costs, and demonstrated payback. Provide mechanical systems based on achieving the lowest life cycle cost of the approved alternatives. Ensure that all operation and maintenance costs are included in any life cycle cost analysis. Follow procedures for Life Cycle Cost Analysis (LCCA) stated in UFC 1-200-02. HVAC system (including fuel source) preliminary design must be determined at the concept stage justified by a LCCA.

2-1.2 Maintainability.

Maintainability and reliability are paramount to the operation of DoD buildings. Mechanical equipment not required to be located outside must be located in an equipment room. All mechanical equipment must be based on a minimum of three manufacturers. Catalog cuts from those three manufacturers must be included in the mechanical design analysis. Size the mechanical room to accommodate the space required to house all equipment and piping. A three dimensional envelope must be shown on the mechanical drawings for each item of equipment showing the maximum dimensions of those three manufacturers including the space necessary for maintenance and replacement. Verify adequate door dimensions to permit passage of equipment into mechanical spaces. Provide system designs with the features necessary for easy access for maintenance and for successful testing, adjusting, balancing, and system commissioning. Provide protection for equipment materials located in corrosive environments.

2-1.3 Seismic Protection

Design mechanical systems with respect to seismic protection in accordance with UFC 3-310-04. Provide details to structural engineer for support verification and sizing.

2-1.4 Weather Data

Weather data needed for design calculations and analysis must be obtained from UFC 3-400-02.

2-1.5 Conflicts in Design

Avoid conflicts with other disciplines and building features.

2-1.6 Conflicts in Criteria.

Where, in any specific case, different sections of any mechanical UFC or referenced standards specify different materials, methods of construction or other requirements, the most restrictive requirement will govern.

2-1.7 Specifications

All projects including DBB and DB will use the applicable UFGS as part of the design and construction documentation. \1\ Construction specifications projects shall require all materials to be protected from moisture and conditions that have potential to result in deterioration of material properties or in mold growth during site storage and construction. Protective measures must be taken to ensure that the construction process adequately shelters the materials to prevent mold growth and material degradation during construction. /1/

2-2 ASSOCIATED MECHANICAL SYSTEMS CRITERIA.

2-2.1 Facility Plumbing Systems

Design and construct plumbing systems for facilities in accordance with this document and the current issue of UFC 3-420-01. \1\ When solar preheat and heating of domestic hot water is shown to be LCC effective, systems must be in accordance with UFC 3-440-01. /1/

2-2.2 Facility HVAC Systems and Controls.

Design and construct Heating, Ventilating, and Air Conditioning (HVAC) systems for facilities in accordance with this document and the current issues of UFC 3-410-01. \1\ Insulate piping with an operating temperature below dewpoint with jacketed insulation meeting the cold piping requirements. The insulation jacket must be sealed to provide an exterior vapor barrier. /1/

2-2.3 Utility Monitoring and Control Systems.

Utility Monitoring and Control System Front Ends must be designed and constructed in accordance with UFC 3-470-01 and UFGS 25 10 10*.*

2-2.4 Exterior Mechanical Distribution Systems.

Design and construct all exterior steam, chilled water, and hot water distribution systems in accordance with this document and UFC 3-430-01FA.

2-2.5 Petroleum Fuel Systems.

Design and construct petroleum fueling systems in accordance with this document and the current issue of UFC 3-460-01. Provisions for maintenance of fueling facilities must be provided in accordance with UFC 3-460-03 for the **Air Force** and **Army**. The maintenance aspects of Navy fuel facilities must follow MO-230.

2-2.6 Industrial Ventilation Systems.

Design industrial ventilation systems in accordance with UFC 3-410-04. Provide air flow and static pressure calculations with each design.

Mechanical requirements for stationary battery installations that do not perform battery maintenance must be designed in accordance with UFC 3-520-05.

2-2.7 Compressed Air Systems.

Design and construct exterior compressed air distribution systems in accordance with this document and the current issue of UFC 3-430-09. Interior distribution must be designed and constructed in accordance with the Compressed Air and Gas Institute's Compressed Air and Gas Handbook and the ASME BPVC (Boiler and Pressure Vessel Codes)***.***

2-2.8 Refrigeration Systems for Cold Storage Facilities.

Design and construct refrigeration systems for cold storage facilities in accordance with this document, UFC 3-410-01 and the current issue of UFC 4-826-10.

2-2.9 Central Plants.

Design and construct central heating plants in accordance with this document and the current issue of UFC 3-430-08N for the **Navy** or 3-430-02FA for the **Army** and **Air Force**.

When a central plant is provided to serve multiple buildings, meter all utility services (gas, oil, steam, chilled, and hot water) at the central plant (both supply and return) and at each building served (supply only). Provide flow and temperature measurement for steam, chilled and hot water demand and measure BTU for energy consumption.

2-2.10 Mechanical Systems for Health Care Facilities.

Mechanical system designs for health care facilities will be in accordance with the current issue of UFC 4-510-01.

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CHAPTER 3 DOCUMENTATION REQUIREMENTS

3-1 DESIGN ANALYSIS.

The Design Analysis must be submitted at a preliminary design stage equivalent to 35% design for concurrence of the results. The Design Analysis must consist of a Basis of Design Narrative and Calculations. The analysis must be updated as necessary as the design progresses. The results of this analysis are used for design decision-making in reducing total life cycle cost, while meeting mission objectives.

3-1.1 Basis of Design Narrative.

Provide a Basis of Design narrative as part of all design analysis.

3-1.1.1 User Requirements.

Document ventilation, temperature and humidity requirements, occupancies, functions, usage schedules, equipment loads, and exhaust requirements by space.

3-1.1.2 Criteria / Codes.

Identify the governing codes and criteria utilized for the design. Include the titles and the date of the applicable edition or publication.

3-1.1.3 Site Conditions.

Conduct detailed field investigation and interview the appropriate field personnel. Do not rely solely on the as-built drawings.

Determine energy sources available at the project site. Describe the source of thermal energy that will be used (i.e. Extension of central high pressure steam, hot water, natural gas, or stand alone heat source with the type of fuel utilized). Use fuel conversion factors provided in Appendix B for the analysis.

3-1.1.4 System Selection.

Provide a narrative description of all system alternatives considered. Describe in detail all systems and components selected at a preliminary design stage equivalent to 35% design to include the results of the LCCA and modeled energy use.

3-1.1.5 Special Mechanical Systems

Provide a description of special mechanical systems such as compressed air, hydraulic, nitrogen, lubrication oil, etc.

3-1.1.6 Other Basis of Design Narrative Requirements.

Provide any additional basis of design documentation as required by the specific mechanical UFCs.

3-1.2 Calculations and Analysis.

Show calculations and assumptions supporting equipment selections in a clear and organized manner. When charts or tables are used in the design analysis, cite the source and date of the publication.

3-1.2.1 Sizing Calculations.

Provide calculations for sizing equipment, piping, ductwork and all accessories. Provide the model number and manufacturer of each major piece of equipment used as the basis for the design.

3-1.2.2 LCCA.

Provide LCCA on optimized system level alternatives modeled in accordance with UFC 1-200-02. Provide energy model, including model inputs and outputs, on optimized system level alternatives by energy type in accordance with UFC 1-200-02.

3-1.2.3 Energy Compliance Analysis (ECA).

If required by UFC 1-200-02, provide a computerized Energy Compliance Analysis. The ECA is a building level analysis which takes into account the interaction between architectural, electrical and mechanical components of the facility design and confirms compliance with the energy reduction goals.

3-1.2.4 Other Calculation Requirements.

Provide any additional calculation documentation as required by the specific mechanical UFCs.

3-2 FINAL DRAWING REQUIREMENTS.

Drawings must be accurate and to scale. Drawings must show equipment, ductwork, and piping sufficiently to indicate all aspects of installation. Where practical, group all notes, legends, and schedules at the right of the drawings above the title block.

3-2.1 Drawing Units.

Unless otherwise authorized, the IP System of measurement must be used on CONUS projects and the SI system of measurement must be utilized on OCONUS projects. Metric and English pipe sizes are listed in Appendix C.

3-2.2 Legend.

Provide legends to clarify all symbols and abbreviations used on the drawings.

3-2.3 Seismic.

Show all pertinent seismic detailing for the mechanical systems on the contract drawings.

3-2.4 Demolition Plans.

“Demolition” plans should be separate and distinct from “new work” plans.

3-2.5 Floor Plans and Site Plans.

Exercise judgment to avoid overly congested drawings. Provide north arrows an all building and site plans. The orientation of drawings must be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans must be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation must be maintained with all disciplines. Enlarged plans must be drawn at no less than 1:50 (¼” = 1’-0”).

3-2.6 Sections and Elevations.

Provide as required to supplement plan views.

3-2.7 Access Space.

Identify space necessary to access and replace items that require maintenance, such as filters, coils, heat exchangers, tube bundles, strainers, and chillers on the drawings in three-dimensions.

3-2.8 Special Detailing

Provide details on the drawings necessary to ensure drainage for “winterizing” equipment where appropriate.

3-2.9 Equipment Schedules.

The equipment actually installed on a project may be different from that used as your basis of design. Therefore, mechanical equipment schedules must reflect actual required equipment capacities as calculated, not capacities provided by manufacturers' catalog data. This helps ensure that the installed equipment is optimally sized for the application.

3-2.10 Other Drawing Requirements.

Provide any additional drawing requirements indicated in the specific mechanical UFCs.

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APPENDIX A REFERENCES

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
www.asme.org
ASME BPVC, Boiler and Pressure Vessel Codes

COMPRESSED AIR AND GAS INSTITUTE (CAGI)
www.cagi.org

The Compressed Air and Gas Handbook

UNITED STATES NAVY

MO-230, Maintenance and Operation of Petroleum Fuel Facilities, http://www.wbdg.org/ccb/NAVFAC/OPER/mo230.pdf

UNITED STATES DEPARTMENT OF DEFENSE

MIL-STD 3007, Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications, http://www.wbdg.org/ccb/FEDMIL/std3007f.pdf

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA
http://dod.wbdg.org/

UFC 1-200-01, General Building Requirements

UFC 1-200-02, High Performance and Sustainable Building Requirements

UFC 3-310-04, Seismic Design for Buildings

UFC 3-400-02, Design: Engineering Weather Data

UFC 3-410-01, Heating, Ventilating, and Air Conditioning Systems

UFC 3-410-02, Lonworks (R) Direct Digital Control for HVAC and Other Local Building Systems

UFC 3-410-04, Industrial Ventilation

UFC 3-420-01, Plumbing Systems

UFC 3-430-01FA, Heating and Cooling Distribution Systems

UFC 3-430-02FA, Central Steam Boiler Plants

UFC 3-430-07, Inspection and Certification of Boilers and Unfired Pressure Vessels

UFC 3-430-08N, Central Heating Plants

UFC 3-430-09, Exterior Mechanical Utility Distribution

UFC 3-430-11 Boiler Control Systems

UFC 3-440-01, \1\ Facility-Scale Renewable Energy Systems /1/

\1\ /1/

UFC 3-450-01, Noise and Vibration Control

UFC 3-460-01, Design: Petroleum Fuel Facilities

UFC 3-460-03, O&M: Maintenance of Petroleum Systems

UFC 3-470-01, Lonworks (R) Utility Monitoring and Control System (UMCS)

UFC 3-520-05, Stationary Battery Areas

UFC 4-390-01, O&M: Unmanned Pressure Test Facilities Safety Certification Manual

UFC 4-510-01, Design: Medical Military Facilities

UFC 4-826-10, Design: Refrigeration Systems for Cold Storage

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)
http://dod.wbdg.org/

UFGS 25 10 10, Utility Monitoring and Control System (UMCS) Front End Integration

APPENDIX B STANDARD CONVERSIONS AND TABLES

Table B-1 - Fuel Conversion Factors

Type of Fuel	Conversion Factors (See note (a))	Notes
Anthracite Coal	28.4 Million Btu/Short Ton	
	29.9 kJ/kg	
Bituminous Coal	24.6 Million Btu/Short Ton	
	25.9 kJ/kg	
Electricity	3413 Btu/KWH	
	12.3 MJ	
No. 2 Distillate Fuel Oil	138,700 Btu/Gallon	
	38.7 MJ/L	
Residual Fuel Oil	149,700 Btu/Gallon	
	41.8 MJ/L	
Kerosene	135,000 Btu/Gallon	
	37.7 MJ/L	
LP Gas	95,500 Btu/Gallon	
	26.6 MJ/L	
Natural Gas	1,031 Btu/Cubic Foot	
	38.5 MJ/L	
Purchased or Steam from Central Plant	1,000 Btu/Pound	See note (b)
	2.3 MJ/kg	

Notes:

(a) At specific installations where the energy source Btu content is known to vary consistently by 10% or more from the values given below, the local value may be used provided there is adequate data on file for two years or more to justify the revision and that this value is expected to hold true for at least five years following building occupancy.

(b) High temperature, medium temperature, or chilled water from a central plant must use the heat value of fluid based on the actual temperature and pressure delivered to the 1.5 m (5 ft) line.

Table B-2. Metric Pipe Size Equivalence

NPS (Inches)	DN (mm)	NPS (Inches)	DN (mm)
1/8	6	2-1/2	65
3/16	7	3	80
1/4	8	3-1/2	90
3/8	10	4	100
1/2	15	4-1/2	115
5/8	18	5	125
3/4	20	6	150
1	25	8	200
1-1/4	32	10	250
1-1/2	40	12	300
2	50		

Notes:
1. NPS is the inch-pound designation for “nominal pipe size”.
2. DN is the metric designation for “diameter nominal”.
3. For pipe sizes over 12 inches, use the conversion factor of 25 mm per inch.

Table B-3. Metric Ductwork Dimensions

Inches	mm
3	80
4	100
5	130
6	150
7	180
8	200
10	250
12	300

Notes:
1. For dimensions over 12 inches, increase mm size in increments of 50

APPENDIX C GLOSSARY

ACRONYMS

AFCEE	Air Force Center for Engineering and the Environment
AHJ	Authority Having Jurisdiction
ASME	American Society of Mechanical Engineers
BIA	Bilateral Infrastructure Agreement
BPVC	Boiler and Pressure Vessel Codes
BTU	British Thermal Unit
CAGI	Compressed Air and Gas Institute
CONUS	Continental United States
DB	Design Build
DBB	Design Bid Build
DN	Diameter Nominal
DoD	Department of Defense
ECA	Energy Compliance Analysis
Ft	Foot
HQUSACE	Headquarters United States Army Corp of Engineers
HNFA	Host Nation Funded Construction Agreements
HVAC	Heating, Ventilating and Air Conditioning
IP	Inch-Pound
Kg	Kilogram
Kj	Kilojoule
Kwh	Kilowatt-Hours
L	Liter
LCC	Life Cycle Cost

LCCA	Life Cycle Cost Analysis
LP	Liquid Petroleum
Mil-Std	Military Standard
MJ	Million joules
m	meter
mm	Millimeters
MO	Maintenance & Operation
NAVFAC	Naval Facilities Engineering Command
NPS	Nominal Pipe Size
O&M	Operation and Maintenance
OCONUS	Outside the Continental United States
RFP	Request for Proposal
SOFA	Status of Forces Agreement
UFC	Unified Facility Criteria
UFGS	Unified Facilities Guide Specification
UMCS	Utility Monitoring & Control System
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics

FC 3-401-02N
01 September 2024

FACILITIES CRITERIA (FC)

NAVY AND MARINE CORPS EXISTING BUILDING COMMISSIONING

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FACILITIES CRITERIA (FC)

NAVY AND MARINE CORPS EXISTING BUILDING COMMISSIONING

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

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FOREWORD

Facilities Criteria (FC) provide functional requirements (i.e., defined by users and operational needs of a particular facility type) for specific DoD Component(s), and are intended for use with unified technical requirements published in DoD Unified Facilities Criteria (UFC). FC are applicable only to the DoD Component(s) indicated in the title and do not represent unified DoD requirements. Differences in functional requirements between DoD Components may exist due to differences in policies and operational needs.

All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the contracting team must ensure compliance with the most stringent of the FC, the SOFA, the HNFA, and the BIA, as applicable.

Because FC are coordinated with unified DoD technical requirements, they form an element of the DoD UFC system applicable to specific facility types. The UFC system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applicable to the Military Departments, Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) memorandum dated 29 May 2002. The UFC System also includes technical requirements and functional requirements for specific facility types, both published as UFC documents and FC documents.

FC are living documents and will be periodically reviewed, updated, and made available to users as part of the Service's responsibility for providing criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and the Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet site listed below.

FC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

AUTHORIZED BY:

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Chief Engineer and Assistant Commander for Planning, Design and Construction
Naval Facilities Engineering Systems Command (NAVFAC)

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

42 USC 8253, as modified by the Energy Independence and Security Act of 2007 (EISA 2007) and the Energy Act of 2020, requires a comprehensive energy and water evaluation be completed on Federal buildings that constitute at least 75 percent of building energy use every four years; these evaluations include identifying and assessing recommissioning or retrocommissioning measures. For Navy and Marine Corps buildings, the NAVFAC publication P-602, *3 Pillars of Energy Security (Reliability, Resilience, & Efficiency)*, aligns with the prior mandates in requiring comprehensive energy and water evaluations be conducted on covered facilities once every four years.

1-2 PURPOSE AND SCOPE.

This FC provides a process standard that aligns best practices with ASHRAE and industry standards for existing building commissioning (EBCx). EBCx includes both recommissioning and retrocommissioning. It is written for use by building maintenance engineers and program professionals. This document has been developed to ensure consistency of efforts and resulting deliverables from performance of EBCx services. This document outlines requirements for building systems commonly included in EBCx efforts and excludes those systems typically covered by other required inspections and not included in an EBCx scope of work (such as fire protection/sprinkler systems, fire alarm systems, cable television and closed circuit television systems, conveying systems, and cybersecurity systems).

1-3 ORGANIZATION.

This document breaks the overall EBCx process down into phases, generally following those outlined in ASHRAE 0.2 as well as BCxA Existing Building Commissioning Best Practices. The EBCx phases work together; as an example, Assessment Phase results suggest the appropriate tasks in the Investigation Phase, which reveal the most beneficial Implementation Phase actions. Chapters 3 thru 8 cover each phase in depth. This document is organized as follows:

- CHAPTER 1 introduces the scope of this document and overall requirements
- CHAPTER 2 provides an overview of EBCx
- CHAPTER 3 contains the steps within the Planning Phase
- CHAPTER 4 details the steps within the Assessment Phase
- CHAPTER 5 contains the Investigation Phase steps
- CHAPTER 6 details the Implementation Phase steps
- CHAPTER 7 details the steps within the Hand-off Phase
- CHAPTER 8 contains the steps within the Ongoing Commissioning Phase

1-4 APPLICABILITY.

This document applies to DoD building assets equal to or greater than 25,000 square feet (2,323 square meters) and buildings which house energy intensive operations (such as data centers, health facilities or utility plants). This document applies where DoD is performing or managing the performance of EBCx efforts on existing buildings or systems. Existing building commissioning pays benefits on buildings where there is a focus on energy efficiency, reliability of systems, building size, greenhouse gas emissions, decarbonization, facility resiliency, buildings with subpar performance (excessive trouble calls), and mission criticality. Resiliency performance impacts include robustness, durability, maintainability, and rapid recovery following a disruption. This document does not apply to a construction project; follow the requirements of UFC 1-200-02 and related UFGS guide specifications for commissioning which seeks to verify design and performance of new construction or renovation projects.

Commissioning of existing buildings assists in enhancing “military installation resilience”; as defined in 10 USC 101(e), this term means the capability of a military installation to avoid, prepare for, minimize the effect of, adapt to, and recover from extreme weather events, or from anticipated or unanticipated changes in environmental conditions or energy disruptions. This FC document relies on existing standards, guidelines and best practices recognized by firms and individuals that are certified to perform commissioning services. These are consensus documents developed by organizations such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Building Commissioning Association (BCxA), and the National Environmental Balancing Bureau (NEBB).

1-5 GENERAL BUILDING REQUIREMENTS.

For design and construction project-related efforts, comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety.

1-5.1 Required Upgrades in Corrosive Environments.

When upgrades resulting from EBCx efforts are implemented, incorporate in the design systems and details to meet the environmental corrosivity conditions for the specific project location, as defined by its Environmental Severity Classification (ESC). See UFC 1-200-01 for determination of ESC for project locations. Design upgrades may also be required due to the humidity conditions; humid locations are those in ASHRAE climate zones 0A, 1A, 2A, 3A, 3C, 4C, and 5C (as identified in ASHRAE 90.1).

Required corrosion-related upgrades to building systems are identified in UFC 1-200-01 and “Core” UFC’s. UFC 1-200-01 contains general requirements for corrosion-related upgrades covering multiple disciplines; UFC 3-410-01 includes requirements for heating, ventilating, and air-conditioning (HVAC) system components and UFC 3-501-

01 includes requirements for electrical system components. Upgrade requirements for other systems are found in their related UFC documents.

1-6 CYBERSECURITY.

To maintain proper cybersecurity measures, facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-7 BEST PRACTICES.

APPENDIX A contains best practices which are not required but have shown to produce the best results and ensure EBCx efforts are consistent and comprehensive.

1-8 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-9 REFERENCES.

APPENDIX C contains a list of references used in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

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CHAPTER 2 OVERVIEW

2-1 EBCx DEFINED.

Existing building commissioning (EBCx) is a quality-focused process for attaining the current facility requirements (CFR) of an existing building and its systems and assemblies. The process focuses on planning, investigating, implementing, verifying, and documenting that the building and its systems and assemblies are operated and maintained to meet the CFR, with a program in place to maintain the enhancements for the remaining life of the building. EBCx includes both recommissioning and retrocommissioning. Recommissioning is the application of the commissioning (Cx) process to an existing building or system that underwent the Cx Process during project delivery. Retrocommissioning applies the Cx Process to an existing building or system that was not previously commissioned.

EBCx is a process of inspecting, testing, analyzing, adjusting, and optimizing existing building systems to improve how building equipment and systems function together. EBCx often resolves problems that occurred during design or construction, or addresses expected building system performance degradation problems that have developed throughout the building's life. Properly executed, EBCx improves a building's operations and maintenance procedures and enhances overall building performance while meeting the Government's and occupant needs.

2-1.1 Scope.

The scope of EBCx may be either comprehensive or targeted on specific known issues or underperforming building systems. The building systems which may be included in comprehensive EBCx efforts are further outlined in paragraph titled Comprehensive Commissioning. Clearly outline the extent of the scope in the Request for Proposal (RFP) to a Cx Provider, or in a scoping document when utilizing a Government EBCx team.

If the EBCx efforts are being undertaken to achieve compliance with the 42 USC 8253 requirements, which require a comprehensive evaluation be completed on each Federal building every four years, the scope of the EBCx must include the energy- and water-consuming building systems at a minimum. EBCx efforts targeted on only specific problematic building systems do not qualify as a comprehensive building energy evaluation required by 42 USC 8253 every four years.

2-1.2 Purpose/Intent.

The intent of EBCx is to identify a corrective process for repairing equipment and optimizing building systems and operations for energy efficiency, occupant comfort, air quality, enhanced building resiliency and extended equipment useful life. EBCx applies to buildings with no prior commissioning or where building systems no longer meet or exceed minimum requirements due to equipment failure or work-arounds, improper system adjustments, renovations or significant changes in building space utilization.

The goal of EBCx is to make building systems perform interactively to meet the Current Facility Requirements (CFR) and provide the tools to maintain the system performance over time.

2-1.3 Benefits.

Typical benefits of EBCx efforts include:

- Reduces energy and water usage
- Reduces the number of system deficiencies and inefficiencies and better focuses the maintenance efforts and resources to meet the needs of end users.
- Improves the building system's overall performance by optimizing energy-efficiency and system integration.
- Reduces building operating expenses.
- Identifies potential indoor environmental quality issues and ensures indoor air quality meets the minimum American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) requirements.
- Improves thermal comfort and reduces occupant complaints.
- Ensures that system operations meet building manager's expectations.
- Improves equipment performance and extends equipment life expectancy.
- Through training, enhances operations and maintenance (O&M) staff capabilities and expertise to operate and maintain the equipment more effectively and efficiently.
- Reduces service calls and demands on O&M staff.
- Identifies safety hazards such as unprotected electrical wiring, fall hazards, and other dangerous conditions.
- Discovers unique design and historic information about the building uncovered during drawing research.
- Identifies deficiencies in building enclosure water barrier, air barrier, thermal barrier and vapor retarder.
- Improves/updates building documentation.
- Ensures compliance with Federal building policies and directives.
- Ensures compliance with energy goals and mandates.
- Improves building resiliency by enhancing robustness, durability, maintainability, and ability to recover following a disruption.

2-2 TEAM ROLES AND RESPONSIBILITIES

The personnel required and the extent of their responsibilities differ depending on whether the EBCx is being performed by a consultant firm or an in-house Government EBCx team, as well as which building systems are included. Where EBCx is provided by a Contractor/consultant, Government personnel have support roles in assisting with coordination of the process.

2-2.1 EBCx Team Members.

The EBCx Team is responsible for executing the EBCx scope of work. Roles and responsibilities within the team may include:

- Commissioning (Cx) Provider – oversees and executes EBCx phases.
- Commissioning specialists – specialty team members based on the scope of the EBCx, such as Testing, Adjusting and Balancing (TAB) Contractor, controls specialists, equipment support vendors, energy consultant, and other specialized testing providers.
- Facilities management specialists - assists in selection of buildings, researches past/future building projects and work orders, and coordinates efforts with building manager.

2-2.2 EBCx Support.

Support roles and responsibilities to allow for completion of EBCx efforts include:

- Facilities management leadership – decision-making to assist in selection of buildings and establish EBCx goals and objectives.
- Existing building commissioning (EBCx) program management personnel – when a formalized EBCx program is in place, provides program objectives, tracks funding, and assists with selecting EBCx candidate buildings.
- Utilities management personnel – provides utility-related data for buildings, including meter data and utility rates.
- Regional Energy Program Manager (REPM) – assists with central funding and with selection of buildings.
- Installation Energy Manager (IEM) – often the primary point of contact for EBCx at the installation; coordinates public works resources.
- Building manager – acts as building representative and provides data and other requested information.
- Public works personnel – supports implementation of EBCx measures.

- Architectural and engineering technical support personnel – provides reachback support for complex technical concerns.
- Installation shops maintenance personnel – provides access to secured mechanical spaces, assists with location and operational condition of equipment, and assists in identification of known deficiencies.
- Preventive maintenance (PM) personnel – assists with deferred maintenance; provides maintenance logs.
- Controls shop – responsible for proper operations of energy and water control systems (Cx Provider will need to coordinate with this shop when testing control sequences)

2-3 REQUIRED CERTIFICATIONS AND TRAINING.

2-3.1 Lead EBCx Specialist Certification Requirements.

Individuals that serve as a Lead EBCx Specialist and are in responsible charge of executing EBCx efforts, either in-house or as part of a consultant team, must have obtained one of the commissioning professional certifications identified in Table 2-1; individuals with certifications that are not specific to Existing Building Commissioning must have five years of experience in leading efforts on commissioning existing buildings of similar size and complexity. Individuals which assist with EBCx activities are not required to have these certifications but must be directly supervised by a certified individual.

Table 2-1 Lead EBCx Specialist Required Certification

Organization	Certification
National Environmental Balancing Bureau (NEBB) (www.nebb.org)	Retro-Commissioning of Existing Buildings Certified Professional (RCx CP)
Association of Energy Engineers (AEE) (www.aeecenter.org)	Certified Building Commissioning Professional (CBCP®)
Association of Energy Engineers (AEE) (www.aeecenter.org)	*Existing Building Commissioning Professional (EBCP®)
Associated Air Balancing Council (AABC) Commissioning Group (ACG) (www.commissioning.org)	Certified Commissioning Authority (CxA)
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (www.ashrae.org)	Building Commissioning Professional (BCxP)
University of Wisconsin-Madison (www.pdc.wisc.edu)	Qualified Commissioning Process Provider (QCxP)
Building Commissioning Certification Board (www.bccbonline.org)	Certified Commissioning Professional (CCP)

*Note: EBCP certifications are no longer being issued but are still active.

2-3.2 Building Enclosure Commissioning Certification Requirements.

Individuals that perform EBCx activities on the building enclosure system, either in-house or as part of a consultant team, must have obtained one of the professional certifications listed in Table 2-2.

Table 2-2 Building Enclosure Required Certification

Organization	Certification
National Environmental Balancing Bureau (NEBB) (www.nebb.org)	Building Enclosure Testing Certified Professional (BET CP)
University of Wisconsin-Madison (www.pdc.wisc.edu)	Building Enclosure Commissioning Process Provider (BECxP)
	Accredited Commissioning Authority + Building Enclosure (CxA+BE)
International Institute of Building Enclosure Consultants (IIBEC) (www.iibec.org)	Certified Building Enclosure Commissioning Provider (CBECxP®)

2-3.3 Training Resources.

For individuals who desire to increase their knowledge on specific EBCx processes and activities, training is available from the organizations listed in Table 2-3.

Table 2-3 Training Resources

Organization	Website
Building Commissioning Certification Board (BCCB)	www.bccbonline.org
Association of Energy Engineers (AEE)	www.aeecenter.org
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	www.ashrae.org
National Environmental Balancing Bureau (NEBB)	www.nebb.org
AABC Commissioning Group (ACG)	www.commissioning.org
International Facility Management Association (IFMA)	www.ifma.org or www.fm.training

International Institute of Building Enclosure Consultants (IIBEC)	www.iibec.org
American Society for Health Care Engineering (ASHE)	www.ashe.org

2-4 EXTENT OF COMMISSIONING.

Existing building commissioning may be either comprehensive or targeted on specific known issues or underperforming systems. In either case, the funding and level of effort is based on the building systems that need to be evaluated or improved to meet the goals and objectives of the tenant organization. The most common EBCx scope focuses on the energy- and water-consuming systems in a building, plus other systems that are known to have documented operational or maintenance issues.

2-4.1 Targeted Commissioning.

In existing buildings, not every system requires commissioning to provide a return on the investment. Additionally, the level of effort and the associated cost to carry out the EBCx process on all building systems could exceed the funding available. Thus, in many instances, the EBCx process is targeted on specific systems within a building to address specific known issues and to meet the specified goals or objectives of the tenant organization. It should be noted that EBCx efforts targeted on only specific problematic building systems do not qualify as a comprehensive building energy evaluation required by 42 USC 8253 every four years.

2-4.2 Comprehensive Commissioning.

A comprehensive EBCx task order might include the following building systems:

- HVAC and refrigeration systems and associated controls
- Air-curtain systems
- Domestic water heating and distribution systems
- Domestic water treatment systems
- Sanitary sewer systems
- Building envelope (walls and roofing)
- Structural system
- Electrical power distribution systems (panelboards/switchgear plus known problem areas)
- Emergency and standby power
- Energy storage systems
- Lighting and control systems

- Solar photovoltaic and renewable energy systems
- Security and intrusion detection systems
- Landscape watering systems
- Telephone and intercommunications systems

The following systems are typically covered by other required inspections and are not included in an existing building commissioning scope of work:

- Fire protection/sprinkler system
- Fire alarm system
- Cable television (TV) and closed-circuit television (CCTV) systems
- Conveying systems
- Cybersecurity systems

2-5 THE COMMISSIONING TEAM SKILLS.

The EBCx Team must be led by a certified individual as outlined in paragraph titled Required Certifications and Training. The overall assembled EBCx team must have the following skills and experience:

- Project management
- Project team supervision
- System testing techniques and use of instrumentation
- System troubleshooting
- System analysis
- Energy and water conservation techniques
- Energy and water calculation procedures
- Working knowledge of control systems and sequence strategies
- Capability to train operators
- Good communication skills

2-6 COMMISSIONING EQUIPMENT.

The National Environmental Balancing Bureau (NEBB) maintains an Approved Instruments Requirements list for performing EBCx services (https://nebb.org/firm-certification/instrument-requirements/). This list includes the range and accuracy requirements for instruments based on their testing function, and also designates calibration intervals for these instruments. Duplicate equipment may be required for some items to allow for periods when equipment fails or is not available while being calibrated. Firms or Government teams that conduct EBCx efforts must provide proof to the Government Project Manager that equipment being used has been calibrated according to the manufacturer's or industry standards for each piece of equipment and the date it was last calibrated.

2-7 PHASES OF COMMISSIONING.

The EBCx process as outlined in this document is broken down into phases, generally following those outlined in ASHRAE 0.2 as well as BCxA Existing Building Commissioning Best Practices. The Phases may be performed by separate entities, as described in this document. The remaining Chapters in this document are organized by these Phases, which are as follows:

- Planning
- Assessment
- Investigation
- Implementation
- Hand-off
- Ongoing Commissioning

CHAPTER 3 PLANNING PHASE

3-1 OBJECTIVES.

The Planning Phase is implemented when the EBCx process is being considered for a single building or multiple buildings. When considering EBCx for multiple buildings, this Phase assists in identifying the buildings that are the best candidates for benefitting from the EBCx process. When a decision has been made to perform EBCx on a single building (the building has been confirmed as a good candidate for these services), the Planning Phase is abbreviated. While each phase could be contracted, it is recommended that the Planning Phase and a portion of the Assessment Phase be performed in-house to better establish the scope for execution in subsequent phases. The objectives of this phase are to clarify the scope and expectations of the EBCx process, and to develop a strategy to guide the execution of the efforts.

3-2 PLANNING PHASE FOR MULTIPLE BUILDINGS.

When considering the application of EBCx on multiple buildings, follow these Planning Phase steps:

a. Assemble EBCx program planning team

b. Conduct program planning meeting and workshop (develops EBCx goals and screens buildings)

c. Gather documents

d. Building walk-through

e. Engage a Cx Provider

f. Develop EBCx program plan

3-3 PLANNING PHASE FOR A SINGLE BUILDING.

When a decision has been made to perform EBCx on a single building (the building has been confirmed as a good candidate for these services), the Planning Phase is somewhat shortened as follows:

a. Confirm/Document EBCx goals and objectives

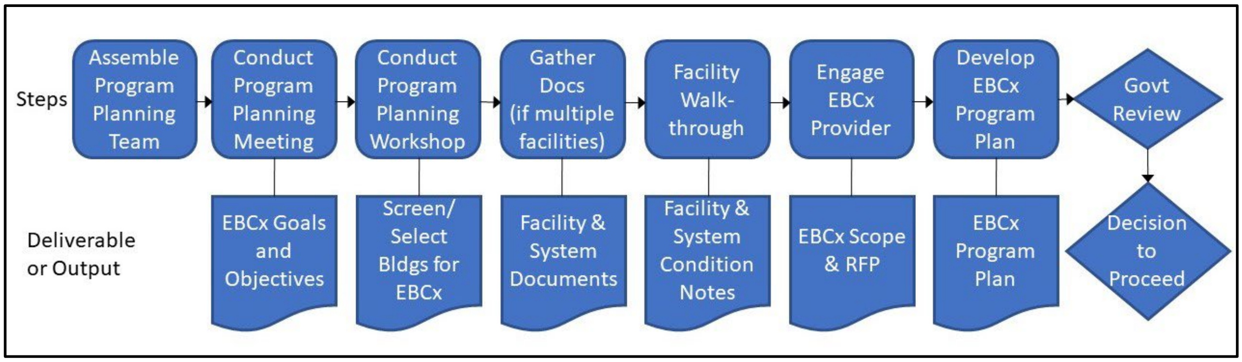
b. Initial walk-through of building

c. Engage a Cx Provider

3-4 PLANNING PHASE STEPS.

The following planning phase steps are undertaken to clarify the scope and expectations of the EBCx process. Some of these are only undertaken when considering multiple buildings, and others are undertaken when planning EBCx for a single building or multiple buildings.

Figure 3-1 Planning Phase Process and Deliverables/Outputs



3-4.1 EBCx Program Planning Team.

An installation may have a formal program and organization for conducting EBCx. If no formal program exists, a program is defined within the Planning Phase when conducting EBCx on multiple buildings. When conducting planning sessions on EBCx for multiple buildings, assemble an EBCx Program Planning Team. This Planning Team consists of facilities management leadership, utilities management personnel, engineering management staff, the installation energy managers and the facility-related control systems (FRCS) manager. As a part of initiating the planning process, this team conducts the following primary activities:

- Determine funding availability for EBCx efforts and develop a funding plan based on the funding source.
- Determine contract availability if aspects of the work are to be performed through an outside contractor. Determine whether in-house Cx resources are available or if an outside Contractor is required.

3-4.2 EBCx Program Planning Meeting and Workshop.

When considering EBCx on multiple buildings, conduct a planning workshop to discuss/confirm the overall goals of the program and orient the team on the EBCx process. An overview meeting is conducted to review the concepts listed below, then an extended workshop is held to complete these steps after information is compiled, such as the data required to conduct the building screening/selection process. Cover the following topics at a minimum (see ASHRAE 0.2 Multiple-Facility Planning Phase section titled "Conduct EBCx Program Planning Meeting" for information to discuss on each of these topics):

- EBCx goals and objectives (see paragraph titled EBCx Goals and Objectives)
- EBCx process overview, including types of systems included, and potential benefits expected.
- Identify buildings considered as candidates for the program.

- What building systems are included in EBCx assessments.
- The building screening/selection process (see paragraph titled Screen/Select Buildings for EBCx Viability)
- Determine measurement and verification (M&V) standards and performance metrics
- Identify the training needed for building managers and O&M staff
- Confirm personnel resources available in-house for EBCx efforts vs. those that need to be performed via outside contract
- Confirm funding sources, contract mechanisms and available funds
- Expected benefits of EBCx
- Preferred timeframe for EBCx execution

3-4.2.1 EBCx Goals and Objectives.

For single buildings or multiple-building EBCx efforts, the Planning Team confirms the desired objectives of the EBCx efforts so these expectations can be conveyed to all parties involved. Objectives may include one or more of the following:

- Bring equipment to its proper operational state.
- Reduce energy and demand cost, increase equipment life.
- Improve indoor environmental quality and increase tenant satisfaction.
- Improve building operation and maintenance.
- Reduce overall complaints.
- Reduce staff time spent on emergency calls.

The Government Project Manager must convey assessment parameters for specialized objectives other than energy and water savings. Objectives beyond traditional EBCx might include system expansion capability, enhanced building resiliency, emissions reduction, or enhanced electrification. EBCx teams are made up of disciplines which can assess these issues; however, it is important to clearly state these objectives in the EBCx scope of work.

3-4.2.2 Screen/Select Buildings for EBCx Viability.

When considering multiple buildings for EBCx, some existing buildings or groups of buildings make better candidates for EBCx than others. Assemble the EBCx Program Planning Team and the Building Managers for the buildings under consideration for EBCx to screen the buildings and identify those that are the preferred candidates for the EBCx Program. The goal of the screening process is to perform EBCx efforts on those buildings which provide the highest returns, such as reductions in energy or operational costs, as well as ensuring continuity of operations for those buildings which are deemed as mission critical. These efforts require compiling data on each candidate building, such as checking planned project lists and reviewing maintenance records; to gain the best information; a brief walk-through of each building and talking with occupants and maintenance personnel are best practices.

Follow these steps in screening buildings for the EBCx Program (see Appendix A, paragraph titled Navy and Marine Corps Templates for location of a best practice template available for use in the screening process):

- Step 1 – Confirm it is a “building” and it is a DoD asset:
  - Per UFC 1-300-08, a building is “A roofed and floored facility enclosed by exterior walls and consisting of one or more levels that is suitable for single or multiple functions.”
  - Through available asset data, confirm the building is a DoD asset (and not locally owned).
- Step 2 – Consider the following criteria when making a building selection:
  - Buildings equal to or greater than 25,000 square feet (2,323 square meters) and buildings which house energy intensive operations (such as data centers, health facilities or utility plants).
  - Buildings which are not scheduled for demolition.
  - Buildings with prior energy audits that recommend EBCx as an Energy Conservation Measure (ECM) (note: A building is not required to have a prior energy audit to be considered a good candidate for EBCx).
  - Buildings with a Condition Index (CI) greater than 60.
  - Buildings with high energy use index (EUI) that cannot be explained or unexplained increases in energy consumption. Compare the EUI for the candidate building to similar buildings using benchmarking. Benchmarking can be done using a tool such as the Commercial Buildings Energy Consumption Survey (CBECS): www.eia.gov/consumption/commercial/
  - Buildings with persistent failure of building equipment, control systems, or both (note: failed control systems make it difficult to diagnose systems and test performance).
  - Buildings with access to a Direct Digital Control (DDC) operator workstation, where DDC controls are present
  - Buildings whose current use or configuration have been modified from the original design intent.
  - Buildings with occupant complaints about temperature, airflow, and comfort.

   - Buildings that do not have deferred maintenance based on Preventive Maintenance (PM) and Service Call records to ensure that important maintenance tickets have been addressed.
   - Buildings that are not scheduled for capital improvements (which replace EBCx systems before the payback period had elapsed and equipment has reached its useful life).
   - Buildings with Building Automation System (BAS) control systems or complex mechanical systems.
   - Buildings with unexplained increases in numbers of work orders/services requests.
   - Buildings with meters (electric, water, gas, or steam) installed prior to EBCx.
- Step 3 – Where funding is not available to perform EBCx on all candidate buildings, prioritize buildings by mission criticality and known issues affecting resiliency:
   - Prioritize buildings which are critical to performing the Installation's mission. For additional information on criticality, contact Installation Facilities Management (IFM) or the Installation Energy Management (IEM) office for a list of existing critical buildings that may require commissioning.
   - Prioritize buildings with known issues affecting their resiliency, defined as having lessened ability to provide for mission in the face of all hazards, including extreme weather events or changes in environmental conditions, or recover operations quickly after a disruption in operation (such as having known power reliability issues, a mission critical building with an inoperable backup power generation system, HVAC systems with difficulties operating in expected extreme hot or cold conditions, building enclosures in occupied spaces with gaps which allow external air flows in extreme conditions).

3-4.3 Gather Documentation.

When considering multiple buildings for EBCx, gather documentation during the follow-on Assessment Phase. For EBCx on an individual building, obtain documentation in the Planning Phase to understand the condition of the systems, where potential issues exist, and to establish the scope of work for the Cx Provider, whether they are in-house or contracted. Gather the following documents:

- Original "as-built" construction drawings
- Original construction specifications
- Renovation construction drawings

- Minimum one year of utility bills or usage and cost data (including electrical, natural gas, water, wastewater, fuel, steam Hot Water (HW) or Chilled Water (CW))
- Utility rates
- Previous energy audit, commissioning, or EBCx reports
- TAB reports for HVAC system
- Existing equipment submittals or shop drawings
- Controls systems “as-built” submittals
- Copies of written control sequences or diagrams
- Copies of existing building operations and maintenance guides
- One-year summary report of maintenance and repair records
- Six months of HVAC BAS/DDC trend data alarms as available
- Equipment replacement records

3-4.4 Building Initial Walk-through.

The initial walk-through of the building helps to gain an understanding of the condition of the spaces and state of the building and systems. Collect information on the types and quantities of equipment, and if there is pending corrective repair work. Discuss with the maintenance personnel where known issues are and speak with occupants regarding current thermal comfort issues.

3-4.5 Engage Commissioning Provider.

While each phase could be contracted, it is recommended that the Planning Phase and a portion of the Assessment Phase be performed in-house to better establish the scope for execution in subsequent phases. Performing a portion of the Assessment Phase will help to understand enough about the building(s) to develop an initial scope and budget for the EBCx task. For the EBCx Team, whether being performed in-house or via Contractor personnel, clearly define the scope of the EBCx assessment, the parameters of the building(s) being evaluated, and assistance being provided by installation or building personnel. Parameters needed to enable a well-defined scope of work include the following at a minimum (see Appendix A, paragraph titled Navy and Marine Corps Templates, for the location of a best practice template for the EBCx Contractor scope of work):

- EBCx project objectives
- Whether Government provides the CFR or Contractor develops
- List and quantity of building equipment and systems to be evaluated
- Condition of equipment and known outstanding repairs

- List of problem areas or known issues
- State if electrical, gas and water meters are installed and operational
- State if approximate costs for energy and water use are available
- Specific procedures required, or emphasis on specific spaces (such as systems supporting data/IT systems or mission critical spaces)
- Existing controls systems; capabilities of the BAS for trending and reporting
- Clarify if Cx Provider provides controls Contractor or Government
- Allowed work hours
- Instructions for coordination of building availability
- List of documents that will be provided, and whether they'll be provided electronically or may only be viewed on-site
- Description of support to expect from operations staff for interviews and answering questions
- Required sample size and pass rate
- List the installation security access requirements
- List the building access requirements (badging, escort)
- Identify security requirements regarding use of cell phone cameras, standalone cameras, and thermal imaging cameras
- Requirements for deliverables, including draft and final reports
- What extent, if any, of Implementation Phase or Ongoing Commissioning Phase activities are conducted by the Cx Provider
- Desired schedule, including milestones or check-in points
- Potential measurement and verification (M&V) plan
- Which party develops Performance Verification Tests
- List of deliverables required and format
- Requirement for out-briefing or Post-EBCx presentation
- List of points of contact (building utilities, control system vendors, building access coordination, building maintenance)

3-4.6 EBCx Program Plan.

For Planning Phases when considering multiple buildings for EBCx, develop the information resulting from the EBCx Program Planning Meeting and Workshop in a cohesive planning document (see paragraph titled EBCx Program Planning Meeting and Workshop. Topics in this plan include the following at a minimum:

- EBCx goals and objectives
- Buildings considered as candidates for the program.
- Building systems included in EBCx assessments.
- The building screening/selection process utilized, including ranking metrics
- Prioritized/selected list of buildings
- Measurement and verification (M&V) requirements
- Training needed for building managers and O&M staff
- Personnel resources available in-house for EBCx efforts and those that require performance via outside contract
- Budget, funding sources, and contract mechanisms
- Expected benefits of EBCx
- Schedule for EBCx execution
- EBCx program planning team

3-4.7 Government Review and Decision to Proceed.

For Planning Phases when considering multiple buildings for EBCx, submit the developed EBCx Program Plan for review and approval. This review evaluates the process followed for screening the buildings and the decision/selection of buildings planned for EBCx. Additionally, the planned method of performing EBCx efforts is assessed, whether through in-house teams or contracted resources; potential contracting mechanisms are also confirmed.

3-5 PLANNING PHASE DELIVERABLES.

The Planning Phase deliverables consist of the following:

- EBCx Program Plan
- Compiled building documentation
- Contractor RFP scope of work

CHAPTER 4 ASSESSMENT PHASE

4-1 OBJECTIVES.

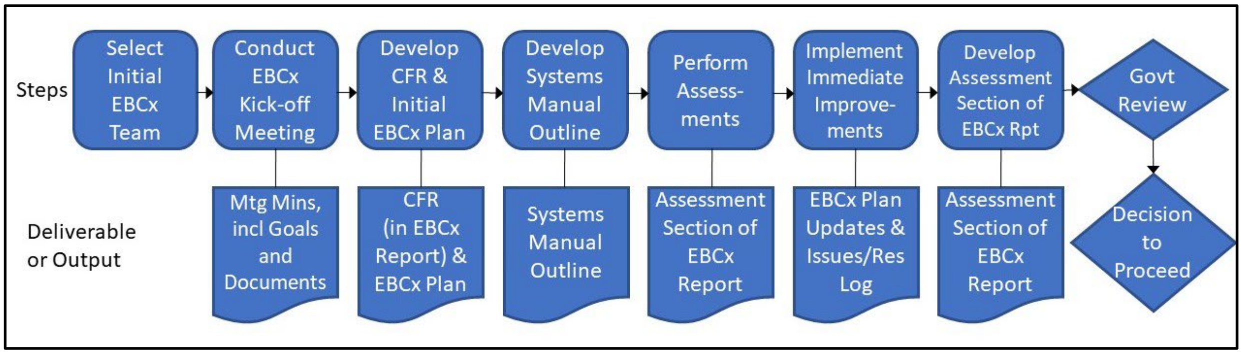
The Assessment Phase consists of performing preparatory activities in developing the Current Facility Requirements (CFR) and an EBCx Plan for a single building, and performing an assessment of the building. It is not a full evaluation but rather a cursory data gathering and brief walk-through of the building. The goal of the on-site Assessment Phase is to record building system conditions, identify obvious performance issues, and flag potential opportunities for more in-depth analysis. The Assessment Phase approach must align with the Government's objectives and goals for the overall EBCx efforts (such as energy reduction, enhancing occupant comfort, or reducing service calls). The objectives of this phase are to gain enough of an understanding about the individual building to develop an initial scope, schedule, budget, and approach for the follow-on Investigation Phase, as well as an estimate of the potential improvements to the building's performance.

4-2 ASSESSMENT PHASE STEPS.

There is some overlap in the Planning and Assessment Phases. And Assessment Phase steps may be performed by a different entity than the Planning Phase, thus some initial steps are used to confirm the scope and expectations for the EBCx process. Assessment Phase steps are as follows:

a. Select the initial EBCx Team
b. Conduct an EBCx kick-off meeting
c. Develop CFR
d. Develop the initial EBCx Plan
e. Establish the Systems Manual outline
f. Perform assessments
g. Implement immediate improvements
h. Develop Assessment Report portion of EBCx Report
i. Obtain Government review and decision to proceed

Figure 4-1 Assessment Phase Process and Deliverables/Outputs



4-2.1 The Initial EBCx Team.

Define the EBCx Team to oversee and accomplish the Cx activities. To what extent a Contractor is responsible for the activities is affected largely by the resources available at the installation. The initial team consists of the Government representatives, the Commissioning Provider, and additional team members based on the EBCx goals and the building systems included in the scope. After responses are received from Contractor support requests, decisions are made for securing the services of the most appropriate team and procuring these services utilizing available contracting mechanisms.

4-2.2 Kick-off Meeting.

Following issuance of Notices to Proceed to Contractors, or an agreement to utilize a Government in-house team, conduct a kick-off meeting to develop an understanding of the planned EBCx processes and coordinate the work activities. The focus of this pre-assessment meeting is to determine which EBCx members are required to support the assessment, which requested documents remain outstanding, and what the access needs will be during the assessment. Also review assessment strategies and deliverables during the meeting. Required attendees include Government and Contractor personnel playing a key role in the EBCx activities. Topics for the kick-off meeting include the following:

- Confirm EBCx goals and objectives
- Confirm documentation requested
- Introduce EBCx team members
- Confirm EBCx roles, including local support
- Communication and coordination plan
  - Site visit security requirements and coordination
  - Planned meetings
- Specific EBCx plan/activities

  - Outline of activities
  - Building systems being evaluated
  - Approach to measurement and verification
  - Planned assessments/tests
  - Access required
  - Impacts to operations
  - Government staff participation/assistance
  - Training approach
  - Deliverables/Submittals
- Planned EBCx schedule

Following the meeting, develop formal meeting minutes and issue to attendees as well as stakeholders who were unable to attend.

4-2.2.1 EBCx Goals and Objectives.

If a different entity is involved in the Assessment Phase from the Planning Phase, confirm the goals and objectives of the EBCx efforts. Confirmation of the goals and objectives as designated in the scope of work is important prior to proceeding with the activities of this phase because these determine the appropriate assessment methods and level of testing. A list of potential objectives for EBCx efforts is included in Chapter 3 of this document.

4-2.2.2 Documentation Requested.

At the kick-off meeting, confirm if the list of documentation from Chapter 3 has been provided. The Government identifies items that do not exist for the building being assessed.

4-2.3 Current Facility Requirements (CFR).

The CFR is the foundational information for the EBCx efforts in that it defines the specific operating parameters for the building to support its' mission. Establishing these CFR parameters is critical to understanding how an existing building is performing when compared to its' intended design, and establishes the targets for successful EBCx results. A CFR must reflect the current needs and requirements of the users or occupants. For example, functional uses may have changed since the building was originally constructed; these space renovations may have resulted in revising the operation of building systems. For buildings that were commissioned during construction/renovation, or that have had prior retrocommissioning efforts, the EBCx efforts involve updating the Owner's Project Requirements (OPR) established during the original commissioning process. For existing buildings with no prior commissioning efforts, developing the requirements defined within the CFR require input from building staff, occupants, users, maintenance personnel and management; thus, obtaining this information typically requires facilitation of a series of meetings or a workshop as well as interviews and surveys.

The minimum content requirements for the CFR are stated in ASHRAE 0.2, Assessment Phase section titled “Develop CFR”. ASHRAE 1.2 provides an in-depth outline of CFR information for HVAC systems; provide similar information for other building systems included in the scope. Annex I of ASHRAE 0.2 provides a best practice approach for conducting a workshop to obtain information for the CFR; the Commissioning Provider facilitates this workshop. Annex J of ASHRAE 0.2 provides an example format for the CFR.

4-2.4 The Initial EBCx Plan.

The EBCx Plan outlines a strategic method of assessment that attempts to identify indicators of poor performance and opportunities for improved building system optimization. This plan provides the basis from which the follow-on Investigation and Implementation Phases proceed. The minimum content requirements for the EBCx Plan are stated in ASHRAE 0.2, Assessment Phase section titled “Develop the EBCx Plan”. This same section in ASHRAE 1.2 provides an in-depth outline of EBCx Plan information for HVAC systems; provide similar information for other building systems included in the scope. Include strategies and activities in the EBCx Plan to meet each CFR item.

4-2.5 Systems Manual Outline.

The Systems Manual contains the information needed to understand, operate and maintain the building systems that are included in the EBCx scope. If the building has not been commissioned in the past, the Assessment Phase efforts include beginning to develop the sections for the complete Systems Manual. If a Systems Manual exists from prior commissioning efforts, the Cx Provider reviews it for accuracy and completeness, and updates and adds information as necessary. ASHRAE 0.2, Assessment Phase section titled “Establish the Systems Manual Outline”, identifies required topics in the Systems Manual, with an example outline included in Annex M of ASHRAE 0.2.

4-2.6 Building and System Assessments.

The assessment of the building provides the first opportunity for the EBCx Team to document baseline performance of the systems and assemblies. Baselines are documented assessments of current operation for items such as energy use, energy demand reduction, ability to provide occupant comfort, frequency and type of service calls, and reliability of building systems and equipment. Utilize the assessment strategies as outlined in the EBCx Plan. This assessment seeks to provide a good understanding of the building systems and assemblies, their state and condition, and the operational parameters currently in place. Ensure this information is well documented as it provides the initial comparison of building performance against the criteria defined in the CFR. This baseline information is used to measure anticipated benefits and performance improvements obtained through the EBCx process. Where needed, these assessments are performed in more detail during the follow-on Investigation Phase.

4-2.6.1 System Assessments.

Perform the following assessment activities on systems in the EBCx scope (additional details on specific building systems are included below):

a. Determine if assessments will address all equipment or a sample of equipment.

b. Identify procedures, requirements, and schedule, to gain access to areas of the building. Determine accessibility to equipment, systems, and components for inspection and testing.

c. Perform a visual inspection of major equipment. Review documents as needed (such as O&M records and on-site systems documents).

d. Document observed deferred maintenance and O&M issues.

e. Evaluate building performance in accordance with benchmarking methods defined in the CFR and document maintenance and operational issues.

f. Determine change of use or function of systems, assemblies, or components with initial design.

g. Document occupant and user issues discovered during walk-throughs or surveys.

h. Document safety hazards observed during building walk-throughs (such as unprotected electrical wiring, fall hazards, and other dangerous conditions).

i. Identify known resources, such as operations and maintenance support personnel.

j. Identify subject areas where additional training needs are necessary, based on both the complexity of systems and the personnel’s expertise in operating and maintaining them.

k. Record the general condition of the systems, including age, maintenance issues, observed damage, and design or installation flaws.

l. Perform additional walk-through observations or interviews/surveys as necessary to gain a general understanding of the baseline condition of existing building systems and assemblies.

4-2.6.2 HVAC & Refrigeration System Assessments.

Perform Assessment Phase activities on HVAC&R systems in accordance with ASHRAE 1.2, Assessment Phase Section titled “Perform Assessment”.

4-2.6.3 Building Enclosure System Assessments.

Perform initial assessment of building enclosure systems through review of documentation, interviews, and visual assessments as follows.

4-2.6.3.1 Review of Building Enclosure Documentation.

Review the original design plans of the building and renovation drawings, as well as records of changes or previous condition surveys, to assess the following which may affect the performance of the building enclosure:

- Air barrier continuity
- Materials used and known life cycle issues
- Original performance expected
- Inherent thermal bridging issues
- Identify clearly the four control layers for the building enclosure: a) rain/moisture control layer, b) air control layer, c) vapor control layer, and d) thermal control layer
- Determine if non-occupied areas such as crawl spaces and attics are designed as vented or non-vented spaces, or the design is unclear and they are operating as unintended hybrid systems (which harm building performance).

4-2.6.3.2 Interviews with Building Manager and Occupants.

Interview the building manager, maintenance personnel and building occupants regarding the following issues:

- Changes to purpose or function of the building (such as warehouse to office space)
- Known water penetration issues, observed high humidity, or deteriorated interior finishes
- Air movement detected around windows or doors
- Glare problems
- Temperature issues in spaces
- Unpleasant odors
- Excessive background noise in spaces

4-2.6.3.3 Visual Inspections of Building.

Perform visual inspection of the building to assess the following for conditions adversely affecting building performance:

- Topography slopes with the potential for ponding water against the building
- Deterioration issues (such as sealants, masonry pointing and spalling, window gaskets)
- Evidence of excessive dampness, vegetative growth, or staining on the building exterior
- Roof issues (such as deterioration of membranes or flashings, poor adhesion, tenting of membranes, ponding, vegetative growth, or evidence of roof drain overflows)
- Corrosion issues
- Evidence of foundation movement (such as cracks or displaced or out of plane elements)
- Obvious changes of cladding materials or changes in building footprint as compared to record original and renovation construction drawings
- Crawl space issues:
  - Evidence of condensation or water penetration into the space
  - For ventilated crawl spaces, check sub-floor insulation for continuity
  - At a minimum, crawl spaces must have a vapor barrier sealed at laps, exterior walls, and penetrations.
- Evidence of exterior wall issues observed from the interior:
  - Obvious signs of water entry, especially around windows, doors, foundation walls, and at the roof-to-wall connection. Signs may include stains, mold, peeling paint, efflorescence, peeling drywall tape, or standing water or dampness.
  - Fogging on the inside of insulated glass panels.
  - Dark stains on the exterior wall around light switches and receptacles and other penetrations in the drywall (common indications of air infiltration).
  - “Ghosting” (dark stains) at drywall screw heads or metal studs, resulting from drywall with a high moisture content. This is often caused by thermal bridging, by a lack of exterior insulation, or incorrectly installed vapor barrier resulting in a dew point condition within the wall cavity. A lack of an air barrier also results in dew point issues in the wall cavity.
  - Check seals around windows and doors for continuity and resilience.
- Evidence of issues above ceilings:
  - Stains on the ceiling drywall or acoustical tile (caused by roof leaks or by condensation dripping from building systems above the ceiling).

  - Excessive rusting on bar joists or structural steel (may indicate condensation caused by air infiltration, often at the roof-to-wall interface).
- Carpet or floor tile may indicate the presence of water by discoloration or loss of adhesion (caused by water infiltration or condensation on insufficiently insulated slabs-on-grade).
- Air curtains with operational issues

4-2.6.4 Electrical System Assessments.

Perform initial assessment of electrical systems through review of documentation and interviews as follows.

4-2.6.4.1 Review of Electrical System Documentation.

Review the original design plans of the building and renovation drawings, as well as records of changes or previous condition surveys, to assess the following which may adversely affect the performance of the electrical systems:

- Current systems installed
- Materials used and known life cycle issues
- Original performance expected
- Inherent increased energy usage issues
- Current stage in life cycle of existing equipment for continued use opportunity
- Bulb/lamp type replacement vs. fixture replacement

4-2.6.4.2 Interviews with Building Manager and Occupants.

Conduct interviews to determine how the building is being used, identify known system issues, and confirm how the building is serving the occupant’s needs. Interview the building manager, maintenance personnel and building occupants regarding the following issues:

- Past changes to purpose or function of the building (such as warehouse to office space)
- Known electrical issues, or high cost of maintenance on equipment
- Nuisance tripping of circuit breakers
- Generator (Emergency Power)
  - Excessive fuel costs (equipment running poorly)
  - Nuisance breakdowns (frequency of and cost for repairs)

   - Life Cycle (expected equipment life vs. current age)
   - Adequacy of fuel storage capacity (if function/mission of building has changed, new function may have additional energy demand that requires increased fuel storage)
- Current Lighting Systems
   - Fixture types (examples include incandescent, fluorescents, and light-emitting diode (LED))
   - Lighting Controls (examples include switches, occupancy sensors, time clocks, and building management system (BMS))
- Renewable Energy Systems
   - Solar Arrays, wind turbines
   - Life cycle (expected equipment life vs. current age)

4-2.7 Issues and Resolution Log.

Create an initial Issues and Resolution Log which contains detailed descriptions of the findings and recommendations from the initial assessments. This log contains information outlined in the ASHRAE 0.2, Assessment Phase section titled “Issues and Resolution Log”. The log contains issues found, recommendations for corrective actions, estimated costs and benefits, implementation actions and status, and hand-off activities such as training and actions for maintaining performance improvements. Maintain/update this log through the entire EBCx process.

4-2.8 Implement Immediate Improvements.

Bring to the attention of the Building Manager issues found, especially those related to safety, security, health, or operational issues that can be easily remedied and do not require further evaluation (will obviously not adversely impact other systems). Corrective actions that do not incur costs and provide immediate payback can be implemented during the EBCx process; however, do not implement corrective actions without coordinating with maintenance staff responsible for upkeep on the building due to the possibility of creating unintended adverse issues (for example, opening a valve may improve the operation of the mechanical system, but the maintenance staff may have closed the valve temporarily until repairs can be performed on a system leak).

For minor improvements that require installation maintenance staff involvement, coordinate with installation personnel such that work orders are submitted for correcting these issues. Document and include in both the EBCx Report and the Issues and Resolution Log these immediately implemented modifications and corrective actions, along with their projected benefits.

4-2.9 Assessment Report Portion of EBCx Report.

The EBCx Report begins with the creation of the Assessment Report. The Assessment Report becomes the initial chapter of the EBCx Report and documents the findings and results of the Assessment Phase activities. The minimum content requirements for the Assessment Report portion of the EBCx Report are stated in ASHRAE 0.2, Assessment Phase section titled "Initiate EBCx Report with Assessment Report". This same section in ASHRAE 1.2 identifies information required for HVAC systems. Provide the information outlined in ASHRAE 0.2 for the building systems included in the EBCx scope.

4-2.10 Government Review and Decision to Proceed.

Government representatives will review the Assessment Phase deliverables to determine if the Assessment Phase activities are complete and they concur with the planned approach for proceeding into the Investigation Phase. Review comments are submitted to the Cx Provider and submittals are revised and re-submitted as necessary. For projects considering multiple buildings for EBCx, the Government will review the revised EBCx Program Plan for concurrence with recommendations on the buildings planned for subsequent evaluation.

4-3 ASSESSMENT PHASE DELIVERABLES.

The Assessment Phase deliverables consist of the following:

- CFR (included in EBCx Report)
- EBCx Plan
- Initial EBCx Report, including the Assessment Section
- Systems Manual Outline
- Updated EBCx Program Plan (if applicable to multiple building projects)
- Initial Issues and Resolution Log

4-3.1 EBCx Plan.

The fully developed EBCx Plan has multiple report sections which outline the strategies for executing the EBCx phases. Sections are initially developed in one phase and are updated as the EBCx efforts progress into subsequent phases. The minimum content requirements for the EBCx Plan are stated in ASHRAE 0.2, Assessment Phase section titled "Develop the EBCx Plan". Sections of the overall EBCx Plan and the phase in which they are developed are as follows (refer to the referenced phase within this document for the requirements of plan report section contents; see Appendix A for the location of best practice templates for the EBCx Program Plan and the EBCx Plan):

- EBCx Program Plan – developed for multiple-building EBCx efforts; initially developed in Planning Phase and updated in Assessment Phase

- Initial EBCx Plan – created in the Assessment Phase
- Measurement and Verification (M&V) Plan – initial approach is developed in Initial EBCx Plan during Assessment Phase, then plan is updated in subsequent phases for the detailed M&V of the recommendations that are implemented. M&V Plan includes the details for both baseline and post-implementation performance period testing required for quantifying the performance and achieved benefits of the process.
- Training Plan – included in the Initial EBCx Plan during Assessment Phase, then plan is updated in subsequent phases based on personnel needs and system complexity
- Investigation Plan – added to the EBCx Plan during the Investigation Phase
- Implementation Plan – added to the EBCx Plan during the Implementation Phase
- OCx Plan – developed in the Hand-off Phase, then updated in the OCx Phase.

4-3.2 EBCx Report.

The full EBCx Report has multiple report sections which document the activities undertaken and results of the EBCx process. Sections of the overall EBCx Report and the phase in which they are developed are as follows (refer to the referenced phase within this document for the requirements of the report section contents; see Appendix A for the location of best practice templates for the EBCx Report):

- Initial EBCx Report with Assessment Report – created in the Assessment Phase, includes initially recommended CFR and initial Issues and Resolution Log.
- Investigation Report section – added to EBCx Report during Investigation Phase, including results and findings, and updated content.
- Implementation Report section – added to EBCx Report during Implementation Phase, including work undertaken and implementation results. Other content includes test documentation, updated Issues and Resolution Log, site visit records, verification documentation, M&V documentation, and training documentation.
- Final EBCx Report, including Lessons Learned Report section – created in the Hand-off Phase to include lessons learned, necessary updates to prior content, final training and verification documentation.

The OCx Report is a separate report from the EBCx Report and is developed during the OCx Phase. It is most common for the Government to be responsible for OCx Phase efforts, either utilizing installation maintenance resources or installation support contracts.

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CHAPTER 5 INVESTIGATION PHASE

5-1 OBJECTIVES.

The Investigation Phase consists of detailed site investigations, which compare the actual as-is building conditions and system performance with the Current Facility Requirements (CFR). This phase reveals existing conditions in the building, evaluates the need for change, and identifies requirements for additional systems, assemblies, or additions. The benefits and expected payback of each recommended change are derived. The objectives of the Investigation Phase are to understand and document existing conditions and performance to identify improvements needed to bring the building into compliance with the CFR.

This phase concludes with the completion of the Investigation Report section of the EBCx Report, which identifies scope and benefits of recommended building modifications and improvements as well as quick fix improvements already implemented during the Investigation. This is the data intensive portion of EBCx and may be most appropriate for contracting to EBCx specialists. When contracting, the issues and opportunities identified in the Assessment Phase determine the type of specialist needed; for example, if issues are broad and widespread across systems, an Energy Services Contractor (ESCO) may be the best fit, but if the issues are controls-specific a local controls vendor/Contractor may be the right team member.

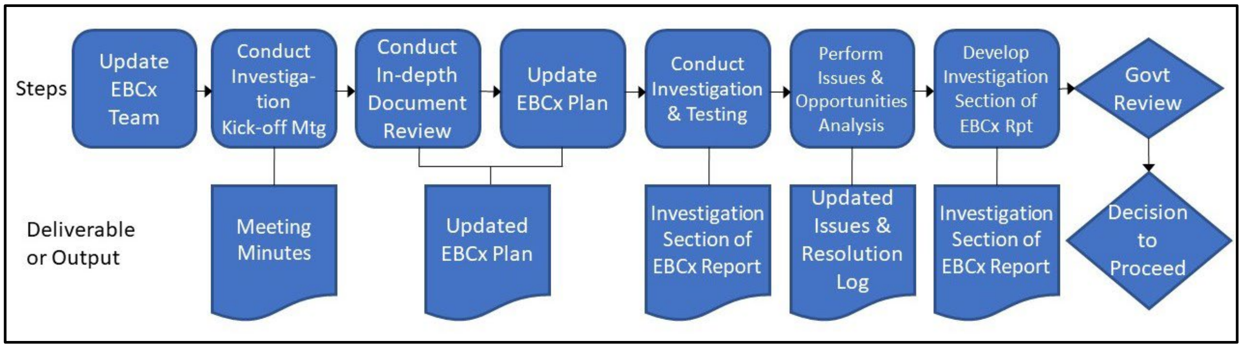
5-2 INVESTIGATION PHASE STEPS.

The Investigation Phase involves performing detailed testing and analysis of specific building systems, discovering operational characteristics, verifying needed modifications, and quantifying implementations needed and improvements expected.

Investigation Phase steps are as follows:

a. Update EBCx Team
b. Conduct Investigation Phase kick-off meeting
c. Conduct in-depth building documentation review
d. Update EBCx Plan
e. Perform site Investigations and testing
f. Perform issues and opportunities analysis
g. Update EBCx Report with Investigation Report
h. Present recommendations to Government and adjust plans
i. Obtain Government review and decision to proceed

Figure 5-1 Investigation Phase Process and Deliverables/Outputs



5-2.1 Updated EBCx Team.

Based on the results of the evaluations conducted in the Assessment Phase, which identify the testing and inspections required in the Investigation Phase, the EBCx Team may require additional specialists or support. Identify these new team members and their roles and responsibilities in a revised version of the EBCx Plan.

5-2.2 Investigation Phase Kick-off Meeting.

Conduct an Investigation Phase kick-off meeting to provide an overview of the EBCx Plan, review findings from the Assessment Phase, and coordinate the upcoming work activities. Also review investigation tests/inspections and deliverables during the meeting. Required attendees include Government and Contractor personnel playing a key role in the Investigation Phase activities, as well as building operations and maintenance staff. Topics for this meeting include the following:

- EBCx goals and objectives
- Introduction of new EBCx team members
- Confirmation of EBCx roles, including local support
- Review of communication and coordination plan
  - Security requirements and coordination
  - Planned meetings
- Specific Investigation Phase Plan/Activities
  - Outline of activities
  - Building systems being evaluated
  - Approach to measurement and verification (M&V), with special focus on baseline testing
  - Planned Functional Performance Tests (FPT's)/inspections
  - Access required

- Impacts to operations
- Government staff participation/assistance
- Training approach
- Deliverables/Submittals

- Planned EBCx schedule

Following the meeting, develop formal meeting minutes and issue to attendees as well as stakeholders who were unable to attend.

5-2.3 In-Depth Building Documentation Review.

Conduct a more detailed review of the documentation gathered during the Assessment Phase. This detailed review and analysis assists in identifying which tests and inspections are the most appropriate for the Investigation Phase efforts. This review seeks to reveal information about the intended original basis of design, the existing baseline design, as well as the current operational procedures. With this information, the Cx Provider seeks to determine the deviations between current operations, the original building/systems design, and the current facility requirements (CFR). Goals of this review include:

- Gaining a complete picture of equipment and assemblies included in the EBCx scope
- Identifying potential problem areas to investigate
- Understanding the intended design of building systems and assemblies
- Creating a list of specific equipment and assemblies to evaluate during the Investigation Phase and the appropriate methods of testing and inspection

At a minimum, the detailed review includes the following:

- Evaluation of original and new drawings, specifications, historical utility records, and previous CFRs and commissioning records
- Interactions between building systems and assemblies (such as building envelope components that impact HVAC system performance)
- Prior building evaluation reports, such as energy performance analysis, roof inspections, architectural studies, energy audit reports, TAB reports, capital planning documents, sustainability assessments, safety/health reports, Cx reports, or similar documents to determine what has already been evaluated, recommended for improvements, improved, or not yet implemented
- Building/systems operations and maintenance manuals, with special focus on controls systems (such as those related to HVAC, lighting, security, and fire alarm)

- Maintenance records to assess preventive maintenance and identify potential systems issues

5-2.4 Updated EBCx Plan.

Update the EBCx Plan to include an Investigation Plan. The Investigation Plan is a detailed outline of the planned processes for analyzing existing building conditions and identifying upgrades and improvements needed to meet the Government's CFR. The plan addresses every system and assembly included in the EBCx scope of work. The Government will review and accept the Investigation Plan prior to on-site investigation activities being performed.

The Investigation Plan must include, at a minimum, the information outlined in ASHRAE 0.2 Investigation Phase section titled "Update EBCx Plan".

5-2.5 Site Investigations and Testing.

Carry out physical inspections and tests to evaluate condition and performance as detailed in the reviewed and accepted EBCx Investigation Plan, and record observations and data. The two elements of physical site investigation are condition evaluation and performance evaluation. Condition evaluation includes an assessment of the installed condition of the equipment, systems, and assemblies, such as appearance, physical damage, deterioration of condition, upgraded features, and change of use. Performance evaluation includes an assessment of how the equipment, systems, and assemblies are operated and how they are performing relative to expected performance and the CFR.

During the physical site investigation, evaluate and document the condition and performance of the equipment, systems, and assemblies, as identified in the Investigation Plan. Performance evaluation may include active and passive testing. Execute the tests and repeat as necessary to obtain conclusive information about the performance of systems. During execution of the Investigation Plan, issues may be uncovered that lead to expansion of the plan or to the elimination of specific planned activities. When revisions of an accepted Investigation Plan are required, submit the revised plan to the Government for formal acceptance before proceeding with execution of an altered plan. Conduct on-site investigations in accordance with ASHRAE 0.2 Investigation Phase section titled "Perform Site Investigation and Testing", as well as additional information contained within this document.

5-2.5.1 Detailed Site Survey.

The detailed site survey involves evaluating and documenting the condition and performance of the equipment, systems, and assemblies, as included in the EBCx scope of work and identified in the Investigation Plan. This survey focuses on areas of concern revealed from interviews/surveys, document reviews, and prior brief walk-throughs of the building. The detailed site survey includes assessments to evaluate condition and performance, involving the following actions at a minimum:

- Assess condition, including damage, and noting age of equipment and expected remaining life
- Identify indications of deferred maintenance which could be affecting performance
- Note new features or changes in use of equipment
- Denote issues that affect the equipment's ability to be appropriately operated or maintained (such as lack of adequate access)
- Compare how system/components are operated vs. CFR or good practice
  - Set-points
  - Modes of operation (such as daytime, 24/7, or seasonal)
  - Load

5-2.5.2 Calibrations of BAS-Trended Points.

If BAS systems are operating, verify the accuracy of sensors, valves and actuators and statuses to ensure precision of BAS screen shots and trend data. At a minimum, perform this on the devices that impact control and BAS points. Complete calibration prior to initiating trends – coordinate with building manager prior to performing calibration.

If controls are obsolete or non-functioning, include in the EBCx improvements corrective actions to repair or replace the controls. If the BAS/DDC system has been modified from the original design, interview the O&M staff to investigate why the change was made.

5-2.5.3 Energy Usage and Building Performance Baseline.

Establish an energy usage baseline early in the project and track improvements as corrective actions are identified and implemented. Compare this current energy usage to benchmark buildings to identify the potential for improvement. In addition to energy use, available performance data may also include maintenance work orders, comfort complaint logs, indoor air quality parameters, occupant/user satisfaction survey results, and BAS trend data or data logger data. Obtaining this information establishes a performance baseline prior to implementation actions and helps determine the positive impact of EBCx efforts and the benefits gained.

5-2.5.4 System and Equipment Performance Monitoring.

The EBCx Team executes the system and equipment monitoring as outlined in the Investigation Plan section of the EBCx Plan. This involves gathering data through diagnostic monitoring methods to identify poor performance and potential improvements. For example, to monitor HVAC systems, diagnostic monitoring methods include BAS trending, portable data logger trending, and energy and weather data collection. Perform similar diagnostic testing to assess performance of other building systems included in the EBCx scope.

5-2.5.5 Additional Building Personnel and Occupant Interviews.

Conduct additional interviews with the Building Manager, O&M personnel and building occupants to gain a more in-depth picture of the current use of the building and operation of its systems. While surveys can serve the purpose of gathering initial feedback from the building occupants/users, also conduct formal interviews with building managers and O&M personnel. The goals of obtaining this information are to identify current problem issues, uncover potential improvement opportunities and confirm the CFR. See Appendix A for the location of best practice templates for the building occupant questionnaire.

5-2.5.6 Building Automation Controls System Reviews.

Conduct a thorough and detailed review of the building automation system, focusing on establishing the current sequence of operations, identifying/confirming accurate graphics, and evaluating unit alarms/settings. Review building automation system graphic screens, alarm logs, and schedules for each piece of HVAC equipment, including a complete review of setpoints or reset parameters. Identify conditions which result in wasted energy use. Document the "as-found" conditions and the current operation of the systems (information is critical for subsequent measurement and verification activities). Record identified problems and improvement recommendations to the sequence of operations in the Issues and Resolutions Log.

5-2.5.7 Functional Performance Test (FPT) Procedures.

Develop functional performance test (FPT) procedures for the systems identified in the EBCx scope of work. Functional testing is often necessary to determine how systems react to key operating conditions. Test plans for energy efficiency focused projects both confirm existing system operation to identify improvements, and test or confirm ideas for improvement. Develop the FPT's with the goal of verifying that EBCx efforts, after system improvements, aid in the building achieving the CFR parameters. The information to be included in a thorough test procedure and test form is outlined in ASHRAE 0.2 Investigation Phase section titled "Update EBCx Plan". The developed FPT's are included in the Investigation Phase portion of the EBCx Plan which is submitted to the Government for acceptance of the procedures prior to scheduling testing.

5-2.5.8 System Functional Testing.

Following Government acceptance of the FPT's, functional testing is conducted to evaluate existing systems performance and identify areas requiring improvements to meet the CFR. Issues identified in the Assessment Phase or early in the Investigation Phase are considered for more in-depth evaluation during system testing to determine root causes and potential solutions. Ensure required equipment and personnel, both

EBCx Team and Government support, are on-site prior to commencing testing. Schedule tests with building management staff so that disruptions to normal operations are avoided or minimized. Schedule testing which requires outages or operations impacts with adequate notice and communicate to the building manager, O&M personnel, and occupants/users. Testing may need to be deferred based on climate conditions, occupancy situations or planned events. Additional testing guidelines for specific systems are included below.

5-2.5.8.1 HVAC & Refrigeration System Investigation and Testing.

Perform testing of HVAC&R systems in accordance with ASHRAE 1.2, Investigation Phase section titled “Perform Site Investigation and Testing”.

5-2.5.8.2 Building Enclosure Investigation and Testing.

Conduct further investigation and testing of building enclosure issues in accordance with the following:

- Test for air movement through the enclosure in accordance with ASTM E1186. This standard covers multiple test methods. For initially testing large surface areas, infrared scanning allows for rapid surveying; for follow-up leak detection testing of local areas, the smoke tracer, theatrical fog, anemometer, sound detection, bubble detection, and tracer gas techniques are typically more appropriate methods.
- Test for air leakage in accordance with either ASTM E779 or ASTM E1827.
- Test for water infiltration through building walls in accordance with ASTM E2128.
- Test for continuity of insulation by use of infrared imaging in accordance with ASTM C1060.
- Test for roof leaks in accordance with ASTM D8231 and ASTM C1153.

5-2.5.8.3 Electrical Systems Investigation and Testing.

Conduct further investigation and testing of electrical systems in accordance with the following (Note: It is important to note that the local Authority Having Jurisdiction may have more stringent requirements for operational requirements; these must be confirmed.):

- Emergency and Stand-by Power Systems:
  - Perform inspections and operational testing in accordance with UFC 3-540-07, NFPA 110 section titled “Operational Inspection and Testing”, and the manufacturer’s instructions.

- Lighting Control Systems:
  - Test lighting controls in accordance with IECC (C405 & C408.3 – Lighting system functional Testing), NEMA 410 – (Performance testing for lighting controls and switching devices), and manufacturer's installation and operation instructions (sequence of operations).
- Power and distribution systems:
  - Conduct infrared camera thermography tests on equipment in accordance with ISO 18251-1: Non-destructive Testing – Infrared Thermography – Part 1, Characteristics of System and Equipment; and ANSI/NETA MTS, Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems. Follow the required safety protocols of NFPA 70E, Standard for Electrical Safety in the Workplace.
- Renewable energy systems:
  - Photovoltaic (solar arrays): test functionality in accordance with NFPA 70; and IEC (International Electrotechnical Commission) 62446-1, Photovoltaic systems – Requirements for testing, documentation, and maintenance Part 1: Grid connected systems – documentation, commissioning tests, and inspection.
- Energy storage systems:
  - Uninterruptable power supply (UPS): test functionality in accordance with NFPA 70; and IEC (International Electrotechnical Commission) 62040-3 Uninterruptable Power Systems – Part 3 Performance and testing requirements – UPS.

5-2.5.9 Data for Energy Calculations and Implementation.

Gather data for savings calculations and detailed implementation recommendations. This includes documenting current energy usage for a system or piece of equipment being recommended for repairs or replacement. If electrical data measurement is not allowed or practical, electrical usage may be derived using data such as equipment sizes and run times.

5-2.5.10 Simple Repairs.

Corrective actions that are discovered by the EBCx Team during the Investigation Phase and provide immediate payback through no or low costs can be implemented during the EBCx process; however, do not implement corrective actions without coordinating with maintenance staff responsible for upkeep on the building due to the possibility of creating unintended adverse issues (for example, opening a valve may improve the operation of the mechanical system, but the maintenance staff may have closed the valve temporarily until repairs can be performed on a system leak). For minor improvements that require installation maintenance staff involvement, coordinate with installation personnel such that work orders are submitted for correcting these issues. Document and include in both the EBCx Report and the Issues and Resolution Log these immediately implemented modifications and corrective actions, along with their projected benefits. ASHRAE 1.2 lists examples of these quick fixes as follows:

- Systems control calibration/repairs: air-distribution component repairs, water/steam distribution component repairs, variable air volume (VAV) or constant volume (CV) box calibration
- Mechanical system repairs: blockage from air-distribution devices, connecting broken flex duct from a duct tap or diffuser, replacing a broken fan belt, damper linkage, resetting dampers, resetting air handling unit (AHU) or fan coil unit (FCU) air flows with significant variance from design
- Plumbing systems: fixture and appliance repair, water system repair, water pressure and hot water temperature adjustment corrections
- Electrical repairs: such as loose terminations or lighting repairs, lighting schedule adjustments
- Correcting systems operating schedules: system running 24/365
- Turning off equipment that does not need to be operating.
- Releasing overridden control set points and parameters.
- Returning equipment to automatic mode
- Deferred maintenance issues: filter replacement, coil cleaning, clean pipe strainers/tower screens, adjust fan belts, replace failed components

5-2.6 Issues and Opportunities Analysis.

Analyze issues, conditions, and performance information acquired from site investigation and testing to identify possible solutions and corrective action recommendations. Review information gathered from previous commissioning activities to increase understanding of issues that adversely affect the building and system conditions and performance. Update the Issues and Resolution Log with identified issues and related recommendations for improvement.

5-2.6.1 Data Analysis.

The off-site portion of the Investigation Phase involves evaluating the data collected during on-site inspections and tests to draw conclusions about existing or potential system performance. Data analysis forms the basis for the recommendations for improving the building and systems condition and performance. Keep in mind that these recommendations must, at a minimum, identify those improvements required to achieve the CFR, plus those corrective actions required to address poor conditions and are leading to subpar performance of the building and its' systems.

5-2.6.2 Energy Impacts and Cost Calculations.

During the Investigation Phase, each recommendation which impacts energy usage included in the Issues and Resolution Log requires developing a simplified Life Cycle Cost Analysis (LCCA). While some commissioning activities will result in reduced energy usage, some activities will increase energy usage. A negative payback or LCCA may result from these situations and should be captured. The LCCA requires development of the cost of repairs/upgrades and the expected annual energy impacts. Develop the estimated construction costs for each recommendation utilizing traditional cost estimating techniques (as outlined in UFC 3-740-05) and include the mark-ups necessary to reflect a total cost if undertaken as a standalone project. The construction costs developed during the Investigation Phase can be rough order of magnitude costs based on the EBCx Team's recent projects; the follow-on Implementation Phase requires more detailed costing efforts of each accepted recommendation prior to procuring the upgrades.

The LCCA requires comparing the current energy usage to the energy use estimated for the new equipment, or estimating the change in energy use resulting from the current condition being corrected. Obtain the local installation's utility rates to derive the energy costs. Develop a simple payback period, in years, for each energy saving recommendation to identify the time required to recover the initial costs of the recommended improvement. For the simple payback, divide the total cost of the improvement recommendation by the projected annual energy savings. The Federal Energy Management Program (FEMP) has online energy- and water-savings calculators that are simple to use and cover specific types of equipment (such as boilers, water heaters, and lighting fixtures). These calculators and other resources can be found at https://www.energy.gov/femp/federal-energy-management-tools. See Appendix A for best practice template for performing savings calculations.

5-2.6.3 List of Findings and Recommendations.

Using the Investigation Phase results, including on-site testing/inspections and analysis of the data, create a list of recommendations. This list is derived from the Issues and Resolution Log. The list includes key information useful for the Government to select recommendations for implementation. The in-depth supporting data is included in the Issues and Resolution Log (included in the Investigation Report portion of the EBCx Report). For the content of the List of Findings and Recommendations, include the information outlined in ASHRAE 0.2 Investigation Phase section titled "List of Findings and Recommendations". Include separate recommendation lists for those that are quick fixes and can be implemented by O&M personnel or installation work orders, and others that are more extensive and require execution as capital projects.

As a basis for classifying recommendations, ASHRAE 1.2 recommends that improvements with a simple payback of less than two years be implemented, and those with a simple payback greater than two years be considered for implementation as a capital improvement project. Keep in mind that some recommendations may be more attractive based on qualitative impacts, rather than their savings gained from the improvement; for example, a key qualitative benefit often achieved is the ability for the tenant to fully support its' mission. The list of findings and recommendations must clearly identify qualitative benefits. Additionally, state the associated greenhouse gas emissions impact related to the implementation of each energy-saving recommendation (in tons of CO_2 emissions avoided). Coordinate with the Installation Energy Manager for local greenhouse gas conversion factors to utilize; in the absence of specific direction from the Installation Energy Manager, utilize the regional conversion factors published on the U.S. Environmental Protection Agency's Avoided Emissions and Generation Tool (AVERT) website (https://www.epa.gov/avert/avoided-emission-rates-generated-avert).

5-2.7 Investigation Report Portion of EBCx Report.

Develop and add to the EBCx Report the Investigation Report portion which documents the findings and results of the Investigation Phase activities. The minimum content requirements for the Investigation Report portion of the EBCx Report are stated in ASHRAE 0.2, Investigation Phase section titled "Update EBCx Report with Investigation Report". This same section in ASHRAE 1.2 identifies information required for HVAC systems. Provide the information outlined in ASHRAE 0.2 for the building systems included in the EBCx scope.

5-2.8 Recommendations and Plan Adjustments.

Conduct a meeting to present the recommendations resulting from the Investigation Phase. Based on these discussions, make adjustments based on the most likely means of implementing the recommendations. For example, at an installation with sufficient resources and access to contracting mechanisms to implement specific types of repairs or upgrades, those recommendations could be prioritized for early completion and other recommendations deferred to a later timeframe. These deferred recommendations could be implemented as a capital project involving similar upgrades at other buildings.

Recommendations may be prioritized for early implementation based on the following parameters, from highest to lowest priority:

- Life safety or code compliance issue that requires immediate action (note: safety evaluations are not included in the scope of standard EBCx efforts, but identify safety issues discovered in the normal course of EBCx activities in the corrective actions list; examples include electrical boxes with exposed faceplates, exposed wiring, and obvious fall hazards).
- Deferred maintenance issue with easy implementation
- No cost to implement
- Common repair/adjustment through installation work order or service contract

- Corrective action that enhances resiliency of a mission critical building (such as an inoperable backup power generation system), or reduces the risk of a building being able to support its' mission
- Corrective action that provides quality of life improvement (such as restoring operations of the HVAC system to provide proper occupant comfort or indoor environmental quality)
- Capital improvement project (requires design and construction) with high energy savings, low cost, or short payback period
- Capital improvement project with higher cost or extended payback period

5-2.9 Government Review and Decision to Proceed.

Government representatives will review the Investigation Phase deliverables to determine if the activities are complete and they concur with the planned approach for proceeding into the Implementation Phase. Review comments are submitted to the Cx Provider and submittals are revised and re-submitted as necessary.

When a recommendation involves design and construction efforts such as replacement of an entire building system, these are not performed as part of EBCx efforts but follow the Government's design process. Follow-on commissioning efforts to verify design and performance of new construction or renovation projects will then follow the requirements of UFC 1-200-02 and related UFGS guide specifications.

5-3 INVESTIGATION PHASE DELIVERABLES.

The Investigation Phase deliverables consist of the following:

- Updated EBCx Plan
- Updated EBCx Report, including the Investigation Report

CHAPTER 6 IMPLEMENTATION PHASE

6-1 OBJECTIVES.

During the Implementation Phase, the Government decides which Investigation Phase recommendations to implement and how they will be accomplished. The selected recommendations are implemented and evaluated to verify they achieve the expected benefits and satisfy the Current Facility Requirements (CFR). The objectives of the Implementation Phase are to execute the recommendations selected from the Investigation Phase, verify performance meets the CFR, and report the results of implementation. It is important to emphasize that the main benefits of EBCx, such as achieving energy savings and optimizing system performance, are not realized until corrective actions are implemented.

The Assessment, Investigation, and Implementation Phases are typically iterative processes. If during investigation it is found that a repair can be easily made, or a change/repair is required to complete the investigation, this item can be implemented during the Investigation Phase. An iterative implementation might occur when a repair needs to take place before the system can be fully investigated or when changes made need verifying and modifying multiple times before the targeted results are achieved. This phase concludes with the verification of the system's performance and the updating of the Systems Manuals.

6-2 IMPLEMENTATION PHASE STEPS.

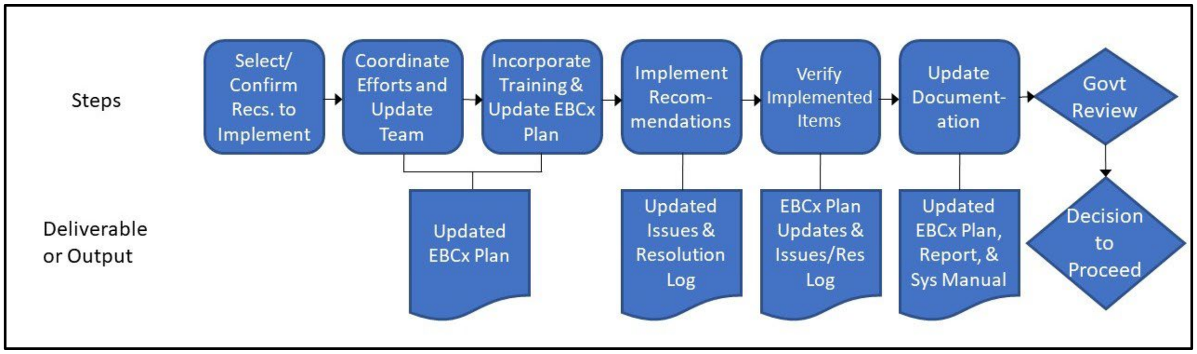
Recommendations from the Investigation Phase can be grouped into Implementation Phase packages completed through different execution routes. Depending on their complexity and cost, these can be executed through installation public works resources, installation service contracts, or if extensive and costly, may require some level of design and construction procurement. Thus, the Implementation Phase involves oversight of construction or service contract work in the building(s). The goals of the Implementation Phase are to select the most beneficial recommendations to achieving the established goals and objectives of the EBCx project, select the execution route, implement the selected measures, and verify or performance test that these measures achieve the expected benefits. The Implementation and Hand-off Phases are conducted by the same project delivery team whether it is an in-house or contracted group.

Implementation Phase steps are as follows:

a. Select/Confirm recommendations to implement
b. Coordinate implementation
c. Update EBCx Team
d. Incorporate informal training
e. Update EBCx Plan

f. Implement recommendations
g. Verify completed recommendations and performance
h. Update EBCx documentation
i. Obtain Government review and decision to proceed

Figure 6-1 Implementation Phase Process and Deliverables/Outputs



6-2.1 Implementation Recommendations Selection/Confirmation.

This step involves identifying those improvements planned for the Implementation Phase and others deferred with a timetable for planned implementation as capital improvement projects. The ultimate goal of this phase is having the systems perform efficiently to meet the CFR. Involve the O&M staff in the implementation decision process. At the completion of the prior Investigation Phase, a meeting is held to review recommendations and set priorities for implementation based on the installation resources and contracting mechanisms available. The Implementation Phase then begins with reviewing these priorities and timeframes and confirming the recommendations that were selected for implementation.

6-2.2 Implementation Coordination.

The Cx Provider assists with coordinating the completion of the selected recommendations. For recommendations that can be handled through installation resources or service contracts, or through a modification to the EBCx contract, the Cx Provider acts as a third-party commissioning resource to ensure the resulting improvements meet the CFR (provided if Implementation Phase services are included in the Cx Provider's scope of work).

Recommendations from EBCx efforts requiring involvement of design and construction are typically handled as projects separate from the EBCx process. However, these projects require third-party commissioning efforts in accordance with UFGS 01 91 00.15 BUILDING COMMISSIONING.

6-2.3 Updated EBCx Team.

The EBCx team members for the Implementation Phase typically change based on the recommendations planned for implementation. The team may include building operations staff, installation O&M personnel, subcontractors, system vendors, or other specialists contracted directly to the Government or to the Cx Provider.

6-2.4 Informal Training.

The Cx Provider coordinates the Implementation Phase to allow for involvement in implementation and verification testing by the installation or building O&M staff (depending on which party is responsible for maintaining the system). This involvement serves as informal hands-on training for operating and maintaining the systems after the improvements are in place. This involvement also establishes an understanding of the expected system performance and aids in identifying performance degradation and ensuring extended equipment life. The level of involvement depends on the types of recommendations implemented and the methods chosen for implementation (contracted vs. in-house implementation).

6-2.5 Updated EBCx Plan.

This step involves developing the portions of the EBCx Plan associated with the Implementation Phase. The EBCx Plan portions developed or updated in this phase are as follows:

- Implementation Plan
- Implementation Verification Plan
- Updated Training Plan
- Updated Measurement and Verification (M&V) Plan

6-2.5.1 Implementation Plan.

Develop an Implementation Plan containing the detailed roles and responsibilities of EBCx team members, including identification of new team members. Include a communication plan for the new team structure. In addition, incorporate any necessary Plan changes to the execution process based on updates to local resource availability conveyed from the Government to the Cx Provider. Also include the details of the planned implementation of recommendations. Submit to the Government for review and acceptance. Once the Implementation Plan is accepted by the Government, implementation activities can be performed.

For each recommendation accepted by the Government for implementation, the Implementation Plan includes the following information:

a. EBCx team members involved in the implementation and their roles and responsibilities.

b. Planned schedule of implementation as coordinated with occupants, building security, custodians, and utility services. Clearly communicate and coordinate any operational impacts including outages and shutdowns.

c. Detailed scope of work, including implementation methods, work required for sustained performance improvement, and verification procedures with roles/responsibilities. Implementations involving HVAC systems must include additional scope actions as outlined in ASHRAE 1.2, Implementation Phase section titled “Create Implementation Plan”

6-2.5.2 Implementation Verification Plan.

Update the EBCx Plan to include an Implementation Verification Plan. This outlines the detailed implementation verification tests and physical inspection procedures, as well as forms and checklists utilized for each selected recommendation. These tests and inspections represent those required to ensure that corrections and improvements were successfully implemented such that systems meet the CFR. Submit the Plan to the Government for review and acceptance. Once the Implementation Verification Plan is accepted by the Government, verification activities can be performed.

The Implementation Verification Plan includes the following information:

a. Roles and responsibilities of EBCx team members, including new verification specialists.

b. Verification tests and inspection procedures are required to ensure that implemented recommendations are installed and functioning in accordance with the CFR. Verification Plans for implementations involving HVAC systems must follow ASHRAE 1.2, Implementation Phase section titled “Develop Implementation Verification Plan”. Plans for other building systems must include similar information, with tests and inspections following the standards for those systems as outlined in Chapter 5 of this document.

6-2.5.3 Updated Training Plan.

Update or further develop the formal Training Plan developed in prior phases to include necessary changes based on Implementation Phase activities. Ensure the training addresses the implemented recommendations and changes to the operating procedures.

6-2.5.4 Updated Measurement and Verification (M&V) Plan.

Update the M&V Plan based on the known scope of work for recommendations planned for implementation. While the Implementation Verification Plan included the test and inspection procedures required for verification of the implemented recommendation, this updated M&V Plan includes the details for both baseline and post-implementation performance period testing required for quantifying the performance and achieved benefits of the process. Where specific M&V protocols are required, include the specific means and methods necessary to comply with the requirements of the chosen protocol. Submit to the Government for review and acceptance. Once the updated M&V Plan is accepted by the Government, implementation activities can be performed.

6-2.6 Recommendations Implementation.

The Cx Provider implements those recommendations selected and within their scope of work. When recommendations are being performed by resources not under the Cx Provider's contract, the Provider serves as a third-party to verify proper implementation such that CFR are achieved. Implementation activities by the Cx Provider include:

- Verifying design and submittals related to recommendations
- Conduct an implementation kick-off meeting
- Conduct site visits for verification
- Update Issues and Resolution Log

The minimum requirements for the Cx Provider during implementation are outlined in ASHRAE 0.2, Implementation Phase section titled "Implement Recommendations". Implementations involving HVAC systems must follow ASHRAE 1.2 Implementation Phase section titled "Implement Recommendations" and subsections; similar actions are required for the other systems included in the scope of work.

6-2.7 Completed Recommendations and Performance Verification.

Once installation is complete, the Cx Provider tests and inspects the completed recommendations to confirm the CFR are achieved; tests and inspections are conducted in accordance with the accepted EBCx Plan and Implementation Verification Plan. Document verification tests and physical inspections as outlined in the EBCx Plan, including tests and physical inspection data records, capture test data, observations, and M&V data. ASHRAE 1.2 Implementation Phase section titled "Verify Completed Recommendations" includes requirements specific to HVAC systems, including situations when deferred testing of systems may be necessary.

6-2.8 Documentation.

Develop or update the following documentation during the Implementation Phase:

- Update EBCx Plan on completion of tests
- Update EBCx Report to include the Implementation Report
- Update Systems Manual
- Update CFR (in EBCx Report)
- Update list of findings and recommendations (in EBCx Report)
- Test and inspection documentation (in EBCx Report)

- Update Issues and Resolution Log (in EBCx Report)
- Site visit records (in EBCx Report)
- Verification documentation (in EBCx Report)
- M&V documentation (in EBCx Report)
- Training documentation (in EBCx Report)

The minimum Implementation Phase documentation requirements are outlined in ASHRAE 0.2, Implementation Phase section titled “Update the EBCx Documentation”.

6-2.9 Government Review and Decision to Proceed.

Government representatives will review the Implementation Phase deliverables to determine if the activities were completed. The EBCx Plan and EBCx Report sections for this Phase are initially developed by the Cx Provider and submitted to the Government for review and acceptance. Review comments are submitted to the Cx Provider and submittals are revised and re-submitted as necessary. Once the EBCx Plan and EBCx Report sections for this Phase are accepted by the Government, Hand-off Phase activities may proceed.

6-3 IMPLEMENTATION PHASE DELIVERABLES.

The Implementation Phase deliverables consist of the following:

- Updated EBCx Plan
- Updated EBCx Report, including the Implementation Report
- Updated Systems Manual materials

CHAPTER 7 HAND-OFF PHASE

7-1 OBJECTIVES.

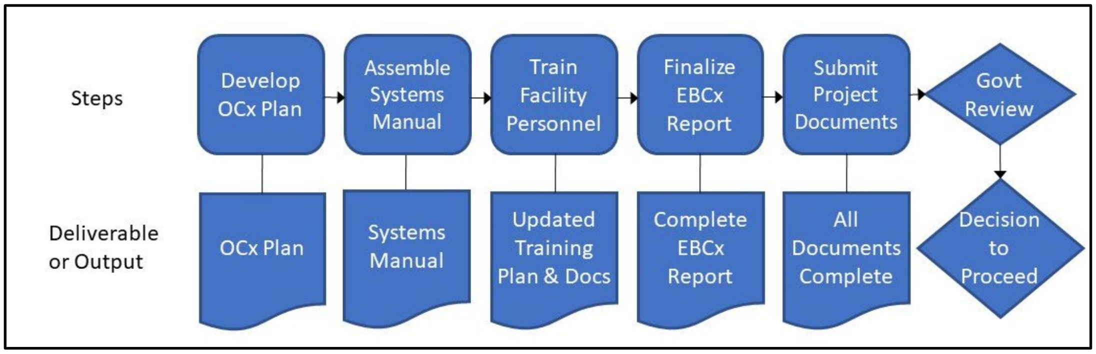
The Hand-off Phase represents the transition between the EBCx Team and the personnel responsible for operating and maintaining the systems. The goals are to provide the O&M team with the information, training, and procedures to ensure persistence of benefits. While many phases of EBCx may be independently performed by in-house or contractor teams, the Implementation and Hand-off of individual upgrade measures must be conducted by the same project delivery team whether it is an in-house or contracted group. During the Hand-Off Phase, the EBCx Team works to ensure the required documentation in the EBCx Report has been completed and is aligned with the EBCx Program (if one exists) and the EBCx Plan. This phase includes the development of the Ongoing Commissioning (OCx) Plan, the finalizing of the required systems documentation, and the submittal of completed deliverables. The objectives of the Hand-Off Phase are to provide the completed documents from the Cx Provider to the Government and provide training to the Government's personnel.

7-2 HAND-OFF PHASE STEPS.

Hand-Off Phase steps are as follows:

a. Develop OCx Plan
b. Assemble Systems Manual
c. Train building personnel
d. Finalize EBCx Report
e. Provide project documents to Government
f. Obtain Government review and decision to proceed

Figure 7-1 Hand-off Phase Process and Deliverables/Outputs



7-2.1 OCx Plan.

The OCx Plan documents how the building performance will be monitored going forward, what systems are included, what parameters are tracked, and how identified issues are corrected. It is most common for the Government to be responsible for ongoing commissioning activities, either utilizing installation maintenance personnel or installation support contracts. Develop the OCx Plan based on the knowledge of which resources will be utilized. The minimum content required in the OCx Plan is outlined in ASHRAE 0.2, Hand-off Phase section titled “Develop OCx Plan”.

7-2.2 Systems Manual.

Assemble the Systems Manual to incorporate changes to assemblies and systems that occurred during EBCx activities. Also incorporate documentation generated during and after the Implementation Phase into the Systems Manual. Update the Facility Guide, a component of the Systems Manual, to reflect changes to assemblies and systems. Add training documentation to the Systems Manual as training is performed. A comprehensive list of requirements for the Systems Manual is outlined in ASHRAE 0.2, Assessment Phase section titled “Establish the Systems Manual Outline”. Annex M of ASHRAE 0.2 provides an example outline of a Systems Manual.

7-2.3 Building Personnel Training.

Train building personnel based on the Training Plan developed as a part of the EBCx Plan. Training is most effective when consisting of a combination of classroom style and in-the-field type instruction. Training sessions are separated into topics targeted for building staff and O&M personnel. Refer to ASHRAE 0.2, Hand-off Phase section titled “Train Facility Personnel” for procedures and the training topics required for each personnel group.

7-2.4 Final EBCx Report.

Update the EBCx Report to reflect necessary changes to the EBCx Program Plan and OCx Plan. Update the EBCx Report to include the final training documentation and verification.

7-2.5 Government Review and Decision to Proceed.

Government representatives will review the Hand-Off Phase deliverables to determine if the Hand-Off Phase activities are complete and they concur with the planned approach for proceeding into the Ongoing Commissioning Phase (if the EBCx Contract includes the OCx Phase). Review comments are submitted to the Cx Provider and submittals are revised and re-submitted as necessary.

7-3 HAND-OFF PHASE DELIVERABLES.

The Hand-Off Phase deliverables consist of the following:

- Updated EBCx Report
- Systems Manual, including the Facility Guide
- OCx Plan

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CHAPTER 8 ONGOING COMMISSIONING PHASE

8-1 OBJECTIVES.

Whether this phase is included in the initial EBCx contract is resource-dependent. The Ongoing Commissioning (OCx) phase is typically conducted with separate resources from the EBCx Team involved in prior phases, either utilizing installation maintenance resources or contracted through installation support contracts.

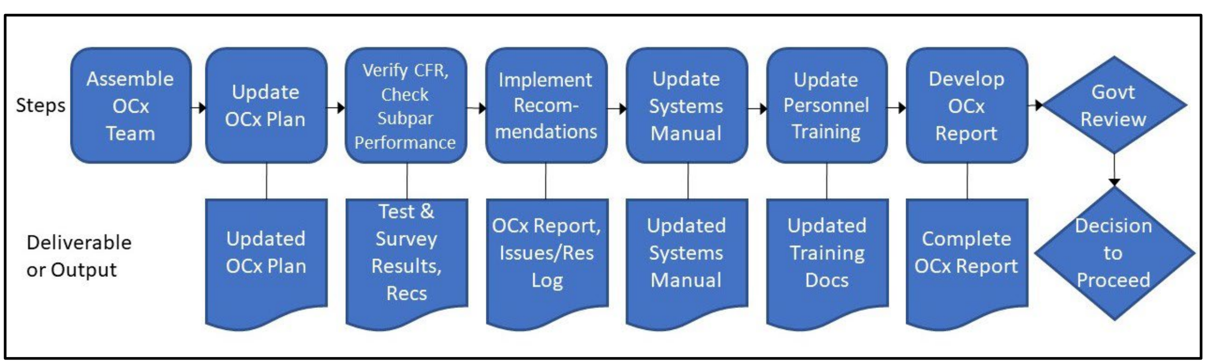
The OCx Phase is a program that consists of Cx Process activities that repeat regularly throughout the life of the building subsequent to the Hand-Off Phase. An OCx program repeats the EBCx activities on a scheduled, periodic basis to ensure the systems are continuously evaluated against the updated CFR. This phase is ongoing and involves developing an OCx Plan, continuously verifying the achievement of CFR's, and updating Systems Manuals and personnel training as needed. The overall objective of the OCx Program is to ensure that the benefits obtained from the EBCx Plan and other building improvements are sustained over time and improved if possible.

8-2 ONGOING COMMISSIONING PHASE STEPS.

Ongoing Commissioning Phase steps are as follows:

a. Assemble the OCx Team
b. Update the OCx Plan
c. Verify achievement of CFR
d. Investigate unacceptable performance or outcome
e. Implement recommendations
f. Update Systems Manual
g. Update building personnel training
h. Develop OCx Report
i. Obtain Government review

Figure 8-1 OCx Phase Process and Deliverables/Outputs



8-2.1 OCx Team.

The OCx Phase tasks may be performed in-house or contracted utilizing a service or Indefinite Delivery Indefinite Quantity (IDIQ) contract. It is most common for the Government to be responsible for OCx activities, either utilizing installation maintenance personnel or installation support contracts. The make-up of the OCx Team varies based on which building systems require ongoing commissioning. The Government must identify a person with clear responsibility for ensuring the OCx efforts are carried out on the building systems included in the scope and take place at the required intervals to ensure sustained optimal performance of the systems.

8-2.2 Updated OCx Plan.

Update the OCx plan as developed in the Hand-off Phase with the knowledge of the resources planned for these efforts. OCx Plan updates are made to ensure parameters which require monitoring are defined along with metrics for determining compliance with the CFR. The minimum content required in the OCx Plan is outlined in ASHRAE 0.2, Hand-off Phase section titled “Develop OCx Plan”. OCx Plan updates include:

- Review scope of OCx activities, including determining that assigned resources have the availability and capabilities needed for each activity.
- Ensure frequency of OCx activities are clearly defined and reviewed by the OCx Team.
- Clearly define remaining scope items from the EBCx Report, including deferred inspections/testing and recommendations that have not yet been implemented.

8-2.3 CFR Verification.

The initial iteration of the OCx process includes verifying that the building and system performance is acceptable to the Government, as defined during Implementation and Hand-off Phases, is still being achieved and is correctly defined. Sustaining this performance becomes the primary focus of the ongoing OCx Program and can be demonstrated by defining, tracking, and evaluating various aspects of building condition or performance, such as operations, maintenance procedures, and occupant/user satisfaction and needs. Thus, these OCx Program activities involve monitoring the actual condition or performance of the defined CFR parameters and providing feedback to the OCx Team of deviations that require corrective action.

The OCx Team may conduct periodic workshops to update information in the CFR to identify improvement opportunities and select the appropriate corrective actions. To gain feedback, the OCx Team may also conduct periodic interviews with O&M personnel and building occupant/user surveys. These OCx efforts seek to measure the current building performance against the CFR with the goal of sustaining the improvements gained through the EBCx process.

8-2.4 Unacceptable Performance Investigation.

Whenever the OCx process discovers significant negative deviations from the intended CFR baseline or parameters, the cause of the performance or condition degradation must be identified to specify a solution. This requires condition assessment, testing, and analysis of the results to determine the extent of the subpar performance or degree of deviation from desired results. The OCx Team follows the same activities as outlined in the Assessment and Investigation Phases of this document, including on-site detailed inspections and performance testing of the systems and assemblies.

Once the issue is confirmed and the appropriate corrective actions are identified, enter this information on the Issues and Resolution Log, including the estimated costs and expected resulting benefits. Similar to the approach for the EBCx Implementation Phase, include methods in the recommendations to maintain the improvements made and benefits realized.

8-2.5 Recommendations/Corrective Action Implementation.

The OCx Team develops a written plan for implementing the recommendations, including planned schedules and responsible parties. Clearly identify corrective actions which require outages or building operations impacts. Following coordination with the building manager and building occupants, implement the accepted recommendations in accordance with that plan. Upon completion of the corrective action, verify that the expected improvements have been achieved. Document lessons learned to prevent a recurrence of the issue, develop a cost-benefit analysis, and include these in the OCx Report.

Bring to the attention of the Building Manager issues, especially those related to safety, security, health, or operational issues, that can be easily remedied and do not require further evaluation (will obviously not adversely impact other systems). Those Corrective actions that do not incur costs and provide immediate payback can be implemented during the OCx process; however, do not implement corrective actions without coordinating with maintenance staff responsible for upkeep on the building due to the possibility of creating unintended adverse issues (for example, opening a valve may improve the operation of the mechanical system, but the maintenance staff may have closed the valve temporarily until repairs can be performed on a system leak). For minor improvements that require installation maintenance staff involvement, coordinate with installation personnel such that a work order is submitted for correcting these issues. Document and include in both the OCx Report and the Issues and Resolution Log these immediately implemented modifications and corrective actions, along with their projected benefits.

8-2.6 Updated Systems Manual.

Review the building Systems Manual at regular intervals and make updates to ensure information is current. Update the Systems Manual with key performance parameters and building operating procedures whenever they are changed. Establish monitoring procedures to compare building performance against the baseline at frequent intervals to ensure performance improvements are maintained. In addition, revise the Systems Manual when changes in occupancy, use, or renovations require changes to the CFR.

8-2.7 Updated Building Personnel Training.

Include in the OCx Program updated or refresher training of operations and maintenance personnel at regular intervals to ensure the procedures required to maintain building performance are followed to meet the CFR and ensure persistence of benefits. Prior training sessions may require updating in the case of building/system or operational changes. Additionally, ensure training addresses implemented recommendations, lessons-learned, and changes to the operating procedures.

8-2.8 OCx Report.

Develop and update the OCx Report at regular intervals to document the performance of the building/systems and the benefits/results of the OCx efforts. The OCx Report must contain, at a minimum, the content outlined in ASHRAE 0.2, OCx Phase section titled “Write/Deliver OCx Report”.

8-2.9 Government Review.

Government representatives will review the OCx Phase deliverables to determine if activities are complete. Review and acceptance of the OCx Plan takes place before the EBCx efforts proceed further into the OCx Phase (note that the Government is most often responsible for the OCx Phase). Review comments are submitted to the Cx Provider and submittals are revised and re-submitted as necessary.

8-3 ONGOING COMMISSIONING PHASE DELIVERABLES.

The OCx Phase deliverables consist of the following:

- Updated OCx Plan
- Updated CFR
- Updated Systems Manual
- OCx Report (submitted periodically)

APPENDIX A BEST PRACTICES

A-1 EBCx TEMPLATES.

The following templates are available for use and should be utilized to ensure efforts are consistent and comprehensive.

A-1.1 Industry Templates

The following templates or formats are available for use from industry resources and can be utilized for EBCx efforts:

- EBCx Program Plan: Annex H of ASHRAE 0.2 includes planning templates for multiple-building EBCx efforts.
- EBCx Plan: sections are outlined in ASHRAE 0.2, Assessment Phase section titled "Develop the EBCx Plan". Annex G attachments to ASHRAE 0.2 contains example EBCx Plans.
- EBCx Report: Annex L attachments to ASHRAE 0.2 contains example EBCx Reports.
- EBCx building occupant questionnaire form – can utilize the template developed by the Army and posted on the WBDG website (https://www.wbdg.org/building-commissioning/additional-commissioning-resources/army-templates).

A-1.2 Navy and Marine Corps Templates

The following templates have been developed specifically for Navy and Marine Corps EBCx efforts:

- Navy and Marine Corps EBCx building selection and scoring or ranking
- Savings calculations for repair, replacement or maintenance items
- Navy and Marine Corps EBCx contractor support contract scope of work

These are available on the Whole Building Design Guide (WBDG) website resource page for "Building Commissioning" under "Additional Commissioning Resources (https://www.wbdg.org/building-commissioning/additional-commissioning-resources).

A-2 BEST PRACTICES FOR ENHANCED RESILIENCY.

Building resiliency is defined in this document as the ability to provide for mission in the face of all hazards or recover operations quickly after a disruption in operation (such as having known power reliability issues, HVAC systems with difficulties operating in expected extreme hot or cold conditions, or building enclosures in occupied spaces with gaps which allow external air flows in extreme conditions). Where the EBCx scope includes assessment for building resiliency, efforts should include the following systems issues at a minimum.

A-2.1 Mechanical Systems.

Assess mechanical systems for issues such as the following:

- HVAC systems with difficulties operating in expected extreme hot or cold conditions
- Ensuring controls are designed for systems to return to operation following non-normal operating conditions or power outage
- Verifying that support systems operate in non-normal operations (such as chillers or boilers not operating to support air handler requiring chilled or hot water)
- Other mechanical, controls or plumbing systems issues that are adversely impacting the occupant’s ability to perform their mission

A-2.2 Electrical Systems.

Assess electrical systems for issues such as the following:

- Testing backup generators, including “black start”
- Load bank testing
- Power monitoring (to determine the presence of, or need for, surge protection to address “dirty power” issues)
- Assessing that critical issues for mission are on backup power

A-2.3 Building Enclosure Systems.

Assess building enclosure systems for issues such as the following:

- Building enclosures in occupied spaces with gaps which allow external air flows in extreme weather conditions
- Leaks from roofs or exterior walls affecting use of occupied spaces

A-3 ADDITIONAL RESOURCES.

The following organizations have developed additional resources such as templates and other guidelines for conducting EBCx efforts:

- ASHRAE (www.ashrae.org)
- BCxA (www.bcxa.org)
- NEBB (www.nebb.org)

A-4 LESSONS LEARNED.

The following are lessons learned which can provide benefits in ensuring a comprehensive evaluation of systems and lead to optimized performance of building systems.

A-4.1 Hand-off Phase Best Practices.

The following have shown to provide improved training results and retention of information, as well as improving future EBCx efforts through incorporating lessons learned.

A-4.1.1 Training Effectiveness Verification.

Verify the effectiveness of training within a reasonable period of the completion of each training program. The intent of this testing is to verify that the trainees were provided with pertinent information and can demonstrate their ability to operate and maintain the building to meet the CFR and ensure persistence of benefits. Example training verification methodologies are provided in Annex L5 of ASHRAE 0.2.

A-4.1.2 Lessons-Learned Workshop.

Conduct a lessons-learned workshop after the completion of the training and the update of the Systems Manual. The intent of the discussion is to determine improvements in both the EBCx process and building operations. These lessons learned are recorded in the EBCx Report, especially when the EBCx efforts may have corrected issues resulting from an action during the planning, design, or construction phases – recording this information allows the EBCx Report to serve as a feedback loop to allow for avoiding future deficiencies in design and construction.

Attendees of the lessons-learned workshop include the key participants and stakeholders of the EBCx process. Example approaches to the lessons-learned workshop are provided in Annex L6 of ASHRAE 0.2.

A-4.2 BCxA Existing Building Commissioning Best Practices.

The BCxA document titled “Existing Building Commissioning Best Practices” contains content resulting from lessons learned on conducting EBCx efforts. It is recommended that EBCx teams utilize it as a resource when conducting EBCx on Government buildings.

A-4.3 ANSI/NEBB Standard S120.

ANSI/NEBB S120, Appendix H, includes lessons learned on areas that commonly present issues on a typical EBCx project. It is recommended that EBCx teams review these areas in projects.

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APPENDIX B GLOSSARY

B-1 ACRONYMS.

AABC	Associated Air Balancing Council
ACG	AABC Commissioning Group
AEE	Association of Energy Engineers
AFCEC	Air Force Civil Engineer Center
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation System
BCCB	Building Commissioning Certification Board
BCxA	Building Commissioning Association
BIA	Bilateral Infrastructure Agreement
BMS	Building Management System
CBECS	Commercial Buildings Energy Consumption Survey
CCR	Criteria Change Request
CCTV	Closed Circuit Television
CFR	Current Facility Requirements
CI	Condition Index
CP	Certified Professional
CV	Constant Volume
CW	Chilled Water
Cx	Commissioning
DDC	Direct Digital Control
DoD	Department of Defense
EBCx	Existing Building Commissioning

ECM	Energy Conservation Measure
EISA	Energy Independence and Security Act
ESCO	Energy Services Contractor
EUI	Energy Use Index
FC	Facilities Criteria
FCU	Fan Coil Unit
FEMP	Federal Energy Management Program
FPT	Functional Performance Test
FRCS	Facility-Related Control Systems
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
HVAC	Heating, Ventilating and Air-Conditioning
HVAC&R	Heating, Ventilating, Air-Conditioning and Refrigerating
HW	Hot Water
IDIQ	Indefinite Delivery Indefinite Quantity
IEC	International Electrotechnical Commission
IECC	International Energy Conservation Code
IEM	Installation Energy Manager/Management
IFM	Installation Facilities Management
IFMA	International Facility Management Association
IIBEC	International Institute of Building Enclosure Professionals
IT	Information Technology
LCCA	Life Cycle Cost Analysis
LED	Light Emitting Diode
M&V	Measurement and Verification

NAVFAC	Naval Facilities Engineering Systems Command
NEBB	National Environmental Balancing Bureau
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
O&M	Operations and Maintenance
OCx	Ongoing Commissioning
OPR	Owner’s Project Requirements
PM	Preventive Maintenance
RCx	Retrocommissioning
REPM	Regional Energy Program Manager
RFP	Request for Proposal
SOFA	Status of Forces Agreements
TAB	Testing, Adjusting and Balancing
TV	Television
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
U.S.	United States
VAV	Variable Air Volume

B-2 DEFINITION OF TERMS.

Except where indicated otherwise, definitions below match those used in ASHRAE documents for Commissioning and Existing Building Commissioning.

Acceptance: a formal action taken by a person with appropriate authority (which may or may not be contractually defined) to declare that some aspect of the project meets defined requirements, thus permitting subsequent activities to proceed.

Commissioning (Cx): a quality-focused process for enhancing the delivery of a project. The process focuses on verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR).

Current Facility Requirements (CFR): a written document in which the Owner details the current functional requirements of a facility and the expectations of how it should be used and operated. This may include goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information to meet the requirements of occupants, users, and Owner(s) of the facility.

Existing Building Commissioning (EBCx) Plan: a document that outlines the organization, goals, schedule, allocation of resources, and documentation requirements of the EBCx Process.

Existing Building Commissioning (EBCx) Process: a quality-focused process for attaining the CFR of an existing building and its systems and assemblies. The process focuses on planning, investigating, implementing, verifying, and documenting that the facility and its systems and assemblies are operated and maintained to meet the CFR, with a program in place to maintain the enhancements for the remaining life of the facility. Existing Building Commissioning includes both Recommissioning and Retrocommissioning.

Existing Building Commissioning (EBCx) Team: individuals who through coordinated actions are responsible for implementing the EBCx Process.

Facility guide (FG): a basic building systems description and operating plan with general procedures and confirmed facility operating conditions, setpoints, schedules, and operating procedures to properly operate the facility.

Functional test procedures (FPT): a written collection of tests that, when executed in the test process, allow verification of the performance of a system or assembly.

Issues and Resolution Log: a formal and ongoing record of problems or concerns and their resolution that have been raised by members of the Cx Team during the course of the Cx Process.

Measurement and Verification (M&V) Plan: a plan for gathering relevant data over time to evaluate performance and benefits. M&V Plan includes the details for both baseline and post-implementation performance period testing required for quantifying the performance and achieved benefits of the process.

Ongoing Commissioning (OCx) Process: a continuation of the Cx Process after the Hand-Off Phase to verify that a facility continues to meet current and evolving CFR (OPR for new construction). OCx Process Activities occur throughout the life of the facility; some of these will be close to continuous in implementation and others will be either scheduled or unscheduled (as needed).

Recommissioning: an application of the Cx Process requirements to an existing facility or system that underwent the Cx Process during project delivery (see Existing-Building Commissioning [EBCx] Process).

Retrocommissioning: the Cx Process applied to an existing building or system that was not previously commissioned (see Existing Building Commissioning [EBCx] Process).

Simple Payback: as used in NIST Handbook 135, “simple payback” is a measure of the length of time required for the cumulative savings from a project to recover its initial investment cost and other accrued costs, without considering the time value of money.

Systems Manual: a system-focused composite document that includes the design and construction documentation, FG and operation manual, maintenance information, training information, Cx Process records, and additional information of use to the Owner during occupancy and operation.

Test procedure: a written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Training Plan: a written document that details the expectations, schedule, budget, and deliverables of EBCx process activities related to training of project operations and maintenance personnel, users, and occupants.

Verification: the process by which specific documents, components, equipment, assemblies, systems, and interfaces among systems are confirmed to comply with the criteria described in the CFR.

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APPENDIX C REFERENCES

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

https://www.ashrae.org/

NOTE: Include all references Errata, except Errata for Addenda. Include Interpretations, except Interpretations for Addenda. Do not include Addenda.

ASHRAE 0.2, *Commissioning Process for Existing Systems and Assemblies*

ASHRAE 1.2, *Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies*

ANSI/ASHRAE/IES Standard 90.1 (ASHRAE 90.1), *Energy Standards for Buildings Except Low Rise Residential Buildings* (refer to UFC 1-200-02 for the version that applies)

AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM)

https://www.astm.org/

ASTM C1060, *Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings*

ASTM C1153, *Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging*

ASTM D8231, *Standard Practice for the Use of a Low Voltage Electronic Scanning System for Detecting and Locating Breaches in Roofing and Waterproofing Membranes*

ASTM E779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*

ASTM E1186, *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*

ASTM E1827, *Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*

ASTM E2128, *Standard Guide for Evaluating Water Leakage of Building Walls*

BUILDING COMMISSIONING ASSOCIATION (BCxA)

https://www.bcxa.org/

BCxA, *Existing Building Commissioning Best Practices*

ENVIRONMENTAL PROTECTION AGENCY (EPA)

EISA 2007, *Energy Independence and Security Act*, 19 December 2007
https://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act

INTERNATIONAL CODE COUNCIL (ICC)

https://www.iccsafe.org/

IECC*, International Energy Conservation Code, 2021*

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

https://www.netaworld.org

ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

https://www.iec.ch/homepage

IEC 62446-1, *Photovoltaic (PV) Systems*

IEC 62040-3, *Uninterruptible Power Systems (UPS)*

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

https://www.iso.org

ISO 18251-1, *Non-destructive Testing – Infrared Thermography – Part 1: Characteristics of System and Equipment*

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

https://www.nema.org/

NEMA 410, *Performance Testing for Lighting Controls and Switching Devices with Electronic Drivers and Discharge Ballasts*

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

https://nebb.org/

ANSI/NEBB S120, *Technical Retro-Commissioning of Existing Buildings*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

https://www.nfpa.org/

NFPA 70, *National Electrical Code*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 110, *Standard for Emergency and Standby Power Systems*

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

https://www.nist.gov/

NIST Handbook 135, *Life Cycle Costing Manual for the Federal Energy Management Program*

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (NAVFAC)

https://www.wbdg.org/ffc/navy-navfac/p-publications

P-602, 3 Pillars of Energy Security (Reliability, Resilience, & Efficiency)

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 1-200-01, *DoD Building Code*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 1-300-08, *Criteria for Transfer and Acceptance of DoD Real Property*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-501-01, *Electrical Engineering*

UFC 3-540-07, *Operation and Maintenance (O&M): Generators*

UFC 3-740-05, *Construction Cost Estimating*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems (FRCS)*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs

UFGS 01 91 00.15, *Building Commissioning*

UNITED STATES CODE

http://uscode.house.gov

10 USC 101(e), *Definitions, Facilities and Operations*

42 USC 8253, *Energy and water management requirements*

UNITED STATES GOVERNMENT POLICY

https://science.house.gov/2020/12/energy-act-of-2020

Energy Act of 2020

UFC 3-410-01
1 July 2013
Change 9, 09 January 2024

UNIFIED FACILITIES CRITERIA (UFC)

HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **\1**\ ... /**1**/)

Change No.	Date	Location
1	October 2014	Numerous clarifications, corrections, additions and deletions throughout the document in response to Criteria Change Requests (CCRs) and Tri-Service reviews; the addition of Appendices E, F and G.
2	October 2015	Changes to Chapters 3, 4, 5 and Appendix A in response to CCRs and Tri-Service reviews.
3	January 2017	Criteria Change Request to address variable refrigerant flow (VRF) systems.
4	November 2017	Changes to Chapters 3 and 4 and Appendices A and B in response to CCRs and Tri-Service reviews.
5	November 2019	Added Environmental Severity Classification and humidity design requirements and updated corrosion prevention requirements in 1-3.1, 3-6.11, 3-6.11.1, 4-2.4.5, 5-2.25, B-12 and B-13.
6	March 2020	Changes to Chapter 3 for VRF requirements and Chapter 4 for referencing IMC-2018. Numerous clarifications, corrections, additions and deletions throughout the document in response to Criteria Change Requests (CCRs) and Tri-Service reviews.
7	February 2021	Change in 3-6.17.3 Design Requirements for VRF Systems paragraph no. 3, and 3-7.6 Electric Resistance Heating.
8	July 2021	Criteria Change Requests to address variable refrigerant flow (VRF) systems.

9	09 January 2024	Updated ASHRAE 90.1 reference in Appendix A References. Updated Summary Sheet stating no revision will be made to this UFC concerning variable refrigerant flow (VRF) systems without Federal Register notification. Updated ASHRAE 62.1 reference in Appendix A References.

This UFC supersedes UFC 3-400-10N, dated July 2006; UFC 3-410-01FA, dated 15 May 2003; MIL-HDBK-1190, Chapter 10, dated 1 September 1987; and TI 800-01, Chapter 13, dated 20 July 1998.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and the Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

Superseding: This UFC supersedes UFC 3-400-10N, *Mechanical Engineering*; UFC 3-410-01FA, *Heating, Ventilating, and Air Conditioning*; MIL-HDBK-1190, *Facility Planning and Design*, Chapter 10; and TI 800-01, *Design Criteria*, Chapter 13.

Description: This UFC provides requirements for the design of facility heating, ventilating, and Air Conditioning systems. It incorporates the provisions of the International Code Council's International Mechanical Code (IMC) and ASHRAE design guidance to the greatest extent possible. This UFC is to be applied in conjunction with the core mechanical UFC 3-401-01. **\9** No revision will be made to this UFC concerning variable refrigerant flow (VRF) systems without Federal Register notification. **/9/**

Reasons for Document:

- To unify Department of Defense facility HVAC criteria and create more consistency in DoD designs.
- To incorporate and modify the provisions of the IMC to meet DoD needs.
- To update existing criteria to reflect new and revised industry standards.

Impact:

- Standardized guidance for facility HVAC design among the Services.
- Provides more detail on documentation requirements for design analysis and drawing requirements.
- Incorporates lessons learned from issues which occurred in previous construction contracts.

Unification Issues

- The Navy uses UFC 3-430-08N, *Central Heating Plants* for design of central heating plants while the Army and Air Force use 3-430-02FA, *Central Steam Boiler Plants*. There is an ongoing Army project to update and unify these documents.
- ASHRAE's BACnet® protocol is the preferred control system architecture for Navy & Marine Corp facilities. LonWorks® protocol is the preferred control system architecture for Army facilities. The Army uses UFC 3-410-02 for LonWorks® protocol control systems design.

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TABLES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides requirements and guidance in the design of heating, ventilating, and air-conditioning (HVAC) systems, together with the criteria for selecting HVAC materials and equipment.

1-2 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design and construction of DoD facilities worldwide. Where conflicts in requirements appear between sections of any mechanical UFC or applicable codes or laws, the most restrictive requirement will govern.

1-3 GENERAL BUILDING REQUIREMENTS.

\6 Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, physical security, cybersecurity, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein. **/6/**

1-3.1 \5\ Environmental Severity and Humid Locations.

In corrosive and humid environments, provide design detailing, and use materials, systems, components, and coatings that are durable and minimize the need for preventative and corrective maintenance over the expected service life of the component or system. UFC 1-200-01, section titled “Corrosion Prone Locations” identifies corrosive environments and humid locations requiring special attention. UFC 1-200-01, section titled “Requirements for Corrosion Prone Locations” provides examples of necessary actions. To determine Environmental Severity Classifications (ESC) for specific project locations refer to UFC 1-200-01 Appendix titled “Environmental Severity Classifications (ESC) for DoD Locations”. **/5/**

1-4 \6\ CYBERSECURITY.

All control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

Cybersecurity is implemented to mitigate vulnerabilities to all DoD real property facility-related control systems to a level that is acceptable to the System Owner and Authorizing Official. UFC 4-010-06 provides requirements for integrating cybersecurity into the design and construction of control systems. **/6/**

1-5 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-6 BEST PRACTICES.

Appendix B contains information that is not requirements but is considered best practices based on experience and lessons learned.

1-7 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

1-8 \8\ OPEN CONTROL SYSTEM REQUIREMENTS.

10 USC 2867 requires the adoption of a “Department-wide, Open Protocol, Energy Monitoring and Utility Control System Specification” for use in military construction and military family housing activities. Public law (10 USC 2867) states: “The Secretary of Defense shall adopt an open protocol energy monitoring and utility control system specification for use throughout the Department of Defense in connection with a military construction project, ...” It continues: “The energy monitoring and utility control system specification ... shall cover: (A) ... (B) Indoor environments, including temperature and humidity levels. (C) Heating, ventilation, and cooling components. ...” DoD has published the following control system specifications to meet this requirement:

1. UFGS 25 10 10 Utility Monitoring and Control System (UMCS) Front End and Integration

2. UFGS 23 09 00 Instrumentation and Control for HVAC

3. UFGS 23 09 23.01 LonWorks Digital Control for HVAC and Other Building Control Systems

4. UFGS 23 09 23.02 BACnet Digital Control for HVAC and Other Building Control Systems

All HVAC control systems must meet the requirements of UFGS 23 09 00 and either UFGS 23 09 23.01 or UFGS 23 09 23.02 These specifications require the installation of non-proprietary control networks down to the level of each individual device in the system.

1-9 EPA HFC-REFRIGERANT REGULATIONS.

Beginning 1-Jan-2019, the EPA implemented new rules to regulate HFC refrigerant systems including those used for comfort cooling. This regulation includes R-410A, a common HFC refrigerant used in DX systems. The new rules lowered the threshold leak rate to 10% loss annually. Systems exceeding this rate must be repaired within 30-days or else face mandatory system shutdown, costly retrofits, or replacement. (The Services estimate a current annual refrigerant leak rate of 25%.) **/8/**

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CHAPTER 2 MECHANICAL CONSENSUS STANDARDS

2-1 PRIMARY VOLUNTARY CONSENSUS STANDARD REFERENCE.

The DoD uses the International Code Council™ International Mechanical Code© as the primary voluntary consensus standard for DoD facility HVAC systems. The scope of the IMC is stated as:

> "*This code must regulate the design, installation, maintenance, alteration and inspection of mechanical systems that are permanently installed and utilized to provide control of environmental conditions and related processes within buildings.*"

2-1.1 International Mechanical Code© Copyright.

The International Mechanical Code© is copyrighted by International Code Council, Inc., Falls Church, Virginia, U.S.A. Without advance written permission from ICC or its duly authorized agent, no portion of the IMC may be reproduced, distributed, or transmitted in any form or by any means, including, without limitation, electronic, optical, or mechanical means (by way of example and not limitation, photocopying, or recording by or in an information storage and retrieval system). For information on permission to copy IMC material exceeding fair use, please contact the International Code Council, Inc.

2-1.2 IMC Additions, Deletions, and Revisions.

The additions, deletions, and revisions to the IMC sections listed in Chapter 4 "Supplemental Technical Criteria" of this document preserve the appropriate supplemental technical criteria for use in current and future designs of DoD facilities. When and if these supplemental technical criteria are adopted into the IMC, they will be removed from this document. When interpreting the IMC, the advisory provisions must be considered mandatory; interpret the word "should" as "must." The format of Chapter 4, including English and metric unit references, does not follow the UFC format, but instead follows the format established in the IMC, to the extent possible.

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CHAPTER 3 GENERAL DESIGN REQUIREMENTS

3-1 \1\ HVAC /1/ SYSTEM SELECTION \1\ AND LIFE CYCLE COST ANALYSIS CONSIDERATIONS.

\6 The designer must develop three energy efficient solutions for each individual energy system and prepare a LCCA to determine the heating and cooling systems, fuel sources and major system components. Designers should follow Appendix E - HVAC Systems Selection Flow Chart for this selection process. The analysis must conform to the life cycle cost and energy criteria specified in UFC 1-200-02 **/6/**. For Army projects only: Centralized versus De-centralized Plants - De-centralized plants may be a more cost effective alternative for a new or replacement project. The designer must follow the "Evaluation of District and Islanded/Decentralized Utility Options with Life-Cycle Cost Analysis Guidance" in Appendix G to determine which alternative is most life cycle cost effective. **/1/**

3-2 \6\ [FOR NAVY PROJECTS ONLY] VENTILATION AIR.

\4 These requirements apply to Navy projects. Final determination of equipment's dehumidification capabilities is subject to approval by the Navy based on submitted equipment selections, control sequences, and psychrometrics. **/6/**

A Dedicated Outdoor Air System (DOAS) is the only allowed method for providing dehumidification of ventilation air (outside air) when replacing an existing DOAS delivering any quantity of ventilation air or when the sum of all ventilation air into facility is greater than 750 cfm (354 lps) and either of the following conditions apply:

- Design includes any direct-expansion or chilled water equipment such as heat pumps, packaged terminal air conditioners, split systems, and fan coil units delivering any quantity of outside air with limited dehumidification capability referred to below as light-duty equipment
- Design includes any direct-expansion equipment delivering any quantity of outside air with cycling refrigeration circuit(s) not manufactured and controlled for continuous dehumidification referred to below as medium-duty equipment

3-2.1 DOAS Associated with Light-Duty Equipment.

DOAS's associated with light-duty equipment must be selected, designed, and controlled as follows:

- Cooling coil must be selected to meet outside air sensible and latent loads plus space latent load
- Cooling coil must be selected and controlled to maintain a continuous coil leaving air temperature no greater than 55.0 °F for applications requiring

space conditions of 78.0 °F dry-bulb / 57.9 °F dewpoint / 50-percent relative humidity

- Cooling coil must be selected and controlled to maintain a continuous coil leaving air temperature suitable for applications requiring space conditions more stringent than 78.0 °F dry-bulb / 57.9 °F dewpoint / 50-percent relative humidity
- Reheat coil must be selected and controlled to maintain a unit discharge air temperature equivalent to the facility average design temperatures for comfort cooling and comfort heating

  (73.0 °F for 78.0 °F comfort cooling / 68.0 °F comfort heating)
- DOAS must not be subject to intermediate season (no-heat / no-cool) shutdown
- DOAS must distribute airflow directly to zones without passing through light-duty equipment
- DOAS air inlets and outlets must deliver airflow quantities equal to or greater than 50 cfm (24 lps) through each device to allow for proper system balancing

3-2.2 DOAS Associated with Medium-Duty Equipment.

DOAS's associated with medium-duty equipment must be selected, designed, and controlled as follows:

- Cooling coil must be selected to meet outside air sensible and latent loads, but not space loads
- Cooling coil must be selected and controlled to maintain a continuous coil leaving air temperature no greater than 58.0 °F for applications requiring space conditions of 78.0 °F dry-bulb / 57.9 °F dewpoint / 50-percent relative humidity
- Cooling coil must be selected and controlled to maintain a continuous coil leaving air temperature suitable for applications requiring space conditions more stringent than 78.0 °F dry-bulb / 57.9 °F dewpoint / 50-percent relative humidity
- Reheat coil must be designed and controlled to maintain a unit discharge air temperature equivalent to DOAS's coil leaving air setpoint temperature plus 5.0 °F to maintain discharge ductwork relative humidity less than 90-percent to help prevent ductwork microbial growth
- DOAS must distribute airflow directly into inlet of associated equipment and must not distribute airflow directly into zones

3-2.3 DOAS Associated with Light-Duty or Medium-Duty Equipment.

DOAS's associated with light-duty or medium-duty equipment, in addition to other requirements, must be selected, designed, and controlled as follows:

- DOAS must be provided with energy recovery devices in accordance with ASHRAE 90.1
- Energy recovery devices must be controlled to never increase energy (enthalpy) of outside air when energy of outside air upstream of energy recovery device is greater than energy of outside air immediately downstream of DOAS's cooling coil
- Energy recovery devices must be controlled to never decrease dry-bulb temperature of outside air when dry-bulb temperature of outside air upstream of energy recovery device is less than dry-bulb temperature of outside air immediately downstream of DOAS's cooling coil
- DOAS must be designed and controlled to be in operation during all occupied periods, but not necessarily unoccupied periods
- Ventilation air does not require humidification regardless of how it is provided into facility
- System controls must monitor the DOAS cooling coil leaving air temperature and unit discharge air temperature regardless of which point is used for control
- A visual alarm must be initiated upon detection of cooling coil leaving air temperature being equal to or greater than 5° F above design dew point temperature at the Operator work station (OWS) or at DOAS for construction without an OWS

3-2.4 Additional Requirements.

Additional requirements are as follows:

- Zone terminal heating / cooling equipment must have occupant control and may be subject to intermediate season heating / cooling curtailment as directed by installation or command policy
- A vapor transmission (hygrothermal) analysis must be provided in accordance with UFC 3-101-01 **/4/**

3-3 \6\ [FOR AIR FORCE PROJECTS ONLY] VENTILATION AIR.

These requirements apply to Air Force projects. Final determination of equipment's dehumidification capabilities is subject to approval by the Air Force subject matter expert (SME) as applicable based on submitted equipment selections, control sequences, and psychrometrics.

A Dedicated Outdoor Air System (DOAS) is the only allowed method for providing dehumidification of ventilation air (outside air) when replacing an existing DOAS delivering any quantity of ventilation air or when the sum of all ventilation air into facility is greater than 750 cfm (354 L/sec) and the 1% occurrence humidity ratio (as documented in the official engineering weather data, or EWD) is above the inside cooling load design dew-point temperature of 57.9°F.

3-3.1 DOAS Requirements.

Systems must be selected, designed, and controlled as follows:

- Cooling coil must be selected to meet outside air sensible and latent loads plus space latent load
- Cooling coil must be selected and controlled to maintain a continuous coil leaving air temperature no greater than 55.0 °F
- Reheat coil must be selected and controlled to maintain a unit discharge air temperature equivalent to the facility average design temperatures for comfort cooling and comfort heating

  (73.0 °F for 78.0 °F comfort cooling / 68.0 °F comfort heating)
- DOAS must not be subject to intermediate season (no-heat / no-cool) shutdown
- DOAS must distribute airflow directly to zones
- DOAS air inlets and outlets must deliver airflow quantities equal to or greater than 50 cfm (1400 L/min) at flow velocities between 400 – 800 ft/min (2 – 4 m/sec) through each device to allow for proper system balancing
- DOAS cooling coil leaving air temperature must be reset to 73°F and reheat coil de-energized when dew-point of outdoor air is at or below 57.9°F
- DOAS must be provided with energy recovery devices in accordance with ASHRAE 90.1
- Energy recovery devices must be controlled to never increase energy (enthalpy) of outside air when energy of outside air upstream of energy recovery device is greater than energy of outside air immediately downstream of DOAS's cooling coil
- Energy recovery devices must be controlled to never decrease dry-bulb temperature of outside air when dry-bulb temperature of outside air upstream of energy recovery device is less than dry-bulb temperature of outside air immediately downstream of DOAS's cooling coil
- DOAS must be designed and controlled to be in operation during all occupied periods

- Ventilation air does not require humidification regardless of how it is provided into facility
- System controls must monitor the DOAS cooling coil leaving air temperature and unit discharge air temperature regardless of which point is used for control
- A visual alarm must be initiated upon detection of cooling coil leaving air temperature being equal to or greater than 5° F above design dew point temperature at the Operator work station (OWS) or at DOAS for construction without an OWS
- A vapor transmission (hygrothermal) analysis must be provided in accordance with UFC 3-101-01

3-3.2 General Ventilation Requirements.

If a DOAS is not required, ventilation air may be brought in through the primary HVAC system only if the system is configured to continuously supply ventilation air. **/6/**

3-4 \4\ \2\ [FOR ARMY PROJECTS ONLY] VENTILATION AIR AND USE OF DOAS.

\6 When the 1% occurrence humidity ratio (as documented in the official engineering weather data, or EWD) for the outside air (OA) is greater than the inside cooling load design set-point (78°F, 57.9°F dew-point) humidity ratio, dehumidification of outdoor air is necessary and a Dedicated Outdoor Air System (DOAS) must be one of the three solutions included by the designer as described in the Appendix E - HVAC System Selection Flow Chart to address the humidity. Conditioning more humid air to design set points and the associated reheat can result in a DOAS being more Life Cycle Cost Effective (LCCE).

The DOAS must also be one of the three solutions included when the ventilation air for the building is 1000 CFM or greater. When larger volumes of ventilation air are required the DOAS may be more LCCE.

The required DOAS solution must apply to new and renovation projects.

Life cycle cost analyses (LCCA) must be performed to include a DOAS. The calculations must show the Energy Use Index (EUI) for the DOAS as well as the other solutions.

For buildings that may be unoccupied for extended periods of time, a DOAS may be necessary to maintain humidity conditions in the building to avoid mold growth or moisture damage during such time periods. An example building would be a barracks for which the assigned unit deploys. Coordinate with the installation Directorate of Public Works or component equivalent to determine when this is necessary. When this is required, ensure that the DOAS is designed, including capacity and controls, to properly dehumidify the building.

The DOAS coils must be designed to condition OA, occupant and space loads.

An alarm must be included with the HVAC controls that would indicate if the outside air damper failed to open during occupied period.
A DOAS is required whether or not life cycle cost effective per the following paragraphs:

When zone sensible cooling systems (e.g. fan coil units, chilled beams, heat pumps, etc.) are employed, Dedicated Outdoor Air Systems (DOAS) must be utilized to dehumidify all outside air for conditioned spaces. Use of DOAS may be applicable for use with central air handling systems when LCCE. The DOAS will separate the ventilation function from the space air conditioning function, (refer to Appendix F). Size the DOAS to condition the ventilation air necessary to remove the latent heat from the ventilation air and the latent heat from the space. The DOAS cooling coil must be sized using the 0.4 outdoor peak dew point design value and it's Mean Coincident Dry Bulb (MCDB) for the outside air conditions in accordance with ASHRAE Fundamentals Handbook. Coil loads must be checked against peak conditions. **/6/**

On DOAS units, system controls must monitor the discharge temperature to prevent condensation in the space or zone. Provide energy recovery devices where life-cycle cost-effective or where required by ASHRAE 90.1.

Consider the following when completing your Life Cycle Cost Analysis (LCCA) of your HVAC systems selection:

- The additional outside air required per ASHRAE 62.1 for VAV systems that condition ventilation air (multiple space equation).
- Fan coil unit maintenance considering the available capacity of maintenance staff
- Cost saving from the energy savings of fan coil unit or VAV (recirculated air) cycling (as stated above)
- The HVAC system application, (e.g. fan coil units may not be practical for a large open- space layouts or mission applicable).
- The loss of the ability to provide air-side economizer to include the added cost (incl. maintenance) for water side economizer.

/2/ /4/

3-5 HEATING AND COOLING LOAD CALCULATIONS.

Heating and cooling system design loads for the purpose of sizing systems, appliances and equipment must be determined in accordance with the following requirements.

\2 The HVAC design analysis for new facilities or renovation of existing facilities must include a psychrometric analysis documenting that the system meets design criteria. The analysis must provide calculations of system cooling load, energy/mass transfer through conditioning equipment and fans, and a system schematic indicating state point dry bulb and wet bulb temperatures (or humidity ratios) of outside air, mixed air, supply air, and return air flow streams. The system must provide the capability to condition ventilation air and maintain space relative humidity over the full range of cooling load.
/2/

3-5.1 Load Calculations.

Heating and cooling system design loads must be determined in accordance with the calculation procedures described in the ANSI/ASHRAE/ACCA Standard 183 unless otherwise specified herein.

Provide no more than a **\1** 1.15 **/1/** safety factor for heating equipment and distribution sizing to account for morning warm-up.

3-5.2 Outdoor Design Conditions.

Use UFC 3-400-02 for outdoor design conditions **\2** for **Navy** projects. For **Army** and **Air Force** projects, use ASHRAE Fundamentals Handbook or UFC 3-400-02. **/2/**

3-5.2.1 \1\ Spaces /1/ Conditioned for Comfort Cooling.

Size equipment and all system components to maintain and control indoor design conditions at each of the following: (1) the 1.0 percent dry bulb and the corresponding mean coincident wet bulb (MCWB) temperature and (2) the 1.0 percent humidity ratio and corresponding mean coincident dry bulb (MCDB) temperature.

3-5.2.2 \1\ Spaces /1/ Conditioned for Specialized Technical Requirements.

Size equipment and all system components to maintain and control indoor design conditions at each of the following: (1) the 0.4 percent dry bulb temperature and the corresponding MCWB temperature and (2) the 1.0 percent humidity ratio and corresponding MCDB.

3-5.2.3 \1\ Spaces /1/ Conditioned for Comfort Cooling Using Evaporative Equipment.

Size equipment and all system components to maintain and control indoor design conditions at each of the following: the 1.0 percent wet bulb temperature and corresponding MCDB.

3-5.2.4 \1\ Spaces /1/ Conditioned for Comfort Heating.

Size equipment and all system components to maintain and control indoor design conditions at the 99 percent dry bulb temperature.

3-5.2.5 Condensers and condensing units.

For **\1** sizing condensers and condensing units, add 5°F (3°C) to the outdoor dry bulb temperature. **/1/**

3-5.3 Indoor Design Conditions.

Indoor cooling and heating conditions are determined as follows **\1** unless specified in a facility type UFC or as approved by the authority having jurisdiction (AHJ). **/1/**

3-5.3.1 \1\ Spaces /1/ Conditioned for Comfort Cooling.

\4 78.0° F (25.6 °C) dry-bulb / 57.9° F (14.4 °C) dewpoint / 50-percent relative humidity. **/4/** The design must take into account the moisture gain in the space.

3-5.3.2 \1\ Spaces /1/ Conditioned for Comfort Cooling Using Evaporative Equipment.

80°F (26.7°C) dry bulb and a maximum of 55°F (12.8°C) dew point.

3-5.3.3 \1\ Spaces /1/ Conditioned for Comfort Heating.

68°F (20°C) dry bulb.

During unoccupied hours, temperatures must be set no higher than 55°F (12.8°C).

\1 Provide humidification where the indoor relative humidity for comfort heating is expected to fall below 30 percent at design conditions. **/1/** Coordinate with the architect to design the building envelope to prevent condensation in the wall/roof systems during the time humidification is in operation. Include in the design analysis a dew point analysis profile (ASHRAE Fundamentals Chapter 23) for winter design conditions, showing condensation boundaries. The dew point analysis must consider the effect of air movement into the walls for buildings under positive pressurization relative to the outdoors.

3-5.3.4 \1\ Spaces /1/ Conditioned for Heating - High to Moderate Physical Activity.

55°F (12.8°C) dry bulb. Examples of these facilities include areas in maintenance shops where engines are rebuilt and aircraft shops where instrumentation is repaired, warehouses areas where there are forklift loading operations, and aircraft hangars with high bay areas and limited amounts of people.

3-5.3.5 \1\ Spaces /1/ Conditioned for Heating - Freeze Protection.

40°F (4.5°C) at the 99.6 percent dry bulb outdoor design temperature.

3-5.3.6 \1\ Spaces /1/ Which are Naturally or Mechanically Ventilated Only \1\ for Comfort. /1/

80°F (26.7°C) dry bulb and 55°F (12.8°C) dew point maximum and 68°F (20°C) dry bulb minimum.

3-5.3.7 \1\ Spaces /1/ Conditioned for Process Cooling and Heating.

Process cooling and heating indoor design conditions are determined by the respective process requirements.

3-6 SPECIFIC FACILITY-TYPE HVAC REQUIREMENTS.

3-6.1 Facility Air Conditioning Eligibility.

Facilities are eligible for air conditioning where facilities of similar structure and function in the local private sector are equipped with air conditioning.

\6 Air conditioning for comfort cooling is not allowed for the following facilities **\1** unless approved by the AHJ for Army and Air Force projects. **/1/** Air conditioning for comfort cooling is not allowed for the following facilities unless required to meet ASHRAE 55 for occupied spaces and work areas for Navy projects. **/6/** Comfort conditioning is allowed in administrative areas of these facilities.

- Motor vehicle storage garages
- Aircraft maintenance facilities & hangars
- Special areas requiring high ventilation rates (i.e., woodshops, paint booth) **\1** unless approved by the AHJ **/1/**
- Vehicle storage areas of crash and fire stations
- Boiler plants and rooms
- Greenhouses
- General Warehouses

\6 For Navy projects only: Evaluate air conditioning for work areas to determine most life cycle cost effective approach. Include equipment that will contribute to generating heat loads when sizing air conditioning equipment. Consult with end user on operations that will occur in work areas that may also contribute to sizing air conditioning equipment.

For Army projects only: Manufacturing or maintenance processes may require temperature and humidity air conditions that need to be considered when determining the eligibility for comfort cooling. Cooling can be provided if the 1% occurrence temperature or humidity set point is above the temperature or humidity set point required by the equipment manufacturer or maintenance process. Comfort cooling for the aforementioned facilities can be considered on a case by case basis if cooling is common in industry for that type of facility but must still be approved by the AHJ. **/6/**

3-6.2 Natural or Mechanical Ventilation Requirements.

In areas where mechanical or natural ventilation may be feasible, evaluate the use of these methods in lieu of other air conditioning methods to meet interior design conditions. Ambient noise levels and the availability of prevailing winds should be addressed in the evaluation. Include the effect of outdoor humidity levels when designing the mechanical ventilation systems.

3-6.3 Nonpermanent Construction.

The design of air conditioning for semi-permanent or temporary facilities must be on a minimum cost basis with exposed duct work, electrical work, and refrigerant or water piping and all other possible economies used. See UFC 1-201-01 for temporary contingency operations facility requirements.

3-6.4 Intermittent Occupancy Facilities.

Facilities such as reserve centers, chapels, auditoriums, and theatres are occupied at irregular or infrequent intervals. Typically, only a small portion of a reserve center is occupied during normal working hours, while the balance of the facility is used primarily for weekends only. Consider the anticipated occupancy pattern when developing equipment layout and sequence of operation in order to ensure that overall life cycle cost is minimized. Evaluate opportunities such as thermal storage systems and demand controlled ventilation by occupancy sensors for these facility types. **\6\ /6/**

3-6.5 Vestibules.

Vestibules must be heated to 50°F (10°C) to melt tracked-in snow in locations where conditions warrant. Otherwise, vestibules must not be heated or air conditioned.

3-6.6 Closets and Storage in Air Conditioned Facilities.

These areas must be either directly air conditioned (greater than 50 sq. ft (4.6 sq. meters) of floor space) or provided with exhausts to transfer conditioned air from adjacent spaces (lesser than 50 sq. ft (4.6 sq. meters) of floor space).

3-6.7 Aircraft Maintenance Shops.

Provide air conditioning for those functional areas where required for quality control of equipment, material, and task. **\1** Localized or spot air conditioning is allowed at individual workstations. **/1/**

3-6.8 Data Processing Centers and \1\ Server Rooms. /1/

HVAC designs for data processing centers **\1** and server rooms must follow DOE-FEMP “Best Practices Guide for Energy-Efficient Data Center Design unless specific manufacturer’s guidance exceeds the criteria contained within. **/1/**

3-6.9 Health Care Facilities.

HVAC designs for health care facilities will be in accordance with the current issue of UFC 4-510-01.

3-6.10 Laboratories.

The design of HVAC systems must provide control over space temperature conditions including contaminants and fume control appropriate to the space function. **\1\ /1/**Exhaust systems must be provided with fume hoods to remove toxic substances as near to the source of the fumes as practical. Hood and system design must follow the recommendations of the following manual from the American Conference of Government Industrial Hygienists (ACGIH): ACGIH Industrial Ventilation: A Manual of Recommended Practice. Where laboratories are required to be under a negative pressure relative to other areas in the facility, coordinate with the architect to locate these spaces in the interior to prevent negative pressure induced infiltration of outdoor air into exterior wall cavities. Medical labs must meet the requirements of UFC 4-510-01.

3-6.11 Fitness Centers.

HVAC designs for Fitness Centers will be in accordance with this document and the current issue of **\6** UFC 4-740-02 **/6/**.

3-6.12 General Purpose Aircraft Hangars.

\6 HVAC designs for general purpose aircraft hangars will be in accordance with the current issue of UFC 4-211-01. **/6/**

3-6.13 Aircraft Fire and Rescue and Fire Station.

\1 Provide fire apparatus vehicle exhaust removal systems in all new, rehabilitated, or self-help Aircraft Fire and Rescue Station and Fire Stations. Projects must prevent exposure of fire fighters and contamination of living and sleeping areas to exhaust emissions. **/1/** As required by NFPA 1500, such systems must permit the operation of the apparatus with the apparatus doors closed. **\6** Refer to UFC 4-730-10. **/6/**

3-6.14 \6\ Telecommunications Rooms.

HVAC designs for telecommunications rooms will be in accordance with UFC 3-580-01. **/6/**

3-6.15 Laundries and Dry Cleaners.

Mechanical ventilation will generally be the primary method of heat dissipation. Evaporative cooling may be provided where effective. Spot air conditioning or general air conditioning must be provided to keep the temperature in the work areas from exceeding 85°F (29°C). Coil discharge temperatures used in spot cooling must be 50°F (10°C) dry bulb maximum for maximum dehumidification. Where life cycle cost effective, use heat recovery equipment on exhaust air to temper makeup air in cold weather **\2** to reduce the energy consumption **/2/**. **\1** Provide a readily accessible clean-out in all dryer exhaust ducts. **/1/**

3-6.16 Dining Facilities.

HVAC designs for Dining Facilities will be in accordance with this document, the following requirements, and the current issue of FC 4-722-01N and FC 4-722-01F. Provide fire suppression system for hoods in accordance with UFC 3-600-01.

3-6.16.1 Kitchen Ventilation.

Comply with NFPA 96. No air must be returned from the kitchen to the HVAC system. Generally, air flows from the dining areas to the kitchen areas to provide make-up air for kitchen exhausts. Maximize the use of dining area make-up air to the kitchen as this will provide secondary cooling for the kitchen staff. Kitchen hoods with built-in make-up air must be of the horizontal face discharge type.

Localized air conditioning or general air conditioning must be provided to keep temperature in the work areas from exceeding 85°F (29°C) dry bulb, if the main portion of the facility is air conditioned and the criteria for exhaust ventilation are met. Provide a separate ventilation system for the dishwashing area. Furnish tempered 65°F DB minimum (18°C DB minimum) makeup air for the range hood exhaust. The design must not allow recirculation of more than 75 percent of air (excluding hood exhausts) in the kitchen at any time. Kitchen canopy hood exhaust ventilation rates must be 75 fpm (0.4 m/s) for grease filter sections, and 50 fpm (0.25 m/s) for open hood section, measured at the horizontal hood opening. As an alternative, internal baffle-type canopy hood with peripheral slot and a slot velocity of 500 fpm (2.5 m/s) must be provided. Electrically interlocked supply and exhaust air fans must be designed for **\1** at least **/1/** 2-speed operation. **\1** Commercial kitchen Type I or Type II hoods for systems over 1000 CFM must be provided with variable speed, demand control for exhaust air. **/1/** Provide control interlocks for supply and exhaust fans to ensure that the HVAC system balance is maintained and that the proper direction of airflow is maintained during normal operations. Do not use evaporative coolers on kitchen supply air in humid areas

If additional make-up air is required for kitchen exhausts, provide push-pull kitchen hoods with built-in heated make-up air supply.

3-6.16.2 Ductwork for Humid Dishwasher Room Exhaust.

Dishwasher room exhaust ducts must be as short as possible with direct runs to outside of building. Ductwork must **\1** be aluminum or stainless steel and **/1/** have watertight joints, and must have a drain line from the low point. Approximately 25 percent of the exhaust air must be exhausted from the ceiling level.

3-6.16.3 Heat Recovery for Kitchens.

When heat in kitchens rejected by refrigeration equipment exceeds 10,551 W (36,000 Btuh), heat recovery systems must be used **\1** unless not **/1/** life cycle cost effective.

\4\ \3

3-6.17 Variable Refrigerant Flow (VRF) Systems.

VRF systems are a relatively new technology with design considerations and requirements that may differ from traditional HVAC systems.
\8\ /8/

\8 See paragraph 1-8 for Open Control System Requirements. **/8/ \6** As of the publication date for this UFC, all known commercially-available VRF systems rely on a proprietary network with a gateway to provide Open protocol interface; this arrangement does not comply with the UFGS requirements for open protocols. UFC 3-410-02 includes a process by which specific systems can be excepted from some of the open protocol requirements and permitted to use proprietary communications between system components with a gateway or interface meeting the open protocol requirements. **/6/**

3-6.17.1 Design Requirements for VRF Systems.

1. **\6** VRF systems must meet the control system specifications, or the system must be identified for an exception in accordance with UFC 3-410-02. **/6/**

2. The design must not preclude competition between vendors:
    a. Since VRF systems from different manufacturers require different mechanical designs, provide a design with necessary design allowances to permit multiple manufacturers to meet the design. For example, piping designs differ between VRF manufacturers so do not require specific VRF piping design, but rather indicate where piping may be installed.

    b. Edit project specifications and requirements to include contractor design drawings as additional pre-construction drawing SD-02 Shop Drawing submittals. These drawings must document the details of the VRF design, including but not limited to piping layout.

3. Designs must require that the system be configured and installed strictly in accordance with the manufacturer's installation requirement **\7** with the exception of press-fittings, which are not permitted per paragraph #5 below. **/7/**

4. Include and require refrigerant line vibration isolation at all connections to motorized equipment, including but not limited to the refrigerant line connections at each fan coil unit.

5. VRF systems piping/tubing must have all brazed connections that meet ASME B31.5 requirements and the manufacturer's installation requirements. The list of fittings and joints that are prohibited include but are not limited to the following: push-on fittings, extruded fittings, flare fittings, press-connect

fittings, mechanical joints and groove joints. The VRF system must be pressure tested and vacuum tested.

6. VRF systems must be provided to meet ASHRAE 15 and IMC safety requirements pertaining to leakage to rooms and spaces. Calculations must be performed per IAW ASHRAE 15 and IMC and must be provided to demonstrate these requirements are met.

7. The total refrigerant charge of the independent VRF system must be **\8** in compliance with the latest EPA Section 608 Refrigerant Management Regulations. (See paragraph 1-9 EPA HFC-Refrigerant Regulations **/8/** for more information on EPA regulation and refrigerant leakage concerns.)

3-6.17.2 Additional Considerations for VRF Systems.

3-6.17.2.1 Life-Cycle Cost Analysis.

Life Cycle Cost analysis comparing VRF with traditional systems can be difficult given the relative newness of VRF systems, and given that many VRF systems can only be serviced by factory-trained technicians which affects the maintenance costs for the system compared to more traditional systems. When performing life cycle cost analysis for VRF systems use care to properly identify all operation and maintenance costs. See APPENDIX B for more information on considerations regarding life-cycle costs.

3-6.17.2.2 Coordination with Project Site.

As with any system, coordinate the design of a VRF system with the government representative for the project. This is particularly important for VRF systems because their complexity can introduce operational, maintenance and cybersecurity challenges that are not necessarily experienced by traditional HVAC systems. For example: a higher level of training and expertise required to repair the system; differences in capability to operate the system in a degraded or manual mode; safety and operational considerations of running refrigerant lines through occupied spaces.

/3/ /4/

3-7 OTHER HVAC DESIGN CONSIDERATIONS.

3-7.1 Latent Load Considerations.

The design must take into account the moisture gain in the space.

3-7.2 Reheat.

When reheat is required to control indoor relative humidity, use energy recovery where feasible.

3-7.3 Economizer.

\1\ \6 For Army and Air Force projects, water economizer must be used in lieu of air economizers where practicable. The prohibition of air side economizers as stated in this UFC must be followed. **/6/** For Navy projects, use waterside economizers in lieu of airside economizers when applicable and life cycle cost effective. **/1/** Where air economizers are used, provide separate dampers for ventilation air and minimum outdoor air requirements. **\1** For Army and Air Force projects, air economizers must not be used in ASHRAE climate zones 1, 2, 3a, and 4a. For Navy projects, air economizers must be designed with controls and alarms to indicate economizer malfunction. **/1/**

3-7.4 Redundant Systems.

When a system failure would result in unusually high repair costs, or replacement of process equipment, or when activities are disrupted that are mission critical, the designer must submit a request for approval to the applicable AHJ in accordance with MIL-STD-3007, to provide redundant HVAC systems. No exemption is required where redundant HVAC systems are specified by other applicable criteria.

3-7.5 Humidification.

\1\ /1/Use of district steam is prohibited as a humidification method. Use of wetted pad type or water spray type humidifiers is prohibited since these have the potential to inject Legionnaire bacillus as well as other pathogenic organisms into the air stream.

3-7.6 Electric Resistance Heating.

Electric resistance heating must not be used for heating or reheat except where **\4** life cycle cost effective. \7\ Electric resistance heating must follow ASHRAE 90.1 and use of the unburdened rate for life cycle cost calculation. Electric resistance heating is permitted in the following circumstances for Family Housing and Small Remote Facilities whether or not life cycle cost effective. **/4/ /7/**

3-7.6.1 Family Housing.

Electric resistance heating may be used where a bathroom has been added and the existing heating system is inadequate to heat the addition, or where a bathroom has been added and it is unreasonable from an engineering or economic position to extend the existing heating system to the new area. An occupant-activated time switch with a maximum time setting of 30 minutes must be used for electric resistance or infrared heaters in family housing bathrooms. Thermostats must have a maximum setting of 75°F (24°C).

3-7.6.2 Small Remote Facilities.

Electric resistance heating may be used where all of the following criteria are met. Otherwise, use air source heat pumps where life cycle cost effective.

- The individual facility (total building) heating load is less than 15,000 Btu per hour (4 kW) provided natural gas is not available within a reasonable distance.
- The facility has a maximum total energy consumption of less than 60,000 Btu per square foot (190 kilowatt-hrs per square meter) per year (nominal 40-hour week use) or less than 118,000 Btu per square foot (1,340,00 kJ per square meter) per year (around-the-clock use).
- The facility is equipped with thermostats with a maximum setting of 75°F (24°C) and a positive cutoff above 65°F (18°C) outdoor temperature
- All facilities occupied less than 168 hours per week must be equipped with a temperature setback to a maximum of 50°F (10°C) during all unoccupied periods. Small offices or duty stations located within larger unheated or partially heated buildings (e.g., warehouse office, dispatch office in a motor pool, duty room in an armory or reserve facility) requiring less than 15,000 Btu per hour (4kW) may use electric resistance heating under the conditions outlined above.

3-7.6.3 \1\ Non-occupied Spaces.

\6 Electric resistance heating is permitted in the following non-occupied spaces where life cycle cost effective: **/6/**

- In non-occupied spaces in facilities without hot water heating systems.
- Electrical rooms. **/1/**

3-7.7 Steam Systems.

Single-pipe systems must not be used for comfort heating. For safety purposes, low-pressure steam 15 psig (100 kPa gage) and below must be used where terminal equipment is installed in occupied areas. High- **\1** or medium-pressure above 15 psig (100 kPa gage) steam unit heaters may **/1/** be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 13 feet (4 meters) above floor level.

3-7.8 Fan Coil Applications for Ventilation Air.

Fan-coil units must not be used for conditioning ventilation loads.

3-7.9 Ground Coupled Heat Pumps.

3-7.9.1 Sizing.

For projects which are considering Ground Coupled Heat Pumps (GCHP), field test the ground heat transfer capacity at the proposed well field site prior to design. **\6** Follow the requirements of ASHRAE and ANSI/CSA C448. If any conflict occurs between the two standards, the more stringent direction must be followed. **/6/** Nonresidential, commercial scale ground source heat pump systems require the utilization of computer design software. Such software **\1** must consider the interaction with adjacent loops and minimum 40 years **/1/** buildup of rejected heat in the soil.

3-7.9.2 Regulatory Requirements.

Regulatory requirements for vertical wells vary widely among States. Some regulations require partial or full grouting of the borehole. Confirm requirements with the Activity and current state and federal regulations, as well as relevant building codes.

3-7.9.3 Borehole Grouting.

The thermal conductivity of grouting materials is typically low when compared to the conductivity of native soils. Grout acts as an insulator and will, thus, hinder heat transfer to the well field. When governing regulations permit, consider the following alternatives:

1. Reduce the quantity of grout to an absolute minimum. Fine sand may be used as backfill where permitted, but caution must be exercised to ensure the interstitial space between pipe and borehole is filled to enhance conductivity.

2. Use thermally enhanced grout. Consult ASHRAE Ground Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings. Reduce the borehole diameter as much as possible to reduce the insulating effects of grout or backfill.

3-7.9.4 Piping.

Provide a bypass line around each heat pump unit to facilitate flushing and purging the condenser loop without subjecting the heat pump to residual construction debris. Provide test ports (sometimes referred to as “Pete’s plugs”) on the inlet and outlet to each heat pump unit, circulating pump and desuperheater, if incorporated. Provide isolation valves and valved tee connections for flushing and purging of the well field independently from the building condenser water system.

The design and installation of the ground loop heat exchanger (GLHX) must be with future maintenance and troubleshooting in mind. No fittings other than the supply and return takeoffs into a single vertical well are be allowed to be buried. **\6** Use reverse return circuits and headers in large well fields. No more than 20 wells may be allowed on a single branch circuit with a maximum of 20% of the total number of wells for an entire system on a single branch circuit. **/6/** Each individual supply and return loop length from the mechanical room or manifold must be within 15 percent **\1** of each other **/1/** for hydronic balancing purposes. Each supply and return loop off a GLHX manifold must have a shut-off valve and a balancing valve. For heat pumps with reduced flow requirements of 2 GPM/ton or less, consider series return in order to maintain fluid velocities necessary to foster good heat transfer. Base the decision to commit to reverse return on installed cost, pumping costs and the system flow requirements.

Each manifold header must have both a visual temperature gauge and a visual pressure gauge. Each manifold header must have a shut-off valve on both the main supply and return header piping between all field loops and the building. All system manifolds must be within the building or in a vault with adequate room for a person.

3-7.9.5 Heat Exchangers.

Use cupronickel refrigerant-to-water heat exchangers in open condenser loops only.

3-7.9.6 Make-up Water.

Do not provide automatic water makeup in residential GCHP systems. Reserve the added complexity and cost to larger, non-residential systems of 10 tons or larger.

3-7.9.7 Freeze Protection.

In geographic areas with heating dominated climates, an antifreeze solution may be required if condenser loop temperatures are expected to drop below 41°F (5°C). **\1** Minimize use of antifreeze, but if necessary, use propylene glycol **/1/** and keep concentrations to a minimum. Use condenser water circulating pumps with high efficiency **\1** or premium efficiency **/1/** motors. Design them to operate near their peak of maximum efficiency.

3-7.10 Variable Air Volume (VAV) Cooling.

- Do not oversize the system. Do not add safety factors in the load calculations. Size all central air handling equipment and central plant equipment for “block” loads. Design for both peak and part load conditions (minimal wall transmission load, low occupancy, etc.). Submit part load design calculations. Verify proper fan operating characteristics throughout the range from the minimum to the maximum flow conditions that will be experienced.
- For systems using a dedicated outdoor air handler for ventilation air directly connected to a VAV air handler, provide controls to ensure ventilation air requirements are maintained over all load conditions.
- Select the minimum primary air requirements of the VAV terminal units to maintain at least the minimum outside air ventilation requirements.
- **\1** Provide a low velocity filter module upstream of the outdoor air flow monitoring station to prevent dust/dirt build up that may clog the pitot tubes associated with the sensor. **/1/** Provide a duct access door at the inlet to the **\1** sensor **/1/** for periodic inspection and cleaning.
- Do not use discharge dampers or inlet vanes **\1** on VAV air handler for air volume **/1/** modulation. Provide variable frequency drives for air volume modulation.

- **\1** For high-ceiling areas, use a maximum of ten foot ceiling height for air change calculations. **/1/**
- Locate the static pressure sensor for modulating fan capacity two-thirds to three-quarters the distance from the supply fan to the end of the main trunk duct. Locate in a straight run of ductwork. Provide static pressure reset **\1** based on zone requirements **/1/** in accordance with ANSI/ASHRAE/IESNA Standard 90.1 **\1** paragraph in Chapter 6 entitled, “Setpoint Reset”. **/1/** Provide protection against over pressurization of the supply duct system. Use pressure independent (PI) terminal units.
- Use either the Static Regain or the T-Method method to design **\1** primary **/1/** ducts for VAV systems. Equal friction method must be used for VAV return ducts **\1** and ductwork downstream of VAV terminal units. **/1/** Use round and oval prefabricated duct for the primary air distribution to reduce both leakage and friction losses. Primary air connections to VAV terminals must always be made with a rigid duct to avoid high turbulence in the proximity of the VAV terminal flow sensor. Design the primary air duct connections to the VAV terminals with a straight duct section of at least 6 to 8 duct diameters (more if required by specific manufacturers). Reducer and increaser duct fittings installed immediately upstream of the VAV terminal connection collars are prohibited. If the branch duct size is other than the VAV terminal connection collar size, install the reducer or increaser fitting upstream of the aforementioned straight duct section. If a section of flexible duct, or a flexible connection, is required for vibration control, limit the length to no more than **\6** 150 mm (6 inches) **/6/**, and ensure that it is placed at least 6 to 8 duct diameters upstream of the VAV box collar connection/flow sensor.
- Minimum primary airflow rates must be established to attain minimum velocity pressures of no less than 0.03-inch w.g. (7.45 Pa). Do not use system-powered (also called "pressure dependent") terminal units. Discharge dampers must be installed in the supply duct from all series fan-powered VAV boxes (SFPVAV), regardless of the type of fan speed control utilized (3-speed fan switch or solid state speed control).
- When fan-powered VAV terminal boxes are used, perform an acoustic analysis to ensure designs are within acceptable NC criteria noise levels. Pay particular attention to noise attenuation in locations where the boxes are installed in spaces without dropped ceilings. Provide attenuation as required. Acoustical duct liner is not permitted for attenuation.
- Direct expansion equipment must be specifically designed and manufactured for VAV applications. **\1** For Army and Air Force projects, **/1/** the same manufacturer must provide central air handling units, VAV boxes/zone dampers and zone controls.

- When installing VAV terminals at heights in excess of 3.6 m (12 feet) above finished floors, special maintenance accommodations are necessary:

    1. Do not use fan-powered VAV boxes in such locations, since there are many serviceable components involved.

    2. When DDC controls are installed, specify the location of the DDC digital controller to facilitate ease of access.

    3. Ensure floor area likely to remain clear of permanent or semi-permanent equipment is available below the VAV boxes to facilitate the means of access (i.e. scaffolding, etc.).

    4. Specify the ability to monitor VAV box hot water control valve position (if provided with hot water coils), control damper position, primary airflow, flow sensor pressure differential, and box leaving supply air temperature.

    5. Specify the integral mounting of communication ports for the VAV box digital controllers to the room zone temperature sensor. When occupied/unoccupied modes of control are required of the VAV system, specify remote momentary override switch mounted integral to the room zone temperature sensors to permit non-standard schedule operation during unoccupied modes

3-7.11 \1\ Corrosion.

Provide corrosion resistant coatings or materials for any exterior air-conditioning (including heating and ventilating) equipment and equipment handling outside air that is to be installed. **\6** This includes any coils exposed to outside air. Coatings must be factory applied. Any reduction in heat transfer due to coil coatings must be taken into account when selecting equipment. **/6/ \5** Use upgraded materials/coatings in humid locations or project locations with Environmental Severity Classifications (ESC) of C3 thru C5. Humid locations are those in ASHRAE climate zones 0A, 1A, 2A, 3A, 3C, 4C and 5C (as identified in ASHRAE 90.1). See UFC 1-200-01 for determination of ESC for project locations. For example, use stainless steel, fiberglass, or ceramic in lieu of galvanized steel for cooling towers, and aluminum in lieu of steel for exhaust fans. **/1/ /5/**

3-7.11.1 \5\ Areas Prone to Hurricanes and Typhoons.

Locate HVAC equipment indoors whenever possible. Roof-mounted equipment is not recommended in areas prone to hurricanes and typhoons. Hurricane and typhoon prone areas include: The U.S. Atlantic Ocean and Gulf of Mexico coasts where the basic wind speed for Risk Category II buildings is greater than 115 miles/hour (185 km/hour); Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa; other Pacific Ocean islands and other coastal areas in the Pacific and Asia with design wind speeds greater than 115 miles/hour (185 km/hour). Additionally, roof-mounted equipment creates roof construction and maintenance problems. Where roof mounting is unavoidable, evaluate the cost effectiveness of providing roof-top equipment rooms. If locating equipment on exterior is unavoidable, the equipment should be located on the leeward side of the facility to protect from wind.**/5/**

3-7.12 Sound and Vibration Control.

The design of HVAC systems to maintain noise levels below those recommended for the proposed occupancy in accordance with the ASHRAE Handbook and SMACNA guidelines. Preferably, locate sound sensitive rooms away from air handlers and mechanical equipment. Acoustical duct liner is not allowed. Use double wall acoustic duct where sound attenuation cannot be accomplished by other methods and the duct is not serving occupancies that are sensitive to particulates. Increase the outside duct dimensions as required to maintain adequate internal cross sections.

Use ASHRAE Applications Handbook Chapter 48 “Selection Guide for Vibration Isolation” or manufacturers recommendations for vibration isolation design requirements.

3-7.13 Radon.

Provisions for the prevention and mitigation of indoor radon must comply with UFC 3-101-01.

3-7.14 HVAC System Testing & Balancing.

Testing and Balancing of HVAC systems must follow the requirements in UFGS 23 05 93.

\1 Do not exceed nameplate motor amperage in normal operating conditions. **/1/**

3-7.14.1 Balancing Valves and Cocks.

Provide **\1\ /1/** balancing valves for hydronic balance. The designer must specify the size of the balancing valves required in each application, cognizant of the required differential pressure requirements in the pipe systems. A balancing device is required in coil bypasses only when coil drops are in excess of 2 feet w.g. (6 kPa).

3-7.14.2 Flow Control Balancing Valves.

Provide flow control balancing valves in the discharges of all closed circuit pumps and at all hydronic terminal units. For pipe sizes larger than 3 inches (80 mm), a flow orifice combined with a butterfly valve must be specified. Install all flow control balancing valves in accordance with the manufacturer’s recommendations regarding the minimum straight lengths of pipe up and downstream of the device. Designers must select the proper size flow control-balancing valve for each application to ensure the devices are not oversized; valves must be selected using the median flow rating indicated in the manufacturer’s published performance data. Oversized flow control balancing valves yield inaccurate flow readings. Do not use automatic flow control balancing valves. **\1** Do not use triple duty valves. **/1/**

3-7.14.3 Balancing Dampers.

Except for primary VAV supply ductwork **\1** from air handling unit outlet to air terminal unit inlet, **/1/** provide manual volume dampers for all main and branch ducts; these should include all supply, return, and exhaust ducts. Do not use splitter dampers or air extractors for air balancing. Provide opposed blade manual balancing damper for outside air. Indicate opposed blade manual balancing dampers for both the main supply and return duct and the main relief duct on all return air fans; dampers must be in close proximity to the automatic return and relief dampers.

3-7.14.4 Duct Leakage and Testing.

All new duct systems must be constructed no less than a 1-inch (2.5 cm) pressure class and must be leak tested. Refer to Table 6-2 for a duct pressure table example which must be edited and included on the mechanical construction contract drawings. **\1** Provide seal class A on all ductwork. **/1/**

TAB contractors must not be allowed to sum the inlets or supplies to exhaust, return, and supply systems without accurately measuring the total flow rate at the fan for comparison and determination of approximate leaking rates.

3-7.14.5 Variable Speed Drives.

\6 Variable speed drives on pumps or fans must not be manually or automatically adjusted to achieve system balance. Balance systems to deliver design flows with variable speed drives operating at between 55 and 60 Hz so that maximum operational flexibility is maintained. Design conditions for variable speed drives to exceed 60 Hz is prohibited. **/6/** Replace or adjust fan drive sheaves and throttle pump discharges to achieve system balance. Consider trimming pump impellers on larger systems. Verify pump performance at minimum and maximum operating points.

3-7.15 Commissioning Requirements.

Commissioning must be provided as required by UFC 1-200-02. After the successful completion of the Test and Balance activities and prior to final acceptance of the HVAC systems, provide a minimum of four days of trends measured with data loggers **\1** or from the Building Automation System (BAS) **/1/** while the equipment is in full automatic mode to ensure that all systems are working properly under all conditions. **\1** Include the following trending requirements:

- Points to be trended must be the same or similar to App. D, Minimum Control Points List.
- Data points must be at the same time increment.
- Provide trends in graphic format.
- Clearly identify all trend data. **/1/**

CHAPTER 4 SUPPLEMENTAL IMC TECHNICAL CRITERIA

(Note: Chapter and paragraph numbers reference **\6** IMC-2018 ***/6/***)

4-1 GENERAL SUBSTITUTIONS.

All references to “approved” materials must be materials allowed by the applicable Unified Facilities Guide Specification (UFGS).

All references in the International Mechanical Code to the International Building Code must be considered to be references to UFC 1-200-01.

All references in the International Mechanical Code to the International Fuel Gas Code must be considered to be references to NFPA 54 and NFPA 58.

All references in the International Mechanical Code to the International Plumbing Code must be considered to be references to UFC 3-420-01.

All references in the International Mechanical Code to the International Energy Conservation Code must be considered to be references to UFC 1-200-02.

All references in the International Mechanical Code to the International Fire Code must be considered to be references to UFC 3-600-01

All references in the International Mechanical Code to NFPA 70 must be considered to be references to UFC 3-501-01.

4-2 IMC SUPPLEMENTARY PARAGRAPHS.

4-2.1 IMC CHAPTER 1 “*SCOPE AND ADMINISTRATION*” SUPPLEMENTS.

Delete Chapter 1 in its entirety. The administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) and by the authority granted to the Contracting Officer in administering the contract.

4-2.2 IMC CHAPTER 2 “*DEFINITIONS*” SUPPLEMENTS.

4-2.2.1 Definition Replacements.

Replace the definitions published in Chapter 2 with the following definitions:

APPROVED. Acceptable to the code official or other authority having jurisdiction. “Approved” materials must be materials allowed by the applicable Unified Facilities Guide Specification (UFGS).

CODE OFFICIAL. The Code Official is the authority having jurisdiction as described in UFC 1-200-01.

4-2.2.2 Definition Additions.

Add the following definitions to Chapter 2:

OWNER OR OWNER'S REPRESENTATIVE. For Government-owned facilities, the Contracting Officer assigned by the Government to administer the construction contract. For leased facilities, the leaser of the facility.

PERMIT HOLDER. The contractor accomplishing the project.

4-2.3 IMC CHAPTER 3 "G*ENERAL REGULATIONS*" SUPPLEMENTS.

4-2.3.1 Addition - Section 304.1 "General"

Insert after the last sentence of Section 304.1:

"All equipment mounted on a roof must be detailed by the structural engineer. Ductwork must be connected to equipment with flexible connections and supported to ensure proper alignment."

\6

4-2.3.2 Addition - Section 306.5 "Equipment and appliances on roof or elevated structures"

Insert after the last sentence of Section 306.5:

"The means to access the equipment must be shown on the mechanical drawings." **/6/**

\2

4-2.3.3 Addition - Section D306.6 "Mechanical Equipment installed in excess of 12 feet above finished floors"

Add the following section to Chapter 3:

D306.6 Mechanical Equipment installed in excess of 12 feet above finished floors. When mechanical equipment are installed at heights in excess of 12 feet, provide special maintenance accommodations such as a service platform, railings, catwalk with railings, and a permanent ladder or stairs for access of maintenance, repair, and replacement. **/2/**

4-2.3.4 Addition - Section 307.2.1 "Condensate disposal"

Insert after the last sentence of Section 307.2.1:

"Terminate condensate drain lines in accordance with the IMC and local direction."

4-2.3.5 Replacement – Section 309 "Temperature Control"

Replace Section 309 with the following:

Section 309
HVAC CONTROL

309.1 HVAC Control. Follow the mandatory requirements of the section titled "Controls" of ANSI/ASHRAE/IESNA Standard 90.1 as modified below. All air distribution systems must be capable of shutdown to meet the requirements of Standard 18 of UFC 4-010-01 "DoD Minimum Antiterrorism Standards for Buildings". **\2\ /2/**

\4\ 309.2 Control Protocol. ASHRAE's BACnet® protocol is the preferred control system architecture for **Navy** & **Marine Corp** facilities. LonWorks® protocol is the preferred control system architecture for **Army** facilities. Facility HVAC control systems based on the BACnet® protocol must be designed and constructed in accordance with ANSI/ASHRAE Standard 135, UFGS 23 09 00, UFGS 23 09 23.02 and UFGS 23 09 13. LonWorks® items in UFC 3-410-02 are not applicable when identified in UFGS 23 09 00, UFGS 23 09 23.02 and UFGS 23 09 13 for **Navy** & **Marine Corps** projects. Facility HVAC control systems based on the LonWorks® (ANSI/CEA-709.1 and related technologies) must be designed and constructed in accordance with UFC 3-410-02, UFGS 23 09 00, UFGS 23 09 23.01 and UFGS 23 09 13. **/4/**

309.3 Networked Controls. Prior to designing the DDC system, confirm whether an existing energy management network is available for interface on the Base. Provide DDC equipment which is compatible with existing systems to the maximum extent practicable. Where use of a specific DDC system is mandatory, a Justification and Authorization (J&A) for the utilization of proprietary DDC equipment must be provided by the Government.

309.4 Minimum Control Points. \6 Provide a control system with at least the minimum points as indicated in Appendix D. Develop point schedules and required naming conventions in accordance with UFC 3-410-02. For Navy projects, provide DDC BACnet® system in accordance with UFC 3-410-02. **/6/**

309.5 DDC Accreditation. \6 Provide hardware equipment utilizing the latest technology which will accomplish the desired control and will meet the Risk Management Framework (RMF) plan developed to comply with UFC 4-010-06. **/6/**

309.6 DDC Training. Require the DDC installer to provide training for government facility personnel on all new DDC equipment.

309.7 Hot Water System Modulation. Systems using hot water as a heat source will be controlled by a master outdoor temperature sensing unit that modulates the hot water temperature according to the outdoor temperature with a positive cut-off above 65°F (18.3°C) **\1** except when hot water is approved for reheat. **/1/**

4-2.3.6 Deletion - Section 312 "Heating and Cooling Load Calculations"

Delete Section 312 in its entirety.

4-2.4 IMC CHAPTER 4 "*VENTILATION*" SUPPLEMENTS.

4-2.4.1 Replacement – Section 401 "GENERAL"

\6 Replace Section 401.1 through 401.4 and 401.6 content with the following: **/6/**

> **401.1 Scope.** Every occupied space is to be ventilated in accordance with ANSI/ASHRAE Standard 62.1. **\6** Use the "ventilation rate procedure" in calculating minimum outdoor air requirements. **/6/** **\1** For Army and Air Force projects, **/1/** use of CO2 sensors for ventilation control is prohibited unless approved by AHJ.
>
> Maintain toilets, lockers, and utility closets at a negative pressure relative to adjacent areas during occupied periods by exhausting air transferred from these adjacent areas to the outdoors.
>
> **\2** Closets and storage or utility rooms smaller than 4.64 square meters (50 square feet) of floor space within conditioned spaces must have undercut doors allowing airflow through these spaces. Closets and storage or utility spaces larger than 4.64 square meters **\6** (50 square feet) **/6/** of floor space must be supplied with conditioned air. **/2/**
>
> For industrial applications not covered by ANSI/ASHRAE Standard 62.1 use the UFC 3-410-04.

4-2.4.2 Replacement – Section 402 "NATURAL VENTILATION"

Replace all Section 402 content with the following:

> **402.1 Scope.** Natural ventilation systems are to be in accordance with ANSI/ASHRAE Standard 62.1.

4-2.4.3 Replacement – Section 403 "MECHANICAL VENTILATION"

Replace all Section 403 content with the following:

> **403.1 Scope.** **\6** "Mechanical ventilation systems are to be in accordance with facility criteria or ANSI/ASHRAE Standard 62.1." **/6/**

4-2.4.4 Addition - Section 406 "Ventilation of Uninhabited Spaces"

Insert after the last sentence of Section 406:

"All air conditioned facilities with uninhabited spaces outside the air/moisture barrier must be designed to achieve maximum natural ventilation of the uninhabited space. "

\6

4-2.4.5 Replacement - Section 407 "Ambulatory Care Facilities and Group I-2 Occupancy"

Replace Section 407 with the following:

"Ambulatory Care Facilities and Group I-2 occupancy must be designed in accordance with UFC 4-510-01." **/6/**

4-2.4.6 Addition - Section D408 "Equipment Rooms"

Add the following section to Chapter 4:

D408.1 Equipment Spaces. \6 All equipment rooms must have exterior access sized to accommodate all maintenance and equipment replacement throughout the life of the building. Incorporate provisions for future equipment removal and replacement. Provide fall protection as required. Hand rails must be removable.

Equipment rooms on grade must be provided with door(s) on the building exterior.

Equipment rooms above grade must be provided with exterior access that will allow crane or mobile lift access to equipment. Provide fall protection as appropriate. Hand rails must be removable. Coordinate with the Architect on this requirement since it may have historical preservation impacts.

Equipment rooms below grade must be provided with pit access with floor drains, stairs and exterior double door(s) at a minimum. Provide fall protection as required. Hand rails must be removable.

For supplemental mechanical spaces with equipment weighing 125 lbs or less, verify if exterior access is required by the Installation Commander. **/6/**

D408.2 Equipment Room Ventilation. Where a refrigerating system is housed within the equipment room, the design of the room must comply with ASHRAE Standard 15.

D408.3 Equipment Room Ventilation Design. Equipment rooms will usually be ventilated using outside air intake louvers and a thermostatically controlled exhaust fan. Use a supply fan in lieu of an exhaust fan in rooms where atmospheric burners are located. The ventilation fan will have a two-speed motor, which is sized, at the high speed, to have adequate capacity to limit the room dry bulb temperature to a maximum of 10°F (6°C) above the outdoor dry bulb temperature when both equipment and ambient loads are at their maximum peaks. The high speed will be activated 10°F (6°C) below the maximum temperature at which the most sensitive item of equipment in the room can operate. The low speed will operate at 20°F (11°C) below that of the high speed.

D408.4 Equipment Room Air Conditioning. Air conditioning may be provided **\5\ /5/** to prevent severe corrosion **\5** in areas with an Environmental Severity Classification (ESC) of C4 and C5 and in high humidity areas identified in ASHRAE 90.1 as climate zones 0A, 1A, 2A, 3A, 3C, 4C and 5C. See UFC 1-200-01 for determination of ESC for project locations. In project locations as described above, seal the mechanical equipment rooms from air leakage. **/5/\1** Return air must not be taken from equipment rooms by air handlers serving occupied spaces. **/1/**

4-2.5 IMC CHAPTER 5 "*EXHAUST SYSTEMS*" SUPPLEMENTS.

4-2.5.1 Replacement – Section 501.1 "Scope"

Replace Section 501.1 with the following:

501.1 Scope. This chapter governs the design, construction and installation of mechanical exhaust systems, including exhaust systems serving clothes dryers and cooking appliances; hazardous exhaust systems; dust, stock and refuse conveyor systems; subslab soil exhaust systems; smoke control systems; energy recovery ventilation systems and other systems specified in Section 502. Use this chapter and UFC 3-410-04. If any conflict occurs between this chapter and UFC 3-410-04, the requirements of UFC 3-410-04 take precedence. **\6** The mechanical gases must meet the requirements in UFC 4-510-01. **/6/** Mechanical ventilation and exhaust systems for flammable, hazardous, grease laden, or toxic vapors, gases or fumes must follow the codes of practice of NFPA.

4-2.5.2 Addition - Section D501.6 "Roof Fans"

Add the following section to Chapter 5:

D501.6 Roof Fans. Roof exhaust fans should be avoided due to maintenance access restrictions and roof leak potential. If provided and where feasible, use direct drive fan motors with speed controllers to reduce maintenance requirements.

4-2.5.3 Replacement – Section 502.3 "Battery-charging areas for powered industrial trucks and equipment"

Replace Section 502.3 with the following:

502.3 Battery-charging areas for powered industrial trucks and equipment. Ventilation must be provided in an approved manner in battery-charging areas for powered industrial trucks and equipment to prevent a dangerous accumulation of flammable gases. Mechanical ventilation systems are to be in accordance with UFC 3-410-04.

4-2.5.4 \1\ Addition /1/ – Section 502.4 "Stationary storage battery systems"

\1 Insert after sentence of Section 502.4:

/1/ Design stationary secondary battery installations in accordance with UFC 3-520-05. For battery maintenance and repair facilities, use UFC 3-410-04 for design criteria.

\1\ /1/

4-2.5.5 \1\ Addition /1/ – Section 502.5 "Valve-regulated lead-acid batteries in cabinets"

\1 Insert after sentence of Section 502.5:

/1/Valve-regulated lead-acid (VRLA) batteries installed in cabinets must be provided with ventilation in accordance with UFC 3-520-05 and UFC 3-410-04.

4-2.5.6 Replacement – Section 502.13 "Public garages"

Replace Section 502.13 with the following:

502.13 Public garages. Mechanical exhaust systems for public garages must be in accordance with the applicable provisions of NFPA 88A.

4-2.5.7 Replacement – Section 502.19 "Indoor firing ranges"

Replace Section 502.19 with the following:

502.19 Indoor firing ranges. Mechanical ventilation systems must be provided in accordance with MIL-HDBK-1027/3B.

4-2.5.8 Addition - Section 506.1 "General"

Insert after the last sentence of Section 506.1:

"Evaluate the use of heat recovery in kitchens where heat rejected by refrigeration equipment is 50,000 Btuh (15 kW) or more."

4-2.5.9 Replacement – Section 507.3 "Type II hoods"

Replace Section 507.3 with the following:

507.3 Type II hoods. Type II hoods must be installed above dishwashers and appliances that produce heat or moisture and do not produce grease or smoke as a result of the cooking process, except where the heat and moisture loads from such appliances are incorporated into the HVAC system design or into the design of a separate removal system. Type II hoods must be installed above all appliances that produce products of combustion and do not produce grease or smoke as a result of the cooking process. Spaces containing cooking appliances that do not require Type II hoods must be ventilated in accordance with Section 403.3 and ANSI/ASHRAE Standard 62.1. If any conflict occurs between ANSI/ASHRAE Standard 62.1 and Section 403.3, the requirements of ANSI/ASHRAE Standard 62.1 take precedence. For the purpose of determining the floor area required to be exhausted, each individual appliance that is not required to be installed under a Type II hood must be considered as occupying not less than 100 ft^2 (9.3 m^2). Such additional square footage must be provided with exhaust at a rate of 0.70 cfm per square foot [.00356 $m^3/(s\text{-}m^2)$].

4-2.5.10 Replacement – Section 510.2.1 “Lumber yards and woodworking facilities”

Replace Section 510.2.1 with the following:

510.2.1 Lumber yards and woodworking facilities. Equipment or machinery located inside buildings at lumber yards and woodworking facilities which generates or emits combustible dust must be provided with an *approved* dust-collection and exhaust system. The systems must be in conformance with section 510 and UFC 3-600-01. Woodworking exhaust systems must be designed in accordance with UFC 3-410-04N.

4-2.5.11 Addition - Section 513.1 “Scope and purpose”

Insert before the first sentence of Section 513.1:

“Use Section 513 and UFC 3-600-01. If any conflict occurs between Section 513 and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.”

4-2.6 IMC CHAPTER 6 “*DUCT SYSTEMS*” SUPPLEMENTS.

4-2.6.1 Addition - Section 601.2 “Air movement in egress elements”

Insert after the last sentence of Section 601.2:

“Corridors in all new construction must conform to NFPA 90A.”

4-2.6.2 Addition - Section 603.1 "General"

Insert after the last sentence of Section 603.1:

"Design air distribution systems for central HVAC systems to maintain a slightly positive pressure (0.02"w.g.) relative to the outdoors within the area served in order to reduce or eliminate infiltration unless there is a valid need to maintain a negative pressure in that area. Maintain pressure relationships in each pressure zone (defined by full height interior walls, fire/smoke barriers, and external walls) and not exclusively calculated for the building as a whole."

Construct all ductwork to meet SMACNA seal class A. **\2** For **Navy** and **Air Force** projects, use round **\1** or **/1/** oval prefabricated duct to reduce both leakage and friction losses on duct systems above 1.5"w.g. static pressure. For **Army** projects, use round **\1** or **/1/** oval prefabricated duct to reduce both leakage and friction losses on duct systems per ASHRAE Handbook. **/2/**

Consider **\1** round or oval duct **/1/** for all other positive pressure applications. The additional material cost for round or oval prefabricated duct is often offset by reduced installation cost and time and reduced fan energy consumption and air leakage.

Provide air flow measuring devices as a means of determining outside air flow amounts. If an air flow measuring station is provided in the outside air duct, the equipment layout must allow for the straight duct length and size requirements of the air flow measuring station in accordance with the manufacturer's recommendations. **\1** Ensure all outside air entering air flow measuring stations has been filtered. **/1/**

Provide ducted returns from the occupied space for each zone to the air handler on all HVAC systems. **\6** UFC 3-600-01 does not override this requirement. **/6/**

Where negative pressure of indoor spaces relative to other indoor spaces is required, the building layout must place those spaces on the interior to minimize the possibility for negative pressure induced infiltration of the exterior wall cavity.

Ensure that duct design incorporates all features necessary to accommodate testing, adjusting, and balancing (TAB). TAB specifications must call for a plus 10%/minus 0 (zero)% on the outdoor air supply and a plus 0 (zero)%/minus 10% on the exhaust systems to prevent inadvertent building negative pressure after TAB."

4-2.6.3 Addition - Section D603.1.1 "Prohibited construction"

Add the following section to Chapter 6:

> **D603.1.1 Prohibited construction.** Do not use the following types of duct construction where the potential for subterranean termite infestation is high:
>
> - Sub-slab or intra-slab HVAC ducts.
> - Plenum-type, sub-floor HVAC systems, as currently defined in Federal Housing Administration minimum acceptable construction criteria guidance.
> - HVAC ducts in enclosed crawl spaces that are exposed to the ground.
> - HVAC systems where any part of the ducting is in contact with or exposed to the ground.

4-2.6.4 Deletion - Section 603.5 “Nonmetallic ducts”

Delete Section 603.5 in its entirety. **\1** Fiber or gypsum board **/1/** ducts are prohibited.

4-2.6.5 Replacement – Section 603.6.1.1 “Duct length”

Replace Section 603.6.1.1 with the following:

> **603.6.1.1 Duct length.** Flexible air ducts must not exceed **\2** 5 **/2/** feet in length. Do not use flexible duct for offsets greater than 45 degrees or connections to diffusers, registers or grilles greater than 45 degrees.

\6

4-2.6.6 Replacement – Section 603.6.2.1 “Connector length”

Replace Section 603.6.2.1 with the following:

> **603.6.2.1 Connector length.** Flexible air connectors must not exceed 5 feet in length. **/6/**

4-2.6.7 Replacement – Section 603.8 “Underground ducts”

Replace Section 603.8 with the following:

> **603.8 Underground ducts.** The use of underground ducts **\1** for general comfort conditioning **/1/** is prohibited, except for sub slab soil exhaust systems, per Section 512, which are allowed.

4-2.6.8 Addition - Section D603.19 “Control Dampers”

Add the following section to Chapter 6:

> **D603.19 Control Dampers.** Provide parallel blade dampers for two-position, on/off control. Provide opposed blade dampers for

modulating applications, but for best performance, their pressure drop should be between 5% and 20% of the total system pressure drop. They are effective for two-position, on/off applications as well, but are more expensive than parallel dampers. Outside air intakes must be equipped with low leakage dampers which have a maximum leakage rate of 3 CFM/ft^2 at 1"w.g. static pressure.

4-2.6.9 Replacement – Section 604.1 "General"

Replace Section 604.1 with the following:

604.1 General. Duct insulation must conform to the requirements of Sections 604.2 through 604.13 with the following exceptions. Spray polyurethane foam insulation, foam plastic insulation and internal duct insulation is prohibited. **\2** Duct insulation must be external, and duct board or internal duct liner is not allowed. **/2/**

4-2.6.10 Deletion - Section 604.7 "Identification"

Delete Item Number 4 in Section 604.7 in its entirety.

4-2.6.11 Replacement – Section 606.1 "Controls required"

Replace Section 606.1 with the following:

606.1 Controls required. Air distribution systems must be equipped with smoke detectors listed and labeled for installation in air distribution systems as required by Section 606 and UFC 3-600-01. If any conflict occurs between Section 606 and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence. Duct smoke detectors must comply with UL 268A. Other smoke detectors must comply with UL 268. **\1** Locate smoke detectors on plans in accordance with manufacturer's recommendations and downstream from the fan discharge, downstream of the air filters, ahead of any branch connections, and at the center of the duct. **/1/**

4-2.6.12 Replacement – Section 607.1 "General"

Replace Section 607.1 with the following:

607.1 General. The provisions of Section 607 and UFC 3-600-01 must govern the protection of duct penetrations and air transfer openings in assemblies required to be protected. If any conflict occurs between Section 607 and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.

\6 (IMC CHAPTER 7 "COMBUSTION AIR" SUPPLEMENTS Addition to Section 701 "General" was deleted because it was incorporated into IMC-2015.) **/6/**

4-2.7 IMC CHAPTER 8 "*CHIMNEYS & VENTS*" SUPPLEMENTS.

4-2.7.1 Addition - Section 801.2 "General"

Insert after the last sentence of Section 801.2:

> "See ASHRAE HVAC Systems and Equipment Chapter entitled "Chimney, Vent, and Fireplace Systems" for general chimney & vent design information and Table 2 for estimates of typical chimney flow rates. Where natural-draft stacks would be a hazard to aircraft or otherwise objectionable, use mechanical-draft fans discharging into short stub stacks. Equipment spaces equipped with natural draft stacks must not be operated at a negative pressure.

4-2.8 IMC CHAPTER 9 "SPECIFIC APPLIANCES, FIREPLACES AND SOLID FUEL-BURNING EQUIPMENT" SUPPLEMENTS.

4-2.8.1 Addition - Section D901.5 "Combustion equipment"

Add the following section to Chapter 9:

> **D901.5 Combustion equipment.** The installation of combustion equipment, including burners and draft fans, must be in accordance with ASHRAE Handbook, Underwriters Laboratory (UL), National Fire Protection Association (NFPA), and the recommendations of equipment manufacturers. Direct-fired heaters must not be used in areas subject to hazardous concentrations of flammable gas, vapors, or dust. Locate fuel burning equipment; such as packaged slab-mounted HVAC units away from windows, doors or outside air intakes. Gravity flow warm air furnaces must not be used.
>
> **D901.5.1 Gas burners.** All gas-fired equipment must be equipped with a burner, which can be readily converted to burn an alternate fuel.
>
> **D901.5.2 Oil burners.** The selection of oil burners must depend on the grade of the oil being burned, the size of installation, and the need for modulating control. For light oil, atomizing must be accomplished using oil pressure, air, or steam atomizing burners. For heavy oil, atomizing must be accomplished using air or steam atomizing burners.

4-2.8.2 Addition - Section 908.5 "Water supply"

Insert after the last sentence of Section 908.5:

> "Provide automatic blowdown and chemical feed provisions to all cooling towers to maintain cleanliness."

4-2.8.3 Addition - Section D912.4 "Installation"

Add the following section to Chapter 9:

D912.4 Installation. "When using non-condensing gas infrared heaters, the length of the exhaust flue should be minimized. To minimize condensation, run the flue horizontally with a slight pitch down from the heater to a sidewall exit. Heaters should be properly braced where excessive movement, such as by wind through an open hangar bay door, may cause separation of radiant pipe sections and rupture of gas connections. Consider condensing type IR heaters for larger applications. Provide ducted combustion air intake through roof or exterior wall. Direct vents for condensing type IR heaters to carry water vapor and exhaust out of the building.

4-2.8.4 Addition - Section 918.2 "Heat pumps"

Add the following section to Chapter 9:

D918.2.1 Application. Water source units may be used in heating the perimeter spaces of buildings that have interior spaces that must be cooled concurrently. Air-to-air heat pumps must be used only in locations with heating design temperatures (99 percent basis) greater than 12°F (-11.1°C). This restriction must not apply to those locations in which 30 percent or more of the total annual heating hours below 65°F (18°C) occur during the period of May through October. Heating only air-to-air heat pumps may be used in facilities not air-conditioned based on the lowest life cycle cost analysis. When applied to heat pump applications, auxiliary electric heat must be limited to the capacity needed to supplement the heat pump. Larger systems, including built-up systems, may be used where economically feasible.

D918.2.2 Capacities. Air-to-air heat pumps up to 39,565 W (135,000 Btuh) cooling capacity must be certified under the Heat Pump Certification Program of the Air Conditioning, Heating, and Refrigeration Institute (AHRI), unless a detailed life cycle cost analysis indicates selection of a less efficient unit would be more cost-effective. Larger systems, including built-up systems, must be used where economically feasible.

4-2.8.5 Replacement – Section 928 "Evaporative Cooling Equipment"

Replace Section 928 with the following:

Section 928
EVAPORATIVE COOLING EQUIPMENT

928.1 Applications. Evaporative cooling must only be used where the facility in question is eligible for air conditioning, and evaporative cooling can provide the required indoor design conditions based on the appropriate outdoor design conditions. A life cycle cost analysis must be used to determine if evaporative cooling is appropriate for the facility. In many locations where evaporative cooling cannot provide the required indoor conditions year-round, consideration must be given to its use as a supplement to the primary cooling system when preliminary life cycle calculations show the supplementary system to be cost effective. For special applications where close temperature or humidity control is required, consideration must be given to two-stage evaporative cooling or indirect evaporative cooling in the life cycle cost analysis as a supplement to, not in lieu of, the primary cooling system.

928.2 Design Evaporative cooling equipment must:

1. Be installed in accordance with the manufacturer's instructions

2. Be installed on level platforms in accordance with Section 304.10.

3. Have openings in exterior walls or roofs flashed in accordance with UFC 1-200-01.

\6 4. Be sized and provided with potable water backflow protection in accordance with UFC 3-420-01. **/6/**

5. Have air intake opening locations in accordance with Section 401.4.

4-2.9 IMC CHAPTER 10 “BOILERS, WATER HEATERS AND PRESSURE VESSELS” SUPPLEMENTS.

4-2.9.1 Replacement – Section 1001.1 “Scope”

Replace Section 1001.1 with the following:

1001.1 Scope. This chapter governs the installation, alteration and repair of boilers, water heaters and pressure vessels. Use Chapter 10, UFC 3-430-08N, UFC 3-430-02FA, and UFC 3-430-11 for boilers; and Chapter 10 and UFC 3-430-07 for the inspection and certification of boilers and unfired pressure vessels. If any conflict occurs between Chapter 10 and the above UFCs, the requirements of the UFCs take precedence.

4-2.9.2 Addition - Section 1004.2 “Installation”

Insert after the last sentence of Section 1004.2:

“**\6\ /6/** During heating season, multiple boilers should be kept warm and ready should the lead boiler fail to operate. On multiple boiler installations with the largest boiler off line, the remaining boiler(s) must be capable of carrying not less than 65 percent of the maximum winter design load. Where the smallest boiler installed has a capacity of more than twice the minimum summer load, provide an additional boiler or hot water heater sizes for the anticipated summer load."

4-2.9.3 Replacement – Section 1004.3 "Working clearance"

Replace **\1\ /1/** Section 1004.3 with the following:

\1 "Clearance around boilers must be per ANSI/NB23, National Board Inspection Code, Part 1, Sections 2 and 3, each with respective paragraphs entitled, 'Clearances'." **/1/**

4-2.9.4 Addition - Sections D1005.3 – D1005.4

Add the following sections to Chapter 10:

D1005.3 Feedwater systems. Provide heaters for the de-aeration of feedwater for all boiler installations with steam capacities in excess of 20,000 MBtuh (6,000kW). Install feedwater heaters above the boiler feed pump suction at a height sufficient to prevent flashing at the pump inlet at the design feedwater temperature. Provide a bypass and isolation valves for each feedwater heater to permit operation of the boilers at times when the heater is being serviced.

D1005.3.1 Feedwater pump requirements. Feedwater flow rate to the heater must equal the boiler demand. Size feedwater pumps 10 percent larger than the capacity calculated to allow for pump cooling requirements. **\1** Boiler feedwater pumps discharge pressure must conform with National Board Inspection Code, Part 1, Section 2, paragraph entitled, "Pumps". **/1/**

D1005.3.2 Surge tanks. Install the surge tanks upstream of the feedwater heaters where the space-heating load predominates, where large quantities of condensate are returned by condensate pumps, and where steam-driven auxiliaries are used. Size surge tanks for 20 minutes of condensate storage based on boiler steaming capacity.

D1005.4 Boiler auxiliaries. Boiler plant auxiliaries must be electrically driven; however, whenever an uninterrupted supply of steam is essential, provide one of the boilers with steam-driven auxiliaries. Provide individual forced or induced-draft fans with each boiler unit. Provide necessary standby equipment to maintain essential operations.

4-2.9.5 Addition - Section 1009.2 "Closed Type Expansion Tanks"

Insert after the last sentence of Section 1009.2:

"Use diaphragm type expansion tanks. Size the expansion tank according to the latest edition of the ASHRAE Systems Handbook.

Indicate the acceptance volume, nominal dimensions, configuration (i.e. horizontal or vertical) and pre-charge air pressure."

\6

4-2.9.6 Deletion - Section 1009.3 "Open Type Expansion Tanks"

Delete Section 1009.3 in its entirety.

4-2.9.7 Addition - Section 1011.1 "Tests"

Insert after the last sentence of Section 1011.1:

"Provide testing and certifications in accordance with UFC 3-430-07."
/6/

4-2.10 IMC CHAPTER 11 "*REFRIGERATION*" SUPPLEMENTS.

4-2.10.1 Addition - Section D1101.11 "Refrigerant oil"

Add the following section to Chapter 11:

D1101.11 Refrigerant oil. Compressors operating in parallel must have the normal oil level at the same elevation for all machines and the crankcases of these compressors must be provided with gas and oil equalizing lines. When compressors are connected in parallel, arrange the hot-gas discharge lines so that the oil from the common discharge line must not collect in an idle unit while the other units are running, and size the lines to provide an equal pressure drop between each machine and its respective condenser. The suction lines must return refrigerant gas and oil from the evaporator to the compressor during operation of the system, and must not allow oil or liquid refrigerant to be returned as slugs at any time. Provide means for trapping oil in the common suction header to prevent oil slugs from collecting in the idle compressor.

4-2.10.2 Replacement – Section 1102.2 "Refrigerants"

Replace section 1102.2 with the following (subparagraphs must remain to be enforced)

1102.2 Refrigerants. **\6** Refrigerants for new equipment must have an Ozone Depletion Potential (ODP) no greater than 0.0. **/6/**

4-2.10.3 Addition - Sections D1102.3 - D1102.6

Add the following sections to Chapter 11:

D1102.3 Absorption refrigeration. Use absorption equipment only where waste steam from incineration of solid wastes, heat recovery engine or gas turbine exhausts, or exhaust from steam turbine drives for refrigeration compressors or electric generators are available. Absorption chillers must have the capability of operating at variable condenser water temperature without crystallization. Use a throttling valve to modulate flow to the absorbent generator with chilled water temperature, as well as an automatic steam valve that reduces steam pressure and temperature, for energy efficient part load capacity control. Use two-stage absorption refrigeration whenever high-pressure steam or high-temperature water is available.

D1102.4 Reciprocating refrigeration. For reciprocating chillers over 10 tons (35 kW), use capacity control that reduces the power requirement as the load varies. Individual reciprocating machines must not exceed 200 tons (700 kW) capacity, and the total capacity of all reciprocating machines or packaged air-conditioning units equipped with reciprocating compressor used for air conditioning a single facility must not exceed 400 tons (1400 kW). A single packaged unit must not contain more than eight compressors.

D1102.5 Centrifugal refrigeration. When a two-stage centrifugal compressor is selected, a refrigerant intercooler must also be required. For low-temperature applications, where compressors with four or more stages are used, two-stage intercoolers must be used. Use capacity control methods to reduce energy consumption as the load is reduced to minimize life cycle costs. Use variable frequency drives; inlet vane control is not allowed.

D1102.6 Multiple chillers. Where multiple chillers are specified, provide a chilled water pump and a condenser pump for each chiller. With the exception of the criteria listed herein, the number of chillers specified must be optimized in the life cycle cost analysis. In multiple chillers installations the sequence of operation should ensure that the chillers are loaded and unloaded optimally for best performance and energy efficiency. Provide connection and communication between the chiller panels and the DDC system.

4-2.10.4 Addition - Sections 1107.2 “Piping location”

Insert after the last sentence of Section 1107.2:

“For refrigerant piping runs longer than 15 m (50 ft), size refrigerant piping in accordance with manufacturer requirements.”

4-2.11 IMC CHAPTER 12 “*HYDRONIC PIPING*” SUPPLEMENTS.

4-2.11.1 Addition - Sections 1201.2 “Sizing”

Insert after the last sentence of Section 1201.2:

”Provide back-up or standby pumps with lead/lag controls so that the total system capacity is available with any one pump out of service.

On variable flow systems, maintain a minimum system flow of 20-30% of peak flow to avoid pump dead-head and overheating."

4-2.11.2 Addition - Sections D1201.4 – D1201.7

Add the following sections to Chapter 12:

D1201.4 System types. Hydronic systems for comfort applications must be four pipe **\4** hydronic heat cool system (4-pipe independent load system) **/4/**. Piping material for hydronic systems must be either copper or steel. "Triple duty" or "multi- purpose" valves which combine a check valve, throttling valve, and shut-off valve must not be used in piping systems.

D1201.5 Safety. For safety purposes, low-temperature hot water [250°F (120°C) and below] must be used where terminal equipment is installed in occupied areas. Medium-temperature [250 to 350°F (120 to 175°C)] hot water or high-temperature [350 to 400°F (175 to 200°C)] hot water unit heaters **\1** may **/1/** be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 13 ft (4 m) above floor level.

D1201.6 Freeze protection. Freeze protection must be provided by automatic circulation of hydronic pumps when the outside temperature drops below 35°F (2°C) , or by the addition of an appropriate antifreeze solution, or design of a pipe temperature maintenance systems (i.e. heat trace) based on the lowest recorded temperature in UFC 3-400-02.

\4 1. For hydronic systems not needed for winter months, freeze protection may also be accomplished by draining the system prior to seasons that may experience freezing temperatures.

2. Look at the cost effectiveness when using antifreeze solutions considering the labor, material cost and the de-creased capacity. If used due to possible extended power outages or other, be aware that many manufacturers warn against dropping below 20% due to a quicker degradation of corrosion inhibitors. **/4/**

D1201.7 Chilled water systems. Provide a dedicated primary pump and condenser water pump for each chiller. **\6\ \1** Provide backup or standby pump for each chiller and cooling tower. **/1/ /6/** Provide piping and valve configuration that allows each chiller to operate **\1\ /1/** with any condenser water pump. The optimum supply and return water temperature differential must be determined by life cycle cost analysis.

4-2.11.3 Replacement – Section 1204.2 "Required thickness"

Replace Section 1204.2 with the following: Add

1204.2 Required thickness. Hydronic piping must be insulated to a minimum thickness as required by ANSI/ASHRAE/IESNA Standard 90.1. Follow the MICA National Commercial & Industrial Insulation Standards for proper installation of field applied insulation."

4-2.11.4 Replacement – Section 1205.1.5 "Equipment and Appliances"

Replace the last sentence of Section 1205.1.5 with the following:

"Provide shutoff valves to isolate all pumps."

4-2.11.5 Addition - Section 1206.1 "General"

Insert after the last sentence of Section 1206.1:

"Conceal piping in permanent-type structures. Exposed piping attached to or near equipment, or subject to high heat or frequent washing, must be copper, brass, or chromium plate. Prime other exposed piping with paint suitable for metal surfaces and finish-paint with color to match background. Arrange piping runs to minimize interference with personnel and equipment. Provide pressure and temperature taps ("Pete's Plugs") on the inlets and outlets of all coils, pumps, chillers, heat exchangers, and other equipment. Provide expansion loops and/or devices as required for proper piping protection. Detail and dimension loops and schedule joints indicating minimum total traverse and installed expansion traverse. Indicate guide spacing. Avoid the use of expansion joints where possible due to the high resultant thrust. Instead use geometry and ball joints where possible. Where chemical feeders are provided, fill openings should be no higher than 4 feet (1.2 meters) above the finish floor for ease of filling. **\2** Hydronic piping is not permitted to be installed within or pass through electrical or communication rooms. **/2/**"

4-2.11.6 Addition - Section 1206.2 "System drain down"

Insert after the last sentence of Section 1206.2:

"Provide drain lines from air handling units, fan coil units, pressure relief valves, backflow preventers, etc. Provide a water seal on drains as required. Pipe drain valves to floor drains where possible. Where not possible, provide hose connection. Provide manual type air vents. "

4-2.11.7 Addition - Section 1207.2 "Makeup water"

Insert after the last sentence of Section 1207.2:

"Provide automatic makeup water system for each hydronic system in accordance with UFC 3-420-01. Provide pressure gauges up and downstream of the PRV. Provide bypass line with a globe valve for each PRV.

4-2.12 IMC CHAPTER 13 "*FUEL OIL PIPING AND STORAGE*" SUPPLEMENTS.

4-2.12.1 Replacement – Section 1301.1 "Scope"

Replace section 1301.1 with the following:

1301.1 Scope. This chapter governs the design, installation, construction and repair of fuel-oil storage and piping systems. Use Chapter 13 and UFC 3-460-01. If any conflict occurs between Chapter 13 and UFC 3-460-01, the requirements of UFC 3-460-01 take precedence.

4-2.13 IMC CHAPTER 14 "*SOLAR SYSTEMS*" SUPPLEMENTS.

4-2.13.1 Replacement – Section 1401.1 "Scope"

Replace section 1401.1 with the following:

1401.1 Scope. This chapter governs the design, construction, installation, alteration and repair of systems, equipment and appliances intended to use solar energy for space heating or cooling, domestic hot water heating, swimming pool heating or process heating. **\2** Additional guidance is provided in UFC 3-440-01. If any conflict occurs between Chapter 14 and the above UFC, the requirements of the above UFC takes precedence. ***/2/***

CHAPTER 5 DESIGN ANALYSIS AND DRAWING REQUIREMENTS

5-1 DESIGN ANALYSIS.

The Design Analysis must consist of a Basis of Design Narrative and Calculations demonstrating compliance with all UFC requirements.

5-1.1 Basis of Design Narrative Requirements.

In addition to the Basis of Design Narrative requirements indicated in 3-401-01, provide the following:

5-1.1.1 \1\ /1/Design Conditions.

Provide the interior design conditions, including temperature, humidity, filtration, ventilation, air changes, etc., that are used for the design. Provide a tabulation of the design indoor and outdoor heating and cooling conditions for all occupied and unoccupied areas. **\6\ \2** For **Navy** projects, maintain a minimum airflow of four air changes per hour or in accordance with ASHRAE 55 in all regularly occupied spaces during occupied hours. The term “air change” in this particular instance means “air movement” calculated on the basis of four air changes per hour. An example that can satisfy this requirement is the use of ceiling fans. Another example would be for VAV systems where four air changes per hour can be satisfied with the use of fan-powered terminals. **/2/ /6/**

5-1.1.2 Base Utilities.

Describe the source of thermal energy that will be used (i.e. extension of central high pressure steam, hot water, natural gas, or stand-alone heat source with the type of fuel utilized). Where more than one source of thermal energy is considered economically feasible, or where a facility is deemed appropriate for study as defined under the heading entitled “Energy Computations”, include a computerized Life Cycle Cost Analysis to justify the selection.

5-1.1.3 Sustainable Design.

Briefly describe all energy and water conservation features, systems, and components used in the project and the expected energy savings in accordance with UFC 1-200-02 calculation requirements. Describe all features being used for sustainability credits and include the applicable completed forms.

5-1.1.4 Heating System.

Provide a description of the heating system proposed, including an explanation and cost analysis of why this system is preferred over other alternatives. Indicate locations of major components of the system.

5-1.1.5 Cooling System.

Provide a description of the cooling system proposed including an explanation and cost analysis of why this system is preferred over other alternatives. Indicate locations of major components of the system. Identify special humidification or dehumidification requirements. Indicate ASHRAE Standard filter efficiencies and any other special filtration requirements.

5-1.1.6 Ventilation System.

Provide a brief description of the ventilation system proposed. Indicate the outside air ventilation rates in cfm/person (L/s/person) and cfm/ft^2 (L/s/m^2) for various room types. The prescribed rates must be in compliance with ANSI/ASHRAE Standard 62.1. Describe the operation of the ventilation system in summer and winter modes.

5-1.1.7 HVAC Control System.

Briefly describe the HVAC control system type and its functions. If applicable, indicate a requirement to tie into an existing Base-wide EMCS or UMCS/BAS.

\1

/1/

5-1.2 Calculations and Analysis Requirements.

In addition to the calculations and analysis requirements indicated in UFC 3-401-01, provide the following. Identify the source of each calculation including date of reference and chapter, paragraph or section.

5-1.2.1 \1\ Energy Compliance Analysis (ECA).

Provide a Preliminary ECA as required by UFC 3-401-01 and UFC 1-200-02. Provide an updated Final ECA at final submittal. **/1/**

5-1.2.2 "U" Factor Calculations.

Follow the building envelope thermal requirements of UFC 3-101-01, Architecture, Chapter 3. Calculate "U" factors, including thermal bridging, for all composite wall and roof systems using the latest edition of ASHRAE Fundamentals. Include cross sections drawings of all wall and roof systems to supplement the calculations.

5-1.2.3 Heating and Cooling Load Calculations.

Use of professionally recognized, nationally used computerized load calculating program is required. Load calculations are required for each room or zone by the ASHRAE method indicated in the latest edition of the Fundamentals Handbook. Copies of input and output data are required. Psychrometric calculations of each air-conditioning process must be illustrated on psychrometric charts and submitted with the

100% submittal. Clearly identify all points in the conditioning process on the psychrometric chart and verify the sensible, the latent, and the total cooling capacity using the appropriate data from the chart. **\2** Performance requirements should include total cooling capacity, sensible capacity, coil design entering and leaving air conditions (wet and dry bulb temperatures), design airflow rate, face velocities, coil sensible heat ratio, and entering chill water temperature. **/2/** Outputs should demonstrate that indoor design conditions are continuously maintained at both outdoor design criteria.

5-1.2.4 \1\ /1/Outside Air Requirements/Calculations.

Calculate the outside air ventilation requirements as prescribed by the latest edition of ANSI/ASHRAE Standard 62.1. Calculations must consider the factors of "Multiple Spaces", "Ventilation Effectiveness" and "Intermittent or Variable Occupancy" as specified in ANSI/ASHRAE Standard 62.1. Optimize zoning where possible to reduce overall ventilation requirements. Evaluate cost effectiveness of exhaust air and condenser heat recovery. Provide a summary analysis showing compliance with the ventilation requirements. The analysis narrative must document a summary of all factors considered when making design choices regarding IAQ, including alternative ventilation solutions considered and reasons for the selection of the solution chosen. The analysis must also include a room-by-room breakdown of the anticipated **\1** or actual **/1/** number of occupants, the amount of ventilation air required, and any applicable adjustments such as multiple spaces factor, intermittent or variable occupancy factor, the ventilation effectiveness factor, and any other factors such as high relative humidity.

5-1.2.5 Building Air Balance Calculations.

Provide air balance calculations addressing the relationship between supply, return, outside air, and exhaust air quantities and indicating pressurization. Special requirements for space pressurization must be reflected and referenced in the air balance calculations.

5-1.2.6 Duct Pressure Drop Calculations.

Provide pressure drop calculations for all supply, return, outside and exhaust air systems.

5-1.2.7 Hydronic System Pressure Drop Calculations.

Provide pressure drop calculations for all supply and return piping systems.

5-1.2.8 Pipe Expansion Calculations.

Provide pipe stress calculations for all low-pressure 15 psig (103 kPa) steam, condensate and hot water piping systems where pipe diameters exceed 4 inches (100 mm) and/or the length exceeds 100 linear feet (30m) without a directional change. Provide pipe stress calculations for all medium and high-pressure steam and high temperature hot water systems.

5-1.2.9 Equipment Sizing Calculations.

Provide equipment sizing calculations and psychometric calculations and charts, if applicable, to justify the selection of equipment, including the following:

a. Terminal equipment including VAV boxes, fan coil units, etc.

b. Pumps.

c. Control valves and dampers.

d. Meters and metering devices.

e. Fans.

f. Air Handling Units.

g. Chillers.

h. Boilers.

i. Closed Circuit Coolers and Cooling Towers.

5-2 FINAL DRAWING REQUIREMENTS.

In addition to the final drawing requirements indicated in 3-401-01, provide the following:

5-2.1 Site Work.

Show the type and routing of the heat source conveyance system on the drawings. Exterior above and below grade steam and condensate distribution and below grade chilled and hot water distribution plans must be accompanied by profile drawings. Profile drawings must clearly depict all other utilities in the proximity of the new work.

5-2.2 Floor Plans.

When drawing congestion is likely, ductwork and piping should not be shown on the same plan. Single line ductwork layouts are not allowed on final drawings. A two line ductwork layout to scale **\1** must **/1/** be provided. Show thermostat locations on the plans **\1** with clear indication of associated terminal equipment (as applicable). **/1/** Show locations of humidistats on floor plans, when required. Show location of door louvers on floor plans or coordinate with architectural drawings. **\2** Ductwork must not be installed within or beneath slab-on-grade floors. **/2/**

5-2.3 Enlarged Plans.

Provide large-scale details of congested areas on the drawings, with dimensions locating all work relative to structural features of the building.

5-2.4 Mechanical Room Plans.

Mechanical rooms must be drawn at no less than ¼” = 1’-0” (1:50). Congested mechanical rooms must be drawn at no less than ½” = 1’-0” (1:20). Mechanical room plans should be supplemented by at least one section; at least two sections for more complex, congested applications.

5-2.5 Schematic Diagrams.

Provide a 3-dimensional isometric diagram representing the mechanical room piping or a 2-dimensional diagram indicating the entire system. Indicate shutoff valve locations to allow replacement of control valves and system components.

5-2.6 Design Conditions.

Provide a schedule indicating indoor and outdoor design temperatures for each room type.

5-2.7 Equipment Schedules.

Provide an equipment schedule on the drawings indicating actual design conditions, not manufacturer’s catalog data. Include as a minimum:

- Air flow quantities (maximum and minimum if applicable) and static pressure requirements.
- Coil water flow quantities and entering and leaving temperatures.
- Heating and cooling coil sensible and latent capacities including the sensible heat ratio.
- Coil entering and leaving air conditions. For cooling coils include wet bulb **\1** and dry bulb ***/1/*** temperatures at the design flow rate. Ensure these conditions adequately cover the design latent load. For heating coils provide entering and leaving air temperature. Include face velocity for coil selection. **\2** To preclude moisture carryover, coil face velocities must not exceed 167.6 meters per minute (550 feet per minute). ***/2/***
- Coil maximum allowable air side and water side pressure drops.
- Motor electrical characteristics including horsepower, voltage, RPM, and NEMA motor starter size.

5-2.8 Control Valves Schedule.

Provide flow rates, minimum Cv or maximum pressure drop, nominal valve size, service (i.e. steam, hot water, etc.), configuration (i.e. 2-way or 3-way), and action (i.e. modulating or 2-position).

5-2.9 Metric Valve Coefficient.

The metric version of the valve coefficient, Kv, is calculated in cubic meters per second at 1 kPa pressure drop. Do not use Cv, the English version, on a metric project.

5-2.10 Outdoor Air Schedule.

Provide an outdoor air schedule on the drawings. List the outdoor air to each zone with the number of anticipated **\1** or actual **/1/** occupants. Add a footnote to each schedule indicating that the number of occupants listed is for information purposes only.

5-2.11 Vibration Isolator Schedule.

Where vibration and/or noise isolation is required, provide a vibration isolator schedule on the drawings indicating type of isolator, application, and deflection in inches (mm).

5-2.12 Fouling Factors.

Indicate fouling factors for all water-to-air and water-to-water heat exchangers (i.e. coils, converters, chillers, etc). Indicate in the appropriate equipment schedule. Fouling factors must be accompanied with their appropriate **\6** Inch-Pound **/6/** or SI units.

5-2.13 Details.

Details must be edited to reflect the configurations and construction materials shown on the plans.

5-2.14 Access Panels.

Indicate location and size of access panels in floors, walls, and ceilings (except in lay-in tile applications) as required to access valves, smoke dampers, fire dampers, balancing dampers, balancing valves, air vents, drains, duct coils, filters, air flow monitoring stations, equipment, **\1** duct access doors, **/1/** etc. on drawings. **\2** Ensure adequate access for servicing, filter replacements, and coil removal. Sufficiently sized, safe access must be provided for the maintenance of valves, variable air volume (VAV) boxes, dampers, controls, and other HVAC components. **/2/**

5-2.15 Sequence of Operations.

The designer must provide a sequence of operations that includes a step by step instruction for all anticipated modes of heating and cooling system operations to include unoccupied periods. Sequence of operation must include control provisions to maintain **\1** conditions as listed in Chapter 3 of this UFC in paragraph entitled, “Indoor Design Conditions”. **/1/**

5-2.16 Control Diagrams.

Provide for all HVAC systems. Show system control schematics for the sequence of operation specified above on the drawings for each HVAC system. Show controller functions, such as normally open (NO), normally closed (NC), common (C), etc. Indicate all set points. Describe all controlled equipment operating modes, sequence of events, set points, and alarms. For Direct Digital Control (DDC) systems, include an input/output points list and a system architecture schematic.

5-2.17 Roof Fans.

Details of roof exhaust fans must include a requirement for airtight seals between the fan frame and the wood nailer of the roof curb. The details must require the duct of ducted exhaust fans to extend up through the fan curb to a flanged and sealed termination at the top of the curb.

5-2.18 Equipment Supports.

Show hanger rods and structural supports for all ceiling or roof-mounted air handling units, heating/ventilating units, fan coil units, exhaust or supply fans, expansion tanks, etc. in drawing details.

5-2.19 Drain Lines.

Show condensate drain lines from air handling units, fan coil units, etc. Indicate required depth of water trap. Show slope from drain pan.

5-2.20 Balance Dampers.

All dampers and their intended locations must be clearly delineated on the floor plans.

5-2.21 Ductwork Testing.

Indicate those HVAC duct systems to be leak tested on the contract drawings. Specify the test type and test pressure for each duct system (supply air, return air, exhaust air, and outside air ductwork) subject to testing.

5-2.22 Duct Construction Classifications.

Indicate duct static pressure, seal and leakage classifications on the drawings in accordance with SMACNA-HVAC Air Duct Leakage Test Manual. Include a completed “Ductwork Construction and Leakage Testing Table” on the drawings. Table 6-2 provides an example of this table.

5-2.23 \1\ Make-up Water. /1/

Detail all accessories, to include pressure reducing valves (PRV), relief valves, and backflow preventers. Show pressure reducing and relief valve pressure settings. **\1** Provide separate make-up water piping specialties for chilled and hot water systems. **/1/**

5-2.24 Flow and Slope Arrows.

Indicate the flow direction of pipe on the drawings. Show slope direction and rate of slope on all piping systems. **\1** Piping systems also include sanitary, steam, compressed air, condensate drain, and any other gravity drained systems. **/1/**

5-2.25 Guides for Piping.

Show pipe guide locations on all aboveground anchored piping. **\2** Route chilled water piping through pipe chases. Route chilled water piping through hallways where feasible. Conceal piping in the walls or ceilings of occupied spaces where it is not feasible to route through pipe chases and hallways. **/2/ \5** Route chilled water piping in accessible locations to the maximum extent possible for ease of maintenance or replacement. **/5/**

5-2.26 Pipe Anchors.

Show anchor locations on plans. Provide anchor detail(s).

5-2.27 Pressure Gauges.

Indicate pressure gauge ranges; system operating pressures should be midrange on the graduated scale.

5-2.28 Air Vents.

Show location of air vents required in piping systems.

5-2.29 Balance Valves.

Contract drawings must specify the valve size and flow for each application. When an existing system is modified, provide all information required for re-balancing in the construction documents. Detail installation of all flow control balancing valves.

5-2.30 Kitchen Hood Diagram.

Provide a detailed air balance diagram on the drawings for every kitchen/dining facility design to show compliance with the ventilation requirements. Indicate required capture velocities and capture distances for all hoods on the drawings. Provide notes and contractor instructions on plans indicating that fan airflows shown for hoods are approximate and requiring the contractor to balance the system to achieve the capture velocities indicated. The scheduled fan and motor size must allow for adjustment of the airflow.

Table 6-2 Ductwork Construction and Leakage Testing Table Example

System	Duct Pressure Class				Supply				Return/ Outside Air		Duct Test Pressure: Inches of Water Column	Notes
	Inches of Water Column				Round/Oval		Rectangular					
	Supply Duct	Return Duct	Exhaust Duct	Outside Air Duct	Duct Seal Class	Duct Leak Class	Duct Seal Class	Duct Leak Class	Duct Seal Class	Duct Leak Class		
Packaged Rooftop - VAV	4	-	-	-	A	3	A	6	-	-	4.0	1
	-	-2	-	-	-	-	-	-	A	24	2.0	1
Packaged Rooftop -CV	2	-	-	-	-	-	A	12	-	-	2.0	1
	-	-1	-	-	-	-	-	-	A	24	1.0	1
Air Handling Unit with Economizer-Constant Volume	2	-	-	-	A	6	A	12	-	-	2.0	1
	-	-1	-	-	-	-	-	-	A	24	1.0	1
	-	-	-1	-	-	-	A	24	-	-	1.0	1
	-	-	-	-1	-	-	-	-	A	24	1.0	1
Series VAV Terminal Boxes	2	-	-	-	-	-	A	12	-	-	2.0	1
	-	-1	-	-	-	-	-	-	A	24	1.0	1
Exhaust Duct	-		-1	-	-	-	A	24	-	-	1.0	1

Notes:

1. Test in accordance with UFGS 23 05 93, Testing, Adjusting, and Balancing for HVAC and the procedures in SMACNA HVAC Air Duct Leakage Test Manual

2. Each piece of air moving equipment on the project must be shown in the schedule and the required pressure class, duct seal class, duct leak class and test pressure must be indicated. Duct seal class A is required on all duct systems.

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APPENDIX A REFERENCES

AIR CONDITIONING, HEATING, AND REFRIGERATION INSTITUTE
www.ahrinet.org

AHRI Heat Pump Certification Program

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS
www.acgih.org

ACGIH Industrial Ventilation: A Manual of Recommended Practice

AMERICAN NATIONAL STANDARDS INSTITUTE
www.ansi.org

ANSI/CEA-709.1-C-2010, Control Network Protocol Specification

\6 ANSI/CSA C448 Series - 16, Design and installation of ground source heat pump systems for commercial and residential buildings ***/6/***

\4\ AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS
www.ashrae.org

ASHRAE Ground Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings

ASHRAE Handbooks, (Fundamentals, Applications, Systems and Equipment, and Refrigeration)

\6 ASHRAE Standard 15-2016, Safety Standard for Refrigeration Systems ***/6/***

ASHRAE Standard 52.2-2012, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

\9\ \6 ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality***/6/ /9/***

\9 ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (Refer to UFC 1-200-02, for applicable publication date) ***/9/***

ANSI/ASHRAE Standard 135 – 2016, BACnet® - A Data Communication Protocol for Building Automation and Control Networks

ANSI/ASHRAE/ACCA Standard 183-2007, Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings.

/4/

INTERNATIONAL CODE COUNCIL
www.iccsafe.org

\6 IMC-2018, International Mechanical Code **/6/**

MIDWEST INSULATION CONTRACTORS ASSOCIATION
www.micainsulation.org

MICA National Commercial & Industrial Insulation Standards, 1999

NATIONAL FIRE PROTECTION ASSOCIATION
www.nfpa.org

NFPA 54, National Fuel Gas Code

NFPA 58, Liquefied Petroleum Gas Code

NFPA 70, National Electric Code

NFPA 88A, Standard for Parking Structures

NFPA 90A, Air Conditioning and Ventilating Systems

NFPA 96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

SHEET METAL AND AIR CONDITIONING CONTRACTORS NATIONAL ASSOCIATION, INC.
www.smacna.org

SMACNA HVAC Air Duct Leakage Test Manual

UNDERWRITERS LABORATORIES INC.
www.ul.com

UL 268, Smoke Detectors for Fire Alarm Systems

UL 268A, Smoke Detectors for Duct Application

UNITED STATES DEPARTMENT OF DEFENSE

MIL-STD 3007, Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications, http://www.wbdg.org/ccb/FEDMIL/std3007f.pdf

\6\ /6/

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA (UFC)
http://dod.wbdg.org/

FC 4-722-01 F, Air Force Dining Facilities

FC 4-722-01N, Navy and Marine Corps Dining Facilities

\6 UFC 4-740-02, Fitness Centers

/6/

UFC 1-200-01, DoD Building Code (General Building Requirements)

UFC 1-200-02, High Performance and Sustainable Building Requirements

UFC 1-201-01, Non-Permanent DoD Facilities in Support of Military Operations

UFC 3-101-01, Architecture

UFC 3-400-02, Design: Engineering Weather Data

UFC 3-401-01, Mechanical Engineering

\6 UFC 3-410-02, Direct Digital Control for HVAC and Other Building Control Systems **/6/**

UFC 3-410-04, Industrial Ventilation

UFC 3-420-01, Plumbing Systems

UFC 3-430-02FA, Central Steam Boiler Plants

UFC 3-430-07, Inspection and Certification of Boilers and Unfired Pressure Vessels

UFC 3-430-08N, Central Heating Plants

UFC 3-430-11, Boiler Control Systems

UFC 3-440-01, **\2** Facility-Scale Renewable Energy Systems **/2/**

\2\ /2/

UFC 3-460-01, Design: Petroleum Fuel Facilities

UFC 3-501-01, Electrical Engineering

UFC 3-520-05, Stationary Battery Areas

\6 UFC 3-580-01, Telecommunications Interior Infrastructure Planning and Design **/6/**

UFC 3-600-01, Fire Protection Engineering for Facilities

UFC 4-010-01, DoD Minimum Antiterrorism Standards for Buildings

\6 UFC 4-010-06, Cybersecurity of Facility-Related Control Systems **/6/**

\6\ /6/

\6 UFC 4-211-01, Aircraft Maintenance Hangars **/6/**

UFC 4-510-01, Design: Medical Military Facilities

\6 UFC 4-730-10, Fire Stations **/6/**

\4\ UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)
http://dod.wbdg.org/

UFGS 23 05 93, Testing, Adjusting, and Balancing for HVAC

UFGS 23 09 00, Instrumentation and Control for HVAC

UFGS 23 09 13, Instrumentation and Control Devices for HVAC

UFGS 23 09 23.01, LonWorks Digital Control for HVAC and Other Building Control Systems

UFGS 23 09 23.02, BACnet Digital Control for HVAC and Other Building Control Systems

UFGS 25 10 10 Utility Monitoring and Control System (UMCS) Front End and Integration

/4/

UNITED STATES NAVY

MIL-HDBK-1027/3B, *Range Facilities and Miscellaneous Training Facilities Other than Buildings,* http://www.wbdg.org/ccb/NAVFAC/DMMHNAV/1027_3b.pdf

APPENDIX B BEST PRACTICES

B-1 OUTSIDE AIR INTAKES.

Locate outdoor air intakes in areas where the potential for air contamination is lowest. Basic guidelines include the following:

- Maximize distance between intakes and cooling towers, plumbing vents, loading docks, traffic, etc.
- Maintain a minimum distance of 10 meters (30 feet) between intakes and exhausts, more if possible.
- Locate intakes and exhausts on different building faces.

B-2 INDEPENDENT VENTILATION SYSTEMS.

Ventilation systems that are independent of the primary air supply and distribution systems can provide benefits such as increased humidity control, reduced amount of ventilation air than may be otherwise required, and increased equipment operating efficiency.

B-3 PURGE MODE.

Where desirable, the designer may incorporate a purge mode into system design. This mode could be used, for example, to purge the building with outside air during off-hours or to purge an area of the building undergoing maintenance, such as painting.

B-4 FILTRATION.

For administrative facilities, commercial facilities, and similar facility occupancy classifications where indoor air quality is of primary concern, filter the combined supply air, including return and outside air, with a combination of prefilter(s) with a MERV of 8 and final filter(s) with a MERV of 13 when tested in accordance with ASHRAE Standard 52.2. Where the use of extended surface nonsupported pocket (bag) or cartridge filters is unacceptable and satisfactory indoor quality can be achieved using extended surface filters, the use of prefilters is not required. Where practical, provide separate filtration or other means to clean the outdoor air, typically equivalent to that used for the combined air stream, prior to mixing it with the return air. **\1** Provide separate static pressure switch for each filter bank. **/1/** Due to the decrease in system airflow as the pressure drop across the filter increases, size fans for the “dirty” filter condition. This will ensure that each fan has adequate capacity to deliver the design airflow as the filter becomes loaded.

B-5 COMFORT VENTILATION.

Gravity ventilation is rarely adequate as a reliable source for comfort ventilation. It can be used in high-bay areas that are rarely occupied, such as storage buildings, or in areas that are difficult to ventilate, such as hangars. Consider nighttime air flushing of spaces, multi-speed fans, increased insulation, improved shading, and building site to improve the effectiveness of comfort ventilation.

B-6 FAN COIL UNITS.

The limitations of fan-coil units with regards to latent loads associated with simply providing adequate ventilation for occupancies such as living quarters make them unsuitable as the only means of cooling and dehumidification in most locations and for most occupancies, unless the fan coil unit is equipped with a split coil to allow for the continuous conditioning of outside air.

B-7 \1\ DEDICATED OUTSIDE AIR SYSTEM (DOAS). /1/

Consider using a separate system for outdoor air where necessary to maintain a sensible heat ratio of the mixed air entering the primary air-conditioning unit within the required limits of commercially available equipment and/or to reduce corrosive, salt-laden air from entering the primary air distribution system.

B-8 INFRARED HEATING.

Consider infrared radiant heating for high-bay areas or where spot heating is required. Gas, oil, and electricity may be considered as fuel sources.

B-9 RELIABILITY.

For Data Processing and Electronic Office areas use two or more smaller units to satisfy the required cooling capacity. This will generally reduce energy consumption at partial cooling loads and will also increase overall system reliability.

B-10 PHOTOCOPIERS & LASER PRINTERS.

If possible, locate photocopiers and laser printers in a separate room or group them together and provide local exhaust. Maintain the separate room at a negative pressure relative to adjacent areas by transferring air from these adjacent areas to the separate room. Do not add the air exhausted from the separate room or local exhaust to the return air or transfer it to any other areas. Coordinate with the architect to place areas requiring negative pressure relative to other spaces in the interior of the building to minimize the chances for negative pressure induced infiltration.

\4

B-11 VRF SYSTEMS.

A variable refrigerant flow (VRF) system is defined as any system containing two or more interconnected DX refrigerant coils that are designed for installation within a facility's occupied space. They are 'ductless' A/C or heat pump systems in which refrigerant is moved from fan-coil unit to fan-coil unit within the occupied facility spaces.

DoD has placed special requirements on these systems due to their inherent risks. Three primary risk areas have been identified: 1) VRF systems currently contain proprietary hardware and software in conflict with 10 USC 2867, 2) VRF systems increase the risk of adverse mission impacts due to **\8** EPA leak-rate rules on HFC refrigerant systems **/8/** and the challenge of locating and repairing a leak in often hard to access areas, and 3) VRF systems have uncertain life-cycle costs (LCC) making comparisons with traditional HVAC systems difficult.

1. **Proprietary Systems: \8** See paragraph 1-8 for Open Control System Requirements. **/8/** To our knowledge, all VRF systems currently in production use a proprietary control network and thus fail to meet the requirements of **\8** specifications UFGS 25 10 10, UFGS 23 09 00, UFGS 23 09 23.01 and UFGS 23 09 23.02. **/8/** The adoption and use of systems with proprietary control networks is in conflict with the legal requirement of adopting systems with an 'open protocol'. While many VRF systems can connect to a LonWorks or BACnet DDC system through a Gateway device, this does not meet the requirements of an Open system and installation of proprietary networks communicating through a gateway is not permitted by the specifications **\8** unless the system meets the specific requirements and approvals for an exception defined in UFC 3-410-02. **/8/** Further, the facility owner remains dependent upon the original vendor for maintenance and support which also violates the Open system requirements of the specifications. **\8\ /8/**

2. **\8\ EPA HFC-Refrigerant Regulations:** See paragraph 1-9 for EPA HFC-Refrigerant Regulations. **/8/** VRF systems have attributes that significantly increase DoD exposure to adverse impacts **\8** concerning refrigerant. **/8/** For instance, VRF systems have refrigerant line lengths much greater than traditional DX systems. These lines extend through the occupied space and are mounted above ceilings and through walls. Tracing and repairing a leak on a VRF system is many times more difficult with an additional access requirement of maintenance crews to the workspace environment. In classified workspaces, shut down of the mission may be necessary to affect repairs.

3. **Uncertain Life-Cycle Costs:** Currently, VRF systems have an above-average initial capital cost. However, the out-year maintenance costs and labor man-hours are uncertain as VRF systems are relatively new within the U.S. For instance, there is a lack of information on the rate of component wear to predict replacement intervals. ASHRAE Handbooks show a service life of 15-yrs for DX systems yet some life-cycle cost studies indicate a VRF expected life of 30-yrs. In addition, the proprietary nature of VRF systems implies a disproportionate reliance on contract repair and proprietary parts vice in-house maintenance.

The DoD will continue to monitor and/or investigate these risk elements and update the UFC as appropriate.

/4/

B-12 \5\ CAPACITY OF EQUIPMENT.

Select air conditioning equipment to ensure the minimum anticipated cooling load is larger than the capacity of the lowest stage of the equipment. Use multiple air conditioning units if this is not possible. **/5/**

B-13 \5\ LOCATION OF EXHAUST REGISTERS FOR MOISTURE REMOVAL.

Locate exhaust registers as close as possible to the source of the moisture being exhausted. **/5/**

APPENDIX C GLOSSARY

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
\6 AFCEC	Air Force Civil Engineer Center **/6/**
AHJ	Authority Having Jurisdiction
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BAS	Building Automation System
BIA	Bilateral Infrastructure Agreement
BOCA	Building Officials and Code Administrators International
Btu	British Thermal Units
Btuh	British Thermal Units per Hour
ºC	Degrees Celsius
C	Common
CFM	Cubic Feet Per Minute
CO2	Carbon Dioxide
DB	Dry Bulb Temperature
DDC	Direct Digital Control
\6\\ /6/	
DOAS	Dedicated Outdoor Air System
DoD	Department of Defense
EMCS	Energy Monitoring Control System
EPACT05	Energy Policy Act of 2005
ESC	Environmental Severity Classification

ºF	Fahrenheit
FAR	Federal Acquisition Regulations
FAVER	Fire Apparatus Vehicle Exhaust Removal Systems
fpm	Feet Per Minute
ft	Feet
ft^2	Square Feet
GCHP	Ground Coupled Heat Pumps
GLHX	Ground Loop Heat Exchanger
GPM	Gallons per Minute
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters United States Army Corp of Engineers
HVAC	Heating, Ventilating, and Air Conditioning
Hz	Hertz
ICBO	International Conference of Building Officials
ICC	International Code Council
IGSHPA	International Ground Source Heat Pump Association
IMC	International Mechanical Code
IR	Infrared
J&A	Justification and Authorization
kJ	Kilojoule
km	Kilometer
kPa	Kilopascal
kW	Kilowatt
L	Liters
LCCA	Life Cycle Cost Analysis

m	Meters
m/s	Meters per Second
m^2	Square Meters
m^3	Cubic Meters
MBtuh	Thousand British Thermal Units per Hour
MCDB	Mean Coincident Dry Bulb
MCWB	Mean Coincident Wet Bulb
MICA	Midwest Insulation Contractors Association
MILCON	Military Construction
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
mm	Millimeters
NAVFAC	Naval Facilities Engineering Command
NC	Normally Closed
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NO	Normally Open
ODP	Ozone Depletion Potential
Pa	Pascal’s
PI	Pressure Independent
PRV	Pressure Reducing Valve
psig	Pounds Per Square Inch (Gage)
RFP	Request for Proposal
RPM	Revolutions per Minute
s	Second

SBCCI	Southern Building Code Congress International
SFPVAV	Series Fan-Powered VAV Boxes
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SOFA	Status of Forces Agreement
STD	Standard
TAB	Testing, Adjusting and Balancing
TI	Technical Instruction
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriters Laboratories, Inc.
UMCS	Utility Monitoring Control System
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
VAV	Variable Air Volume
VRLA	Valve-regulated lead-acid
W	Watts
w.g.	Water Gage

APPENDIX D MINIMUM CONTROL POINTS LIST

Table D-1 DDC Minimum Points List

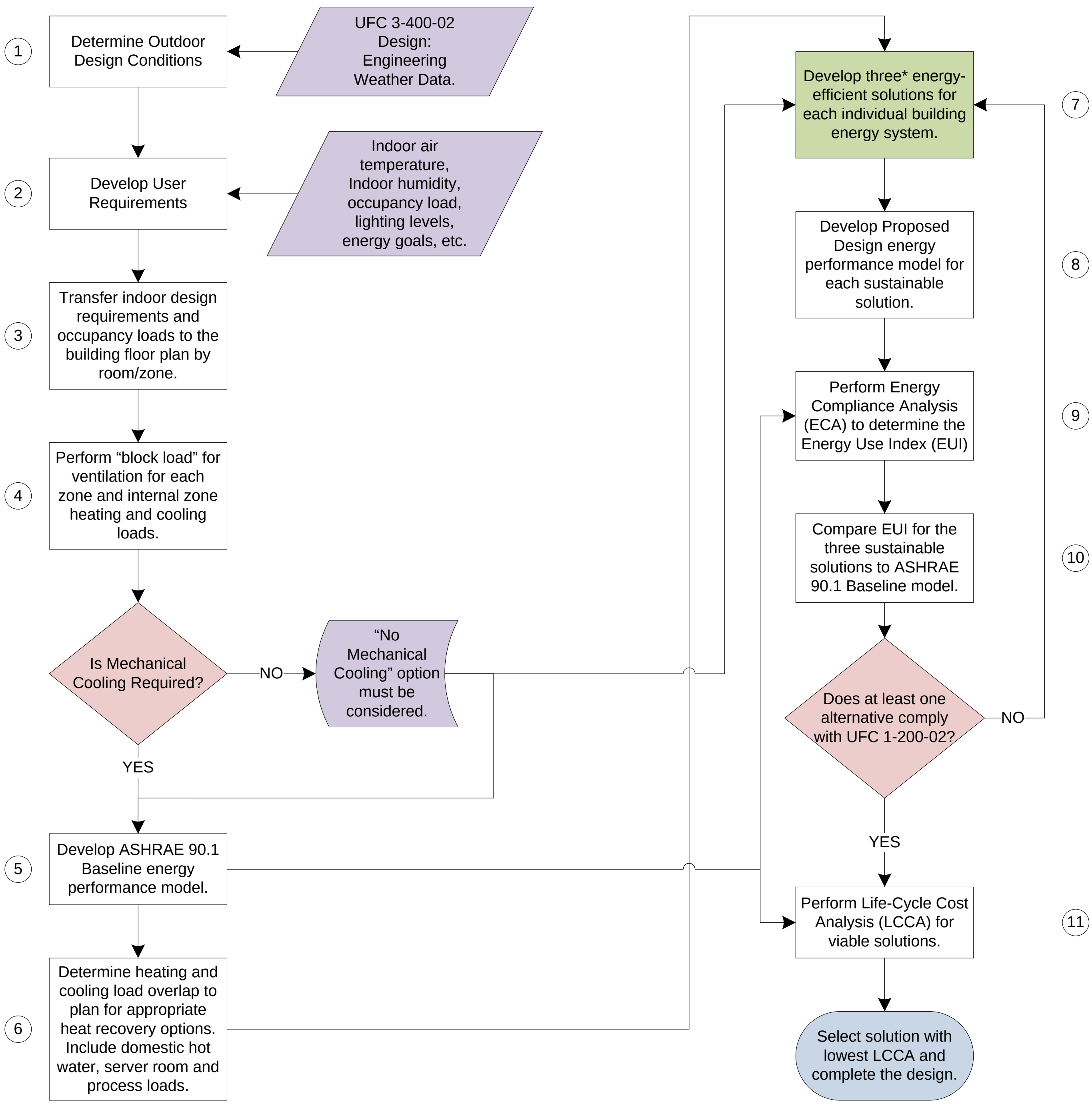
Hot Water Heating System	**VAV System**
a) Hot water pump status b) **\1** Hot water pump start/stop **/1/** c) Hot water supply temperature d) Hot water return temperature e) Hot water flow rate f) Hot water mixing valve position g) Differential pressure across pump h) Boiler status i) **\1** Boiler enable/disable **/1/** j) **\1** Boiler failure **/1/** alarms k) Heat exchanger inlet temperatures l) Heat exchanger leaving temperatures **\1\ /1/**m) Variable speed pump drive frequency n) Condensate return pump status	a) VAV box inlet velocity pressure b) Airflow rate of each VAV box **\1** (primary) **/1/** c) **\1** VAV box **/1/** fan control start/stop d) **\1** VAV box fan status **/1/** e) VAV box damper position f) Discharge air temperature at each VAV box g) VAV box hot water valve position h) Electric reheat (on/off and number of stages) i) Space temperature for each zone with set point adjustment
Chilled Water System	**Air Distribution System**
a) Chiller enable/disable b) Chiller status c) **\1** Chiller failure alarms **/1/** d) Entering and leaving water temperatures at each chiller e) Chilled water flow rates for each chiller f) Secondary loop chilled water flow rate g) Chilled water supply and return temperatures for the central plant h) Water temperature in the common piping of the primary/secondary loop i) Chilled water system differential pressure at central chilled water plant j) Chilled water system differential pressured used for control of secondary pumps k) Primary chilled water pump start/stop l) Primary chilled water pump status **\1\ /1/** **\1\ /1/** m) Cooling tower fan status (high-low-off) n) Cooling tower fans - Adjustable frequency drive functions and alarms o) Condenser water supply and return temperature p) Cooling tower bypass valve position q) Variable speed pump drive frequency r) **\1** Heat exchanger inlet temperatures **/1/** s) **\1** Heat exchanger outlet temperatures **/1/**	a) Supply air temperature b) Supply air static pressure c) Supply airflow rate d) Outside air temperature e) **\1** Outside air relative humidity **/1/** f) Return air temperature g) Mixed air temperature h) Discharge temperature from each heating or cooling coil i) Filter status j) **\1** Supply/return/exhaust **/1/** damper positions k) Outside air damper positions l) Chilled water valve positions m) Hot water valve positions n) Electric heater status (on/off and number of stages energized or % power) o) Freezestat **\1** status **/1/** p) Smoke detector **\1** status **/1/** q) **\1** Supply/return **/1/** fan start/stop r) **\1** Supply/return **/1/** fan speed control s) **\1** Supply/return **/1/** fan run status t) **\1** Supply/return **/1/** fan fault status u) Exhaust fan run status v) Outside air fan run status w) Heat recovery wheel rotation status x) Fire damper status y) Variable frequency drive fan status z) **\1** Smoke damper status **/1/**

General Building Systems	
\6 a) Building electrical meter* b) Building water meter* c) Building natural gas meter* d) Building steam meter* **/6/** e) **\1** HVAC equipment shutdown switch status **/1/**	

\6\ *For Navy projects: Metering for the building (facility wide consumption) needs to be coordinated with the RFP and base utilities. DDC monitoring, accumulating, and totalizing is not required for utilities connected to the AMI metering system or if the base has a base wide utilities smart metering system. Sub metering for the different utilities shall be connected to the DDC as required per the RFP and ASHRAE 90.1 requirements. /6/

APPENDIX E – HVAC SYSTEM SELECTION FLOW CHART

\1\



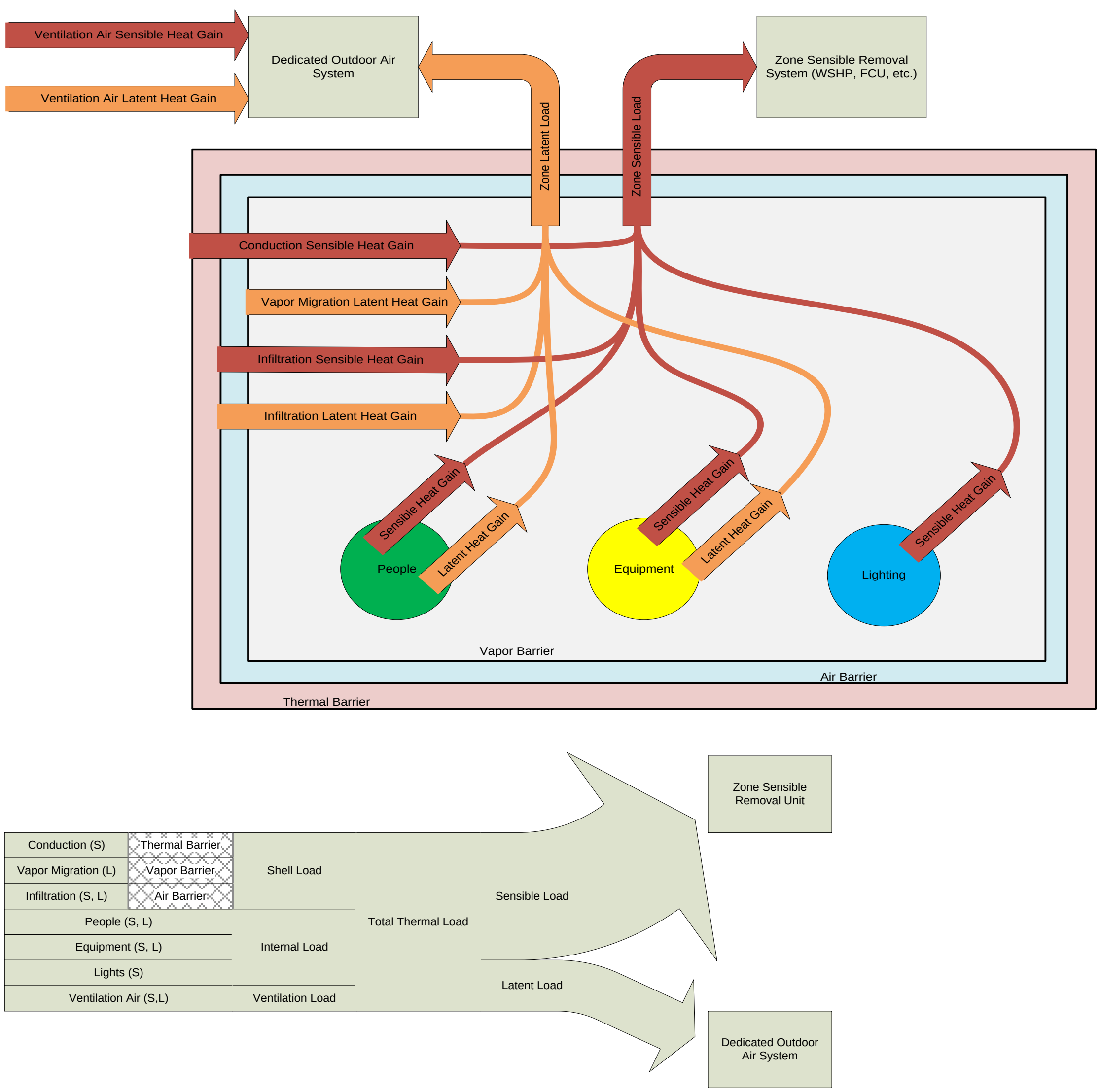
This diagram is interactive with the rest of this UFC. The reader may navigate to the section of the UFC governing each step by clicking on that step.

*For some applications, three technically-feasible solutions may not exist. Develop as many solutions as are practical for these applications. Use Appendix F for Army projects only for examples of 90% energy-efficient HVAC system solutions. **/1/**

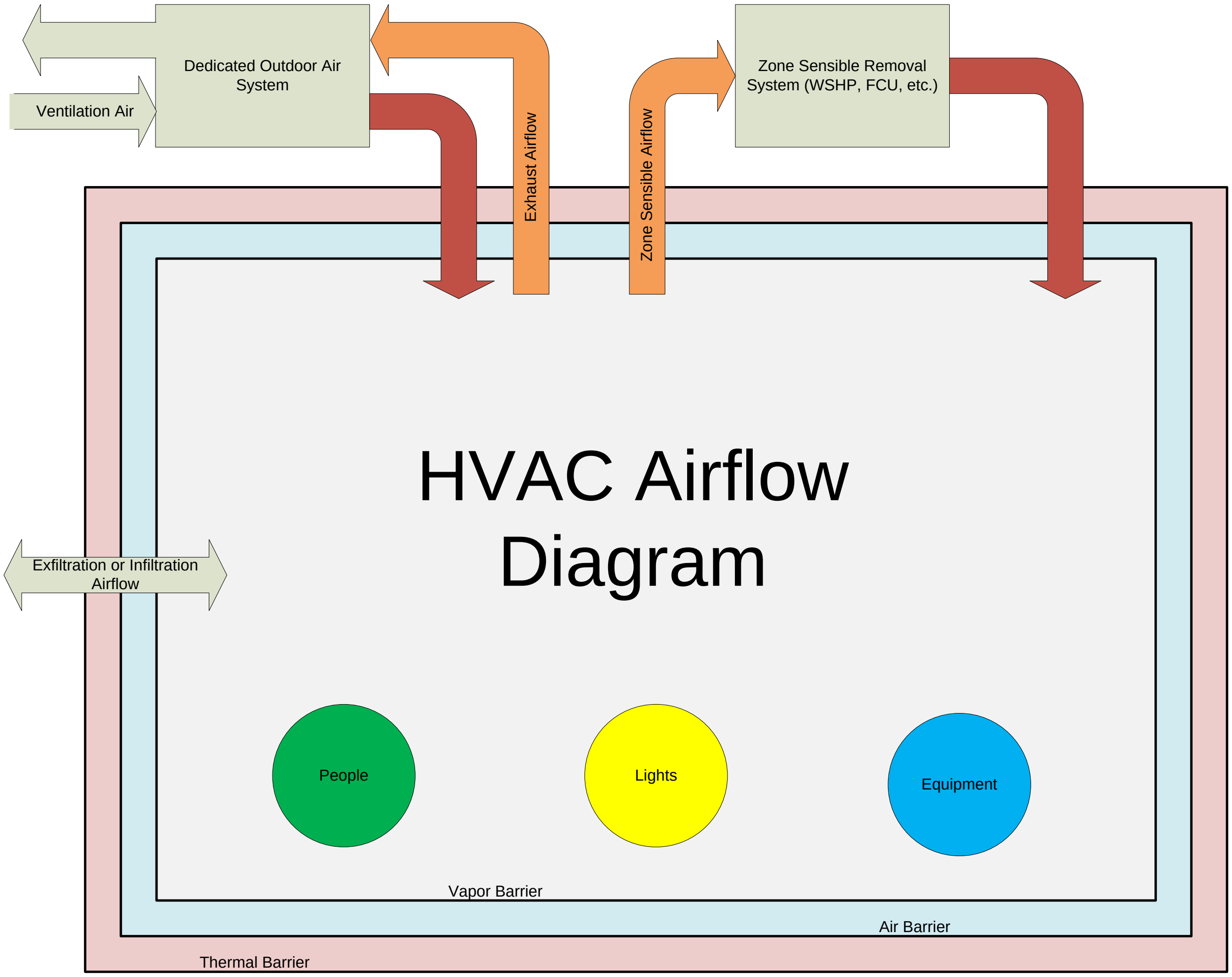
APPENDIX F – 90% ENERGY-EFFICIENT HVAC SOLUTIONS (FOR ARMY PROJECTS ONLY)

\1 The following present schematic solutions that have proven to be energy-efficient solutions for HVAC systems. The generic load-flow and airflow schematics are presented first, followed by specific equipment-based schematic examples.

HVAC Load Flow Diagram



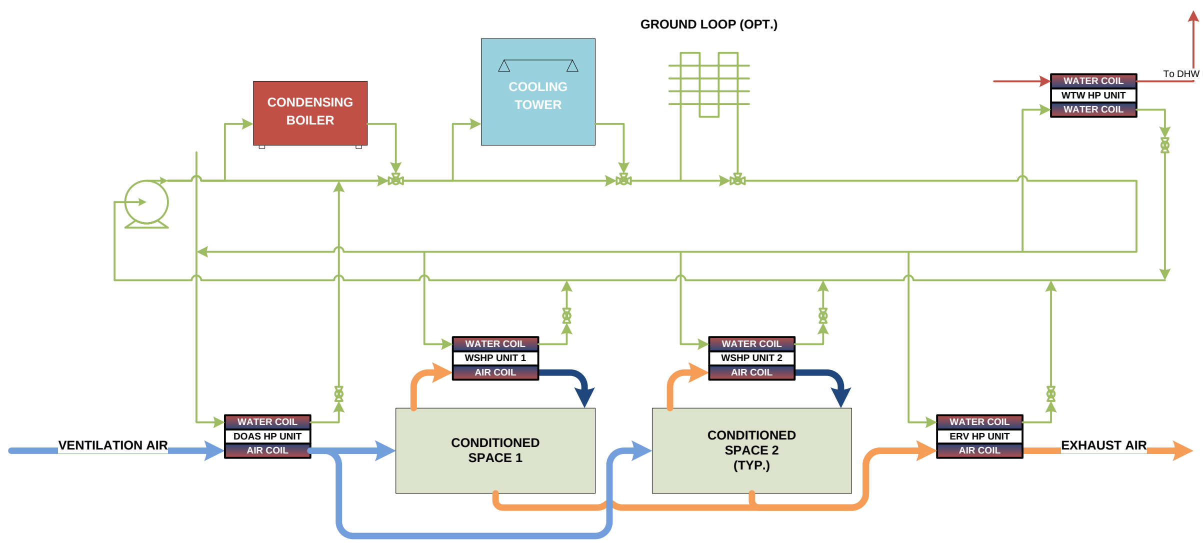
The HVAC Load Flow Diagram shows the components of HVAC load that are typically considered in an HVAC System Analysis. Per this UFC, the Dedicated Outdoor Air System (DOAS) should handle the latent loads for both the Ventilation Air and the Zone. The DOAS is typically a stand-alone, constant-pressure Variable Air Volume (VAV) system. The DOAS supplies each zone with outside air through a two-position VAV box that is operated in accordance with the sequence of operation. The Zone Sensible Removal System will maintain the zone temperature.



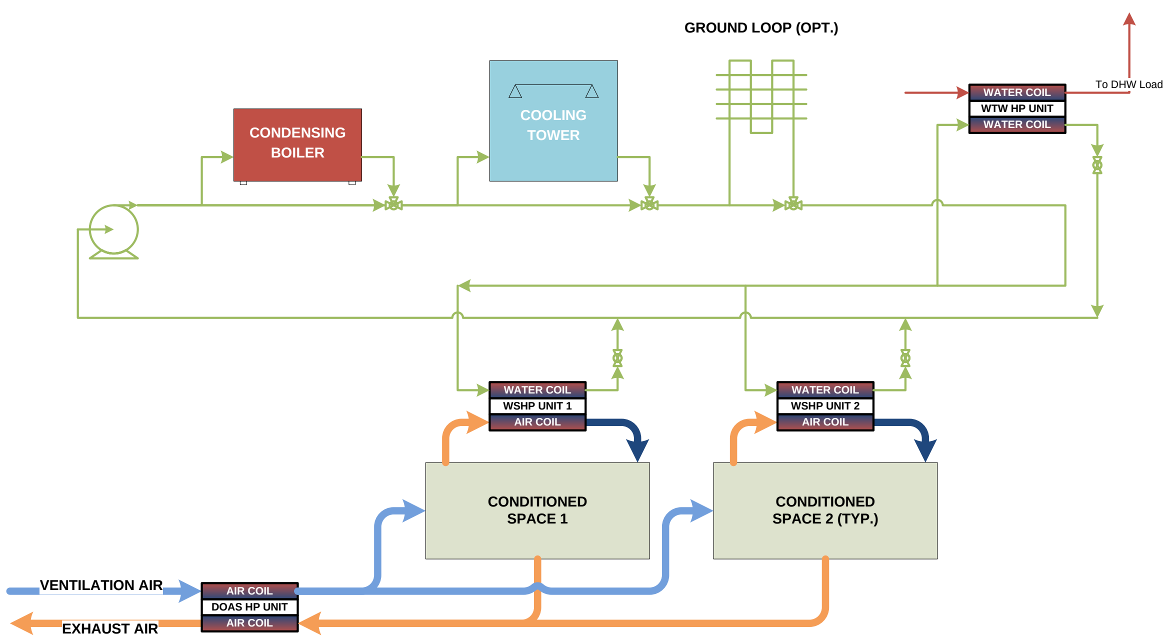
The HVAC Airflow Diagram shows the typical airflow considerations for a design. HVAC designs should provide a one-line diagram of the air flow to each zone, within each zone and, where there is a required pressure differential, between zones. The peak sensible and latent load for each zone should be indicated on the diagram and assigned to the appropriate system.

The diagrams on the following pages present equipment-based schematics for energy-efficient systems.

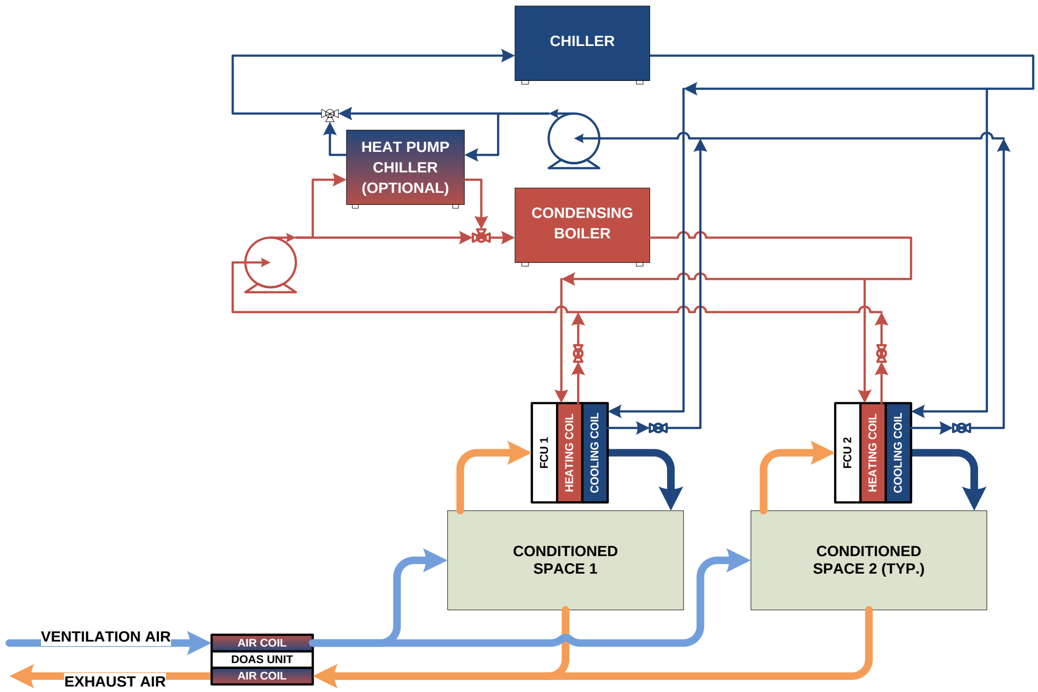
Energy Recovery Loop with separate DOAS and Exhaust ERV



Energy Recovery Loop with integrated DOAS and Exhaust ERV



Fan Coil Units with conventional DOAS
(optional Heat Pump Chiller)



/1/

APPENDIX G - EVALUATION OF DISTRICT AND ISLANDED/DECENTRALIZED UTILITY OPTIONS WITH LIFE-CYCLE COST ANALYSIS GUIDANCE (FOR ARMY PROJECTS ONLY)

\1

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT CHIEF OF STAFF FOR INSTALLATION MANAGEMENT
600 ARMY PENTAGON
WASHINGTON, DC 20310-0600

DAIM-OD

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: District and Islanded/Decentralized Heating Systems Selection Evaluation with Life Cycle Cost Analysis Guidance

1. Reference: USACE Memorandum, SAB, 18 Dec 2012 (encl).

2. Updated guidance on the selection evaluation process for District and Islanded Decentralized Heating Systems is provided with this memo to assist U.S. Army garrisons and activities in determining the most cost effective lifecycle option for heating solutions. This guidance is the result of a jointly sponsored review funded by ACSIM and executed by USACE.

3. HQ USACE will coordinate with the Air Force and Navy to incorporate the checklist into the existing UFC, Central Heating Plants, UFC 3-430-0SN.

4. Questions regarding the guidance should be directed to Mr. Robert Rizzieri, HQUSACE, 202-761-7769, robert.rizzieri@us.arrny .mil.

FOR THE ASSISTANT CHIEF OF STAFF FOR INSTALLATION MANAGEMENT:

AYCOCK.ALLISON.TRAVIS.1053246857
AL AYCOCK
Major General, GS
Director, Operations Directorate

Encl

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Evaluation of District and Islanded/Decentralized Utility Options with Life-Cycle Cost Analysis Guidance

Enclosure

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

CEMP-NWD

DEC 18 2012

MEMORANDUM FOR Director of Operations, MG Aycock, Office of the Assistant Chief of Staff for Installation Management (DAIM-OD), 600 Army Pentagon, Washington, DC20310-0600

SUBJECT: District and Islanded/Decentralized Heating Systems selection evaluation with Life Cycle Cost Analysis Guidance

1. This is in response to your request to update technical guidance on "district and islanded/decentralized" heating systems selection resulting from our studies of Joint Base Lewis McCord and Fort Carson. The guidance will help to bring consistency and alignment across the Army.

2. The attached enclosure of the "Evaluation of District and Islanded/Decentralized Utility Options with Life Cycle Cost Analysis Guidance" is ready for distribution. This guidance has been coordinated with Headquarters, Installation Management Command (IMCOM) and your staff, and they are in agreement with its content. We will now commence coordination with the Air Force and Navy to incorporate this checklist into the existing UFC, Central Heating Plants, UFC 3-430-08N.

3. The study that produced the attached checklist concluded that recapitalization of existing central plants in kind are often not the most life-cycle cost effective solution. New technologies, strategies and alternative fuels may result in lower life cycle costs, and efficiency of central plants improves when distribution networks are minimized through denser development and infill of existing sites. Care must be exercised when completing the checklist to ensure that alternatives systems are considered appropriately.

4. Request your office establish policy and distribute to all Landholding Commands. Upon your approval of the policy, USACE will follow through with implementing guidance in the UFC and to our Districts.

5. Questions regarding the interim guidance should be directed to Mr. Robert Rizzieri, HQUSACE, 202-761-7769, Robert.rizzieri@us.army.mil.

Encl

LLOYD C. CALDWELL, P.E.
Director of Military Programs

Evaluation of District and Islanded/Decentralized Utility Options

with Life-Cycle Cost Analysis Guidance

Army Installations are under increasing pressures to ensure capability to meet their designated missions while reducing their overall energy footprint within the local community in a fiscally responsible manner. This guidance is intended to be applied to District and Islanded/Decentralized systems such as District hot water or steam distribution systems, Islanded hot water distribution systems, and District co-generation systems, among others. Definitions of District and Islanded/Decentralized systems can be found at the end of this guidance. This guidance shall be applied to all new construction projects and projects where capital expenditures are being used to replace generation equipment and/or the distribution network for the purpose of rehabilitation. Emergency repairs are excluded from the studies described herein.

1. Evaluations to determine the most cost effective method for delivering utilities to facilities shall follow this decision making process:
    a. Define scope and system requirements
    b. Define alternatives to be considered
    c. Develop Life-Cycle Cost Analysis
    d. Determine most cost effective option

2. Questions to consider when evaluating how utilities will be delivered to facilities include:
    a. Is this a new construction project or project expending capital to replace generation equipment and/or the distribution network for the purpose of rehabilitation?
    b. What fuel sources are available?
    c. What is the required output (heat, hot water, electricity)?
    d. What is the anticipated utility load factor?

3. Evaluations to determine the most cost effective method for delivering utilities to facilities shall comply with the following minimum requirements:
    a. Be completed in the context of the broader Federal and Army energy mandates.
        i. Energy Policy Act of 2005
        ii. Energy Independence and Security Act of 2007
        iii. National Defense Authorization Act
        iv. Office of The Assistant Secretary of the Army for Installations and Environment Strategic Plan
        v. Army Installation Management Community Campaign Plan
        vi. Other: ________________________

    b. Include alternatives to the base case that each meets the defined utility needs using different technologies or bundling of technologies. Although a multi-step transition plan may be used to modernize existing legacy equipment, it is imperative that the alternatives under comparison each meet the defined utility needs. A minimum of three alternatives shall be considered in each study.
        i. Alternative 1 (Base Case): ________________________
        ii. Alternative 2: ________________________
        iii. Alternative 3: ________________________
        iv. Alternative 4: ________________________
        v. Alternative 5: ________________________

Evaluation of District and Islanded/Decentralized Utility Options

with Life-Cycle Cost Analysis Guidance

c. Include a Life-Cycle Cost Analysis (LCCA) which has been conducted for each alternative under consideration. Major LCCA criteria are described in Paragraph 5 and LCCA procedures are described in Paragraph 6.
   i. LCCA Completed by: ___________________________

d. Include sufficient detailed information such that an independent technical review (ITR) can duplicate the results. Assumptions made for the required end state and base and comparison cases shall be clearly identified and documented.
   i. Assumptions have been clearly documented in evaluation

e. Receive an independent technical review (ITR). The ITR shall be a formal review of the study to ensure that planned and completed work complies with predetermined requirements, industry standards, and engineering practices. The ITR team shall be comprised of qualified individuals who have technical expertise applicable to the technologies being studied and shall not have been directly involved in generating the study under review.
   i. USACE is available to support Installations or other Army Offices in validating the qualifications of the ITR team under consideration. Contact HQUSACE, Chief Installation Support, CEMP-CI, at 202-761-5763 for assistance in confirming that the firm or organization being considered to perform the ITR is fully qualified.
   ii. USACE has qualified offices that can perform the described ITRs upon request.
   iii. ITR Conducted by: ___________________________

f. Include a narrative describing which alternative was determined to be most cost effective. This decision will be guided by the results of the LCCA.
   i. Most cost effective option identified and explained

g. Include a narrative describing the appropriate programming course of actions required to implement the recommended alternative. Programming course of action shall consider Army regulations on project programming and work classification.

h. Army shall review new laws and policies to determine if study re-evaluations are warranted. Army and installations shall review mission changes to determine if study re-evaluation is warranted.

4. At a minimum, the following alternatives shall be considered where applicable:
   a. Base case. When there is an existing system the base case alternative shall assume no change to the system.

   b. Completely Decentralized. New or renovated solution that meets individual utility needs of buildings using local, dedicated equipment at each facility. Example: Heating and domestic hot water needs of buildings are met using local dedicated boilers at each facility.

   c. Completely District. New or renovated solution that meets individual utility needs of buildings using one district energy plant (which may or may not include co-generation or tri-generation) with supply and return

Evaluation of District and Islanded/Decentralized Utility Options

with Life-Cycle Cost Analysis Guidance

lines between the buildings and district plant. Example: Heating and domestic hot water needs of buildings are met using a single district heating plant with supply and return lines between the buildings and district heating plant.

d. Island. New or renovated solution that meets individual utility needs of buildings using a combination of decentralized solutions in clusters larger than individual buildings. Example: Heating and domestic hot water needs of buildings are met using a combination of decentralized solutions in clusters larger than individual buildings.

5. The following factors have been determined as having primary influence in LCCA outcomes for provision of building utilities. It is imperative that sound economic and engineering data be developed to support each of the following factors and all calculations and assumptions be clearly documented:
    a. First costs of installation
        i. Capital cost of new equipment: Pricing shall be based on quotations received from manufacturers. Where quotations from manufacturers are not available pricing shall be based on RS Means data. Costs shall be comprehensive and include all components required for a complete and usable system to include distribution network costs.
        ii. Distribution network costs: These are often a significant percentage of capital costs and should be clearly identified for District and Islanded system analyses.
        iii. Labor for installation priced per location: Pricing shall be based on data from recent projects at the Army Installation on projects of comparable scope and scale. Where such projects do not exist pricing shall be based on RS Means data.
    b. Maintenance costs
        i. Required Maintenance: Hours shall be based on manufacturer provided component and system maintenance requirements and life expectancies. If components and/or systems are recommended to be replaced within the 40 year study period the manufacturer's recommendations shall be accounted for in the LCCA.
        ii. Labor Rates: Pricing shall be based on data from existing Army Installation maintenance contracts of comparable scope and scale. Where such contracts do not exist pricing shall be based on RS Means data.
    c. Operations cost
        i. Energy and fuel prices including consideration for interruptible opportunities: Pricing shall be based on current prices experienced at the Installation. Escalation rates shall be determined using the most current version of the Annual Supplement to NIST Handbook 135 and NBS Special Publication 709, titled "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis" and using information from the Department of Energy, Energy Information Administration.
        ii. Energy and fuel used by system: Usage data shall be based on measured use for existing facilities. If measured data does not exist, usage shall be estimated using engineering analysis. For planned projects consumption rates shall be estimated using engineering analysis. Fuel consumption rates shall be obtained from the manufacturer for the life of the equipment being considered. Occupancy schedules and heating/cooling degree days shall be used to determine an average system load factor.

Evaluation of District and Islanded/Decentralized Utility Options

with Life-Cycle Cost Analysis Guidance

System load factor and equipment fuel consumption rates shall be used to estimate the total fuel consumption and thus the life-cycle cost for fuel use.

iii. Labor for operation priced per location: Pricing shall be based on data from existing Army Installation operation contracts of comparable scope and scale. Where such contracts do not exist pricing shall be based on RS Means data.

Primary Factor	Alternative 1 (Base Case)	Alternative 2 (New, Completely Decentralized)	Alternative 3 (New, Completely District)	Alternative 4 (Hybrid)	Alternative 5 (______)
Capital cost of new equipment ($)					
Capital cost of distribution network ($)					
Labor for installation of new equipment ($)					
Manufacturer recommended maintenance (hours)					
Labor required for maintenance ($)					
Fuel price ($)					
Fuel usage (appropriate units for fuel used)					
Labor required for operations ($)					

d. Note: The factors above are not all inclusive factors for a comprehensive LCCA on provision of building utilities. Additional factors identified in NIST Handbook 135 which shall be considered in the LCCA include but are not limited to the following:

i. Renovation and demolition costs: Pricing shall be based on data from recent projects at the Army Installation on projects of comparable scope and scale. Where such projects do not exist pricing shall be based on RS Means data.

ii. Costs for water treatment: Pricing shall be based on data from recent projects at the Army Installation on projects of comparable scope and scale. Where such projects do not exist pricing shall be based on RS Means data.

Evaluation of District and Islanded/Decentralized Utility Options

with Life-Cycle Cost Analysis Guidance

iii. Costs associated with concurrent applicable projects: Ensure cost savings associated with concurrent projects that open roads, trenches, or accomplish other projects that would support the alternative under consideration are adequately captured.
iv. Requirements for equipment redundancy: Costs shall be included when backup equipment is required to meet statutory standby requirements (Example: generator for critical hospital loads).
v. Salvage value at end of useful life: Pricing shall be based on data from recent projects at the Army Installation on projects of comparable scope and scale. Where such projects do not exist pricing shall be based on RS Means data.

6. The Life-Cycle Cost Analysis identified above shall be conducted in accordance with the most current version of the National Institute of Standards and Technology (NIST) Handbook 135, "Life-Cycle Costing Manual for the Federal Energy Management Program", associated supplements and U.S. Army Corps of Engineers Engineering and Construction Bulletin 2012-13, "Energy Implementation Guidance Update, ASHRAE 189.1, Life-Cycle Cost Analysis Requirements". The study period shall be set at 40 years. Final LCCA documentation shall include a comprehensive summary that defines each alternative considered with assumptions and references provided for each parameter; the assumptions shall be clear and of a level of detail sufficient to be used by a third party to duplicate the results of the LCCA. LCCAs shall be completed using the same matrix of information consistently across alternatives to ensure a fair comparison is made between alternatives. For example, building loads and cost of fuel shall be consistent between base and alternatives.
   a. LCCA complies with NIST Handbook 135
   b. LCCA study period set at 40 years
   c. Comprehensive summary defining alternatives considered with assumptions and references for each parameter is provided
   d. Alternatives use same matrix of information
   e. LCCA for each alternative reflects all costs associated with meeting the identified long term energy goals

7. The alternative whose LCCA has the lowest life cycle cost is considered the most cost effective solution. Further guidance on analyzing the results of LCCAs can be found in NIST Handbook 135.

8. Definitions
   a. **District System**. A community scale utility system connecting multiple users through a distribution network that provides heating, domestic hot water, and/or electricity to facilities.

   b. **Islanded/Decentralized System**. A utility system for providing heating, domestic hot water, and/or electricity to one or more co-located buildings at or near the point of use with a limited distribution network.

UFC 3-410-02
18 July 2018
Change 2, 12 April 2021

UNIFIED FACILITIES CRITERIA (UFC)

DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS **1**\ (Preparing Activity) /**1/**

NAVAL FACILITIES ENGINEERING COMMAND **1\ /1**/

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	2 March 2020	Changed Preparing Activity from Navy to Army. Added paragraph 2-4 USE OF PROPRIETARY NETWORKS, to accommodate new requirements for an exception to the use of open protocols within specific system types when certain criteria are met.
2	1 April 2021	Changed “UFC 3-401-01” to UFC 3-470-01” in paragraphs 1-2.1.3 and 1-3.2.3. Changed “APPENDIX A” to “APPENDIX D” in paragraph 5-4.2. Deleted first sentence of paragraph 6-6.1.

This UFC supersedes UFC 3-410-02, dated 5 2012.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-410-02 *Direct Digital Control for HVAC and Building Control Systems,* formerly *LonWorks® Direct Digital Control for HVAC and Other Local Building Systems*

Superseding: None

Description: Design guidance and requirements for Open Direct Digital Control Systems. The guidance is particularly detailed due to the complex and definitive requirements required for the design of a digital control system and for the procurement of an Open system that supports integration into a multi-vendor system.

Reasons for Document: Initial version of this UFC covered LNS-Based LonWorks only. Extensive revisions were required to accommodate BACnet and the Niagara Framework.

Impact: There are negligible cost impacts; however, these benefits should be realized:

- The ability to procure systems competitively that can be integrated into a single supervisory system rather than requiring the procurement of several supervisory systems.

- Competitive procurement of control systems will result in cost savings. . Describe the impact. This should describe impact on design cost, initial cost, energy savings, or life cycle costs.

Unification Issues: None

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FIGURES

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Designers, installers, and operations and maintenance (O&M) staff have struggled with the complexities and incompatibilities of multi-vendor building automation direct digital control (DDC) systems almost since they were introduced in the 1980's. DDC systems are routinely designed and procured on a building-by-building or sub-system by sub-system basis, most notably for heating, ventilating, and air-conditioning (HVAC) systems. In the absence of specifications and criteria for Open systems, Government procurement rules which require competitive bidding make it extremely difficult if not impossible to procure new DDC systems that are compatible with existing ones and that are also compatible with a basewide or campus-wide supervisory system.

In the absence of sole-source procurement, new but incompatible DDC systems result at best in inefficiencies and at worst in complex and non-functioning systems. This is a problem with system-to-system data sharing and is a problem where multiple individual systems need to communicate with a supervisory monitoring and control (front-end) system such as a Utility Monitoring and Control System (UMCS) specified by UFGS 25 10 10. This inability to interoperate is a result of Closed systems due to vendor-specific proprietary elements. In contrast, Open DDC systems are now available. An Open DDC system is characterized by the ability for any qualified entity to readily modify, operate, upgrade, and perform retrofits on the DDC system. An Open system:

- Permits multiple devices from multiple vendors to readily exchange information.
- Provides the capability to easily replace any device with another device procured from multiple sources.
- May have proprietary components within devices, but these proprietary components must be a small percentage of the overall device.
- May have fees associated with use of certain components.

In short, an Open system is one (integrated, multi-vendor) system where there is no future dependence on any one Contractor or controls vendor.

1-1.1 Open system benefits and capabilities.

Open communications and data sharing between multi-vendor systems and with a third party supervisory system is necessary to achieve effective system operation. Some of the benefits and capabilities of Open multi-vendor DDC systems include:

- Competitive procurement, most notably at the building and sub-system level.
- An operator workstation/user interface that provides for the same look and feel for monitoring and control regardless of which vendor's DDC system or sub-

system an operator is viewing. As a result, system operators need only become proficient with one user interface.

- An operator workstation/user interface (software) that provides for management of base-wide system operations such as: remote alarm reporting, remote scheduling (on/off control), remote set point override, data logging and reports, energy management including load shedding, utilities monitoring/measurement for the purpose of monitoring energy performance contracts, and initial diagnosis of service calls. The ability to monitor multiple vendor's systems from a single Operator Workstation/User Interface (OWS/UI) with the same look and feel across all vendor's systems. As a result, through a single user interface, system operators and managers are afforded the means to efficiently and effectively manage base-wide operations.

- A whole-building approach to systems integration. This includes the efficient inter-connection of HVAC control sub-systems. For example, terminal unit equipment, such as VAV boxes can be readily interfaced to the servicing air handler to provide a call for cooling. In addition, the whole-building approach provides the capability for integrating non-HVAC sub-systems such as fire and security

- (For a LonWorks system) groundwork for establishment of a non-proprietary and openly accessible 'point-database' in support of communications-network management requirements.

1-1.2 References to UFGS 23 09 23.XX.

This UFC is intended to be used with UFGS 23 09 00 (Instrumentation and Control for HVAC), UFGS 23 09 23.01 (LonWorks® Direct Digital Control for HVAC and Other Building Systems), and UFGS 23 09 23.02 (BACnet Direct Digital Control for HVAC and Other Building Systems). This document will often use "UFGS 23 09 23.XX" when the intent is to refer to both the LonWorks and BACnet UFGS.

1-2 OPEN SYSTEM TECHNOLOGIES.

The Open systems approach described in this UFC is based on several possible technologies: BACnet, LONWORKS, or Niagara Framework.

1-2.1.1 BACnet.

The term "BACnet" is used in this UFC as the shorthand reference to the ANSI/ASHRAE Standard 135, specifically referring to the communications protocol specified there-in. The term "BACnet" is also used in this UFC to loosely describe a collection of technologies, including hardware, and software, vendors and installers relating to or based on the ASHRAE Standard 135 communications protocol. While every attempt has been made to distinguish which meaning is intended, in some cases the reader must make the determination from context

1-2.1.2 LONWORKS®

ANSI/CEA standard 709.1-C communications protocol (sometimes referred to as LonTalk®) and on LONWORKS® Network Services (LNS®) network operating system. The standard protocol supports Open communications while LNS supports Open network management. 'CEA 709.1' is used in this UFC as the shorthand reference to the ANSI/CEA standard 709.1-C communications protocol. In this UFC the term LONWORKS® is used to loosely describe a collection of technologies (including hardware, and software), vendors and installers relating to or based on the CEA 709.1 communications protocol

1-2.1.3 Niagara Framework.

The Niagara Framework is a protocol and set of technologies developed and owned by Tridium Inc. which is licensed to multiple vendors. Different vendors provide this system under different product names, but the overall term used by Tridium is “Niagara”. The Niagara Framework may be used in conjunction with either the BACnet or LonWorks option to design a system using BACnet or LonWorks that also can interoperate with a Niagara Framework front end installed in accordance with UFGS 25 10 10 and/or **\2** UFC 3-470-01, Utility Monitoring And Control System (UMCS) Front End and Integration ***/2/***. Note that use of Niagara Framework will override/trump some design options that would normally be used in a BACnet or LonWorks system.

1-2.2 Control system types

The combination of technologies result in 4 possible building control system types:

- A BACnet building using the BACnet standard
- A BACnet building using both the BACnet standard and the Niagara Framework
- A LonWorks building using CEA 709.1 and LNS
- A LonWorks building using both CEA 709.1 and the Niagara Framework

1-2.3 Open system design complexity

The design of an Open system is not simple. It requires attention to a great deal of detail. This UFC, the specifications, and accompanying drawings were developed to minimize the time and effort required on the part of the designer.

The level of detail contained in the guide specification and this UFC is necessary because of the variety of approaches that can be used to implement BACnet, or CEA 709.1-C, or Niagara Framework where, in the absence of this detail, would very likely result in incompatible systems.

1-3 PURPOSE AND SCOPE.

1-3.1 Purpose

The design concept described in this UFC provides definitive guidance intended to streamline DDC system design and installation leading to maintainable, interoperable, extensible, and non-proprietary control systems. This UFC also contains minimal project requirements. The purpose of this UFC is two-fold, to provide for commonality and compatibility of control systems:

- Commonality. Describes a definitive methodology for the design of building-level control systems and strategies (primarily for HVAC) where the intent is to achieve at least a degree of commonality in systems designed and procured through different channels. Common sequences of operation are specified in UFGS 23 09 93.

- Compatibility. Describes a definitive methodology to obtain multi-vendor systems that can communicate and interoperate with each other and with a supervisory monitoring and control system such as a basewide UMCS through the use of an Open communications protocol.

1-3.2 Scope.

This UFC describes the design of HVAC control systems and the associated building control network that can interface to a UMCS in an Open and non-proprietary manner.

1-3.2.1 HVAC control sequences and instrumentation.

These topics are covered in UFGS 23 09 13, UFGS 23 09 93.

1-3.2.2 Building controllers and control network.

This UFC describes designer selections for DDC hardware and software as well as the Building Control Network (BCN) communications including data exchange, architecture, and cabling.

1-3.2.3 UMCS interface.

The DDC system can function as a stand-alone system with reduced functionality (limited user interface, no trending etc.) but is intended to be integrated into a UMCS in accordance with the UMCS guidance (UFC 3-401-01 and UFGS 25 10 10) to provide for remote supervisory monitoring and control of the DDC system. This UFC (3-410-02) and UFGS 23 09 23.XX helps to ensure that the building-level control system is capable of being interconnected with a UMCS installed in accordance with UFGS 25 10 10 and/or **\2** UFC 3-470-01, Utility Monitoring And Control System (UMCS) Front End and Integration **/2/**. Even in the absence of a UMCS, this UFC describes the methodology for designer selection and specification of data exchange parameters including requirements that will facilitate subsequent non-proprietary UMCS interface.

1-3.2.4 Other systems.

Although not directly addressed or specified in the UFC or UFGS the methodology, approach, and many of the requirements defined in this UFC and UFGS 23 09 23.XX can be used in the design of other (non-HVAC) Open DDC systems such as water and sanitary sewer systems, electrical systems, lighting, and other utility systems and equipment.

1-4 APPLICABILITY.

This UFC is applicable to all HVAC control system design, both for new construction and renovation. This UFC and the guide specifications may also be applied to other non-HVAC building control when those systems use LonWorks or BACnet.

1-5 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, DoD Building Code (General Building Requirements). UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-6 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

1-7 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms. In addition, UFGS 23 09 00 contains an extensive list of definitions.

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CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 USE OF UFGS 23 09 XX SERIES OF SPECIFICATIONS.

Unless specifically indicated in this UFC or with specific written permission from the authority having jurisdiction, the design of a building control system must use UFGS 23 09 00 and either UFGS 23 09 23.01 or UFGS 23 09 23.02 (as appropriate) without edits beyond the use of tailoring options and designer option.

2-2 USE OF UFGS 23 09 23.XX.

The implementation of a building control system requires highly specific and prescriptive specifications. UFGS 23 09 23.01 (for LonWorks based BCS) and UFGS 23 09 23.02 (for BACnet based BCS) incorporates these requirements, and makes use of SpecsIntact Tailoring Options and designer options (bracketed text with notes) to allow for project-specific editing.

Unless specifically indicated in this UFC or with specific written permission from the authority having jurisdiction, the design of a building control system must use either UFGS 23 09 23.01 or UFGS 23 09 23.02 (as appropriate) without edits beyond the use of tailoring options and designer options.

2-3 TAILORING AND DESIGNER OPTIONS IN UFGS 23 09 23.XX.

The use of tailoring options and designer options in either UFGS 23 09 23.01 or UFGS 23 09 23.02 must be in accordance with this UFC.

2-4 \1\ USE OF PROPRIETARY NETWORKS. /1/

\1\ The use of multiple devices communicating on a proprietary networks is allowed as an exception to the open protocol requirements of UFGS 23 09 23.01 or UFGS 23 09 23.02 only when the specific requirements in the following paragraphs are met. Note that internal communications within a single piece of packaged equipment (package unit) need not meet the open protocol requirements, but the packaged equipment must be provided with an interface meeting the open protocol requirements.

When including proprietary networks in a design as permitted in this UFC, the systems specifically permitted to use proprietary networks must be indicated in UFGS 23 09 00. /**1**/

2-4.1 \1\ Proprietary Networks for Simple Split Systems. /1/

\1\ A simple split (DX) system consisting of a single indoor unit and a single outdoor unit from the same manufacturer is always permitted to use a proprietary network between the two units provided that one unit has an open protocol interface meeting the requirements of the UFGS. Include a Points Schedule in the design package for the split system at the system interface. /**1**/

2-4.2 \1\ Proprietary Networks for Multi-Split Systems (Including Variable Refrigerant Flow (VRF) Systems). /1/

\1 Multi-split (including variable refrigerant flow (VRF)) systems using proprietary networks connecting multiple units which operate together must meet the following requirements:

- A gateway must be provided between the proprietary network and the open protocol control system required by UFGS 23 09 23.01 or UFGS 23 09 23.02 to provide a functional interface between the two networks. The open protocol side of the gateway must meet the requirements of UFGS 23 09 23.01 or UFGS 23 09 23.02.
- A Point Schedule for the system must be included in the design package to define the functional interface of the system to the open protocol control system.
- All units must be products of a single manufacturer.
- The units must operate using a common sequence of operation which operates the units in a manner that requires operational parameters be shared between them. The units must use a factory provided program for the sequence of operation; this program may be field configurable but units must not be field programmed.
- The solution using the proprietary network must have a lower life-cycle cost than at least two (2) alternate solutions not using proprietary networks.
- The System Owner receiving the control system must approve of and accept the use of the system. When a System Owner does not accept a system using a proprietary network it must not be used regardless of other factors.
- For USACE projects, the Utility Monitoring and Control System Mandatory Center of Expertise (UMCS MCX) must review the design, life cycle cost analysis, and System Owner approval and concur prior to specifying a system using a proprietary network.

When allowing proprietary networks for multi-split systems, the life cycle cost analysis, System Owner approval, and UMCS-MCX concurrence (for USACE projects) must be included in the design documents. The systems specifically permitted to use proprietary networks must be indicated in the table provided in UFGS 23 09 00. /**1**/

2-4.3 \1\ Proprietary Networks for Chiller and Boiler Plants. /1/

\1 Boilers or chillers using proprietary networks connecting multiple units which operate together must meet the following requirements:

- A gateway must be provided between the proprietary network and the open protocol control system required by UFGS 23 09 23.01 or UFGS 23 09 23.02 to provide a functional interface between the two networks. The open protocol side of the gateway must meet the requirements of UFGS 23 09 23.01 or UFGS 23 09 23.02.

- A Point Schedule for the system must be included in the design package to define the functional interface of the system to the open protocol control system.

- All units must be from the same manufacturer.

- All units must be co-located in the same room, and the network connecting them must be fully contained in that room.

- The units must operate using a common "plant" sequence of operation which stages the units in a manner that requires operational parameters be shared between them and which cannot be accomplished with a single lead-lag command from a third-party controller.

- The design must include specific model chiller and boilers. If the design is not specifying the exact equipment, do not include the exception as part of the design; UFGS 23 09 00 includes a mechanism by which the installing contractor can request the exception if needed. (In most cases, this means that this exception will apply primarily to design-build projects and not design-bid-build.)

When allowing proprietary networks for chiller or boiler plants, the design documents must include a statement that the system meets the necessary requirements for use of a proprietary networks and the systems specifically permitted to use proprietary networks must be included in the table provided in UFGS 23 09 00. /**1**/

2-4.4 \1\ All Other Systems. /1/

1\\ The specific exceptions defined in this UFC were determined as warranted based on implementation and maintenance considerations, and on industry capabilities to provide solutions meeting open systems requirements and apply only to the indicated systems. For all other systems, the use of multiple devices communicating on a proprietary networks requires a waiver from UFC requirements.

To suggest additional systems for consideration for establishing exception procedures, submit a Criteria Change Request (CCR) to this UFC. /**1**/

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CHAPTER 3 DESIGN

3-1 INTRODUCTION.

This chapter describes building-level Open-communications control system architecture, device functionality, and control devices for HVAC and other building-level monitoring and control applications. The communications network and devices are based on one of:

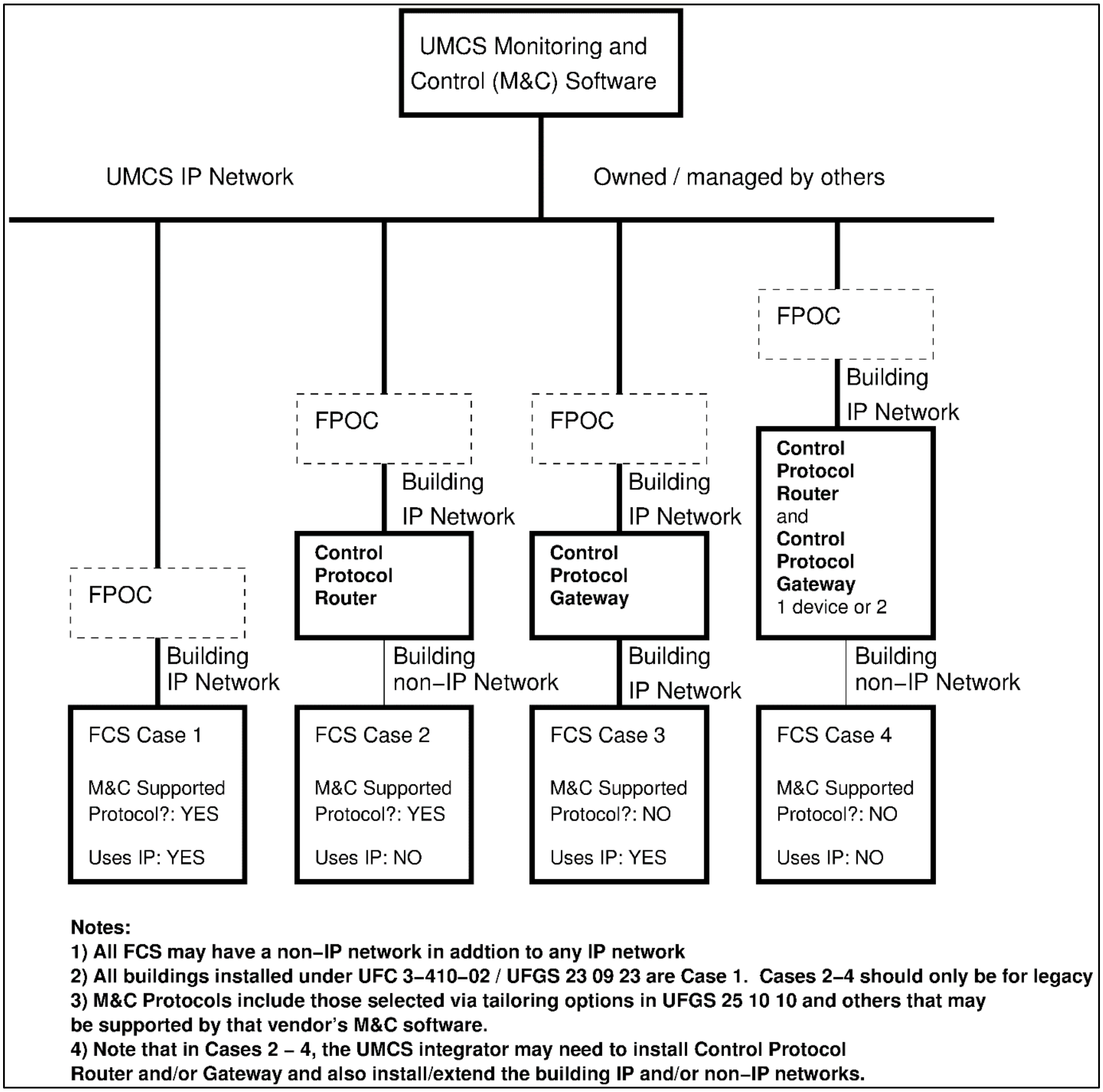
- LonWorks® technology and CEA 709.1 communications protocol with LNS
- LonWorks and the Niagara Framework
- BACnet, ASHRAE-135
- BACnet and the Niagara Framework

This UFC will primarily focus on either the LonWorks or BACnet option, with supplemental material provided to cover the Niagara Framework variant. Design of an Open-communications building-level control system does not require an extensive familiarity with CEA 709.1 protocol, BACnet, or the Niagara Framework, but it is critical that the designer understand that these protocols can be implemented in a manner that is not Open and thus can lead to incompatible systems. Therefore, this chapter contains supplemental information to be used in conjunction with UFGS 23 09 23.XX.

3-2 BASEWIDE UMCS ARCHITECTURE.

As illustrated Figure 3-1, a basewide system consists of a UMCS (specified by UFGS 25 10 10) containing to one or more building-level DDC systems (specified by UFGS 23 09 00 and UFGS 23 09 23.XX). The network architecture consists of a basewide IP network and one or more building-level networks. DDC UFGS 23 09 23.XX refers to the building-level network as the Building Control Network (BCN). A field point of connection (FPOC) provides an interface between the basewide IP and BCN networks. Since the FPOC is the location where the contractor-installed Building Control Network (BCN) meets the basewide IP network, the location of the FPOC must be coordinated with the base IT/networking staff.

Figure 3-1 UMCS Architecture



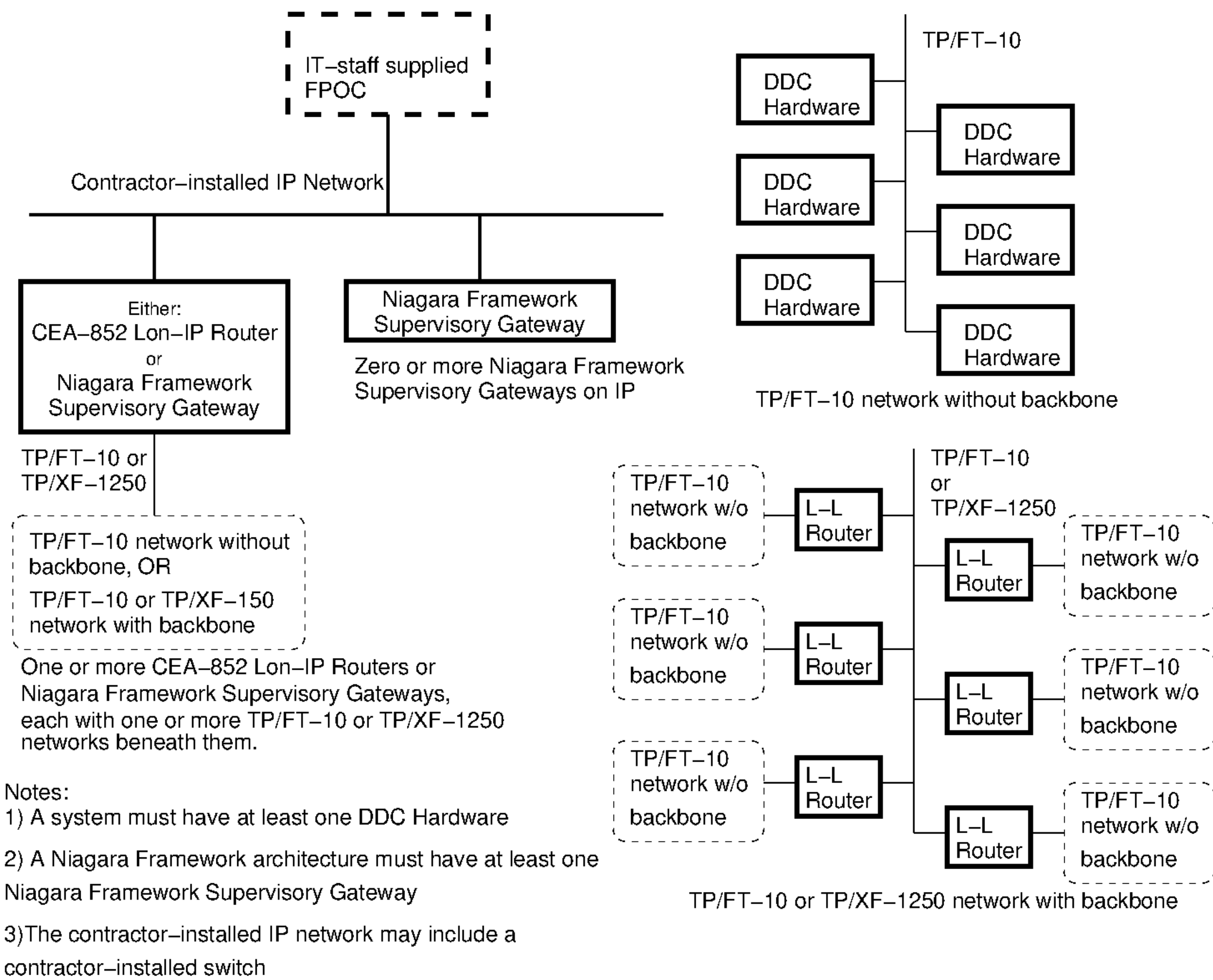
3-3 LONWORKS BCN ARCHITECTURE.

3-3.1 General.

As illustrated in Figure 3-2, a LonWorks (with or without Niagara Framework) BCN consists of an IP network with one or more (in the case of LonWorks with LNS) CEA 852 routers or (in the case of LonWorks with Niagara) Niagara Framework Supervisory Gateways. Beneath each CEA 852 router or Niagara Framework Supervisory Gateway is either TP/XF-1250 media or TP/FT-10 media (not all Niagara Framework Supervisory Gateways will necessarily have a network beneath them). TP/XF-1250 media functions as a non-IP network backbone and will only have Lon-to-Lon routers connected to it. Each Lon-to-Lon router will, in turn, have TP/FT-10 media connected, with individual DDC Hardware connected to the individual TP/FT-10 networks.

TP/FT-10 media directly connected to a CEA 852 router or Niagara Framework Supervisory Gateway may have DDC Hardware connected to it, or it may be used as a non-IP network backbone (identical to the use of TP/XF-1250 media). When used as a non-IP network backbone it will only have Lon-to-Lon routers connected to it (with TP/FT-10 networks and DDC Hardware connected to the individual Lon-to-Lon routers). The LNS-based LonWorks architecture produces a logically flat network in the building where each node can communicate directly with any other node without the intervention of another controller.

Figure 3-2 LonWorks Building Network Architecture



3-3.2 CEA 709 Media selection.

UFGS 23 09 23.01 specifies the use of one of: IP, TP/XF-1250, or TP/FT-10 media; each has advantages and disadvantages:

- IP is necessary because the UMCS uses IP, so at some point the network needs to connect to IP. For a smaller building, this may as simple as a single IP port on a CEA 852 router or Niagara Framework Supervisory Gateway. Larger buildings will likely have multiple devices on IP and a contractor-installed IP network. IP also has by far the greatest bandwidth of the media types. IP does have the downside of having the most IA (Information Assurance) issues. Future management of the IP network will vary from service to service and possibly even from site to site, but all IP networks will be required to meet some level of Information Assurance (IA) requirements.

- TP/XF-1250 communicates at 1250 kbps, which is considerably faster than TP/FT-10, but not as fast as IP. TP/XF-1250 is not part of the CEA 709 standard, but it is a de-facto standard for a high-speed Lon media. There are very few DDC Hardware devices using TP/XF-1250, so its use is limited to that of a backbone media. TP/XF-1250 must be installed in a doubly-terminated bus configuration.

- TP/FT-10 communicates at 78 kbps, which is the slowest of the 3 but still sufficiently fast to allow its use as the main media type in fairly large installations. It is covered by CEA 709 and is universally supported; almost all devices support TP/FT-10 and in these specifications it is the only media that can be connected to DDC Hardware (other than Niagara Framework Supervisory Gateways). TP/FT-10 must be installed in a doubly-terminated bus configuration

Use of other media types may limit future competition by giving an advantage to the limited number of vendors whose products support the non-standard media. Therefore use of alternative media is prohibited by the guide specifications. There may be some situations where a different CEA 709 media is needed – such the use of Power Line for retrofits where it is impossible to run new media or fiber optic for inter-building runs where electrical isolation is required. Do not specify or permit alternate media without written authorization from the AHJ.

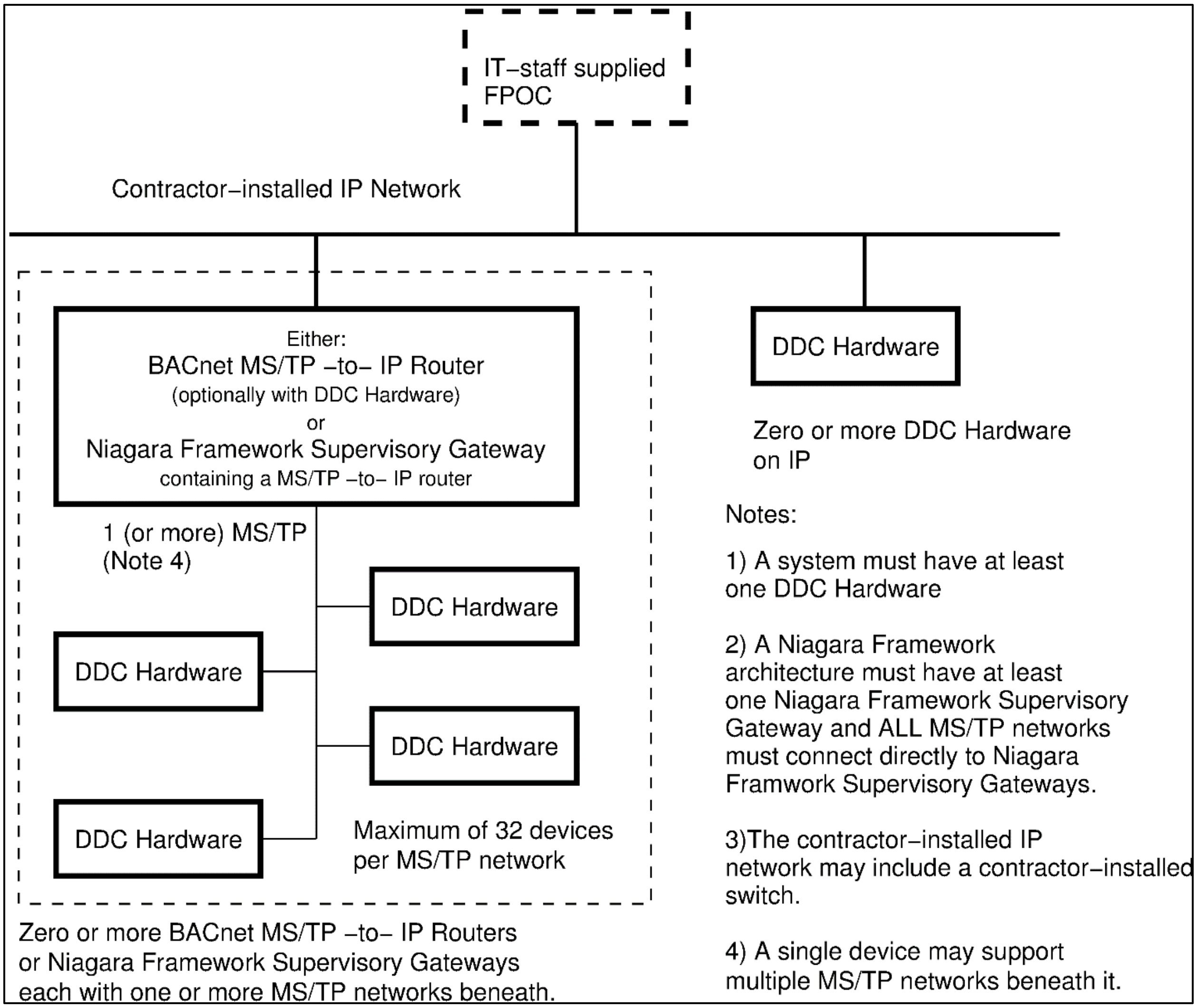
3-4 BACNET BCN ARCHITECTURE.

BACnet uses the term internetwork to refer to the entire connected BACnet system, consisting of one or more interconnected individual BACnet networks. A particular site may have multiple disconnected internetworks; each would be a separate BACnet system.

As illustrated in Figure 3-3, a BACnet (with or without Niagara Framework) BCN consists of an IP network with a mixture of DDC Hardware (including, in the case of the Niagara Framework, Niagara Framework Supervisory Gateways) and BACnet MS/TP –

to- BACnet IP routers (which may be furnished as part of DDC Hardware). Each MS/TP –to- IP router or Niagara Framework Supervisory Gateway may have MS/TP networks beneath it, with DDC Hardware on the individual MS/TP networks. Each project will have a single Field Point of Connection (FPOC) which provides an interface between the basewide IP network and the BCN network installed by that project.

Figure 3-3 BACnet Building Network Architecture



3-4.1 Device and network addressing.

BACnet addressing uses two pieces of data which must be unique throughout the Internetwork - Device IDs and Network Numbers. Unlike Lon-based systems installed under UFGS 23 09 23.01, BACnet does not provide a mechanism to globally manage this data across multiple vendors ***and the installation must manually manage these numbers***:

- Network Number. The network number is assigned to every BACnet network and must be unique across the entire BACnet internetwork. The network number is between 1 and 65,535.
  - The basewide BACnet internetwork should have a single BACnet/IP network; all BACnet devices residing on the IP network should have the same BACnet network number. While this network may well span multiple IP subnets, from the perspective of BACnet, it will logically consist of a single BACnet/IP network and only use a single Network Number. This network must be assigned Network Number=1.
  - Each MS/TP network (of which large projects will have several) also needs a site-wide number. Since network numbers can range from 1 – 65,535, and most sites have at most a few thousand buildings, one option is to assign a range of network numbers to each building by building number. So, for example, building 2705 might have network numbers in the range 27,050 – 27,059. Another option is to assign each vendor a range of network numbers and force the vendors to keep track (site-wide) which numbers they have used. Finally, network numbers could simply be assigned site-wide in increasing consecutive order. This requires some care when multiple independent BACnet projects are underway at the same time.
- Device Object Identifier. Every device on the internetwork must have a unique Object identifier for the Device Object, this is often referred to as the Device ID. This number can be any value between 1 and 4,194,302. Similar to Network Numbers, Device IDs must be globally unique within a site (the BACnet internetwork). The same methods suggested for managing MS/TP network numbers can be used for managing Device IDs, with the additional complication that a single project may include devices from multiple vendors and projects using devices from multiple vendors will need multiple tools to manage Device IDs on a single project

Within a specific project, installers will have some method to maintain unique Device Object Identifiers within the device manufacturer’s product lines. This however does not guarantee unique Device Object Identifiers across manufacturers. ***It also does not ensure unique Device IDs and Network Numbers when a specific project is later integrated into a basewide BACnet internetwork.*** Coordination with the project site concerning their management procedure for these values is critical. If the project site does not have an existing procedure for managing these values coordinate with them to develop one. For the Army, assistance with the resolution of this issue can be obtained from the UMCS MCX at Huntsville Center.

3-4.2 Media selection.

UFGS 23 09 23.02 specifies the use of either MS/TP or IP.

- Master-Slave/ Token Passing (MS/TP) is a data link protocol as defined by the BACnet standard and the majority of DDC controllers used will communicate BACnet MS/TP over a doubly terminated field bus network compliant with EIA/TIA-485. In order to avoid interoperability issues, MS/TP media shall operate at 38.4 kbps, use 3 wire (twisted pair with reference) with shield media and shall be installed with 2 sets of network bias resistors and no more than 32 nodes per segment. MS/TP is by far the slowest of any media types in either UFGS 23 09 23.01 or UFGS 23 09 23.02.

- Some BACnet controllers will likely use BACnet/IP in accordance with ASHRAE-135 (2012) Annex J. While installation of this media is the responsibility of the controls contractor, this network will, when integrated into a basewide UMCS, connect to the basewide IP network. Future management of the IP network will vary from service to service and possibly even from site to site, but all IP networks will be required to meet some level of Information Assurance (IA) requirements.

Use of other media types may limit future competition by giving an advantage to the limited number of vendors whose products support the non-standard media. Therefore use of alternative media should generally be avoided, though there may be cases (retrofits where it is impossible to run new media) where Zigbee (wireless – but carefully coordinate wireless with the site IT and RF management groups) is desired, or inter-building runs where fiber optic should be considered for its electrical isolation characteristics.

3-5 NIAGARA FRAMEWORK NETWORK.

The Niagara Framework provides an overlay system. At the bottom level of the architecture, there are non-Niagara Framework controllers based on either LonWorks or BACnet. Above those controllers are Niagara Framework Supervisory Gateways which connect the individual building to a Niagara Framework UMCS Front End. These devices function as gateways because the protocol for devices under them is either LonWorks or BACnet, while the protocol above these devices (connecting to the UMCS Front End) is the Fox protocol. In most aspects, the architecture when the Niagara Framework is selected is similar to the base (non-Niagara) architectures discussed above. Differences are discussed below.

3-5.1 Niagara Framework and LonWorks.

The Niagara Framework Supervisory Gateway will take the place of the CEA 852 router to provide a connection to the IP network. The Niagara Framework Supervisory Gateway is a gateway and does not route CEA 709.1 to the IP network. The Niagara Framework Supervisory Gateway is DDC hardware and may be connected directly to the IP network.

The Niagara Framework engineering tool will be used for network management instead of an LNS-based tool. For many requirements, an LNS-based requirement is replaced with a similar requirement based on the Niagara Framework engineering tool. The communication between the building control system and the front end will be via Fox, not CEA 709.1

3-5.2 Niagara Framework and BACnet.

The Niagara Framework Supervisory Gateway will function as the BACnet MS/TP–to-IP Router. The Niagara Framework Supervisory Gateway does route BACnet, and all MS/TP networks must be connected to a Niagara Framework Supervisory Gateway.

The communication between the building control system and the front end will be via Fox, not BACnet. Non-Niagara devices on the IP network must use the Niagara Framework Supervisory Gateway to communicate with the Niagara Framework front end.

3-6 CONNECTION TO A UMCS.

The building control system will perform all necessary control functionality in a stand-alone mode but does not provide an operator interface (other than local display panels) for monitoring and control of the network. If the building is to be operated in a stand-alone mode for an extended period and monitoring and control functionality are required, use the applicable portions of UFGS 25 10 10 to obtain a local monitoring and control system. Integration of the building control system to the UMCS is specified in UFC 3-470-01 and UFGS 25 10 10.

3-7 NETWORK HARDWARE.

In addition to media, the control network may contain the following types of hardware.

- Repeaters: A repeater is a device that connects two (or more) pieces of media, and passes all traffic between the two pieces of media. Repeaters may allow for longer cable runs in some cases, but not others. The BACnet specification does not allow the use of repeaters. The LonWorks specification allows the use of routers which are configured as repeaters (but prohibits “physical layer” repeaters).

- Media Converter: A media converter is a repeater that changes media types. The network architecture defined in UFGS 23 09 23.XX does not use media converters, but they may be needed if non-standard media was authorized.

- Router: A router is similar to a repeater, but performs the additional function of packet filtering based on destination address. A router will only pass traffic that needs to be sent to another output port. Routers may also convert between media types. Both UFGS 23 09 23.01 and UFGS 23 09 23.02 specify the use of routers.

- Gateway: A gateway translates from one protocol to another. The use of gateways, other than Niagara Framework Supervisory Gateway in a Niagara Framework project, is severely restricted in UFGS 23 09 23.XX.

3-8 NETWORK DESIGN AND LAYOUT.

Network layout is left largely to the building-level controls Contractor as specified in UFGS 23 09 23.XX.

While the Contractor is responsible for selecting the details of the architecture and ensuring that the proposed system does not saturate the network, UFGS 23 09 23.XX provide specific additional requirements to help ensure those limits are not exceeded:

- Use of higher speed media and use of a backbone architecture

- Group devices that need to communicate often on a common local control bus

- Limit the amount of information sent to the UMCS. A modern UMCS can easily demand data from the local controls faster than the building network can deliver the data. Coordinate with the UMCS installer to limit “always-active” data requests from the UMCS such as trending to those really required by the installation.

- Ensure the Contractor is careful in selecting data transfer rates and integrity methods. Use “Send on Change” with reasonable change values to avoid sending data more often than required. Except for critical data, do not require an acknowledgement or confirmation that data was received.

3-8.1 Data transmission methods.

There are two primary mechanisms through which data transfer data occurs; polling and send on change. These data transfer aspects of the protocol along with the quantity of data transferred govern how much bandwidth is used. Polling occurs when a receiver of data requests data from a transmitter. This is generally a periodic event with a defined period. Polling can occur at any time and a device can always poll another device for data. Send on change, often referred to as Change Of Value (COV), is another form of data transfer where a data source sends (on its own initiative) data to a recipient. In most cases, the specifications require the use of COV.

3-8.2 Data integrity.

DDC networks are not 100% reliable. While proper network design, media selection and installation can improve network reliability, some dropped data packets are inevitable. Both LonWorks and BACnet have mechanisms to ensure reliable data transmission even when the underlying network is unreliable and the specification requires these methods where appropriate.

3-8.3 Number of controllers per system or sequence.

Although sequences are generally implemented in a single controller with sufficient inputs and outputs, the specifications allow a single sequence or system to be split across multiple controllers. There are designer options in the UFGS to select a preference for one approach over the other. Discuss this with the installation to determine if they have a preference. UFGS 23 09 23.XX places the burden on the Contractor to decide when distributed control should be used.

3-9 CYBERSECURITY.

Cybersecurity is an ever-changing area, and it's vital to coordinate IA requirements both with the site networking personnel and with the respective service or agency for each project. UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems* provides guidance on incorporating cybersecurity into the design of control systems, and includes points of contact for each Service. For the Army, control system design, including cybersecurity, should be coordinated with the UMCS Mandatory Center of Expertise (MCX) at Huntsville.

CHAPTER 4 DIRECT DIGITAL CONTROL HARDWARE AND CONTROL DEVICES

4-1 INTRODUCTION.

This chapter describes control devices and the DDC Hardware specified in UFGS 23 09 23.XX including the extended requirements needed to implement an Open system. It also describes the related terms and concepts pertaining to LONWORKS, BACnet, and the Niagara Framework.

4-2 LONWORKS REQUIREMENTS.

4-2.1 General.

Any device, other than network hardware, that communicates over the CEA 709.1 network is considered DDC Hardware. In general, the term DDC Hardware is used interchangeably with the term controller, but there are devices such as smart sensors and actuators that communicate on the network and are considered DDC Hardware but are not traditionally called controllers even though they may in fact have control functionality (like a feedback control loop). All DDC Hardware must:

- Communicate only using CEA 709.1C using a TP/FT-10 transceiver for use on a TP/FT-10 network at 78.1 kbps.

- Use Standard Network Variable Types (SNVTs). SNVTs provide a common set of standards defining how data is sent over the network, including engineering units

- Meet the LonMark Interoperability guidelines. These guidelines provide a foundation for interoperability and devices meeting these guidelines are readily available.

- Be provided with an external interface file (XIF file). This is a text file that tells a Network Management Tool what the interface (inputs, outputs, configuration settings) of the controller is.

Some of these requirements may be difficult to confirm for some devices, specifically programmable controllers. Product data sheets can provide a good indication of whether a device, particularly an application specific controller, meets LonMark Guidelines. In addition, LonMark International has a self-certification checklist that vendors can use to certify that a device meets the LonMark Guidelines.

Where Lonworks falls short is in defining a standard interface between the BCS and the UMCS front end. In particular, there is no well-supported standard for either alarming or trending; therefore these functions are not specified in UFGS 23 09 23.01 (they are specified in UFGS 25 10 10 if the LonWorks tailoring option is selected). DDC Hardware is further broken down into three categories, Application Specific Controllers, Application Generic Controllers, and General Purpose Programmable Controllers, each of which has additional requirements it must meet.

4-2.2 Application specific controller.

An application specific controller (ASC) is supplied with a factory-installed (and fixed) application program. Example ASCs include VAV box controllers, fan coil unit controllers, 'smart' actuators and 'smart' sensors. An ASC is configured for the specific application in which it is used. UFGS 23 09 23.01 requires, with rare exceptions, that ASCs be LonMark Certified to meet a specific Functional Profile. Functional Profiles describe standard node communications and consists of mandatory and optional input and output SNVTs, mandatory and optional configuration properties, and finally a manufacturer specific section. UFGS 23 09 23.01 also requires, with rare exceptions that ASCs be provided with an LNS® Plug-in to provide a semi-standard GUI for device configuration

4-2.3 Application generic controller.

An application generic controller (AGC) is similar to an ASC, but has a limited programming capability. Programming these controllers does not change the controller ProgramID, so these controllers can be (and often are) programmed through an LNS plug-in. UFGS 23 09 23.01 has specific requirements for AGCs which includes a mix of ASC and GPPC requirements. These controllers are capable of executing most of the sequences specified in UFGS 23 09 93. Further, since they can be re-programmed remotely and without changing the ProgramID, they are often preferred to GPPCs.

4-2.4 General purpose programmable controller.

A general purpose programmable controller (GPPC) comes from the factory without a fixed application program and must be programmed for the application in which it is used. This makes the GPPC more flexible and powerful than an ASC, but more complicated and costly as well. UFGS 23 09 23.01 requires the GPPC to conform to the LonMark Interoperability Guide. It also requires that the programming software be provided and that a source-code version of the actual program installed in the GPPC be provided as well.

4-3 BACNET REQUIREMENTS.

4-3.1 General.

Any device, other than network hardware, that communicates over the BACnet network is considered DDC Hardware. In general, the term DDC Hardware is used interchangeably with the term controller – this includes smart sensors and actuators that use the network. Another term commonly used is "device", where a BACnet device is any device that resides on the BACnet network and communicates via the BACnet ASHRAE Standard 135 protocol. All DDC Hardware must:

- Communicate only using BACnet ASHRAE Standard 135.
- Use standard Objects, Properties, and Services. UFGS 23 09 23.02 requires the use of specific Object types to support specific point types.
- Do not use Proprietary Objects or Proprietary Properties. In addition, UFGS 23 09 23.02 places severe restrictions on the use of Proprietary Services.
- Provide Commandable Objects to support overrides.
- Be Listed by BACnet Testing Labs (BTL) (http://www.bacnetinternational.net/btl/). For some applications, devices must be listed as either B-BC (BACnet Building Controllers) or B-OD (BACnet Operator Displays).
- Be installed in a manner consistent with both their BTL listing and with the BTL Implementation Guidelines.

Some of these requirements may be difficult to confirm; the PICS is a good place to start for devices. Note, however, that the PICS only describes capabilities, a particular usage of the device may not implement or support every capability described in the PICS. BACnet provides a fairly extensive range of standards defining the interaction between a UMCS front end (specifically a B-AWS) and a BCS, because of this, UFGS 23 09 23.02 has requirements for scheduling, alarming, and trending in the BCS. When BACnet is selected via tailoring option in UFGS 25 10 10, that specification requires that the front end be BTL listed as a BACnet Advanced Workstation (B-AWS).

4-3.2 Scheduling.

UFGS 23 09 23.02 has specific requirements for scheduling, including that scheduling must be performing using Schedule Objects in B-BC devices with support for Schedule creation/modification/deletion from a B-AWS. This last requirement can be partially offset by the provision of extra blank Schedule Objects.

4-3.3 Alarm generation.

The BACnet standard supports 2 primary forms of alarm generation: Intrinsic, where the Object itself incorporates logic to determine if an alarm condition exists, and Algorithmic, where an Event Enrollment Object contains the alarm generation logic. Algorithmic is in turn broken down into Local -- where the Event Enrollment Object is in the same device as the alarm point and Remote – where the Event Enrollment Object is in a different device. In all cases, a Notification Class Object is also required to send the Event Notification associated with the alarm generation to the B-AWS front end. In order to allow the use of all three types of alarm generation and also ensure that Alarm Generation functionality may be created/modified/deleted from a B-AWS, UFGS 23 09 23.02 has extensive and complex requirements for alarm generation.

4-3.4 Trending.

The BACnet standard provides a Trend Log Object and a Trend Log Multiple Object to support trending. A Trend Log Object supports a single trend; the Trend Log Multiple Object can contain multiple trends. UFGS 23 09 23.02 requires the use of Trend Log and/or Trend Log Multiple Objects and also has additional requirement to support trend creation/modification/deletion from a B-AWS.

4-3.5 Engineering units.

BACnet data does not have pre-determined engineering units and UFGS 23 09 23.02 requires the use of specific engineering units. The choice of either SI or inch-pounds should be coordinated with the site and used on all BACnet projects at that site.

4-4 NIAGARA FRAMEWORK REQUIREMENTS.

4-4.1 General.

Selection of the Niagara Framework is via a tailoring option to either UFGS 23 09 23.01 or UFGS 23 09 23.02. In either case, the requirements normally found in these specification remain largely intact; the tailoring options make specific modifications to support the Niagara Framework. Use of Niagara Framework in the building must be accompanied by selection of the Niagara Framework tailoring option in UFGS 25 10 10.

4-4.2 Niagara Framework and LonWorks (UFGS 23 09.01).

The most significant changes that will result from use of the Niagara Framework tailoring option in UFGS 23 09 23.01 are:

- Network configuration and network management will be via the Niagara Framework Engineering tool rather than an LNS-based tool. Similarly, Niagara Framework Wizards may be required rather than LNS-plugins
- Connections to the IP network will be via Niagara Framework Supervisory Gateways rather than CEA 852 Lon-to-IP routers.
- Scheduling, Alarming, and Trending will be via Niagara Framework Supervisory Gateways located in the building.
- Some DDC Hardware requirements, as they apply to Niagara Framework Supervisory Gateways, are depreciated in favor of Niagara-specific requirements.

4-4.3 Niagara Framework and BACnet (UFGS 23 09.02).

The most significant changes that will result from use of the Niagara Framework tailoring option in UFGS 23 09 23.02 are:

- Niagara Framework Engineering tool will be used for some aspects of device configuration. Note that vendor specific tools will likely still be required for many aspects

- Connections to the IP network will be BACnet MS/TP-to-IP routers in Niagara Framework Supervisory Gateways

- Scheduling, Alarming, and Trending will be via Niagara Framework Supervisory Gateways rather than the normal BACnet implementation methods.

- Some DDC Hardware requirements, as they apply to Niagara Framework Supervisory Gateways, are depreciated in favor of Niagara-specific requirements.

4-5 OTHER ISSUES.

4-5.1 Expansion modules and tethered hardware.

UFGS 23 09 23.XX considers hardware expansion modules and tethered hardware to be part of a single piece of DDC Hardware. Expansion modules typically provide additional I/O and are designed to connect directly to the base (main) DDC Hardware. Tethered hardware is functionally similar to expansion modules, but is connected to the base unit by a cable. The intent of the requirements is to allow a single device to be split among multiple physical pieces of hardware, not to allow multiple devices to be connected together using a proprietary protocol.

4-5.2 Building management interface.

A building-level project might call for a local building management interface. This should only be used in the absence of a UMCS, and is not specified in either UFGS 23 09 23.XX or UFGS 25 10 10. This interface provides web services and can also perform scheduling, logging (trending), alarming, and other supervisory interface functions. Note that if it is later decided to connect the building to a UMCS, the interface will need to be replaced and any functionality in it will need to be accomplished in an Open manner in accordance with UFGS 23 09 23.XX or UFGS 25 10 10. On the other hand, a Niagara Framework Supervisory Gateway can provide this interface and can later be integrated into a Niagara Framework front end. UFGS 23 09 23.XX has a designer option to require serving web pages from the Niagara Framework Supervisory Gateway. Any web server within the building should be carefully coordinated with the site IT staff.

4-5.3 Local Display Panel.

The local display panel (LDP) is a device with a small display screen and some navigational buttons used to view and/or change the value of network variables. Although the functionality of an LDP is limited as compared to an operator workstation computer, it can be a useful diagnostic tool for maintenance staff and can often be used as a limited building interface until the building can be integrated into a UMCS. Coordinate with the site O&M staff regarding number and location of LDPs desired.

Note that there may be drawbacks to allowing overrides from both the M&C software and from an LDP. The value of specifying LDP override capability may be sufficiently beneficial to compensate for the potential confusion, but this should be coordinated with the project site.

4-5.4 Networked sensors and actuators.

Sensors and actuators may be networked devices. A common example would be a variable frequency drive unit containing a network interface. The choice of whether to provide a so-called “smart” sensor or actuator is left to the contractor. These “smart” devices are considered DDC Hardware and must meet both the DDC Hardware requirements as specified in UFGS 23 09 23.XX and any sensor or actuator requirements as specified in UFGS 23 09 13.

4-5.5 Hand-Off-Auto (H-O-A) Switches.

UFGS 23.09.23.XX has a number of general designer options for requiring Hand-Off-Auto switches. These are in addition to those already required by specific sequences of operation. In general, it is preferable to use overrides rather than H-O-A switches and the design should reflect this preference.

CHAPTER 5 CONTROL SYSTEM DRAWINGS

5-1 CONTROL SYSTEM DRAWINGS OVERVIEW.

A complete design must include the following project drawings:

- Index (title sheet)
- Symbols and Legend drawing
- Points Schedule Instructions for the Installing Contractor

as well as the following HVAC system-specific drawings as applicable to the HVAC system:

- Control Schematic
- Ladder Diagram
- Control Logic Diagram (OPTIONAL)
- Sequence of Operation
- Points Schedule
- Thermostat and Occupancy Sensor Schedule
- Occupancy Schedule
- Control Damper Schedule
- Control Valve Schedule

5-2 SAMPLE DRAWINGS.

Sample drawings are available online at the "UFGS Forms, Graphics and Tables" page at the Whole Building Design Guide at https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-graphics-tables. The use of the sample drawings is recommended. Points Schedule drawings must contain all fields in the sample drawing which are relevant to the project, and the use of the sample Points Schedule drawings as a template is strongly recommended.

5-2.1 Brackets in sample drawings.

As part of the editing process to make the sample drawings project-specific, the sample drawings use the following conventions:

- Entries required of the designer are shown bracketed as: [___]

- Entries required of the Contractor are shown bracketed as: < ___ >
- Spaces where no entry is ordinarily required contains a tilde: " ~ " (equivalent to an "n/a" or null value)

The bracketed [___] designer entries in the sample drawings are shown/provided as a guide to the designer. These entries must be verified or changed by the designer. When editing the drawings, delete the brackets after verifying/providing the entry. Contract drawings should contain no designer brackets [___]. Do not leave cells blank. Instead show the tilde ("~") to indicate a null value or that no further entry is required.

5-3 UNIQUE IDENTIFIERS.

Use unique identifiers to identify components across control systems drawings. APPENDIX E describes the point naming convention used in the sample drawings. Unless otherwise required, use the point naming convention in the sample drawings for the project drawings.

5-4 POINTS SCHEDULE.

5-4.1 Overview.

The Points Schedule drawing conveys a great deal of information critical to the design, installation, and subsequent performance of the control system. It includes hardware input/output information, device ranges and settings, and protocol specific information. It also includes information about data that is to be accessible at the operator workstation by the UMCS UFGS 25 10 10 Monitoring and Control software.

5-4.2 Responsibilities.

The designer is responsible for the initial set of Points Schedule entries and for creating the Points Schedule Instructions drawing (using the Instructions in **\2** APPENDIX D ***/2/*** of this UFC) . The Building Controls Contractor is responsible for the bulk of the entries and submits the Points schedule as a Design Drawing for government approval and then finalizes it as an As-Built submittal. The As-Built is then used as a Contract Drawing by the UMCS Contractor. Finally, the completed Point Schedule is submitted by the UMCS Integration Contractor as an As-Built submittal.

Detailed responsibilities for each column in the Point Schedule are shown under the description for each column.

5-4.3 UMCS content shown on UFGS 25 10 10 points schedules.

Some columns in the Points Schedule (labeled "M&C") pertain to functionality provided by the Monitoring and Control (M&C) Software specified in UFGS 25 10 10. These columns include information that the building controls system must provide for present or future use by the UMCS. Then, as stated in the Points Schedule Instructions drawing, when the building control system is integrated into a UMCS, these columns tell the UMCS Contractor what functionality to configure in the M&C Software.

If the building will be 'stand-alone' and M&C functionality is required at the building level (to be provided by the DDC building control system contractor), certain requirements from UMCS UFGS 25 10 10 must be added to the building controls specification or an edited version of UMCS UFGS 25 10 10 must be used in conjunction with the building controls specification. Note that in the absence of adequate documentation on the Points Schedule by the DDC Contractor, the UMCS Contractor will be unable to integrate the building into the UMCS.

5-4.4 Points Schedule Description and Instructions.

APPENDIX D contains a detailed description of the Points Schedule and instructions for its use.

5-5 CONTROL SYSTEM SCHEMATIC.

The control system schematic provides a functional representation of the control system. It shows control loops, control system devices, their symbols, unique identifiers, and associated input and output signals. It also contains space for designer notes. Depending upon the particular system, the control system schematic might also show Sequencing Diagrams. It is used to complement the sequence of operation, along with the other control system drawings, and must be coordinated with the sequence of operation and the devices and signals shown in the other drawings.

5-5.1 Loops and devices.

Each control system schematic consists of one or more loops with associated control hardware and devices including DDC hardware, input devices (sensors and other instrumentation), output devices (valves/dampers/fans/pumps), and multi-function devices. With few exceptions, such as valves, dampers, fans, and pumps, all control devices and signals shown in the Control Schematic should also be shown in the Points Schedule. Valve and damper details are shown in their respective schedules.

The control system schematic must be edited to be project specific and consistent with the other Contract drawings:

- Edit the border as required.
- Provide/show an identifier for the 'system'.
- Add or delete loops and devices as required.
- Show other points (sensors) that will be used for monitoring purposes only and show these Other Points in the Points Schedule.
- Show pneumatic actuation if desired, including positive positioners. By default, valve and damper actuators will use electric actuation.

- Where applicable, show the locations of permanent instrumentation in coordination with other drawings (M-plates).

5-5.2 Sequencing diagrams.

A Sequencing Diagram shows the heating, deadband, and cooling temperature ranges for controlled devices and equipment. Default Sequencing Diagrams are shown on the sample control drawings and must be edited to be project specific. Show device sequencing for primary equipment such as single-zone air handlers, multizone zone temperature controls and terminal unit equipment, such as VAV boxes and fan coil units on the Control Schematic. In most cases, the sequencing is dependent upon the mode of operation such as occupied, unoccupied, and warm-up/cool-down. Sequencing is further described in the respective written Sequence of Operation and, when used, the Control Logic Diagram.

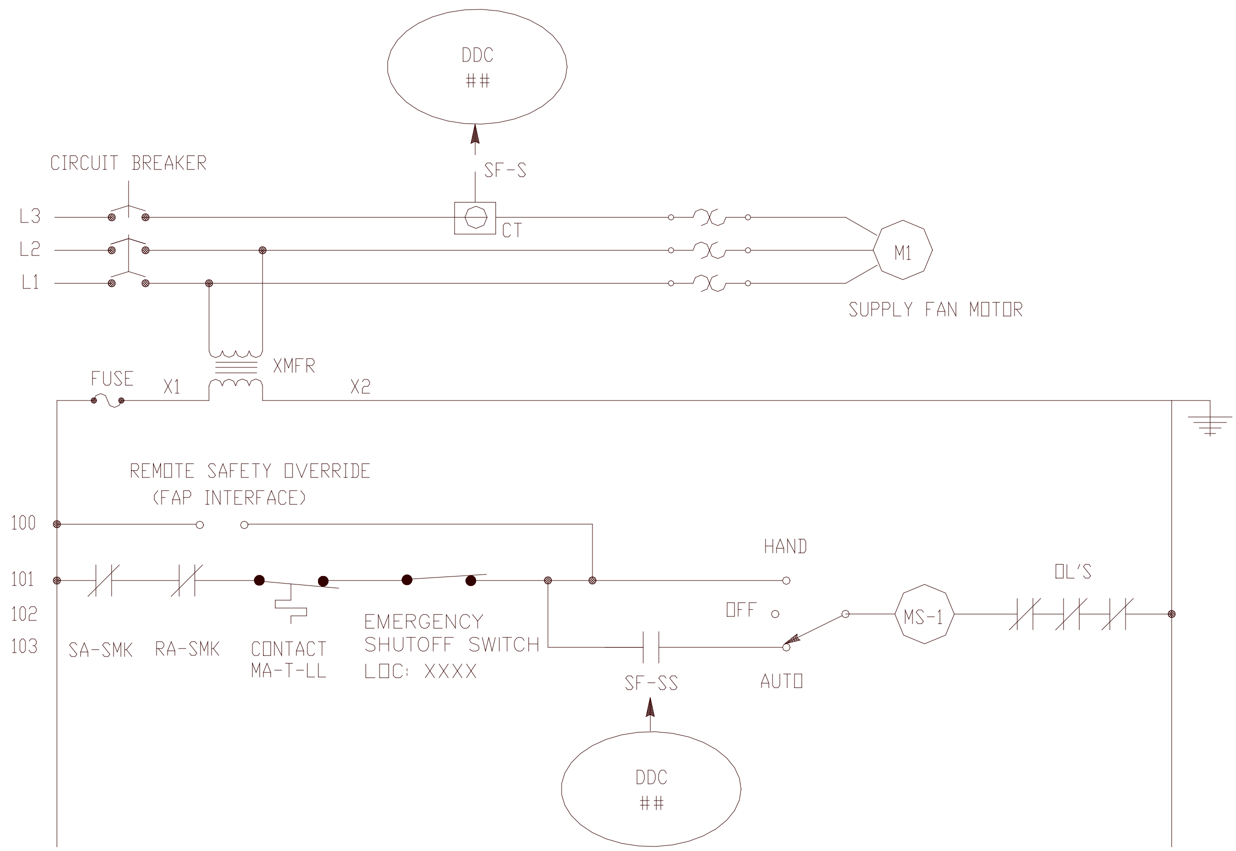
5-5.3 Designer notes.

The Control System Schematic has space provided for designer notes including pre-defined/default notes.

5-6 LADDER DIAGRAM.

The ladder diagram, sometimes referred to as a fan or pump starter circuit or wiring diagram, shows control system equipment interlocks and interfaces. In most cases, these interlocks will be with fan and pump motor starters or variable frequency drive units. In the case of HVAC system equipment, the interlocks will usually include hand-off-auto switches, freeze stats, smoke detectors, fire alarm panel interface, and the emergency shutdown switch. Default Ladder Diagrams are shown on the sample control drawings and should be edited to be project specific.

Figure 5-1 Sample Ladder Diagram



5-7 CONTROL LOGIC DIAGRAM.

The control logic diagram (CLD) drawing is intended to be an unambiguous graphical description of the control system sequence of operation. It provides detail that may not be evident in the written sequence. The focus of the CLD is on control logic, not on a particular hardware implementation. Inclusion of a CLD in the Contract drawing package is optional depending on the desired degree of specificity in the design. Use of a CLD is recommended where precise implementation of a particular control sequence is needed. It is also beneficial as part of project quality verification as it can be used as a tool to verify proper implementation of the control sequence.

The CLD must be edited to be project specific and consistent with the other Contract drawings. A control logic diagram overview is contained in APPENDIX F

5-8 SEQUENCE OF OPERATION.

The sequence of operation drawing shows a written description of the control logic. Example written sequences are in UFGS 23 09 93. To avoid confusion, these sequences were not repeated on the sample control drawings. The sequence must be edited to be project specific and consistent with the other Contract drawings and be copied onto the Sequence of Operation drawing.

5-9 THERMOSTAT AND OCCUPANCY SENSOR SCHEDULE.

The Thermostat and Occupancy Sensor Schedule (Figure 5-2) shows requirements for space mounted devices.

Figure 5-2 Thermostat and Occupancy Sensor Schedule.

SYSTEM SERVICE (AHU)	TERMINAL UNIT IDENTIFIER	SPACES SERVED	STAT LOCATION	ZN-T	ZN-T-SP ADJUST	UNOCC OVERRIDE PUSHBUTTON	UNOCC OVERRIDE TIME	OCC SENSOR
[____]		RM-[____] RM-[____]	RM-[____]	[_]	[_]	[_]	[____]	[_]
[____]		RM-[____] RM-[____] RM-[____]	RM-[____]	[_]	[_]	[_]	[____]	[_]
[____]		RM-[____]	RM-[____]	[_]	[_]	[_]	[____]	[_]

5-9.1 Thermostats.

Note that the definition of a thermostat (STAT) is used somewhat loosely here in that (contrary to the historical definition, but in line with current usage) the thermostat does not necessarily provide a control output (to modulate or position an end device). Instead, the thermostat will contain a temperature sensor and one or more of an occupant adjustable setpoint input, an occupancy sensor, or an unoccupied mode override (manual pushbutton). The intent and application of a thermostat, along with the technical requirements, are clear in the drawings and specifications (including ‘User Input Devices’ and ‘Multifunction Devices’).

5-9.2 Occupancy sensors.

Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Occupancy sensor location, within the room/space, is left up to the Contractor. If ceiling mount sensors are preferred, edit the sequences and/or indicate in the Thermostat and Occupancy Sensor Schedule.

5-9.3 Schedule entries.

Show project specific entries in the Thermostat and Occupancy Sensor Schedule columns:

- System Service: Show an identifier for the system, such as the air handler, that services/supplies the space. Ensure coordination/consistency with other mechanical system drawings.
- Terminal Unit Identifier: Show an identifier when applicable, such as in a VAV system. Ensure coordination/consistency with other mechanical system drawings.
- Spaces Served: Show the room or rooms serviced by the thermostat and/or occupancy sensor. In general, all stats and occupancy sensors for a given terminal unit should be shown on the same line. However, there may be cases where additional rows may be required. For example, if a VAV zone consists of multiple spaces, a single thermostat but multiple occupancy sensors (one in each space/room) may be desired. The designer might choose to show a separate row for each occupancy sensor. Alternatively, a comment could be added to the column entitled 'Other' to clarify the requirement for a single thermostat with multiple space occupancy sensors.
- STAT Location: Show the physical location of the thermostat.
- ZN-T: Thermostats should always include a temperature sensor, so there should always be an 'X' in this column.
- ZN-T-SP Adjust: Show an 'X' if the thermostat is to include an occupant adjustable setpoint (thumb wheel or sliding bar). Where a non-(occupant)-adjustable setpoint is specified, show the (configured) setpoint in the Points Schedule. When using non-adjustable setpoints, be sure to indicate on the Points Schedule that the setpoint must be capable of being overridden from the M&C Software or an LDP.
- OCC Pushbutton: Show an 'X' if the thermostat is to include an occupant accessible pushbutton to override the unoccupied mode and start the servicing system for a duration shown under the UNOCC Override Time.
- OCC Pushbutton Time: If an 'X' is shown in the UNOCC Override Pushbutton column, show the time duration that the system will remain in Occupied mode after pressing the UNOCC Override Pushbutton.
- OCC Sensor: Show an 'X' if the space is to include an occupancy sensor. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the specifications.

5-10 OCCUPANCY SCHEDULE.

The Occupancy Schedule shows the system modes (Occupied, Unoccupied, and Warm-Up/Cool-Down) and when the system should be in each mode. Two sets of times are shown. One for the normal operating schedule set at the UMCS and one for the default schedule in the building which is active if connection to the UMCS is lost. In addition, the number of occupancy sensors that are required to be reporting as 'occupied' before the system air handler is put into occupied mode is shown on this schedule

5-10.1 System default schedule.

The System Default Schedule is configured in the System Scheduler by the controls Contractor. This schedule is a '7-day' schedule. In other words, the schedule can differ by day of the week but not day of the year. This schedule should be as simple as possible with one set of times for weekdays and one for weekends. An extended Occupied mode is recommended and should encompass warm-up/cool-down times. For example, if the building is normally in Warm-Up from 0700-0800 and Occupied mode from 0800-1800, a reasonable default schedule might be for the building to be in Occupied mode from 0530-1930. When choosing times for the default schedules for systems with occupancy sensors, the Occupied mode times can be shorter since the occupancy sensors (or override buttons) can still put the system into an Occupied mode.

5-10.2 Supervisory monitoring and control schedule.

The Supervisory Monitoring and Control (M&C) Schedule is configured at the M&C software by the UFGS 25 10 10 Contractor. Once a building is connected to the UMCS, this is the schedule that systems in the building will use. Although this schedule can include exceptions for holidays, it is recommended that the designer coordinate with the project site before requiring the implementation of these exceptions. Since the date of most holidays needs to be adjusted year-by-year, the project site O&M staff will need to reconfigure them yearly. As with the default schedule, the presence of Occupancy Sensors should be considered when choosing Occupied mode times.

5-10.3 Number of occupancy sensors to put AHU in occupied mode.

Systems with occupancy sensors (or override buttons) can be placed into the Occupied mode by the occupancy sensors when a minimum number of occupancy sensors detect that the space they serve is occupied. Indicate the required number of occupancy sensors in this column.

CHAPTER 6 BUILDING CONTROL SYSTEM DESIGN AND IMPLEMENTATION

6-1 INTRODUCTION.

This chapter describes the planning and design of a DDC project.

6-2 PLANNING.

In addition to the guidance contained in this UFC, the design should be based on site-specific planning documents. Designs must be accomplished in accordance with the customer's site specific requirements such as, in the case of a Corps of Engineers project, the Installation Design Guide (IDG), Master Planning documents, and the UMCS/DDC Implementation Plan. To help obtain maximum benefit of Open DDC systems, designers should encourage their customers to develop a UMCS/DDC Implementation Plan. Development of an Implementation Plan is recommended in Engineering Construction Bulletin (ECB) 2007-8 and is described in ERDC/CERL Technical report TR-08-12 'IMCOM LONWORKS® Building Automation Systems Implementation Strategy'. This Technical Report is available at: http://dtic.mil/dtic/tr/fulltext/u2/a492015.pdf

6-3 CHOICE OF SPECIFICATION AND PROTOCOL.

The first decision that must be reached for the building is the choice of protocol, one of:

- LonWorks with LNS (use UFGS 23 09 23.01 with the LNS tailoring option),
- LonWorks with Niagara Framework (use UFGS 23 09 23.01 with the Niagara Framework tailoring option),
- BACnet (use UFGS 23 09 23.02 with the non-Niagara tailoring option), or
- BACnet with Niagara Framework (use UFGS 23 09 23.02 with the Niagara Framework tailoring option).

In most cases, selection of protocol will be dictated by the need to integrate to a specific UMCS. Selection of protocol is extensively described in UFC 3-470-01.

6-4 INTEGRATION TO UMCS.

Most buildings will eventually be integrated to a UMCS. Even if, at the time, it seems like the project is for a stand-alone building, the realities of O&M staffing at most installations make it advantageous to integrate buildings into a single UMCS and the decision to procure a building with no planning for future integration is generally very short-sighted. There are legitimate exceptions for buildings that will not (and likely will never) be maintained by the installation staff – e.g. hospitals and other tenants who have their own O&M staff. In many cases, it is desirable to perform this integration as part of the building project. In this case, use DDC UFGS 23 09 23.XX for the present building-level project and use an edited version of UMCS UFGS 25 10 10 to specify the integration of the building system to the UMCS (UMCS UFGS 25 10 10 is designed to make this editing task straightforward). If integration is not performed as part of the building project, an integration project will be necessary later using an edited version of UFGS 25 10 10. If there will be a significant time lapse between building construction and integration, the building controls project may wish to include additional LDP functionality.

One possible issue is that the site may not have a UMCS that the project can integrate to, in which case the site should consider adding requirements for a UMCS to the building control project. This can often be an effective approach, particularly if the building project spans multiple buildings. See UFC 3-470-01 and UFGS 25 10 10 for guidance and requirements on procuring a UMCS.

6-5 PROCUREMENT CONSIDERATIONS.

6-5.1.1 Non-proprietary procurement.

Unless there is specific written authorization from the Project Manager or Authority Having Jurisdiction, the project shall use non-proprietary procurement using requirements in UFGS 23 09 23.XX.

6-6 DDC DESIGN.

6-6.1 General.

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Much of the needed detail was attended to during the development of the UFGS and UFC criteria. Still, project specific requirements must be defined by the designer and the specifications and drawings edited accordingly. This notably includes, but is not limited to, editing the Points Schedule drawing to show critical Open system requirements.

The resultant project-specific specification will require the control system Contractor to produce shop drawings, schedules, instructions, test plans, test procedures, testing procedures, and other documents showing the application of products to implement the control system design. The specification will require the Contractor to implement the building-level network in a manner that is consistent with performance requirements defined in the specification. The specification will further require that the Contractor perform calibration, adjustments, and testing of the control system and document the testing to show that the control system functions as designed.

6-7 DRAWING PACKAGE.

Assemble and edit the drawing package as described in CHAPTER 5 CONTROL SYSTEM DRAWINGS.

APPENDIX A REFERENCES

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *DoD Building Code (General Building Requirements)*

UFC 3-470-01, *Utility Monitoring and Control System (UMCS) Front End and Integration*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs

UFGS 23 09 00, *Instrumentation and Control for HVAC*

UFGS 23 09 13, *Instrumentation and Control Devices for HVAC*

UFGS 23 09 23.01, *LonWorks Direct Digital Control for HVAC and Other Building Control Systems*

UFGS 23 09 23.02, *BACnet Direct Digital Control for HVAC and Other Building Control Systems*

UFGS 23 09 93, Sequences of Operation for HVAC Control

UFGS 25 05 11, *Cybersecurity for Facility-Related Control Systems*

UFGS 25 10 10, *Utility Monitoring and Control System (UMCS) Front End and Integration*

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APPENDIX B BEST PRACTICES

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APPENDIX C GLOSSARY

C-1 ACRONYMS

BCN	Building Control Network
BCS	Building Control System
CCR	Criteria Change Request
DDC	Direct Digital Control
FPOC	Field Point of Connection
HVAC	Heating Ventilating and Air Conditioning
IDG	Installation Design Guide
IP	Internet Protocol
IT	Information Technology
LNS	LonWorks Network Services
M&C	Monitoring and Control
MCX	Mandatory Center of Expertise
NCT	Network Configuration Tool
NDAA	National Defense Authorization Act
O&M	Operations and Maintenance
PDF	Portable Document Format
PID	Proportional, Intergal, Derivative
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UMCS	Utility Monitoring and Control System
USACE	U.S. Army Corps of Engineers
VAV	Variable Air Volume

C-2 DEFINITION OF TERMS

Several terms are defined in this appendix for ease of reference, but UFC 4-010-06 contains a more extensive, and definitive, list of terms. Should the definitions provide here and in UFC 4-010-06 conflict, the definitions in UFC 4-0101-06 should be used, and a Criteria Change Request (CCR) should be submitted to update the definitions in this UFC.

C-2.1 Field Control System (FCS) and Field Control Network (FCN).

A Building Control System or Utility Control System. The network used by the field control system is called the field control network (FCN).

C-2.1.1 Building Automation System (BAS).

The system consisting of the UMCS Front-End and connected building control systems which provides for control of the building electrical and mechanical systems as well as a user interface and supervisory capability (i.e. the portion of the UMCS for building control and excluding any connected UCS).

C-2.1.2 Building Control System (BCS) and Building Control Network (BCN).

One type of Field Control System. A control system primarily for building electrical and mechanical systems, typically HVAC (including central plants) and lighting. Building Control Systems are generally composed of direct digital controls (DDC) and do not have a full-featured user interface. They may have some local user interface such as “local display panels” but rely on the UMCS for the full user interface functionality. The network used by the building control system is called the building control network (BCN).

C-2.1.3 Utility Control System (UCS) and Utility Control Network(UCN).

One type of Field Control System. Used for control of utility systems such as an electrical substation, sanitary sewer lift station, water pump station, etc. Building controls are excluded from a UCS, however it is possible to have a Utility Control System and a Building Control System in the same facility, and for those systems to share components such as the Field Point of Connection (FPOC). A UCS may include its own local front-end.

C-2.2 Field Point of Connection (FPOC)

The connection point between the field control network (installed by the controls contractor) and the UMCS network (generally owned and installed by the installation IT staff). The FPOC device is typically on the IP network – usually a managed switch, owned and managed by the installation IT staff, and a focal point for Cybersecurity. Note that this definition has evolved over time and may be at variance with older usage of the term.

C-2.3 Industrial Control System (ICS)

One type of control system. Most specifically a control system which controls an industrial (manufacturing) process. Sometimes also used to refer to other types of control systems, particularly utility control systems such as electrical, gas, or water distribution systems.

Note than ICS is at times used to mean "all control systems", so care must be taken to interpret the term in the appropriate context.

C-2.4 Utility Monitoring and Control System (UMCS)

The system consisting of one or more field control systems connected to a UMCS Front-End which provides for control of the electrical and mechanical systems as well as a user interface and supervisory capability. (i.e. the complete system consisting of the UMCS Front-End with all connected BCS and UCS systems). Note that in the past the term "UMCS" has sometimes been used to mean just "the UMCS front end", but is no longer used in this manner.

C-2.5 Utility Monitoring and Control System (UMCS) Front End

The portion of the UMCS consisting primarily of computers running software to provide a full-featured user interface. In addition to providing a full user interface, this system performs functions such as alarming, scheduling, data logging, electrical demand limiting and report generation. The front end does not directly control physical systems; it interacts with them only through field control systems.

C-2.6 Utility Monitoring and Control System (UMCS) IP Network

The IP network used by the UMCS Front End for communication between Field Control Systems. This includes the IP infrastructure components only. The UMCS IP network is often also referred to as the "platform enclave" for cybersecurity purposes.

C-3 TERMS SPECIFICALLY NOT USED BY THIS UFC

The term SCADA (Supervisory Control and Data Acquisition) is not used as the definition can vary depending on context. In general usage, however, "SCADA" can be taken to mean "UCS".

NDAA 2010 uses the term Energy Monitoring and Utility Control System to refer to a Utility Monitoring and Control System (UMCS). This term is not a standard term used by the controls industry, so this UFC and UFGS 25 10 10 do not use this term.

C-4 OTHER TERMINOLOGY

Other terminology related to control systems is defined in UFGS 25 10 10 and in the field control system specifications (e.g. UFGS 23 09 00, UFGS 23 09.01, and UFGS 23 09.02).

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APPENDIX D POINTS SCHEDULE IINSTRUCTIONS

D-1 USE OF BRACKETS IN THE POINTS SCHEDULE

As with guide specifications, the Points Schedule uses brackets to indicate where entries or selections are required. Unlike with the guide specifications, however, two types of brackets are used in the Points Schedule. “Square brackets” (“[___]”) are used to indicate selections or entries made by the designer, while “angle brackets” (“<___>”) are used to indicate selections or entries that must be made by the building control system contractor.

The building control system contractor is responsible for completing the entire Points Schedule regardless of the presence or absence of “angle brackets”. “Angle brackets” are used in sample drawings to indicate to the designer information they would not typically provide. They may also be used by the designer to highlight specific information they have decided not to provide or have determined must be provided by the Contractor.

D-2 POINTS SCHEDULE DESCRIPTION AND INSTRUCTIONS

Points Schedule columns and entries are described below along with the Designer and Contractor responsibilities related to that column. For each column in the point schedule, the instructions below provide the following data:

APPLICABILITY: Not all columns are used for all protocols. This entry defines which protocol(s) (SpecsIntact tailoring options) the column is used with. “Any” means “use this column regardless of the protocol tailoring option chosen”.

PURPOSE: The intent of the column; why it is necessary

VALID ENTRIES: What are the allowed entries for this column? Note that these are given for a “complete” table, while a designer might, for example, enter “<___>” to indicate that this information will be provided later by the Building Contractor, this is not regarded as a “Valid Entry”. If the information is not needed, then the valid entries are “~” or “N/A” (Note that, to avoid confusion, a blank entry is not a valid entry – do not leave cells blank.):

- An “N/A” (or a greyed out cell, or a combination of N/A and a greyed out cell) is used when there is no possibility of a valid entry for that particular cell.
- A tilde (“~”) is used in a cell where there could be a valid entry, but no entry is required (i.e. it’s specifically used to mean “I could have put a value here but I chose not to enter one”).

DESIGNER: Describes designer responsibilities associated with the entry.

BUILDING CONTRACTOR: Describes building contractor responsibilities associated with the entry.

UMCS CONTRACTOR: Describes UMCS contractor responsibilities associated with the entry.

In some cases, the contractor instructions are further divided by protocol. “Other” means “a protocol other than the ones specifically enumerated”, while “All” means “any and all protocols, including those specifically enumerated”.

Note that while these instructions are complete and authoritative, they may omit some details which are covered either elsewhere in this UFC or the relevant UFGS. In all cases, the designer and contractor are responsible for implementing the requirements of the UFC and UFGS.

D-2.1 General Columns

D-2.1.1 Function

APPLICABILITY: Any protocol

PURPOSE: Describe the functionality of this group of points

VALID ENTRIES: Functional blocks from sequence of operation

DESIGNER: Provide this information

BUILDING CONTRACTOR: None, informational only

UMCS CONTRACTOR: None, informational only

D-2.1.2 Point Name

APPLICABILITY: Any protocol

PURPOSE: The point name

VALID ENTRIES: As shown on sample Points Schedules, or using the point naming convention in APPENDIX E

DESIGNER: Provide this information

BUILDING CONTRACTOR: Provide this information for any additional points needed or where designer did not provide an entry.

UMCS CONTRACTOR: Show these point names on graphic displays

D-2.1.3 Description

APPLICABILITY: Any protocol

PURPOSE: The point description

VALID ENTRIES: Functional description of the point.

DESIGNER: Provide this information

BUILDING CONTRACTOR: Provide this information for any additional points needed or where designer did not provide an entry.

UMCS CONTRACTOR: These values should be displayed on a graphic when an operator requests additional details ("Properties") for a point

D-2.1.4 DDC Hardware ID

APPLICABILITY: Any protocol

PURPOSE: The unique identifier used in the documentation for the DDC Hardware containing the point. This is the identifier for the device used across all drawings.
VALID ENTRIES: Unique Identifier from the Equipment Schedule

DESIGNER: None

BUILDING CONTRACTOR: Provide this information

UMCS CONTRACTOR: None, informational only

D-2.1.5 Setting

APPLICABILITY: Any protocol

PURPOSE: This shows all settings related to the point, such as setpoints and configuration parameters. These are values established in the controller by the building control system contractor, either by dip switches, hardware settings, or engineering software such as controller programming or configuration software.

VALID ENTRIES: Typical values are shown in the sample drawings

DESIGNER: Show setpoints and settings, including appropriate engineering units, as required.

BUILDING CONTRACTOR: Use these settings when configuring devices and provide the setting used where the design did not show or specify one.

UMCS CONTRACTOR: None, informational only

D-2.1.6 Range

APPLICABILITY: Any protocol

PURPOSE: Shows the range of values associated with the point. For example, it could be a zone temperature setpoint adjustment range, a sensor measurement range, occupancy values for an occupancy input, or the status of a safety.

VALID ENTRIES: In general, provide values for the following types of points:

- Zone setpoints
- Switch settings
- Occupancy modes

Note that ranges must meet UFGS 23 09 13 (e.g. permissible range of a temperature sensor). For sensors, show the actual sensor range, which must at least encompass the range specified in section 23 09 13. For actuators show the actual range over which the valve or damper is actuated and indicate whether the maximum value corresponds to a more open or more closed damper or valve.

DESIGNER: Provide this information, including engineering units, or use "< >" to indicate that the building control system contractor is to provide this information

BUILDING CONTRACTOR: Use these ranges when configuring devices, and document the ranges used when designer did not provide an entry.

UMCS CONTRACTOR: None

D-2.1.7 I/O Type

APPLICABILITY: Any protocol

PURPOSE: Shows the input/output signal type (if any) associated with the point.

VALID ENTRIES: One or more of:

- AI: The value comes from a hardware (physical) Analog Input
- AO: The value is output as a hardware (physical) Analog Output
- BI: The value comes from a hardware (physical) Binary Input
- BO: The value is output as a hardware (physical) Binary Output
- PULSE: The value comes from a hardware (physical) Pulse Accumulator Input
- NET-IN: The value is provided from the network (generally from another device)
- NET-OUT: The value is provided to another controller over the network

Note that NET-IN and NET-OUT entries are not used for all values that exist on the network, but rather only when the value is specifically input from or output to another device which uses the value as part of its sequence. Network values used only for trending, alarming, overrides or display at a workstation should not use NET-IN or NET-OUT entries. In other words, absence of a "NET-IN" or "NET-OUT" tag does not mean that the point does not need to be exposed on the network, merely that the point is not shared as part of a sequence.

Note that a point might require two entries, for example an AI that is also used by another device ("AI / NET-OUT").

DESIGNER: In some cases, provide this information to meet specific requirements.

BUILDING CONTRACTOR: Provide this information

UMCS CONTRACTOR: None

D-2.1.8 HOA Required

APPLICABILITY: Any protocol

PURPOSE: Indicates which hardware outputs require HOA switches.

VALID ENTRIES: "Y" to require HOA

DESIGNER: Provide this information

BUILDING CONTRACTOR: Provide HOAs as required

UMCS CONTRACTOR: None – unless monitoring of HOA status is required by specification.

D-2.1.9 Config Type (Configuration Type)

APPLICABILITY: Any protocol

PURPOSE: For points requiring configuration, indicate the type of configuration required for the point

VALID ENTRIES:

- H = Hardware (via switches or adjustments directly on the device).
- C = Configurable
- O or OC = Operator Configurable

(where Configurable and Operator Configurable are defined in the specification)

DESIGNER: Provide this information

BUILDING CONTRACTOR: Provide the appropriate configuration capability in accordance with the specification.

UMCS CONTRACTOR: Provide a means for configuration (such as a configuration page on the system graphic) for each point that is "Operator Configurable" in accordance with the integration requirements.

D-2.1.10 M&C View and Ovrd

APPLICABILITY: Any protocol

PURPOSE: This column indicates whether a point is to be displayed on a workstation via Monitoring and Control (M&C) software, and whether the point must be overridable from the M&C display.

VALID ENTRIES:

- V: View. The point must be displayed on the system graphics
- O: Override. The point must be displayed and overridable via the system graphics
- VO: View and Override. The point must be displayed and overridable via the system graphics (functionally equivalent to "O")

DESIGNER: Provide an entry for each row

BUILDING CONTRACTOR: For V, expose the point to the network so it will be visible to the UMCS. For O, or VO, provide both the value on the network and an override for the value in accordance with the specification points and override capability. Note that additional columns providing protocol specific point details will need to be filled out as well.

UMCS CONTRACTOR: For V, display the point on the system graphic. For O, or VO, display the value on the system graphic and provide the capability to override the point using the override capability provided by the Building Contractor.

D-2.1.11 LDP View and Ovrd

APPLICABILITY: Any protocol

PURPOSE: This column indicates whether a point is to be displayed on an LDP, and whether the point must be overridable from the LDP.

VALID ENTRIES:

- V: View. The point must be displayed on the LDP
- O: Override. The point must be displayed and overridable via the LDP
- VO: View and Override. The point must be displayed and overridable via the LDP (functionally equivalent to "O")

DESIGNER: Provide an entry for each row. Note that there may be conflicts if points are overridden from both the M&C software and from an LDP. For Army projects, do not require overrides from both without specific guidance from the UMCS MCX.

BUILDING CONTRACTOR: For V, display the value on the LDP. For O, or VO, both display the value on the LDP and provide the capability to override the point from the LDP. Note that, depending on how the overrides are implemented, a requirement for Overrides from both the M&C Server and an LDP may require additional configuration in the device as well as additional points in the device and multiple entries in the Points Schedule.

UMCS CONTRACTOR: None

D-2.1.12 Trend Required

APPLICABILITY: Any protocol

PURPOSE: Indicate whether the point should be trended

VALID ENTRIES: “Y”

DESIGNER: Provide this information. Note that all trended points should also have a “V” in the M&C View and Override column.

BUILDING CONTRACTOR: For each point with a “Y” set up a trend in accordance with the specification. Note there is no building contractor action required for in an LNS-based LonWorks system.

UMCS CONTRACTOR: For each point with a “Y”, perform the following in accordance with the specification:

> **LNS-based LonWorks**: Set up a trend
>
> **Other:** Provide trend data upload capability
>
> **All:** Provide a M&C Software interface to access the trend information.

D-2.1.13 Alarming: Alarm condition

APPLICABILITY: Any protocol

PURPOSE: Show the conditions under which an alarm occurs, including any time delays.

VALID ENTRIES: The conditions which, when TRUE, will cause an alarm to be generated. See sample drawings for examples.

DESIGNER: Provide this information

BUILDING CONTRACTOR: Perform alarm generation in DDC Hardware in accordance with the specification. Note there is no building contractor action required for in an LNS-based LonWorks system.

UMCS CONTRACTOR:

LNS-based LonWorks: Perform alarm generation in M&C software in accordance with the specification.

Other: None (but note requirements for ALARM PRIORITY and M&C ROUTING columns).

D-2.1.14 Alarming: Alarm priority

APPLICABILITY: Any protocol

PURPOSE: Indicates which alarms are Informational (in alarm until acknowledged or the condition clears itself) and which are Critical (in alarm until acknowledged and the condition clears itself).

VALID ENTRIES: INFO or CRIT

DESIGNER: Provide this information

BUILDING CONTRACTOR: Configure hardware to assign this priority as part of alarm generation. Note there is no building contractor action required for in an LNS-based LonWorks system.

UMCS CONTRACTOR:

LNS-based LonWorks: Configure M&C Software to assign this priority as part of alarm generation.

All: Take appropriate action at M&C Software based on incoming alarm priority.

D-2.1.15 Alarming: M&C routing

APPLICABILITY: Any protocol

PURPOSE: Show the name of the alarm routing group that is to be used for each alarm to be handled by the UMCS. The routing group defines the destinations for each alarm message and, as specified in UMCS UFGS 25 10 10, each group requires some combination of a pop-up message for a user session, an email to one or more individuals, email to SMS for one or more individuals, or printing to one or more printers.

VALID ENTRIES: Name of a valid alarm routing group as defined on UMCS Contract Drawing.

DESIGNER: Provide this information where integration to a UMCS is planned and the alarm routing groups are known. Otherwise, enter "[___]" indicating that this information will be provided as part of integration.

BUILDING CONTRACTOR: None

UMCS CONTRACTOR: Provide alarm routing in accordance with the routing definition for that alarm routing group.

D-2.2 Protocol-Specific Columns

D-2.2.1 Primary Point Information: Object Type & Instance Number

APPLICABILITY: BACnet, Niagara BACnet

PURPOSE: Document the BACnet Object used for the point, if any. Any point (except for points only used within Niagara Framework) that is displayed at the front end, displayed on an LDP, is trended, is used by another device on the network, or has an alarm condition must have a BACnet Object associated with it and be documented here.

If the Property of interest is not Present_Value, also document the Property that contains the value (for example, a LOOP Object may use the Setpoint Property). In that case, add the Property Identifier after the Object Type / Instance Number.

VALID ENTRIES: BACnet Object Type and Object Instance Number (e.g. AO-8). Typical Object Types are:

- Analog Input (AI)
- Analog Value (AV)
- Analog Output (AO)
- Binary Input (BI)
- Binary Value (BV)
- Binary Output (BO)
- Multi-state Value (MSV)
- Loop (LOOP)

This is not a complete list of Object Types which may be used. In many cases, the specification and sample drawings require specific points use specific Object Types.

DESIGNER: None

BUILDING CONTRACTOR: Provide this entry.

UMCS CONTRACTOR: Use this information when accessing the point over the network.

D-2.2.2 Primary Point Information: SNVT Name

APPLICABILITY: LNS, Niagara LonWorks

PURPOSE: Document the name of the SNVT used for the point. Any point (except for points only used within Niagara Framework) that is displayed at the front end, displayed on an LDP, is trended, is used by another device on the network, or has an alarm condition must be documented here.

VALID ENTRIES: SNVT Name used by the point.

DESIGNER: None

BUILDING CONTRACTOR: Provide this entry.

UMCS CONTRACTOR: Use this SNVT Name when accessing the point over the network.

D-2.2.3 Primary Point Information: SNVT Type

APPLICABILITY: LNS, Niagara LonWorks

PURPOSE: For any point with an entry in the SNVT Name column, document the SNVT Type used for the point.

VALID ENTRIES: Allowed SNVT Types are generally defined in the specification or on the sample drawings.

DESIGNER: If requiring a specific SNVT Type indicate the Type here.

BUILDING CONTRACTOR: When a SNVT Type is shown, provide a SNVT of the indicated type for the point. Otherwise provide this entry.

UMCS CONTRACTOR: Use this SNVT Type when accessing the point over the network

D-2.2.4 Primary Point Information: Niagara ID

APPLICABILITY: Niagara BACnet, Niagara LonWorks

PURPOSE: List the Niagara station ID of the Niagara Framework Supervisory Gateway that the point is mapped into.

VALID ENTRIES: Valid Niagara Station IDs

DESIGNER: None

BUILDING CONTRACTOR: Provide this information

UMCS CONTRACTOR: Use this information when obtaining data from the control system.

D-2.2.5 Network Data Exchange: Gets Data From and Sends Data To

APPLICABILITY: BACnet, Niagara BACnet

PURPOSE: Document other BACnet devices that this point is shared with. This specifically is for <NET-IN> and <NET-OUT> points, but may include other points as well. Do not include the front end as a possible device, but do include all other DDC Hardware such as LDPs that view or override the point.

BACnet provides multiple methods for data to be exchanged between devices.

Any point with a value that is obtained from other DDC Hardware, regardless of method used, must have an entry in the Gets Data From column. Likewise, any point with data that is provided to other DDC Hardware, regardless of method used, must have an entry in the Sends Data To column.

VALID ENTRIES: DDC Hardware IDs of devices obtaining or providing information with the point. Examples are given below in Points Schedule Application Notes.

DESIGNER: None

BUILDING CONTRACTOR: Provide this entry.

UMCS CONTRACTOR: None.

D-2.2.6 Overrides: Object Type and Instance Number

APPLICABILITY: BACnet, Niagara BACnet

PURPOSE: For any point (except for points within a Niagara Framework Supervisory Gateway) requiring an override, document the Object used for overriding the point

VALID ENTRIES:

- “Commandable”: Indicates that the point’s Object is Commandable (Overridable via use of the Priority Array)
- Object Type and Instance Number: If the point is not Commandable, specify the (other) Object, that when written to, will override the point.

DESIGNER: None

BUILDING CONTRACTOR: Provide this entry.

UMCS CONTRACTOR: Use this information / Object ID when overriding the point over the network.

D-2.2.7 Overrides: SNVT Name

APPLICABILITY: LNS, Niagara LonWorks

PURPOSE: For any point (except for points within a Niagara Framework Supervisory Gateway) requiring an override, document the SNVT used for overriding the point

VALID ENTRIES: SNVT Name of point, that when written to, will override the point

DESIGNER: None

BUILDING CONTRACTOR: Provide this entry.

UMCS CONTRACTOR: Use this SNVT Name when overriding the point over the network.

D-2.2.8 Overrides: SNVT Type

APPLICABILITY: LNS, Niagara LonWorks

PURPOSE: For any point with an entry in the Overrides: SNVT Name column, document the SNVT Type used for overriding the point

VALID ENTRIES: SNVT Type used for overriding the point. Note that UFGS 23 09 23.01 has requirements regarding this SNVT type.

DESIGNER: None

BUILDING CONTRACTOR: Provide this entry.

UMCS CONTRACTOR: Use this SNVT Type when overriding the point over the network.

D-2.2.9 Trend Object Location, Type and Instance Number

APPLICABILITY: BACnet

PURPOSE: Indicates the Object ID of the Trend Log Object and whether the Object is local or remote to the device containing the point.

VALID ENTRIES: "~" when no trend was required, otherwise an "L" or "R" and the Object Type and Instance number for the Trend Log (or Trend Log Multiple) Object. Use "L" (Local) when the Object is in the same device as the point and an "R" (Remote) when it's in a different device.

DESIGNER: None.

BUILDING CONTRACTOR: Provide this information. If the Trend is Remote, include the DDC Hardware ID for the remote device in the Notes. Configure TrendLog Object and configure BUFFER_FULL event to request trend upload.

UMCS CONTRACTOR: Provide on-request (via BUFFER_FULL Event) uploading of trend data from this Object.

D-2.2.10 Alarm Information: Alarm Type

APPLICABILITY: BACnet, Niagara BACnet

PURPOSE: Indicates how alarm generation is performed.

VALID ENTRIES:

- “Intrinsic”: Alarm is generated using Intrinsic Reporting
- “Local Algorithmic”: Alarm is generated using Algorithmic Reporting with an Event Enrollment Object in that device
- “Remote Algorithmic”: Alarm is generated using Algorithmic Reporting with an Event Enrollment Object in a different device
- “Niagara Framework”: Alarm is generated using the Niagara Framework

Note that “Niagara Framework” is only allowed if the Niagara Framework is used by the project. Note that “Local Algorithmic” and “Remote Algorithmic” are prohibited if the Niagara Framework is selected.

DESIGNER: None

BUILDING CONTRACTOR: Provide this information. When “Local Algorithmic” or “Remote Algorithmic” fill out the Event Enrollment Object Instance Number column as well. If “Remote Algorithmic” is used, indicate the DDC Hardware ID of the device containing the Event Enrollment Object in the Notes.

UMCS CONTRACTOR: None

D-2.2.11 Alarm Information: Notification Class Object Instance Number

APPLICABILITY: BACnet, Niagara BACnet

PURPOSE: For Intrinsic and Algorithmic alarms, indicates the Notification Class Object used for alarm generation.

VALID ENTRIES: Notification Class Object Instance Number

DESIGNER: None

BUILDING CONTRACTOR: Provide as required.

UMCS CONTRACTOR: Use the Notification Class Object when configuring alarm notifications at the Front End.

D-2.2.12 Alarm Information: Event Enrollment Object Instance Number

APPLICABILITY: BACnet

PURPOSE: Indicates the Event Enrollment Object used for algorithmic alarm generation

VALID ENTRIES: Event Enrollment Object Instance Number.

DESIGNER: None

BUILDING CONTRACTOR: Provide as required.

UMCS CONTRACTOR: None

D-2.3 Configuration Information

APPLICABILITY: Any protocol

PURPOSE: Indicate the means of configuration associated with the point

VALID ENTRIES: The valid entries depend on the configuration requirements for the point:

BACnet:

- Operator Configurable Points: BACnet Object and Property information (Name, Type, Identifiers) containing the configurable value. Indicate whether the property is writable always, or only when Out_Of_Service is TRUE.
- Configurable Points: Indicate one of:
  - BACnet Object and Property information as for Operator Configurable points.
  - The configurable settings from within the engineering software for the device
  - The hardware settings on the device

LonWorks:

Indicate one of:

- “Plug-In” if the point is configurable via an LNS plug-in or Niagara Wizard.

- The network variable or configuration property used to configure the value.
- The hardware settings on the device.

Niagara Framework Supervisory Gateways:

Indicate the point within the Niagara Framework Supervisory Gateway used to configure the value.

DESIGNER: None.

BUILDING CONTRACTOR: Provide this information.

UMCS CONTRACTOR: Use this information when providing configuration screens for Operator Configurable points.

D-2.4 Point Schedule Application Notes

D-2.4.1 Use of BACnet "Gets Data From" and "Sends Data To" Columns

Example 1:

- DDC #1 is the controller for a VAV Air Handler.
- DDC #2 is a Smart Sensor reading the supply air pressure (SA-P)
- There is both an AI Object in DDC #2 for Supply Air Pressure, and an AV Object in the AHU controller (DDC #1) for this value. Note that UFGS 23 09 23.02 requires the use of either the AI Object in the sensor or the AV object in the AHU, it does not require the presence of both Objects.
- The relevant entries are highlighted (cells are filled, text is bolded) in the following Points Schedule excerpt:

POINT NAME	DDC HARDWARE ID	IO Type	OBJECT TYPE AND INSTANCE NUMBER (AND PROPERTY ID)	DATA FROM	DATA TO
SF-C	DDC #1	AO	AO 2		
SA-P-SP	DDC #1	~	AV 8		
SA-P	**DDC #2**	**AI, NET-OUT**	**AI 3**		**DDC #1**
SA-P	**DDC #1**	**NET-IN**	**AV 9**	**DDC #2**	

Example 2:

- DDC #1 is the controller for a VAV Air Handler.
- DDC #2 is a Smart Sensor reading the supply air pressure (SA-P)
- There is an AI Object in DDC #2 but there is no BACnet Object in DDC #1 for

supply air pressure.

- The appropriate entries are highlighted (cells are filled, text is bolded) in the following Points Schedule excerpt:

POINT NAME	DDC HARDWARE ID	IO Type	OBJECT TYPE AND INSTANCE NUMBER (AND PROPERTY ID)	DATA FROM	DATA TO
SF-C	DDC #1	AO	AO 2		
SA-P-SP	DDC #1	~	AV 8		
SA-P	**DDC #2**	**AI, NET-OUT**	**AI 3**		**DDC #1**

Example 3:

- DDC #1 is the controller for a VAV Air Handler.
- DDC #2 is a Smart Sensor reading the supply air pressure (SA-P)
- There is NOT an AI Object in DDC #2 for Supply Air Pressure, but there is an AV Object in the AHU controller (DDC #1) for this value.
- The appropriate entries are highlighted (cells are filled, text is bolded) in the following Points Schedule excerpt:

POINT NAME	DDC HARDWARE ID	IO Type	OBJECT TYPE AND INSTANCE NUMBER (AND PROPERTY ID)	DATA FROM	DATA TO
SF-C	DDC #1	AO	AO 2		
SA-P-SP	DDC #1	~	AV 8		
SA-P	**DDC #1**	**NET-IN**	**AV 9**	**DDC #2**	

APPENDIX E POINT NAMING CONVENTION

E-1 POINT SCHEDULE APPLICATION NOTES.

This appendix defines a point naming convention consisting of abbreviations and acronyms (W-X-Y-Z and ##) that describe the device or signal. Note that a signal can be a hardwired input or output to or from a device as shown in a control schematic or can be a logical constant or variable as shown in a control logic diagram:

- W - Device descriptor; Describes the device, physical location of the device, source of the signal, destination of the signal, or the apparatus/function being controlled. In some cases, a two-part device descriptor is used. For example, MA-FLT is used to describe the mixed air filter.

- X - Measured variable or controlled device; In the case of a sensor or measurement instrument, it is temperature (T), relative humidity (RH), pressure (P), etc. In the case of an output, it can describe the actuated device such as a valve (V) or damper (D).

- Y - Modifier; In some cases, a modifier is required, such as indicating that a signal is a low-limit (LL) or high-limit (HL) input. Alternatively, the modifier may be used to describe the type of control signal such as a modulating command (C), start/stop (SS), enable (ENA), or disable (DIS) signal.

- Z - In some cases, an additional modifier is required, such as indicating that a signal is a setpoint (SP).

- Device or signal number; When there are multiple identical control devices or signals, sequential numbering is used to avoid duplicate unique identifiers. All DDC controllers are numbered (by the Contractor), even if there is only one. The intent is to be able to show a single (common) DDC controller multiple times on a drawing. This can help simplify the control drawings by showing fewer signal lines connected to several DDC controllers instead of showing numerous signal lines connect to a single DDC controller. It also provides leeway to the Contractor to use multiple controllers where project application requirements dictate the need.

E-2 DEVICE DESCRIPTORS.

The following are typical device descriptors (W):

Table E-1 Typical Device Descriptors

Name	Description	Comment
BA	BYPASS AIR	
BLR	BOILER	

Name	Description	Comment
CD	COLD DECK	
CF	CONDENSER FAN	
CHLR	CHILLER	
CLG	COOLING	
CDWR	CONDENSER WATER RETURN	
CDWR	CONDENSATE WATER RETURN	
CDWS	CONDENSER WATER SUPPLY	
CT	COOLING TOWER	
CTF	COOLING TOWER FAN	
CHWR	CHILLED WATER RETURN	
CHWS	CHILLED WATER SUPPLY	
CHW	CHILLED WATER	
DA	DISCHARGE AIR	
DT	DUAL TEMP	
DTWR	DUAL TEMP WATER RETURN	
DTWS	DUAL TEMP WATER SUPPLY	
DX	DIRECT EXPANSION (UNIT)	
EA	EXHAUST AIR	
EF	EXHAUST FAN	

Name	Description	Comment
FAP	FIRE ALARM PANEL	
HD	HOT DECK	
HTG	HEATING	
HTHW	HIGH TEMPERATURE HOT WATER	
HUM	HUMIDIFIER	
HW	HOT WATER	
HWR	HOT WATER RETURN	
HWS	HOT WATER SUPPLY	
HX	HEAT EXCHANGER	
MA	MIXED AIR	
MINOA	MINIMUM OUTSIDE AIR	
OA	OUTSIDE AIR	
PC	PRE-COOLING	
PCHW	PRIMARY CHILLED WATER	
PCHWR	PRIMARY CHILLED WATER RETURN	
PCHWS	PRIMARY CHILLED WATER SUPPLY	
PH	PREHEAT	
PRI	PRIMARY	To distinguish from Secondary
RA	RETURN AIR	
RF	RETURN FAN	
RLA	RELIEF AIR	

Name	Description	Comment
RM	ROOM	Generally, use Zone instead
SA	SUPPLY AIR	
SEC	SECONDARY	To distinguish from Primary
SF	SUPPLY FAN	
STM	STEAM	
SCHD	SCHEDULER	
ZN	ZONE	May use Room instead

E-3 TYPICAL VARIABLES OR CONTROLLED DEVICES.

The following are typical measured variables or controlled devices (X):

Table E-2 Typical Measured Variables or Controller Devices

Name	Description
CO2	CARBON DIOXIDE
D	DAMPER
ECO	ECONOMIZER
F	FLOW
FLT	FILTER
P	PRESSURE
PMP	PUMP
RH	RELATIVE HUMIDITY
SMK	SMOKE
T	TEMPERATURE
V	VALVE

WB	WET BULB (TEMPERATURE)

E-4 TYPICAL MODIFIERS.

The following are typical modifiers (Y and Z):

Table E-3 Typical Modifiers

Name	Description	Comment
2P	TWO-POSITION	Indicates a 2-position output
ADJ	ADJUSTABLE	Indicates a value is to be adjustable
ALM	ALARM	Indicates an alarm annunciation point
C	COMMAND	Indicates an analog output
DB	DEADBAND	
DIFF	DIFFERENCE	
DIS	DISABLE	
ENA	ENABLE	
HL	HIGH LIMIT	
LL	LOW LIMIT	
OCC	OCCUPIED	
RQST	REQUEST	
RTN	RETURN	
S	STATUS	
SPLY	SUPPLY	
SP	SETPOINT	

Name	Description	Comment
SS	START/STOP COMMAND	
SYS	SYSTEM	
UNOCC	UNOCCUPIED	

E-5 EXAMPLE POINT NAMES.

For example, here are the standard point names used in the Points Schedule for VAV AHU with Return Fan:

Table E-4 Example Point Names

Name	Description
MINOA-F	MINIMUM OUTSIDE AIR FLOW
MINOA-D-C	MINIMUM OUTSIDE AIR DAMPER COMMAND
MINOA-F-SP	MINIMUM OUTSIDE AIR FLOW SETPOINT (SETTING)
OA-T	OUTSIDE AIR TEMPERATURE
MA-T	MIXED AIR TEMPERATURE
MA-D-C	MIXED AIR DAMPER COMMAND
ECO-HL-SP	ECONOMIZER HIGH LIMIT SETPOINT
ECO-LL-SP	ECONOMIZER LOW LIMIT SETPOINT
MA-T-SP	MIXED AIR TEMPERATURE SETPOINT
SA-T	SUPPLY AIR TEMPERATURE
CLG-V-C	COOLING VALVE COMMAND
SA-T-SP	SUPPLY AIR TEMPERATURE SETPOINT
RA-T	RETURN AIR TEMPERATURE

Name	Description
MA-FLT-P-HL	MIXED AIR FILTER PRESSURE HIGH LIMIT SWITCH
OA-FLT-P	OUTSIDE AIR FILTER PRESSURE
OA-FLT-P-LL	OUTSIDE AIR FILTER PRESSURE LOW LIMIT
SF-S	SUPPLY FAN STATUS
RF-S	RETURN FAN STATUS
SA-SMK	SUPPLY AIR SMOKE
RA-SMK	RETURN AIR SMOKE
CLG-DA-T-LL	COOLING COIL DISCHARGE AIR TEMP LOW LIMIT
SA-P-HL	SUPPLY AIR PRESSURE HIGH LIMIT
RST-BUT	SYSTEM RESET BUTTON (FOR SAFETIES)
SYS-OCC-SCHED	SYSTEM OCCUPANCY SCHEDULE
UNIT STATUS	UNIT STATUS (HTG AND/OR CLG REQUEST) (SEE NOTES)
SYS-OCC-C	OCCUPANCY COMMAND
SYS-OCC	SYSTEM OCCUPANCY (ACTUAL)
SF-SS	SUPPLY FAN START/STOP
RF-SS	RETURN FAN START/STOP
BLDG-T	BUILDING TEMPERATURE (NIGHT STAT)
BLDG-T-LL	BUILDING TEMPERATURE LOW LIMIT
SF-C	SUPPLY FAN COMMAND
SA-P	SUPPLY AIR PRESSURE
SA-P-SP	SUPPLY AIR PRESSURE SETPOINT

Name	Description
SA-F	SUPPLY AIR FLOW
RA-F	RETURN AIR FLOW
RF-C	RETURN FAN COMMAND
F-DIFF-SP	FLOW DIFFERENCE SETPOINT

E-6 OTHER ABBREVIATIONS.

Other Abbreviations that are often encountered in HVAC controls, but would not normally appear in a Point Name in a Point Schedule are:

Table E-5 Other Abbreviations

Name	Description	Comment
AFMA	AIRFLOW MEASUREMENT ARRAY	
BLDG	BUILDING	
BUT	BUTTON	
COM	COMMON	
COMP	COMPARATOR	
COMP	COMPRESSOR	
CP	CONFIGURATION PROPERTY	
CSR	CURRENT SENSING RELAY	
DDC	DIRECT DIGITAL CONTROL(LER)	
DIR	DIRECT (CONTROL ACTION)	
DISP	DISPLAY	
EP	ELECTRIC TO PNEUMATIC TRANSDUCER	
EPS	ELECTRIC TO PNEUMATIC SWITCH	
I/O	INPUT/OUTPUT	

Name	Description	Comment
IR	INFRARED	
LDP	LOCAL DISPLAY PANEL	
M	MOTOR or MAIN	
M&C	MONITORING & CONTROL (SOFTWARE)	
MS	MOTOR STARTER	
N/A	NOT APPLICABLE	
NC	NORMALLY CLOSED	
nci	NETWORK CONFIGURATION INPUT	
NO	NORMALLY OPEN	
ODT	ON DELAY TIMER	
OL	OVERLOAD	
OWS	OPERATOR WORKSTATION	
PID	PROPORTIONAL INTEGRAL DERIVATIVE	
PP	POSITIVE POSITIONER	For pneumatic actuators
R	RELAY	
REV	REVERSE (CONTROL ACTION)	
RST	RESET	
RT	RATE	
SNVT	STANDARD NETWORK VARIABLE TYPE	
STAT	THERMOSTAT	
TAP	TAP, PRESSURE	
VAV	VARIABLE AIR VOLUME	
VFD	VARIABLE FREQUENCY DRIVE	

Name	Description	Comment
XFMR	TRANSFORMER	

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APPENDIX F CONTROL LOGIC DIAGRAM (CLD) OVERVIEW

F-1 INTRODUCTION

The control logic diagram (CLD) is an unambiguous graphical description of the control system sequence of operation. The focus of the CLD is on control logic, not on a particular hardware implementation. In particular, the CLD does not distinguish between normally open or normally closed contacts, valves, or dampers; these details should instead be indicated on the appropriate wiring diagram, valve/damper schedule, or control schematic drawing. The CLD is concerned with whether a given signal is TRUE or FALSE.

For example, a typical sequence calls for a 'fan status' input (to be used in a fan-proof logic block). The actual hardware could be implemented in a variety of ways, -- a current-sensing-relay on the fan motor, a DP switch across the fan, or an air flow proof switch. The actual hardware used is irrelevant to the CLD. Any one of these possible hardware devices would be shown as a simple binary input to the sequence. Another example would be the freeze stat (CooLinG-Discharge-Air-Temp-LowLimit; CLG-DA-T-LL) which is TRUE when the freeze stat trips; whether that's from a set of NO or NC contacts is a detail for the wiring diagram. Finally, the Controller hardware implementation is not shown; while a given functional block is probably implemented in one controller, a build-up system (such as a RF VAV system with MA Economizer and Ventilation Demand control) may be in one or more controllers – the CLD does not make that distinction.

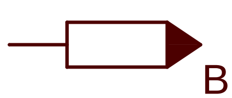
F-2 FUNCTIONAL BLOCKS USED IN CONTROL LOGIC DIAGRAMS.

In the following descriptions, logical values are always referred to as TRUE or FALSE. Synonyms for these names include ON and OFF, as well as 1 and 0.

F-2.1 Signal.

A line represents a signal path within the logic, either analog or binary. This line shows signal inputs and/or outputs to and from functional blocks.

F-2.2 Actuator Output.



2-Position Actuator Output

Modulating Actuator Output

This block represent a physical output from the system, an actuator or valve. It accepts a binary (B) or analog (A) signal and drives a piece of hardware. Since the CLD shows the control logic without reference to the hardware implementation, the actual hardware is unspecified.

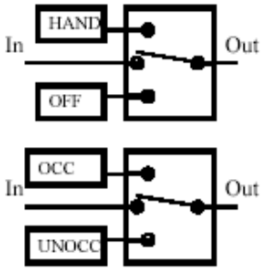
F-2.3 Sensor Input.

Binary Sensor Input

Analog Sensor Input

This block represents a hardware sensor input to the system. It may provide either an analog (A) or binary (B) signal. Again, the exact hardware type is unspecified.

F-2.4 Hand-Off-Auto (H-O-A) Switch.



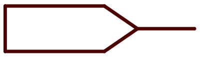
H-O-A Switch

This represents a HAND-OFF-AUTO switch. Sometimes, a H-O-A switch will be shown differently; for example where the position of the H-O-A switch would select some input to control logic. This block is generally used when the output of a control block is selected. The top block shows a normal H-O-A switch, the bottom shows a variant where the manually selected values are OCCUPIED or UNOCCUPIED.

F-2.5 Constant Value.

This logic block represents a constant value, either analog or binary and is usually provided as an input to another logic block.

F-2.6 Signal I/O.



Signal Input

Signal Output

These blocks represent a named signal path within the logic. These are functionally identical to the symbols described earlier, except that this signal is given a name, which allows it to be defined or used elsewhere in the logic.

F-2.7 Logical AND.

Logical AND Function

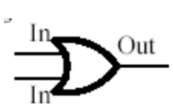
This logic block represents the logical AND function. It takes two or more binary inputs and produces a binary output. Its output is TRUE if and only if all of its inputs are TRUE. If any of its inputs are FALSE, then its output is FALSE.

F-2.8 Logical NOT.

Logical NOT Function

This logic block represents the logical NOT function. It has one binary input and one binary output. Its output is TRUE if and only if its input is FALSE. If its input is TRUE, its output is FALSE.

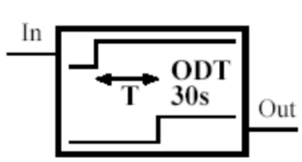
F-2.9 Logical OR.



Logical OR Function

This logic block represents the logical OR function. It has two or more binary inputs and one binary output. Its output is TRUE if any of the inputs are true. If all the inputs are FALSE, the output is FALSE.

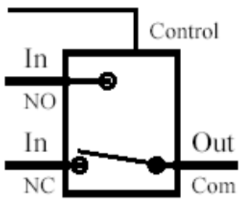
F-2.10 On Delay Timer.



On Delay Timer

This logic block represents an On Delay Timer. It has one binary input and one binary output. In addition it has one parameter, a time (T) value. The output is always equal to the input, except when the input changes value from FALSE to TRUE. In this case, the transition of the output from FALSE to TRUE is delayed by the value of the time parameter. This time value has no effect on the transition from TRUE to FALSE, it only affects the output when the input becomes TRUE.

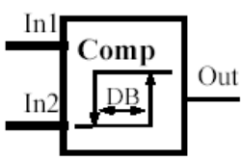
F-2.11 Switch.



Switch

This block represents an analog switch with 2 analog inputs, one analog output, and a binary control input. When the control input is false, the output is the value of the analog signal at the Normally Closed (NC) input. When the control input is true, the output is the value of the analog signal at the NO (Normally Open) input. Note that this convention for NC and NO follows the electrical switch convention; it is opposite from that used for pneumatic switches.

F-2.12 Comparator with Deadband.



Comparator with Deadband

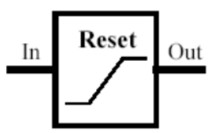
This logic block represents a comparator function with hysteresis. It takes two analog inputs and produces a binary output. It also has one parameter, deadband (DB). As shown in Comparator Table below the output value only changes if the difference between the inputs exceeds half the deadband, if the difference in inputs is less than half the deadband, the output remains at its present value.

Comparator Input and Corresponding Output

Input Conditions	Output Value
(*In1*–*In2*) < -*deadband*/2	FALSE
-*deadband*/2 ≤ (*In1*–*In2*) ≤ *deadband*/2	Output does not change; remains fixed
(*In1*–*In2*) > +*deadband*/2	TRUE

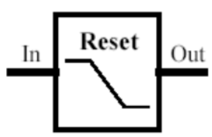
For example, if *In1*=75, *In2*=68 and the *deadband*=4, the output would be TRUE. As *In1* fell, the output would remain TRUE until *In1* went below 66 (68–66=4/2). Essentially, the output of this block is TRUE if the top value is greater than the bottom value and FALSE if the bottom value is greater than the top value (neglecting the deadband).

F-2.13 Reset Schedule.



Reset Schedule

(output increases as input increases)

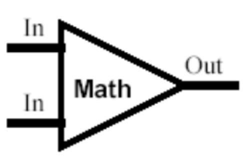


Reset Schedule

(output decreases as input increases)

This block represents a reset schedule. It has one analog input, one analog output, and 4 parameters: InputMin, InputMax, OutputMin, and OutputMax. For the first reset schedule shown, the output increases as the input increases; as the input ranges from InputMin to InputMax, the output varies linearly from OutputMin to OutputMax. Inputs below InputMin or above InputMax result in the output going to OutputMin or OutputMax, respectively. For the second reset schedule shown, the output decreases as the input increases. The reset schedule block can be thought of as a graph, with the input variable on the X-axis and the output variable on the Y-axis.

F-2.14 Math Function.



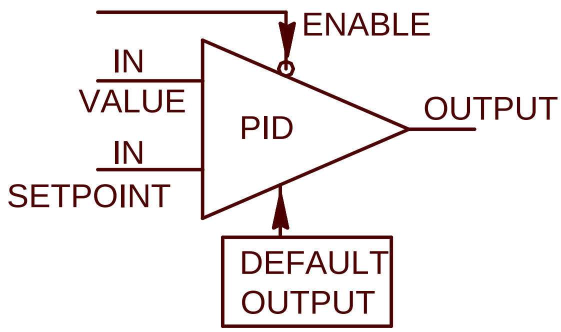
Math Function

This logic block represents a variety of mathematical functions. It takes two or more analog inputs and produces an analog output. Some common functions for this block are shown in the table below.

Common Math Block Functions

Name	Function
Minus	Subtraction
Minimum	Select the minimum value from the input values
Maximum	Select the maximum value from the input values
Plus	Addition

F-2.15 PID Loop with Enable.



This function block represents a proportional-integral-derivative (PID) loop with an Enable input. It has 2 analog inputs (a value and a setpoint), an analog output, a binary enable input, and default output. The DEFAULT OUTPUT is the OUTPUT when the ENABLE is false.

F-2.16 IF Block.

The IF Block is TRUE if the input meets the condition inside the block, otherwise the IF Block’s output is FALSE.

F-2.17 Set/Reset Latch.

This function block represents a latch. The latch has 2 binary inputs, a set input and a reset input, as well as a single binary output. Once set (by a TRUE value at the Set input), the latch's output remains TRUE until reset (by a TRUE value at the reset input). Likewise, once reset, the output remains FALSE until set by a TRUE value at the set input. Essentially, the latch remembers whether it was last Set or Reset.

UFC 3-410-04
13 December 2017

UNIFIED FACILITIES CRITERIA (UFC)

INDUSTRIAL VENTILATION

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

INDUSTRIAL VENTILATION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **\1** ... **/1/**)

Change No.	Date	Location

This UFC supersedes UFC 3-410-04N, *Industrial Ventilation, dated* 21 October 2004.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force \2\ Civil Engineer Center (AFCEC) /2/ are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 3-410-04, *Industrial Ventilation, 13 December 2017*
Superseding: UFC 3-410-04N, *Industrial Ventilation, 21 October 2004*

Description: This UFC provides criteria for the design of ventilation systems that control contaminants generated from industrial processes.

Reasons for Document: This is a new Joint Service document. This new document represents another step in the Joint Services effort to bring uniformity to the planning, design and construction of military facilities. This UFC was developed to provide design requirements to accomplish the following:

- Assist designers in understanding the system requirements for ventilation systems.
- Provide architects, engineers, and construction surveillance personnel with the essential, minimum requirements for the design of ventilation systems that control contaminants generated from industrial processes.
- Clarify the operational intent of the system design.

Impact: The following will result from the publication of this UFC:

- This UFC creates a single source for common DoD industrial ventilation system criteria and an accurate reference to individual Service-specific documents.
- This UFC facilitates updates and revisions and promotes agreement and uniformity of design and construction between the Services.

Non-Unification Issues: The following are issues that remain non-unified and the reasoning for each:

- Section 2-1 identifies different safety standards for each Service. These standards are operational in nature and have not been unified.

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TABLES

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CHAPTER 1 INTRODUCTION

1-1 SCOPE.

This Unified Facilities Criteria (UFC) provides criteria for the design of ventilation systems that control contaminants generated from industrial processes.

1-2 PURPOSE OF CRITERIA.

Criteria are developed to define requirements during the design of industrial ventilation systems. Chapter 2 provides general criteria and Chapters 3 through 10 provide criteria for specific processes. Use the general criteria presented in Chapter 2 along with the applicable specific criteria presented in Chapters 3 through 10 to design the ventilation system. For all other ventilation applications, use the criteria in Chapter 2.

Criteria contained in this UFC should be interpreted as the minimum required and should be improved where current technology or situation warrants. Users of this UFC are advised to consult the most current edition of the standards.

This UFC does not incorporate individual state and local environmental requirements. It is the sole responsibility of the cognizant design personnel to design an industrial ventilation system that complies with state and local environmental requirements. It is also the responsibility of the cognizant design personnel to design an industrial ventilation system that is energy efficient.

1-3 SPECIFIC PROCESSES.

The specific processes addressed in this UFC are asbestos delagging, torpedo refurbishing (Otto Fuel II), composites fabrication and repair, abrasive blasting, woodworking, battery maintenance, and paint spray booths. Requirements for aircraft corrosion control facilities are located in UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*.

1-4 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design and construction of DoD facilities worldwide. Where conflicts in requirements appear between sections of any mechanical UFC or applicable codes or laws, the most restrictive requirement will govern.

1-5 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-6 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy

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CHAPTER 2 GENERAL REQUIREMENTS

2-1 GENERAL CRITERIA.

Installing engineering controls is the preferred method of controlling hazardous processes as specified in 29 CFR 1910.1000(e), *Air Contaminants* and OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual*, AFOSHSTD 91-501 Air Force Consolidated Occupational Safety standard, and EM 385-1-1 *USACE Safety and Health Requirements Manual*. Properly designed industrial ventilation systems are the most common form of engineering controls.

2-2 COORDINATION.

Form a project design team to direct the design of industrial ventilation projects. Include in the design team representatives from:

- Affected industrial shop.
- Public Works or Base Civil Engineer.
- Health and Safety Office.
- Cognizant Regional Engineering Office (REO) (for example: Navy Facility Engineering Command, Army Corps of Engineers District, and Air Force major command engineering office). The REO representative establishes a design team and acts as the team leader in all cases, except when the cognizant REO grants a variance.
- Industrial Hygiene (IH) Offices.

NOTE U.S. NAVY: BUMED or activity IH. Use Navy and Marine Corps Public Health Center as a back-up.

- Systems or major command program manager (where applicable).
- System safety engineer.
- Environmental manager.

2-3 DESIGN PROCEDURE.

Refer to the ACGIH, *Industrial Ventilation; A Manual of Recommended Practice for Design (IV Design Manual)*, Chapter 9, “Local Exhaust Ventilation System Design Calculation Procedures” for system design calculations. In addition, design all industrial ventilation systems in accordance with Steps 1-9 in the paragraphs below.

2-3.1 Step 1.

Identify all significant contaminant sources that require ventilation control. Request the local industrial hygiene office to provide a source characterization with area diagrams of the contaminant sources, and employee work areas. Also, consider how the system being designed might affect the performance of any existing processes, industrial ventilation systems or HVAC systems.

2-3.2 Step 2.

Coordinate with permitting agencies to determine specific permitting requirements. Also determine documentation and system monitoring requirements.

2-3.3 Step 3.

Consider how the facility is to be used or expanded in the future. It may be possible to initially specify fans that are capable of handling future needs at minimal increased cost.

2-3.4 Step 4.

Select or design the exhaust hood that best suits the work piece or operation. Design the exhaust hood to enclose the work piece or operation as much as possible. This will reduce the ventilation rates required to provide contaminant control. This UFC provides optimum exhaust hood designs for many of the operations covered.

2-3.5 Step 5.

Determine the capture velocity required to control generated contaminants. Capture velocities in this UFC are specified assuming there are no cross drafts or turbulence that adversely affects the capture efficiency. Reduce potential for cross drafts or turbulence near a given exhaust hood by properly locating and designing the hood with baffles, and also by designing the replacement air system to complement the exhaust system. Pay close attention to how air diffuses into the room near the local exhaust ventilation system.

2-3.6 Step 6.

Determine the exhaust volumetric flow, in cubic feet per minute (cfm) [cubic meters per second (m^3/s)], required to maintain the capture velocity determined in previous step.

2-3.7 Step 7.

Create a line drawing of the proposed system. Include plan and elevation dimensions, fan location and air cleaning device location. Identify each hood, branch duct and main duct sections.

2-3.8 Step 8.

Size ductwork using the balance by design or the blast gate method. Maintain the required minimum transport velocity throughout the system.

2-3.9 Step 9.

Determine requirements for replacement air. Based on the process, determine if the room must be slightly negative or neutral pressure with respect to the surrounding area. The surrounding area can be either outside the building envelope or an adjacent room or hallway. Determine if tempered replacement air is needed.

2-4 DESIGN CRITERIA.

Several design criteria are common to all industrial ventilation systems; use the ACGIH IV Design Manual and this document for primary guidance. If conflicts exist, this UFC takes precedence. See the following paragraphs in Chapter 2 for general requirements, plus Chapters 3 through 9 for design requirements on specific types of facilities. Incorporate the guidelines provided in UFC 1-200-02, *High Performance and Sustainable Building Requirements*, for system design and equipment selection.

2-4.1 Ductwork.

In addition to the recommendations of the *ACGIH IV Design Manual* and requirements of NFPA 91 section on Duct Materials and Construction, consider the following when designing a ventilation system.

a. Specify duct gage, reinforcement schedule and hanger design and spacing, in accordance with SMACNA RIDCS, *Round Industrial Duct Construction Standards* for round duct and SMACNA RTIDCS, *Rectangular Duct Construction Standards* for rectangular duct.

b. Install clean-out doors in ductwork that conveys particulate material such as wood dust or blasting grit. Mount clean-out doors on top half of horizontal runs near elbows, junctions, and vertical runs.

2-4.2 Fans.

2-4.2.1 Selection.

Except where specified below, fan selection criteria for replacement air fans and exhaust air fans are identical.

a. Select exhaust system industrial fans that meet design pressure and volume flow rate requirements and have the AMCA-certified performance seal. The design pressure requirement must account for any system effects caused by non-uniform airflow into or out of the fan. See AMCA 201, *Fans and Systems* for more information on system effects. Specify a fan class that is appropriate for the design operating point. Do not select fans with forward curved blades for exhaust or recirculating replacement air-systems.

b. When selecting fan capacity, consider if the process room pressure will be positive, negative or neutral with respect to the external areas. Select a fan that will provide the necessary volumetric flow rate to maintain the desired process room pressure. Ensure that all sources of exhaust air are considered when selecting fan capacity. See the paragraph in Chapter 2 entitled, “Replacement Air” for more details.

c. Specify fan shafts that have a uniform diameter along the entire length. Use bearings that are rated with an average life of 200,000 hours.

d. Select only energy efficient motors. If available, select “*NEMA Premium Efficiency* “motors per NEMA MG-1 for motors and generators. Select the motor to handle cold startup amperage for nonstandard air processes.

e. Specify vibration-isolating couplings at the fan inlet and outlet. Mount all fans on vibration isolating bases.

f. If the planner's forecasts change in the processes to occur within the next couple of years, which would require an increase in the amount of replacement or exhaust air, then consider purchasing a larger capacity fan and oversized wiring.

g. Additional fan specification data such as spark resistant construction, drive arrangement, etc. is available in ANSI/AMCA Standards 99-10, *“Standards Handbook”*.

2-4.2.2 Location.

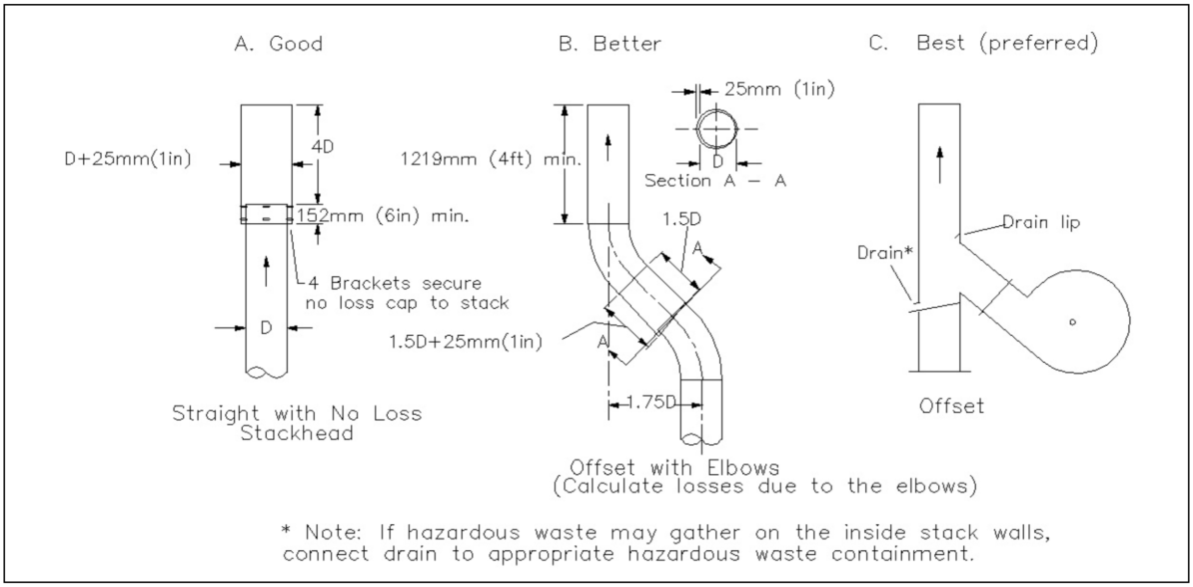
Locate the exhaust fan after the air pollution control equipment to protect fan blades from contaminated air-stream. Provide access for maintenance to all fans, including ladders and guardrails where necessary. Refer to NFPA 70, *National Electrical Code* for motor controller and disconnect location requirements. In all cases, install exhaust fans outside the building that they serve. Installing the fan outside the building envelope will isolate the working space from contaminants during fan maintenance, minimize noise inside the building, and ensure that ductwork within the building envelope is under negative pressure.

2-4.3 Exhaust Stacks.

2-4.3.1 Design Considerations.

Refer to the ACGIH IV Design Manual for exhaust stack design criteria. The best designs are cylindrical, vertical discharge stacks as shown in Figure 2-1. The best protection from rain, when the ventilation system is not running, is the “offset stack” design C, as shown in Figure 2-1. Water may still enter the system with straight stack design A. Provide a means to drain water from the fan housing.

Figure 2-1. Exhaust Stack Designs.



2-4.3.2 Location and Structural Considerations.

Refer to ASHRAE Handbook, *Fundamentals* for information on airflow around buildings. Do not select stack locations based exclusively on prevailing winds. A stack must provide effluent dispersion under all wind conditions. Refer to UFC 1-200-01, *General Building Requirements* for exhaust stack structural design considerations. Some structural considerations are wind load, lightning protection, and stack support. Refer to SMACNA GSSDC, *Guide for Steel Stack Design and Construction* for additional information.

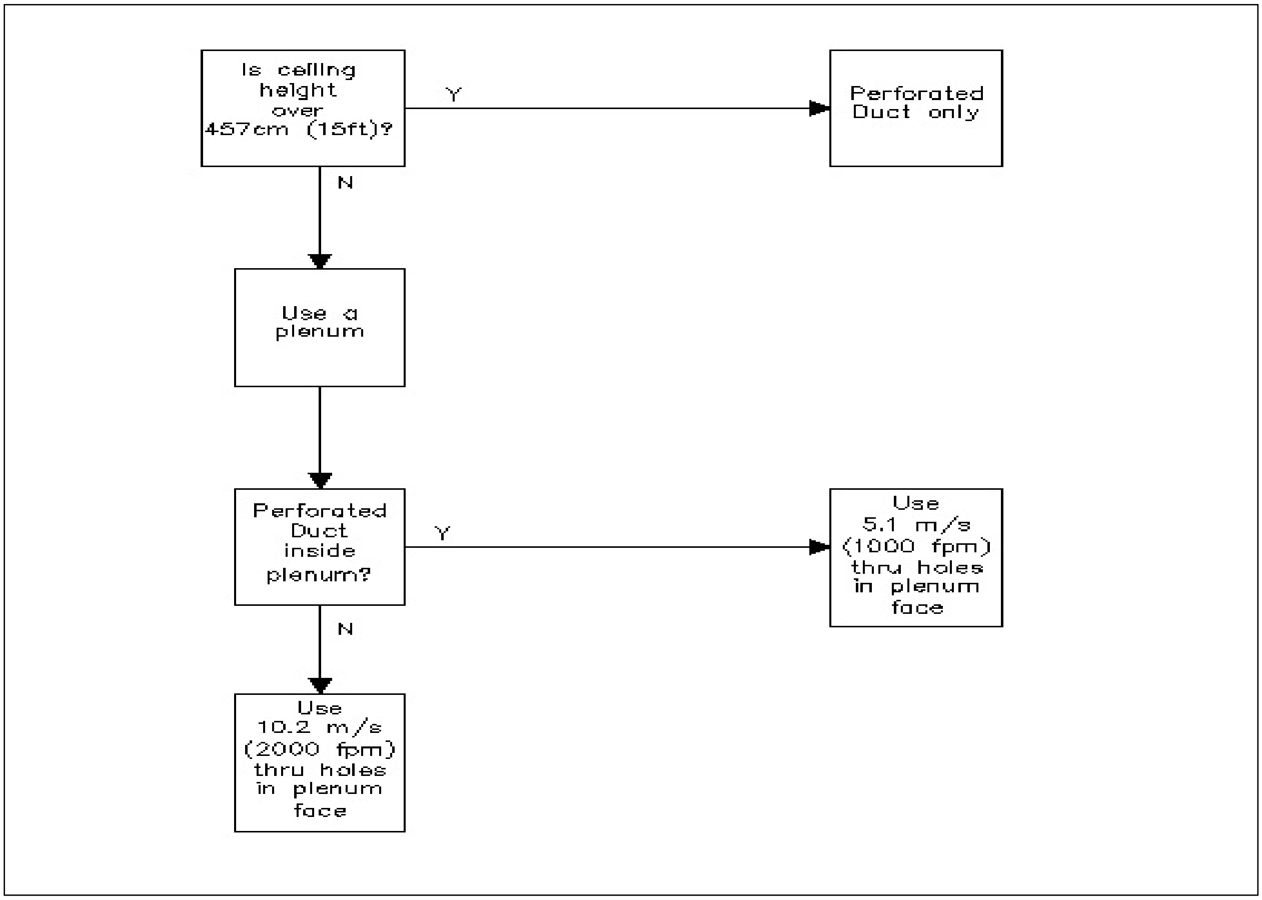
2-4.4 Air Pollution Control Equipment.

Requirements for air pollution equipment vary by process and geographical region in the United States. Contact the local activity environmental manager to determine the pollution control requirements for the process.

2-4.5 Replacement Air.

Replacement air is as important as exhaust air in controlling industrial process contaminants. The quantity and, in particular, the distribution of the replacement air profoundly affects the exhaust hood performance. Properly designed replacement air will (1) ensure that exhaust hoods have enough air to operate properly, (2) help to eliminate cross-drafts through window and doors, (3) ensure proper operation of natural draft stacks, (4) eliminate cold drafts on workers, and (5) eliminate excessive differential pressure on doors and adjoining spaces. (6) Ensure that replacement air does not draw from a loading dock or parking lot area or where exhaust air could be drawn into the system. Design the replacement air system in accordance with the decision tree shown in Figure 2-2.

Figure 2-2. Decision Tree For Replacement Air Design.



2-4.5.1 Space Pressure Modulation.

Modulate the replacement air to maintain the required space pressure differential between the process area and adjacent spaces, while maintaining the exhaust flow. Operate all process areas and/or buildings at a slight negative pressure to prevent the controlled contaminant from migrating into clean areas and prevent fugitive emissions to the atmosphere. Use a variable frequency drive (VFD) motor to control the fan speed. Do not use barometric dampers or sensor controlled transfer grilles to control replacement air quantity.

Exhaust hoods require a specific amount of exhaust air to control the contaminant. Certain conditions (e.g., paint curing or unattended lab hood processes) may permit an exhaust flow reduction. Worker protection takes precedence over energy savings.

2-4.5.2 Plenum Design.

The replacement air configuration which provides the most operational flexibility and worker protection is a down flow design, with the replacement air being delivered from the ceiling. The following discussion is based primarily on a down flow system, although a cross flow system may be utilized if the down flow arrangement proves to be impractical. Consider worker breathing zone when designing and balance the energy usage with worker protection.

Use perforated plate to cover as much of the ceiling (or wall opposite the exhaust hood(s)) as practical. The diameter of the perforation should be between 1/4 in and 3/8 in (6.3 mm and 9.5 mm). Perforated plenums work best when ceiling height is less than 15 ft (4.58 m). Use either of the following two choices for replacement air plenum design:

a. Design for 1,000 fpm (5.1 m/s) replacement air velocity through the open area of the perforated plate if perforated duct is used inside the plenum as shown in Figure 2-3.

b. Design for 2,000 fpm (10.2 m/s) replacement air velocity through the open area of the perforated plate if the plenum is served with ducts using diffusers, grills or registers as shown in Figure 2-4.

Figure 2-3. Plenum Design With Perforated Duct.

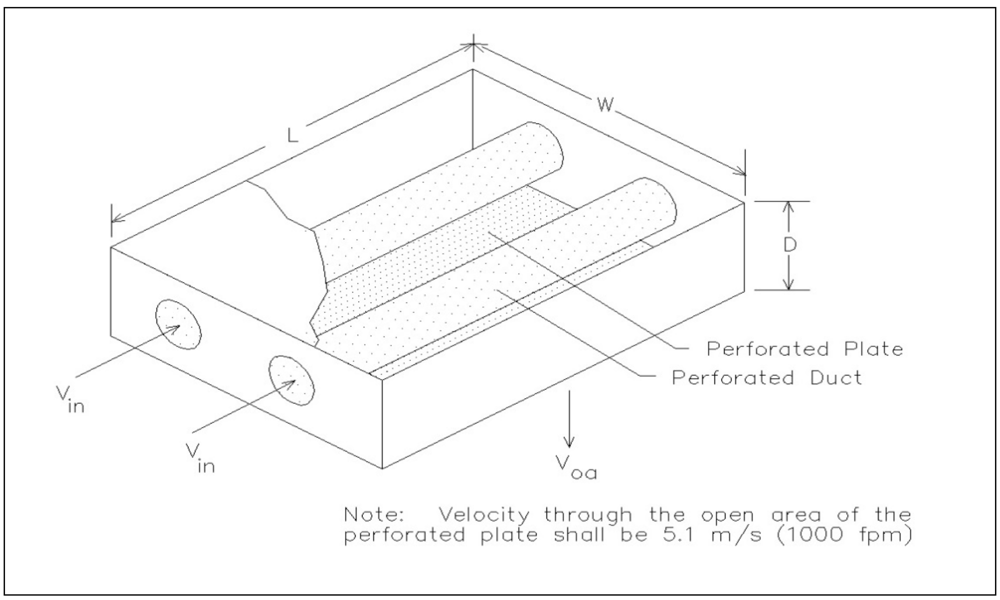
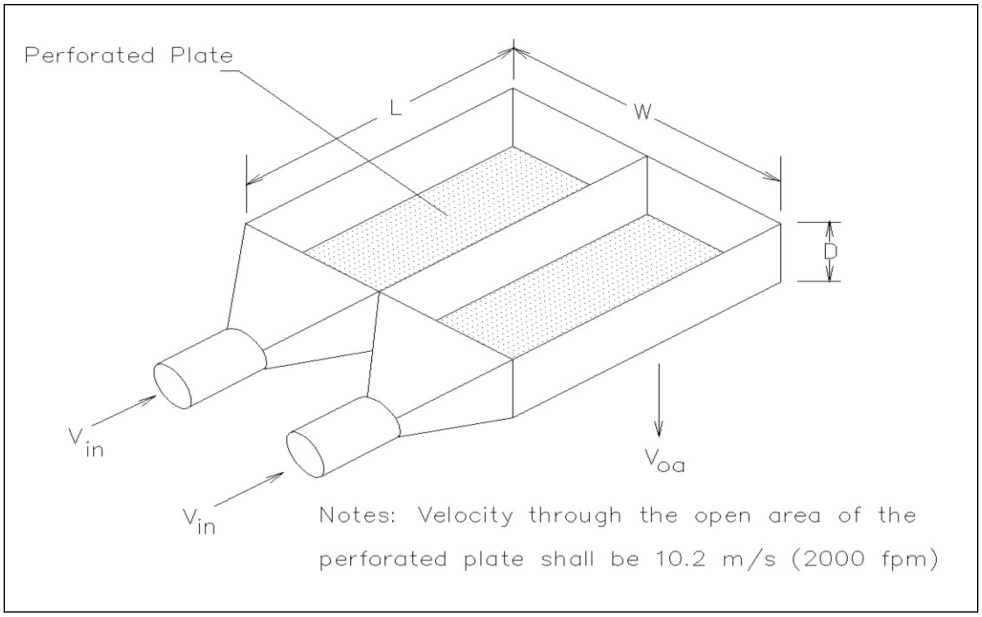


Figure 2-4. Plenum Design Without Perforated Duct.



2-4.5.3 Perforated Duct Design.

Use perforated duct to evenly distribute the flow of replacement air inside a plenum or use alone when ceiling height is greater than 15 ft (4.58 m). Manufacturers provide several different types and sizes of perforated duct. Use recommendations from the manufacturer for duct design. The manufacturer will not only recommend the size, shape, and type of the required perforated duct, but also the location of the orifices and reducers to distribute the air properly.

2-5 CONTROLS.

Provide industrial ventilation system controls and associated alarms to ensure contaminant control, space specific balance and conditioning, a safe and healthy work environment, and system malfunction notification.

Comply with Standard 18, Emergency Air Distribution Shutoff, found in UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*. A hazardous exhaust system may continue to operate if de-energizing the system will violate building codes, fire codes, create an unsafe condition or imperils life safety.

2-5.1 Gauges and Sensors.

Specify gauges and sensors to provide continuous monitoring of system performance. The minimum requirements are:

2-5.1.1 Differential Pressure Sensors

Provide differential pressure sensors, with gauge readouts, across each replacement air filter section and the exhaust air cleaning sections. Program control system alarm set points for each filter differential sensor to indicate when the filter pressure drop falls below the initial “clean” filter differential pressure or rises beyond the final “dirty” filter differential pressure. Provide text and graphical representation for the low pressure alarm and the high pressure alarm indications.

2-5.1.2 Replace Fan Motor Sensors

Operating light on replacement air system fan motor.

2-5.1.3 Static Pressure Sensors

Static pressure sensor at the outlet of the replacement air fan with a gauge readout. Alarms must be triggered when the pressure is lower than the recommended range (as determined by baseline testing).

2-5.1.4 Hood Static Pressure Sensors

Hood static pressure sensor, for critical processes or process where extremely toxic substances are used, with a gauge mounted in a conspicuous place near the hood. An alarm must be triggered when the static pressure is lower or higher than the recommended range (as determined by baseline testing). Do not use the type of inline flow sensor, which measures the pressure drop across an orifice plate. Use only a static pressure tap and differential pressure gauge.

2-5.1.5 Fan Static Pressure Sensors

Static pressure sensor at the exhaust fan inlet with gauge readout. An alarm must be triggered when the pressure is lower than the recommended range (as determined by baseline testing).

2-5.1.6 Exhaust Air Motor Sensor

Operating light on exhaust air system motor. When a sensor indicates a malfunction, trigger an alarm that is both audible and visible in the shop space.

2-5.1.7 Gauge Operating Range

Operating ranges on all gauges clearly marked. Locate gauges on an annunciator panel (except hood static pressure gauges). Provide a 3-way valve at each gauge connection for cleanout and calibration; see Figure 2-5.

2-5.1.8 Differential Pressure Sensor Location

Place room differential pressure sensors away from doors, windows, and replacement air discharge.

2-5.2 Interlocks.

Provide an interlocked on-off switch so that the replacement air and exhaust air systems operate simultaneously. When there are multiple fans, clearly label which exhaust fan is interlocked with which supply fan.

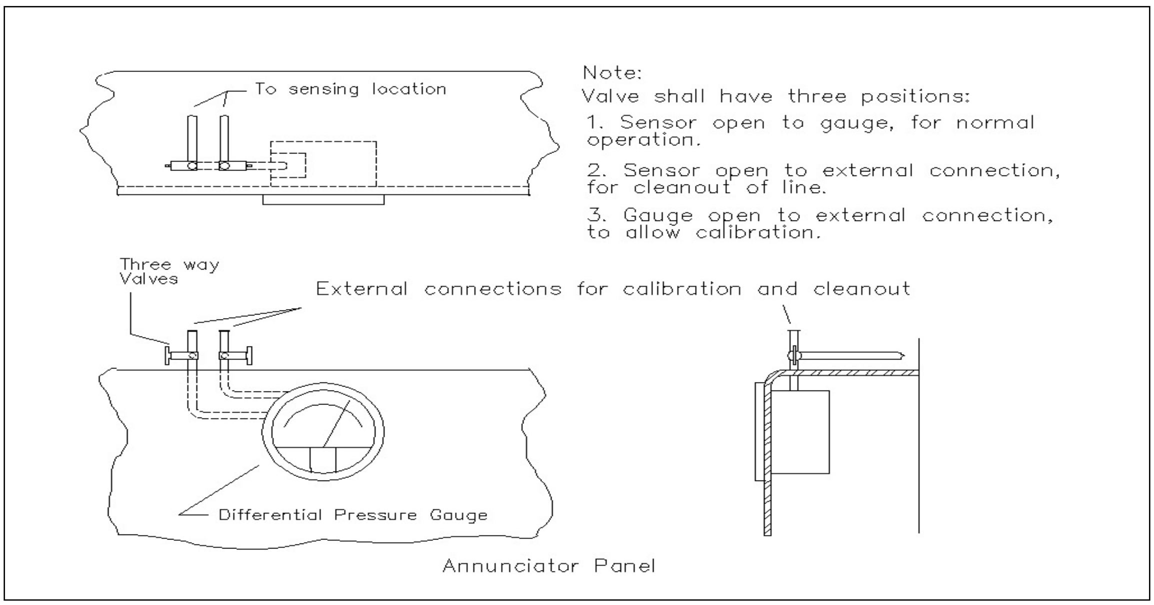
2-5.3 Annunciator Panel.

Provide an annunciator panel to allow for continuous monitoring of ventilation system performance. Locate the panel so it is accessible to shop personnel. The panel must include, but is not limited to, all gauges (except hood static pressure gauges) described in the paragraph in Chapter 2, entitled, “Gauges and Sensors”. Mount fan motor operating lights and interlocked ON/OFF switch on the panel. The interlocked switches must clearly show which exhaust and supply fans are interlocked, where multiple fans are used. The panel must indicate what action to take when operation falls outside the prescribed ranges. For example, “examine/replace filter on R.A. unit when this gauge reads outside indicated range.” Connect sensor outputs to building DDC systems when available.

2-5.4 Security.

Any networked communications from controls must meet the Information Assurance security requirements of the Activity served.

Figure 2-5. Annunciator Panel.



2-6 OPERATIONAL CONSIDERATIONS.

2-6.1 Provision for System Testing.

Provide access to the fan and motor to measure voltage, amperage, and fan speed. Evaluate and incorporate the use of guard rails, working platforms, and OSHA ladders into the design where equipment is located at elevation. Specify that all testing will be done in accordance with the ACGIH *Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance (IV O&M) Manual*, Chapter 3, “Testing and Measurement of Ventilation Systems.”

2-6.2 Energy Conservation.

Incorporate applicable energy conservation measures in the design of all industrial ventilation systems. Criteria herein minimize volume flow rates through appropriate designs. Evaluate life cycle costs for heat recovery systems and specify when appropriate. For HVAC-related issues use UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems.*

2-6.3 Recirculation.

Industrial ventilation systems use a large quantity of air. Exhaust air recirculation is discouraged for most industrial processes and prohibited by OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual* for processes generating lead and asbestos. Follow the re-circulated air guidelines set forth in NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids* for fire protection; the *ACGIH IV Design Manual*, Section 10.8, and ANSI AIHA/ASSE Z9.7, *Recirculation of Air from Industrial Process Exhaust Systems* for health protection, and the applicable OSHA standards when recirculation is included in the design.

2-6.4 Maintenance.

Require the contractor provide an operation and maintenance manual for the system and also provide hands-on training for maintenance and shop personnel. Ensure safe and sufficient maintenance access to the system components.

2-7 SAFETY AND HEALTH CONSIDERATIONS.

2-7.1 Posting.

For those systems where the replacement air is critical to the proper operation of the system, consider posting the following sign at each entrance to the ventilated space:

KEEP DOOR CLOSED
THIS DOOR MUST BE CLOSED FOR EFFECTIVE CONTROL OF CONTAMINANTS

2-7.2 Noise.

Use engineering controls as the primary means of protecting personnel from hazardous noise. It is cheaper to eliminate potential noise problems during the design or procurement stages, than it is to retrofit or modify after installation. Determine the acoustic environment in advance, both to fulfill the design goals and prevent the need for corrections at a later stage.

2-7.2.1 Criteria.

Determine the sound power levels for each piece of equipment used for industrial ventilation. Use this information to predict the acoustic characteristics and the resulting ambient noise level. Refer to UFC 3-101-01, *Architecture*.

Also refer to the appropriate facility-type UFC's for sound transmission requirements (STC's) into adjacent building spaces.

For additional information on noise control refer to UFC 3-450-01, *Noise and Vibration Control*; and OSHA 3048, *Noise Control, A Guide for Workers and Employees*.

2-7.3 Respiratory Protection.

29 CFR 1910.134(d), *Respiratory Protection* specifies requirements for respiratory protection. Consult with an industrial hygienist (IH) or occupational health specialist to determine the appropriate type of respiratory protection required for each process.

2-7.3.1 Breathing Air.

Breathing air for supplied air respirators must meet grade D standards as required by 29 CFR 1910.134(d) and defined in Compressed Gas Association Specification for Air G-7.1. Make up air for the breathing air compressor must be from outside and upwind of any potential exhaust sources. Breathing air couplings must not be compatible with outlets for non-respirable worksite air or other gas systems. Consider providing multiple connection ports for airline respirator hoses to allow worker mobility. Provide a means to permit the IH to test air quality on a routine basis.

2-7.3.2 Air Compressors.

Breathing air systems require a high temperature, carbon monoxide and Oxygen alarm. Alarms must be located where the respirator user and helper can see and hear them. Compressors must have the carbon monoxide level monitored to ensure the air supplied contains below 10 ppm CO. Compressors used to supply breathing air must be constructed and situated with a 30 foot separation from sources of contamination (e.g., exhausts, plumbing vents, loading docks) to prevent entry of contaminated air into the air supply system. The breathing air compressor must minimize moisture content so that the dew point is 10 degrees F (5.56 degrees C) below the ambient temperature. The breathing air system must have suitable in-line air-purifying sorbent beds and filters. Sorbent beds and filter must be maintained per manufacturer's instructions.

2-7.4 Emergency Showers and Eyewash Stations.

Provide in accordance with UFC 3-420-01, *Plumbing Systems*, Appendix D.

2-7.5 Hygiene Facilities.

These facilities are adjacent to or nearby the operation when employees are exposed to certain stressors such as asbestos, cadmium, lead, etc. The facilities may be as simple as a hand washing station or as complicated as multiple clean/dirty rooms in an asbestos delagging shop or a facility using metals such as cadmium, lead or hexavalent chromium. Consult with the local industrial hygiene department to determine the extent of and location for these facilities.

2-8 COMMISSIONING.

This process begins before the conceptual design is complete. It is a strategy that documents the occupants' needs, verifies progress and contract compliance and continues throughout the design, build and acceptance process. DOD projects and construction offices have long used parts of the commissioning process for military construction (MILCON) and some smaller projects. To ensure that issues specific to ventilation are not overlooked, use ASHRAE Guideline 1.1, *HVAC &R Technical Requirements for the Commissioning Process*.

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CHAPTER 3 ASBESTOS DELAGGING FACILITIES

3-1 FUNCTION.

An asbestos delagging facility provides a complete workshop to remove asbestos material from piping, mechanical and structural equipment during ship repair and demolition. The ventilation system design discussed in this section is for activities with extensive asbestos removal operations. The design includes: shop and equipment space, clean and dirty locker rooms for men and women, and administrative space to support the coordination and monitoring of facility operation.

3-2 OPERATIONAL CONSIDERATIONS.

3-2.1 Airborne Contamination.

When asbestos material is removed, the asbestos fibers are dispersed into the air, creating a health hazard. 29 CFR 1910.1001, *Asbestos, General Industry* and 29 CFR 1915.1001, *Asbestos, Shipyards* dictate protective measures for workers in these facilities, including respiratory protection and impermeable outerwear. The regulations also prescribe wetting the asbestos material with amended water (water containing a surfactant), if practicable, to reduce the potential for asbestos fibers to become airborne.

3-2.2 Heat Stress.

The physical nature of the work and impermeable outer garments worn by the workers creates heat stress conditions. Provide supplied air respirators with vortex tubes as specified in EPA-560-OPTS-86-001, *A Guide to Respiratory Protection for the Asbestos Abatement Industry*. Consider cooling the replacement air when supplied air respirators are not available. Consider using "micro climate cooling" or "cool suits," mechanically cooled garments, for individual workers.

3-2.3 Employee Workflow.

Workers enter the clean locker rooms through the control point area. They put on protective outerwear and proceed to the work area. After performing asbestos work, workers remove the outer set of disposable booties as they step in to the decon area.

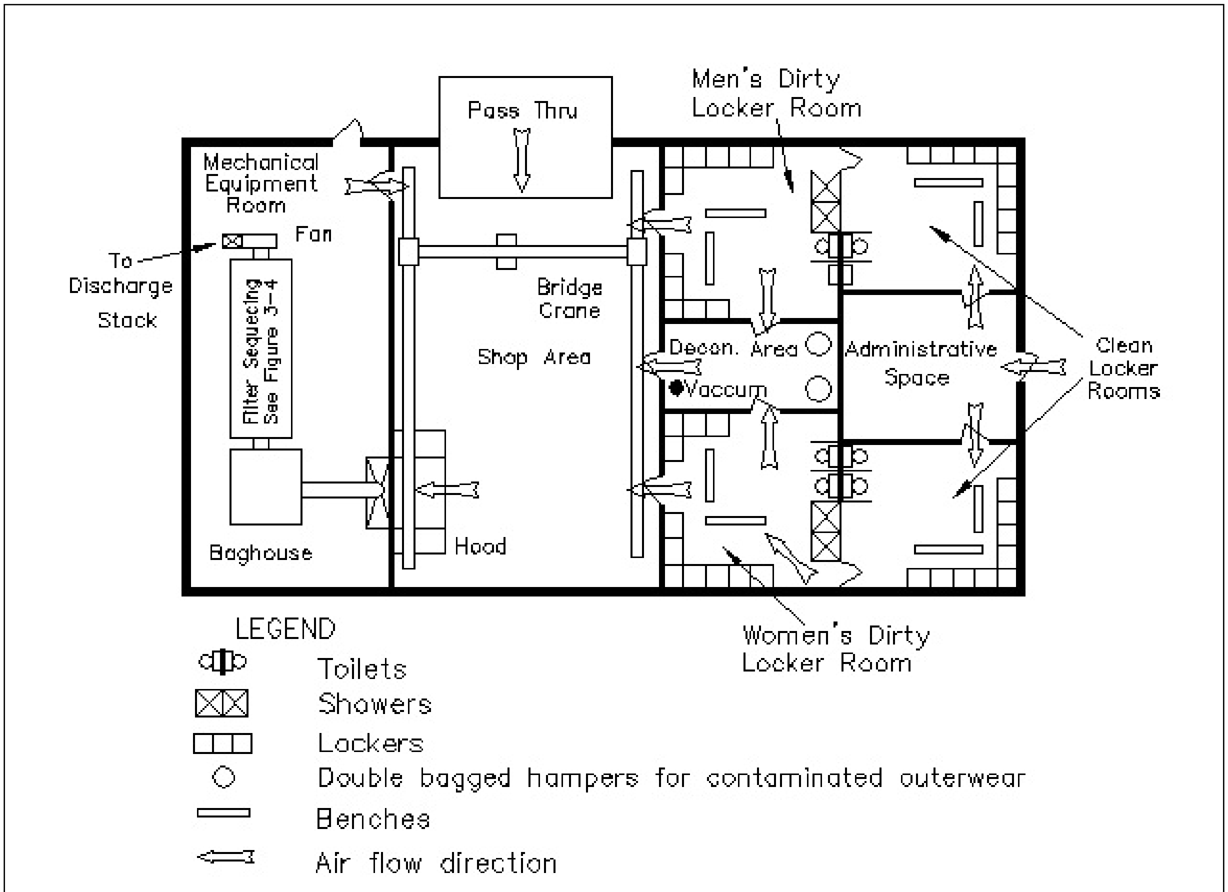
In the Decon room, the workers will vacuum their protective outerwear and dispose of them in containers provided. They enter the dirty locker rooms and remove the remainder of their work garments. Workers then proceed to the clean locker rooms via the showers, which act as a barrier to the migration of asbestos fibers.

In the shower, the worker can remove and wash their respirator and proceed to the clean room to get dressed in their personal clothing and exit to the control point.

3-3 TYPICAL FLOOR PLANS.

Design floor plans to meet the requirements of 29 CFR 1910.1001 and 29 CFR 1915.1001 and the paragraph in Chapter 3 entitled, “Employee Workflow”. Figure 3-1 shows a sample delagging facility floor plan.

Figure 3-1. Delagging Facility Floor Plan.



3-4 DESIGN CRITERIA.

Design the facility using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

3-5 EXHAUST AIR.

Design the exhaust air system to generate 4 exchanges of air/hour and .02 inches (0.5 mm) of water column.

3-5.1 Hood Design.

Design asbestos delagging hood to enclose the work piece as much as possible. Do not use small portable hoods with flexible ductwork because they do not provide consistent capture.

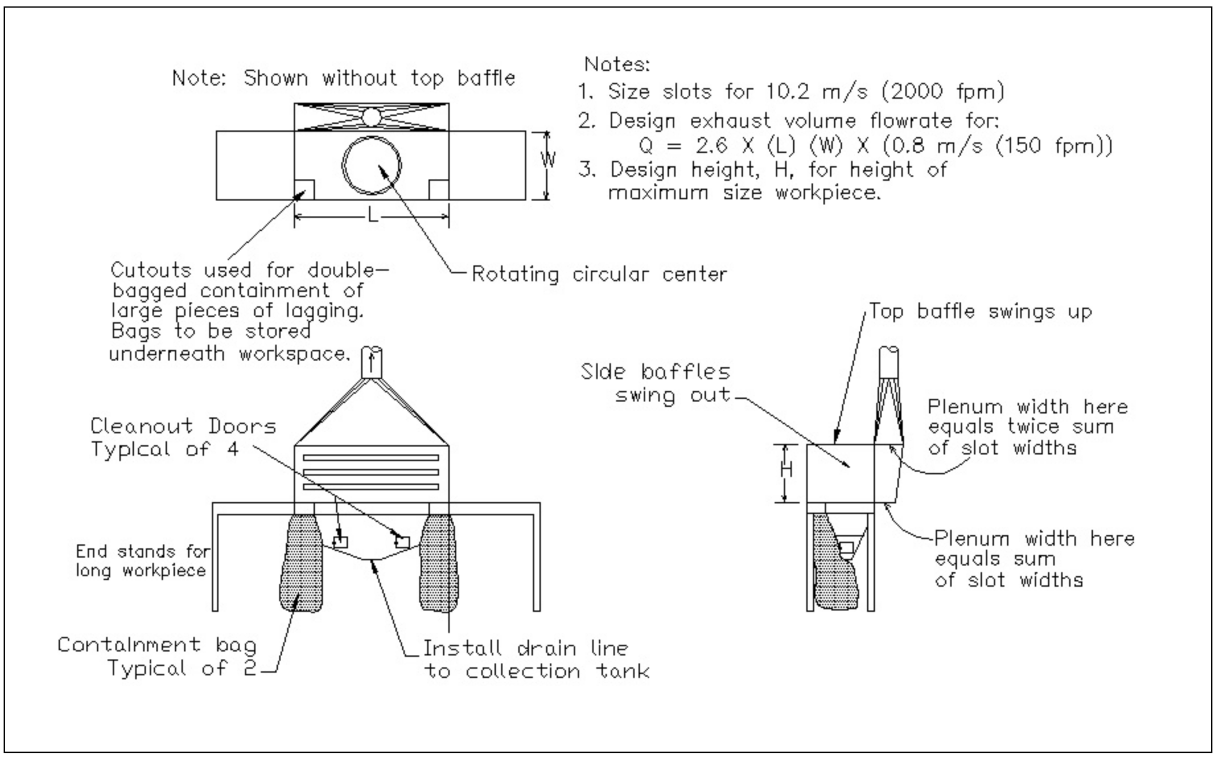
3-5.1.1 Typical Hood Design for High Profile Work Pieces.

Figure 3-2 shows a hood design consisting of a workbench with a central, circular area. Mount the circular area on sealed bearings to allow easy turning of heavy work pieces. This design is best for high profile work pieces (for example, boilers, pumps). The hood captures contaminants through the slots into an exhaust plenum. Design each hood with:

a. Two cleanout doors on the front and two doors on the sides of the hood for easy access to asbestos debris. Provide two small cutouts in the outer corners of the workbench to place large pieces of lagging in double bagged containment.

b. The top baffle swings up to allow access to overhead cranes.

Figure 3-2. Exhaust Hood For High Profile Work Pieces.



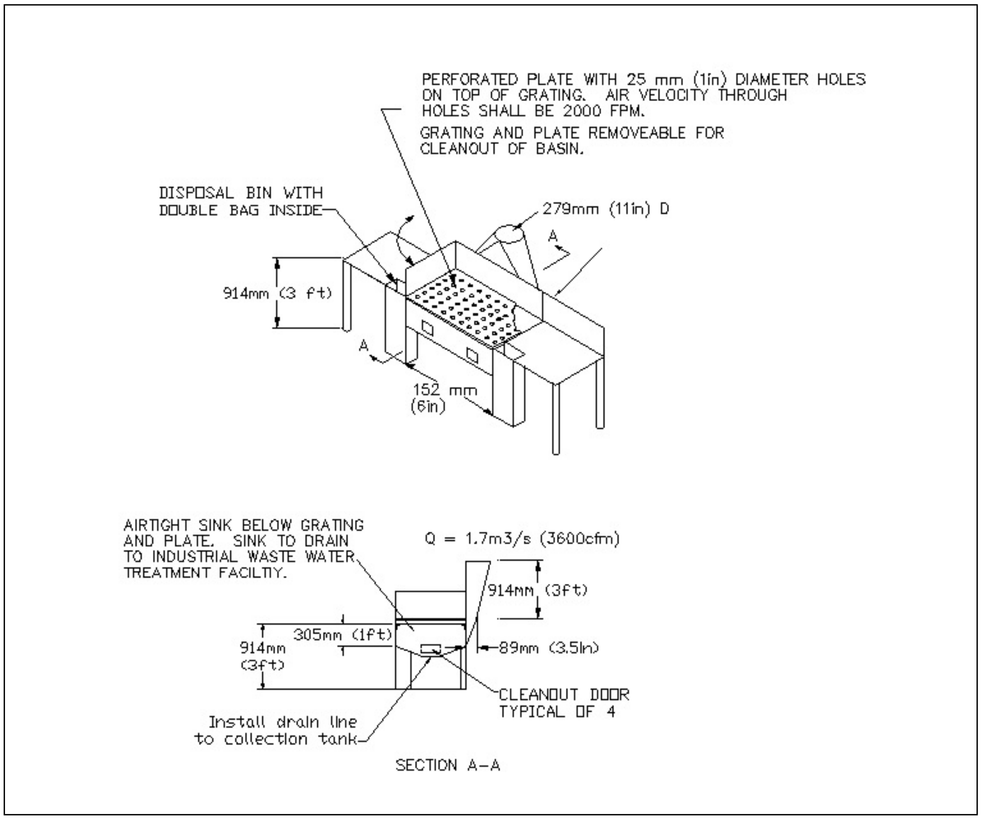
3-5.1.2 Typical Hood Design for Low Profile Work pieces.

Figure 3-3 shows a hood design consisting of a workbench with a grating strong enough to support the heaviest expected work piece. This is a downdraft hood that draws small pieces of lagging through the grating. The perforated plate below the grating creates even airflow over the grating. This design is best for low profile work pieces such as piping. Design each hood with stands and swinging baffles on each end to accommodate long work pieces (e.g., pipes).

3-5.2 Ductwork.

Size the exhaust ductwork to provide a minimum transport velocity of 5,000 fpm (25.4 m/s). The high velocity is necessary because the practice of wetting the fibers makes them heavier and more difficult to transport. See the paragraph in Chapter 2 entitled, “Ductwork” for general duct considerations.

Figure 3-3. Exhaust Hood For Low Profile Work Pieces.



3-5.3 Fans.

See the paragraph in Chapter 2 entitled, “Fans” for general fan considerations.

3-5.4 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, “Exhaust Stacks”.

3-5.5 Air Cleaning Devices.

A delagging facility requires multistage filtering, which consists of a fabric filter collector, prefilters, a mist eliminator, and high efficiency particulate air (HEPA) filters. Prefilters extend the life of the HEPA filters. Use "bag in, bag out" styles of HEPA filters, which allow for safe replacement of the filter element without exposure to asbestos. A mist eliminator before the HEPA filter protects it from the moisture generated during asbestos removal.

a. Have all collectors deliver the collected asbestos to a common pickup point to minimize the risk of exposure. Provide a double acting valve at each collector hopper throat, in accordance with the ACGIH IV Design Manual, Chapter 8, Air Cleaning Devices.

b. Use a single chamber, shaker type collector to minimize the number of collection points.

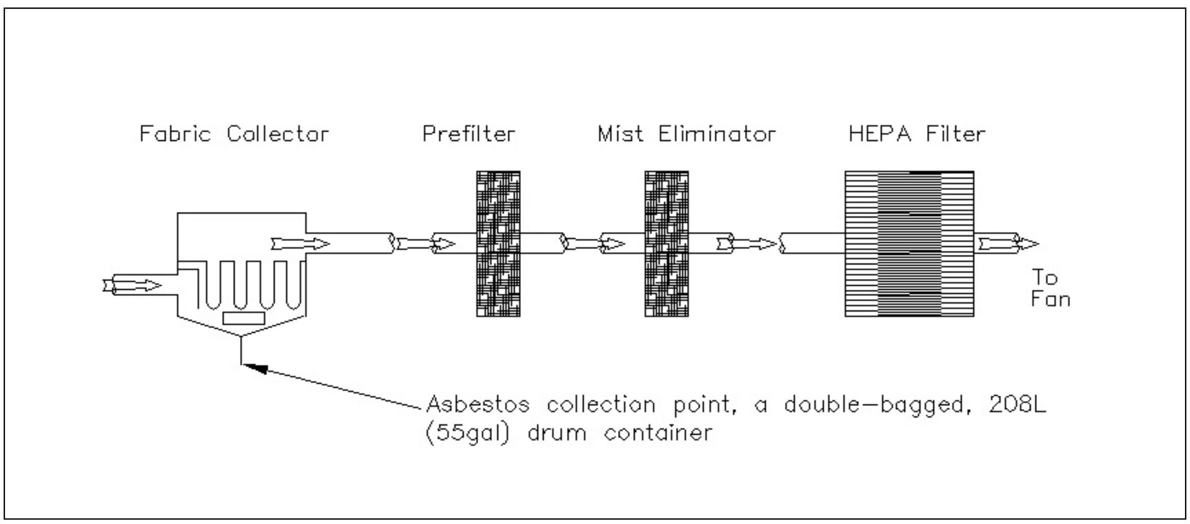
3-5.5.1 Filter Efficiency.

The fabric filter collector requires a minimum efficiency reporting value (MERV) of not less than 15 in accordance with ASHRAE 52.2, *Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size*.

3-5.5.2 Sequencing.

Figure 3-4 illustrates the required sequence of air cleaning devices.

Figure 3-4. Sequence Of Air Cleaning Devices For Asbestos Delagging.



3-5.6 Industrial Vacuum System.

Provide a low volume, high velocity (LVHV) central vacuum system at delagging shops to exhaust fibers and dust from power tools (e.g., grinders and saws) when they are used, as specified in 29 CFR 1910.1001.

3-5.6.1 Central Vacuum System

Design a central vacuum cleaning system, which consists of a motor driven exhauster interconnected with bag type separators.

3-5.6.2 Ductwork

Connect the separator to rigid hose or duct, which extends throughout the plant. Terminate the rigid hose or duct with inlet valves at the various workstations. Provide flexible hose connections to allow workers to do shop cleanup and to decontaminate their protective outerwear.

3-5.6.3 Exhaust Tools and Hoods

Use local exhaust hoods and high velocity exhaust takeoffs for each hand tool. Table 3-1 of this UFC and the ACGIH IV Design Manual provide examples of tools and exhaust system for specific operations.

3-5.6.4 Contaminant Capture Distance

Ensure proper capture velocity is produced at each local exhaust hood. Design vacuum systems to reach within 1/2 inch (12.7 mm) of the contaminant source.

3-5.6.5 Pick-up Velocity

Design the pickup air-stream to have a velocity of two to three times the generation velocity for particle sizes from 20 to 30 micrometers (20 to 30 micron.) Design for an additional velocity of: (1) four to five times the generation velocity to pull the particles up through 300 U.S. standard mesh, or (2) six to eight times the generation velocity to pull the particles up through a 20 U.S. standard mesh.

Table 3-1. Minimum Volumes And Vacuum Hose Size For Asbestos Operations.

Hand Tool	Flow rate cfm (m^3/s)	Hose Size in. (mm)
Pneumatic chisel	125 (0.06)	1.5 (38)
Hand wire brush, 3 x 7 inches	125 (0.06)	1.5 (38)
Rip out knife	175 (0.08)	1.5 (38)
Rip out cast cutter	150 (0.07)	1.5 (38)
Saber saw	150 (0.07)	1.5 (38)
Saw abrasive, 3 inch	150 (0.07)	1.5 (38)
General vacuum	200 (0.09)	2.0 (51)

Adapted from: Hoffman Air and Filtration Systems, “Design of Industrial Vacuum Cleaning Systems and High Velocity, Low Volume Dust Control.”

3-5.6.6 Air to Asbestos Ratio

Design the air volume for no less than two parts of air to one part of asbestos to be captured by weight.

3-5.6.7 Hose Lengths and Locations

Design the vacuum hose length less than 25 ft (7.6 m). Locate inlet valves 30 to 35 feet (9 to 10.7 meters) apart when a 25 ft (7.6 m) length of hose is used. Locate tool vacuum hose connection on the ends of the workbench underneath the stands. Size the hose based on: (1) air volume per hose, (2) number of hoses to be used simultaneously, and (3) air velocity required to convey the material to the separators.

3-5.6.8 PVC Hoses

Use single-ply, lightweight thermoplastic or polyvinyl chloride (PVC) flexible hose, but limit the usage whenever possible.

3-5.6.9 Multi-stage Blower

Use a multistage centrifugal blower for the vacuum system. Size the blower for: (1) total system pressure loss associated with the total number of hoses to be used simultaneously, and (2) maximum exhaust flow rate entering the inlet of the blower.

3-5.6.10 Blower to Bag House Relationship

Feed the blower directly into the bag house used by the industrial exhaust system to minimize the number of asbestos collection points.

3-5.6.11 Filters and Location

Install a prefilter and a HEPA filter in front of the blower to prevent it from becoming contaminated.

3-5.6.12 Balance by Design

Design the vacuum system duct to balance with the exhaust system duct where the two systems connect.

3-5.6.13 Noise

Use manufacturer guidance to design vacuum system and UFC 3-450-01, *Noise and Vibration Control* as preliminary guidance.

3-5.7 Replacement Air.

Design replacement air systems with fan inlet guide vanes, variable speed motors, or "eddy current clutch" units to maintain a pressure (relative to the atmosphere) ranging from -0.02 to -0.05 inches wg (12.4 to 24.9 Pa scale) in the shop spaces.

a. Maintain the pressure in decontamination areas, the equipment room, and dirty locker rooms within a range of -0.01 to -0.04 inches wg (-2.49 to -9.96 Pa). Maintain the pressure in clean spaces within a range of (+0.02 to +0.05 inches wg (+4.98 to +12.4 Pa).

b. For further replacement air system criteria, see the paragraph in Chapter 2, entitled, “Replacement Air”.

3-5.8 System Controls.

Design system controls in accordance with the paragraph in Chapter 2 entitled, “Controls” and the following:

a. Position the annunciator panel at the entrance to the dirty space so operators can monitor operating gauges.

b. Install static pressure sensors at locations that are representative of average static pressure in each controlled space. This will ensure that desired differential pressures are maintained.

c. Trigger a timer if pressure varies from the specified range. Select timer that automatically resets if the problem is corrected within 60 seconds.

d. Trigger both visible and audible alarms if the system cannot correct the difficulty within allotted time. Install multiple alarm beacons if operator's view is obscured during delagging. Monitor the shop's negative pressure continuously, using strip chart recorder, so the operator can detect any pressure changes.

e. Interlock the hand tool power supply with the ventilation system's on-off switch. This will prevent the use of hand tools without ventilation controls.

3-6 TREATMENT OF WASTE EFFLUENT.

All waste water generated in the facility must be considered contaminated effluent and must be filtered to remove solid particulate contaminants prior to entry into the Industrial Waste stream.

Notify and comply with any pretreatment requirements as required by the POTW, state and local authorities prior to discharging any waste water from the facility.

3-7 SAFETY AND HEALTH CONSIDERATIONS.

Consult the local industrial hygienists (IH) for required respiratory protection in accordance with 29 CFR 1910.1001 (f) and (g), 29 CFR 1915.1001(g) and (h). See the paragraph in Chapter 2 entitled, “Respiratory Protection” for additional information.

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CHAPTER 4 OTTO FUEL II FACILITIES

4-1 FUNCTION.

MK-46 and MK-48 torpedo facilities maintain, prepare, and test torpedoes. MK-46 and MK-48 torpedoes use Otto Fuel II, a toxic monopropellant. Further best practices and reference documents can be found in the inactive UFC 4-216-02, *Design: Maintenance Facilities for Ammunition, Explosives, and Toxins*.

4-2 OPERATIONAL CONSIDERATIONS.

Operations in a torpedo facilities create a potential for personnel exposure to one or more of the following: (1) Otto Fuel II, (2) Agitene - parts cleaning solvent used in MK-46 shops, (3) hydrogen cyanide - a product of combustion in torpedoes, and (4) mineral spirits - parts cleaning agent used in MK-48 shops.

4-3 DESIGN CRITERIA.

Design the facilities using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter. Torpedo size differences and maintenance procedures dictate the use of different floor plans and exhaust hood designs for the two types of facilities. Refer to NAVSEA OP5, Volume 1, *Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation and Shipping* for the specific order of operations. In all cases, the industrial ventilation systems must remove hazardous vapor (from Otto Fuel II, and part cleaning solvent) and products of combustion.

4-3.1 Exhaust Air for MK-46 Ventilated Spaces.

The MK-46 floor plan in Figure 4-1 optimizes the workflow while allowing the ventilation system to control airborne contaminants. Figure 4-2 shows an elevation view of this floor plan.

Figure 4-1. Layout for the MK-46 Fuel/Defuel and Afterbody Breakdown Room.

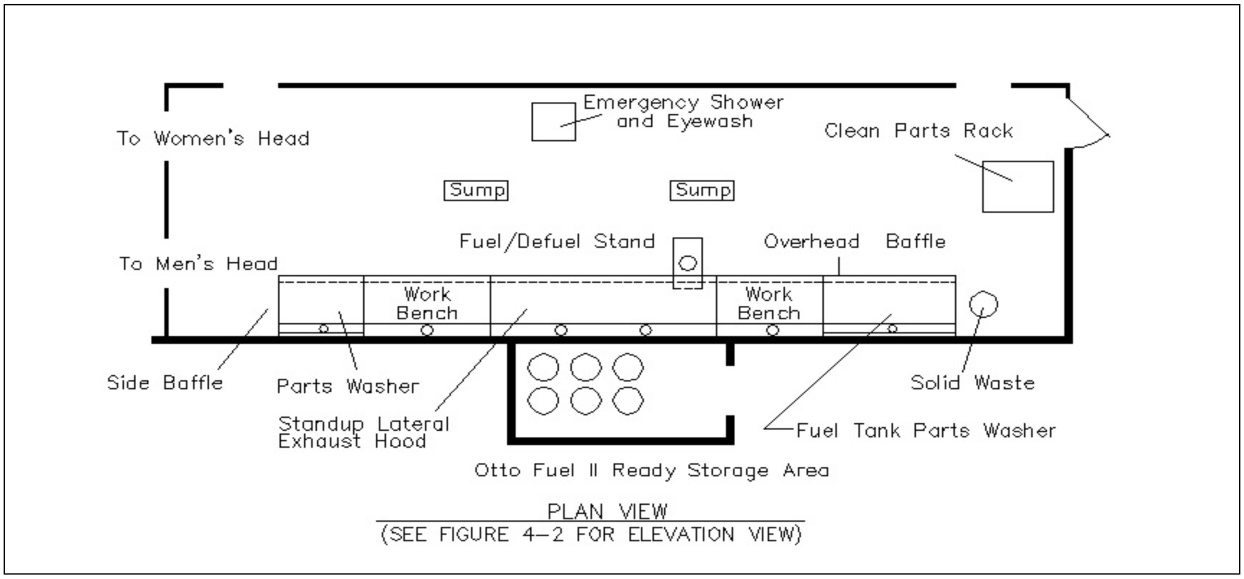
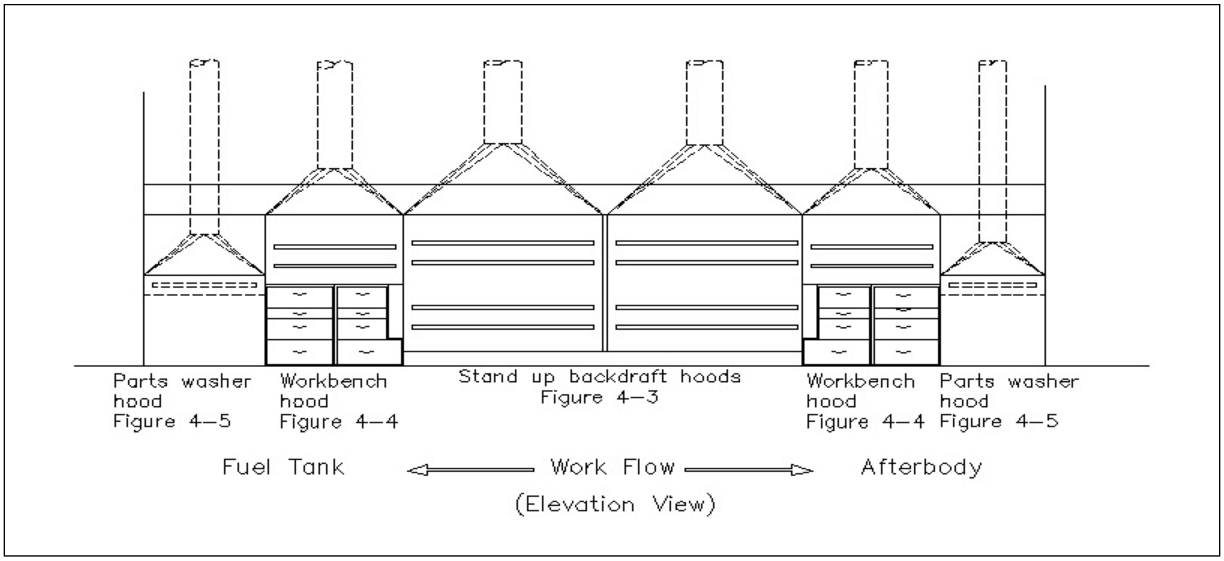


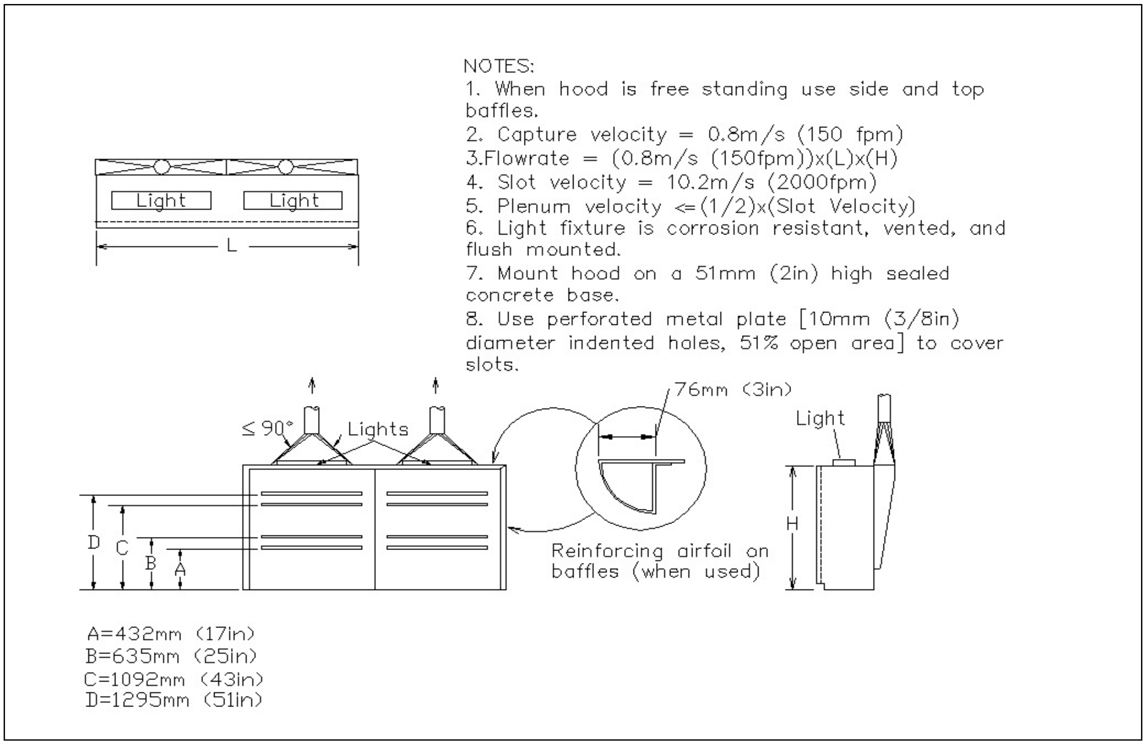
Figure 4-2. Series of Hood in the MK-46 Shop.



4-3.1.1 MK-46 Standup Backdraft Hood.

Workers uncouple the fuel section and the engine section of the torpedo in teardown operations. During these operations, Otto Fuel II remains in the lines, in the components of the engine section, and in the fuel tank. The residual fuel releases vapor into the air. The defueling and refueling processes also release Otto Fuel II vapor. Use the standup backdraft hood as shown on Figure 4-3 to capture Otto Fuel II vapor in afterbody teardown, fueling, and defueling operations.

Figure 4-3. MK-46 Standup Backdraft Hood.



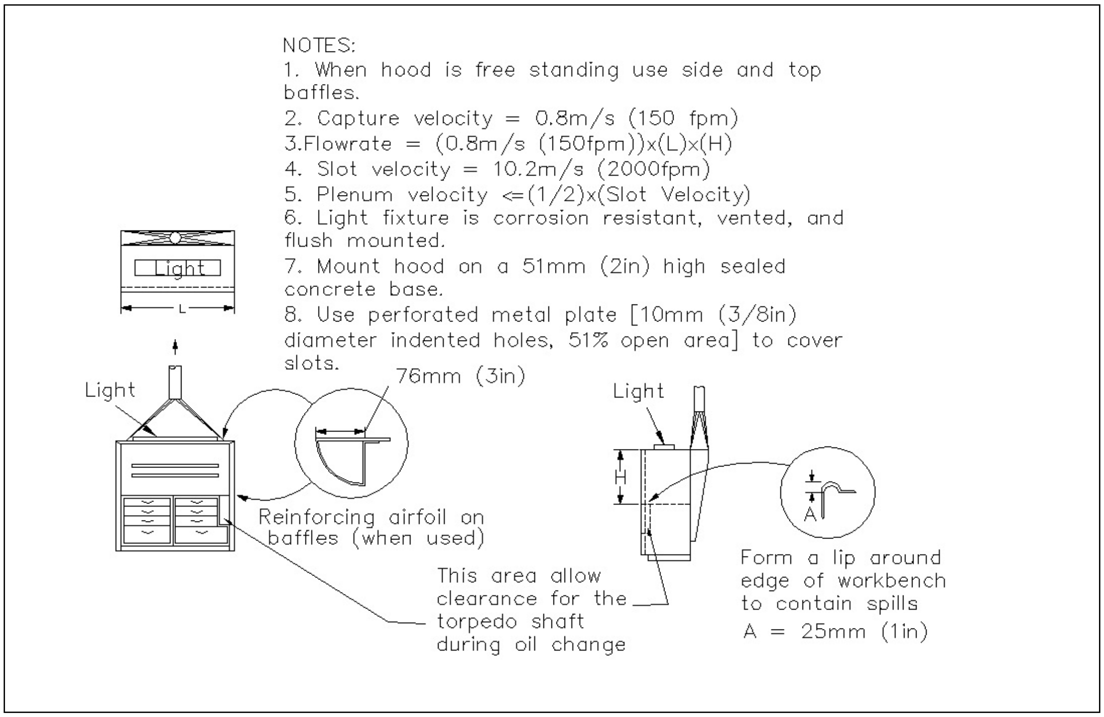
a. Hood transitions (takeoffs) with an included angle no greater than 90 degrees. Length of the hood, served by an exhaust plenum, is not to exceed 8 ft (2.44 m). For example, hoods between 8 and 16 ft (2.44 and 4.88 m) in length have two exhaust takeoffs.

b. Baffles to control airflow from the sides and top of the hood bank as shown on Figure 4-3.

4-3.1.2 MK-46 Workbench Hood.

After defueling and decoupling, workers lift the fuel and engine sections onto two different ventilated workbenches. They remove the stabilizing baffles in the fuel section, inspect, and wipe them clean before loading the baffles into the parts washer. Personnel also dismantle the engine section to inspect the engine, fuel pump, and seawater pump before loading them into the parts washer. Design a backdraft exhaust hood, as illustrated in Figure 4-4, to control contaminants generated by these workbench operations.

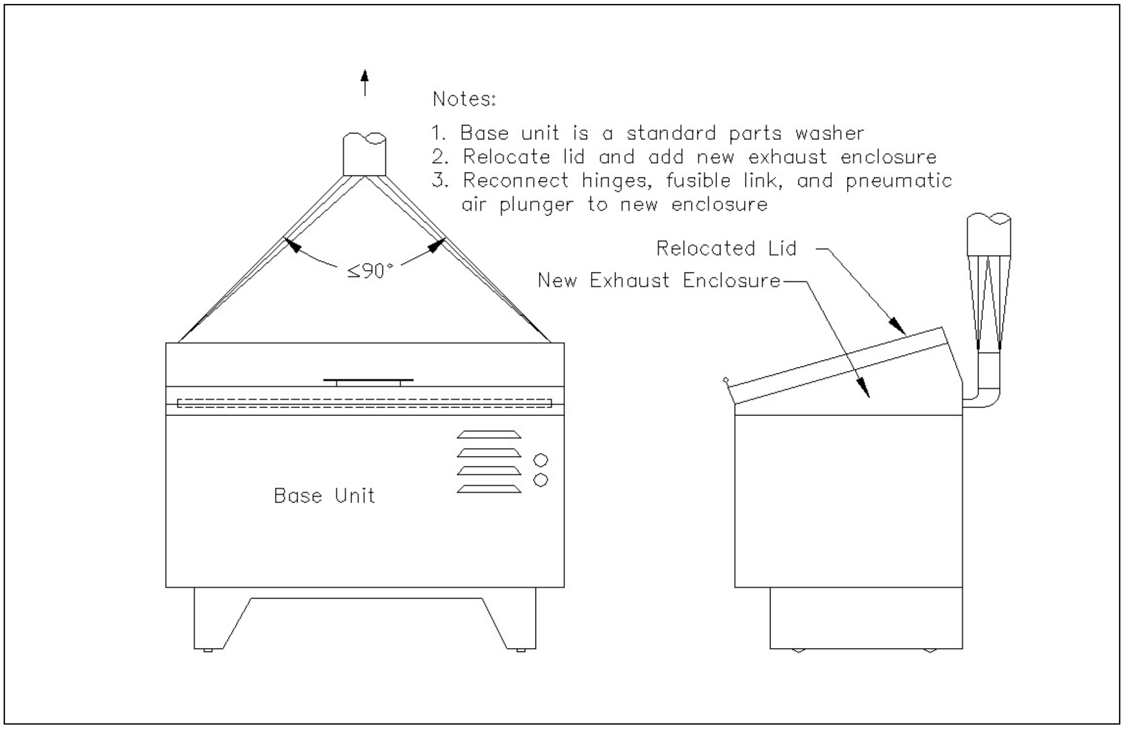
Figure 4-4. MK-46 Workbench Hood.



4-3.1.3 MK-46 Parts Washer Hood.

Design parts washer as shown on Figure 4-5 to clean off oils and excess Otto Fuel II from torpedo components. The parts washer cover must automatically close in case of fire in accordance with NFPA 34, *Standard for Dipping Coating and Printing Processes Using Flammable or Combustible Liquids*. Design the parts washer large enough to completely enclose the work piece. Design the parts washer deep enough to allow a minimum clearance of 6 in (153 mm) between the liquid level and the exhaust slot when the tank is full of parts. Position the parts washer next to the workbenches to shorten the work path and optimize ventilation control.

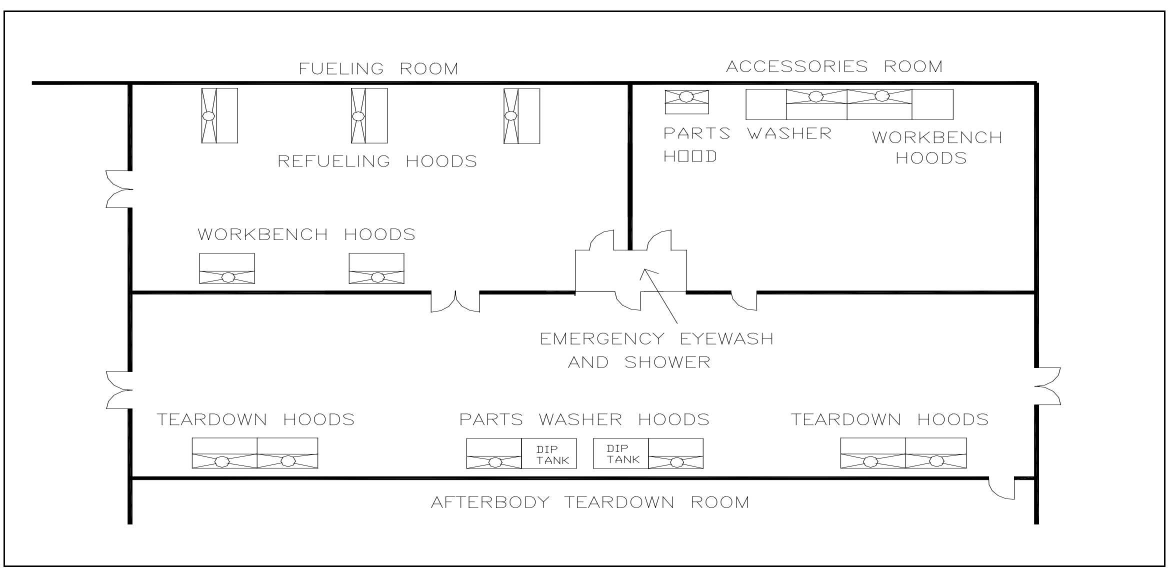
Figure 4-5. MK-46 Parts Washer Hood.



4-3.2 Exhaust Air for MK-48 Ventilated Spaces.

The floor plan shown in Figure 4-6 optimizes the work path while allowing the ventilation system to control airborne contaminants. Obtain detailed MK-48 exhaust hood drawings from Naval Underwater Systems Center.

Figure 4-6. Typical MK-48 Ventilated Space Layout.



4-3.2.1 MK-48 Afterbody Teardown Hood.

Workers uncouple the fuel section and the engine section of the torpedo in the teardown operations. During these operations, Otto Fuel II remains in the lines and the components of the engine section, and in the fuel tank. The residual fuel releases vapor into the air. Design the afterbody teardown hood as shown in Figure 4-7 to capture Otto Fuel II vapor. Design the hood using the following criteria.

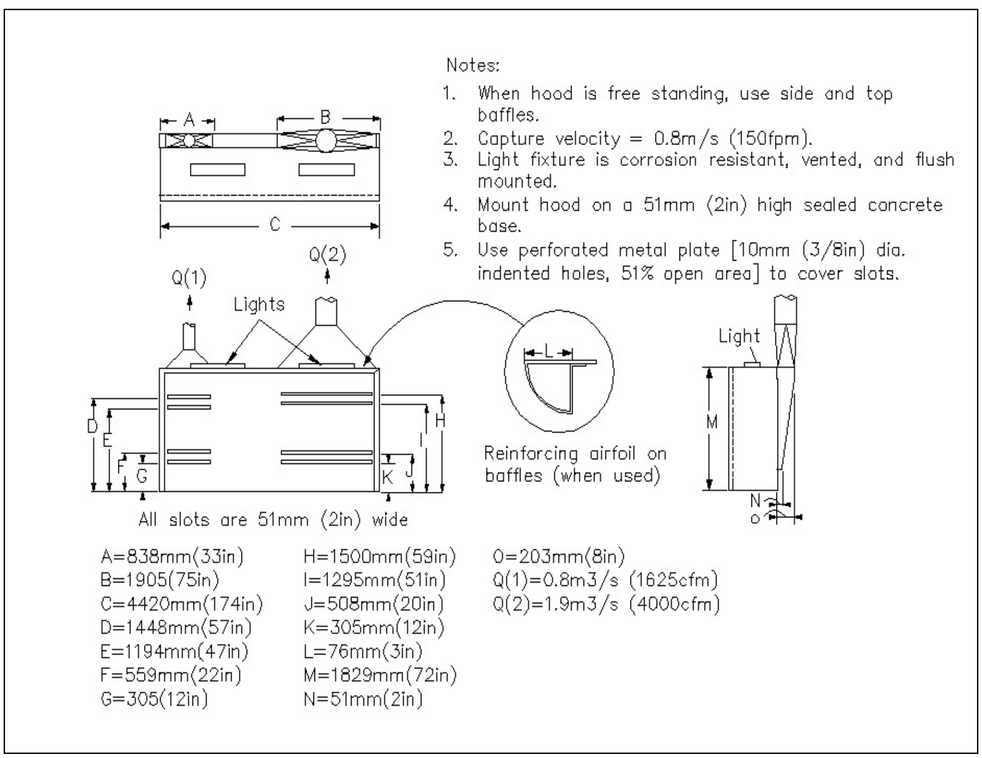
a. Install baffles on the top and side of the hood forming a booth.

b. Install a 3 in (7 mm) airfoil on the outer edge of the hood. The airfoil, bent inward from the baffle, must provide an airfoil effect and prevent turbulence and backflow.

c. Install lighting that is vented and flush mounted in the overhead baffle as shown on Figure 4-7.

d. Bolt the hood to the floor, using a continuous natural rubber gasket on hood bottom to create a seal between the hood and the floor.

Figure 4-7. MK-48 Afterbody Teardown Hood.



4-3.2.2 MK-48 Workbench Hood.

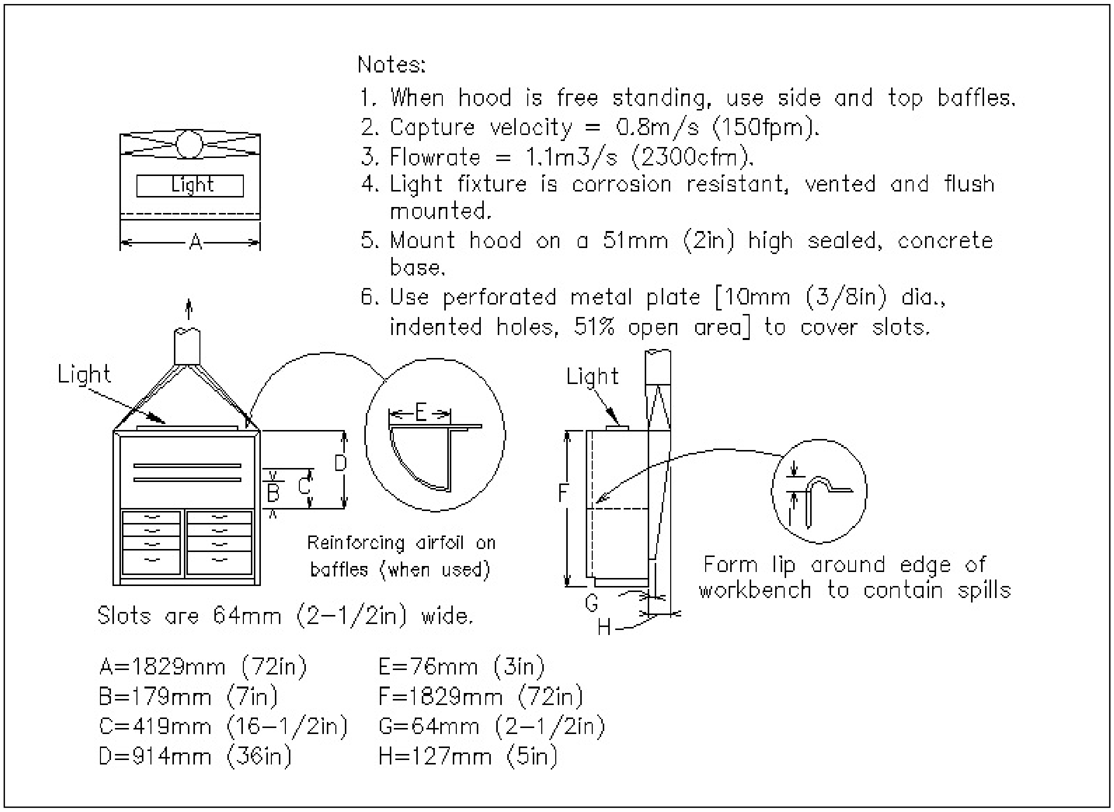
After defueling and decoupling, personnel dismantle and inspect the fuel tank and the engine section. They then load components of the fuel tank and the engine section into the parts washer. Design a backdraft exhaust hood as illustrated in Figure 4-8 to control contaminants generated by these workbench operations. Specify the following criteria for workbench hoods:

a. A 72- by 24-in (1850- x 600-mm) stainless steel workbench top to support the whole exhaust hood. See Figure 4-8 for dimensions of the hoods.

b. A 3-in (76-mm) airfoil rotated inward to prevent turbulence and backflow.

c. Lighting that is vented and flush mounted in the top of the exhaust hood.

Figure 4-8. MK-48 Workbench Hood.



4-3.2.3 MK-48 Parts Washer Hood.

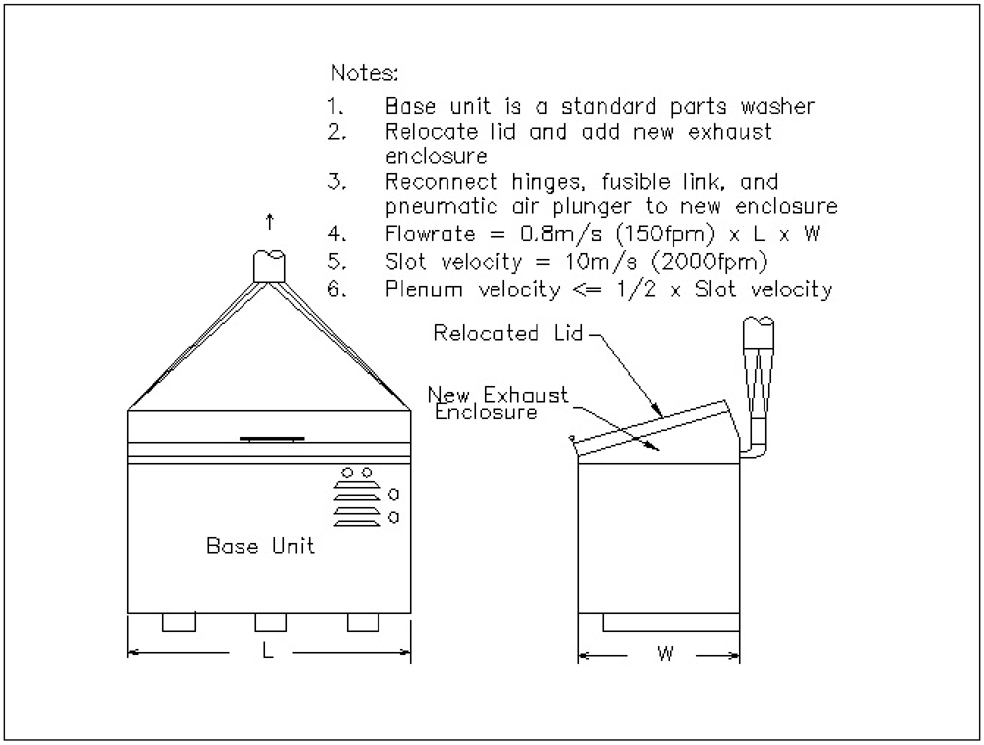
Design or modify the parts washers as shown on Figure 4-9. Specify the following criteria for the parts washers:

a. Fabricate a new enclosure to mount on top of the parts washer.

b. Relocate the cover with a pneumatic plunger and a fusible link assembly.

c. Install an automatic switch to turn on the exhaust fan when the cover is opened and to turn off the exhaust fan when the cover is closed.

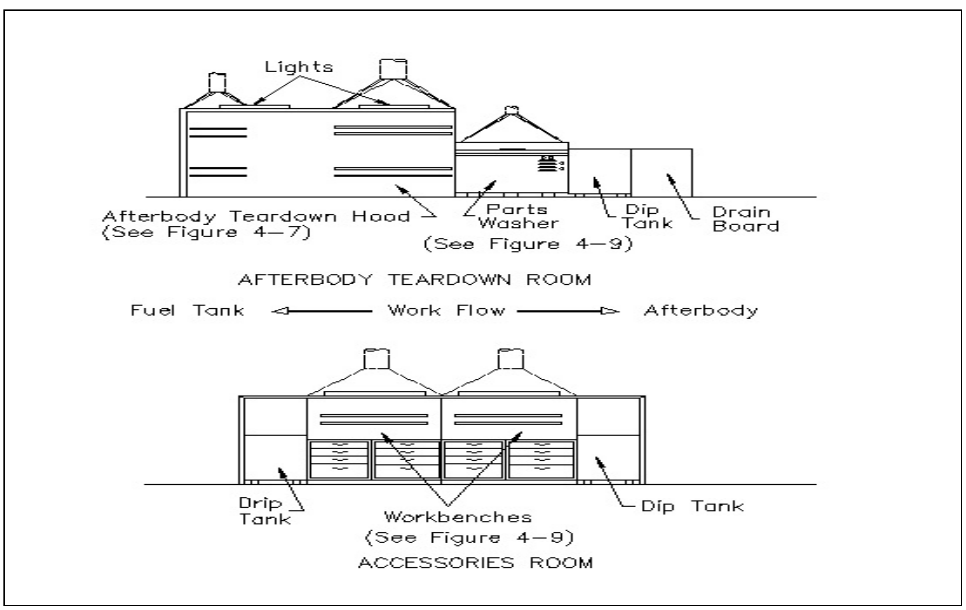
Figure 4-9. MK-48 Parts Washer Hood.



4-3.2.3 Workflow in Afterbody Teardown Room and Accessories Room.

Figure 4-10 illustrates the workflow in both the afterbody teardown room and the accessories room with the proper sequence of hoods.

Figure 4-10. MK-48 Hood Sequence Afterbody Teardown and Accessories Rooms.



4-3.2.4 MK-48 Refueling Hood.

Before refueling, personnel connect the hoses from the fueling equipment to the fuel tank. Once the fueling operation has begun, the operator does not need access to the fuel tank, except to see the hose connections. Therefore, design an enclosing hood to reduce ventilation rates and decrease the potential for exposure to a spill during fueling. Design the hood as illustrated in Figure 4-11. Specify the following criteria for the refueling hoods.

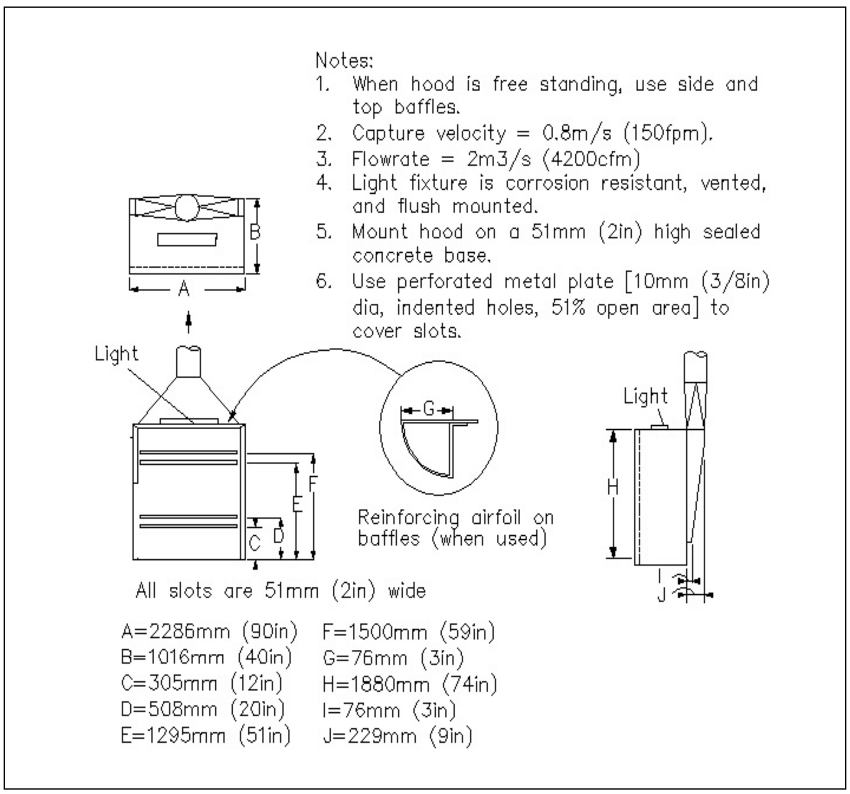
a. A 3-in (76 mm) airfoil rotated inward to prevent turbulence and backflow.

b. Lighting that is vented and flush mounted in the top of the exhaust hood.

c. Hood that bolts the floor, using a continuous natural rubber gasket on hood bottom to create a seal between the hood and the floor.

d. Design the exhaust such that the dip tank can be cleaned using the work station exhaust.

Figure 4-11. MK-48 Refueling Hood.



4-3.2.5 Ductwork.

Follow criteria as specified in the paragraph in Chapter 2 entitled, “Ductwork” for both MK-46 and MK-48 shops and the following:

a. Fabricate all ductwork in contact with Otto Fuel II vapors with (black) carbon steel. Require all joints be either butt welds or flanges.

b. Size the duct to maintain a minimum transport velocity of 2,500 fpm (12.7 m/s).

4-3.2.6 Fans.

Select fans as specified in the paragraph in Chapter 2 entitled, “Fans”.

4-3.3 Weather Stack Design and Location.

Proper dispersion from the stack is critical because Otto Fuel II exhaust is not filtered. See the paragraph in Chapter 2 entitled, “Exhaust Stacks”.

4-3.4 Air Cleaning Devices.

Due to the quantities and types of contaminants generated by these processes, there is no requirement for air pollution control equipment.

4-3.5 Replacement Air.

Design replacement air systems to maintain a pressure (relative to the atmosphere) ranging from -0.02 to -0.06 inches wg (-5.0 to -14.9 Pa) in the spaces with a potential for personnel exposure. Maintain the spaces with a low potential for personnel exposure at a differential pressure ranging from +0.01 to +0.05 inches wg (2.49 to 12.4 Pa).

4-3.5.1 Quantity and Distribution.

Distribute air to produce laminar flow of air from supply to exhaust in the workspace. Use vertical supply distribution method as shown on Figure 4-12. Horizontal supply distribution method as shown on Figure 4-13 is adequate if, and only if, all exhaust hoods are located on the wall opposite the supply plenum. See the paragraph in Chapter 2 entitled, “Replacement Air” for detailed criteria.

Figure 4-12. Vertical distribution method.

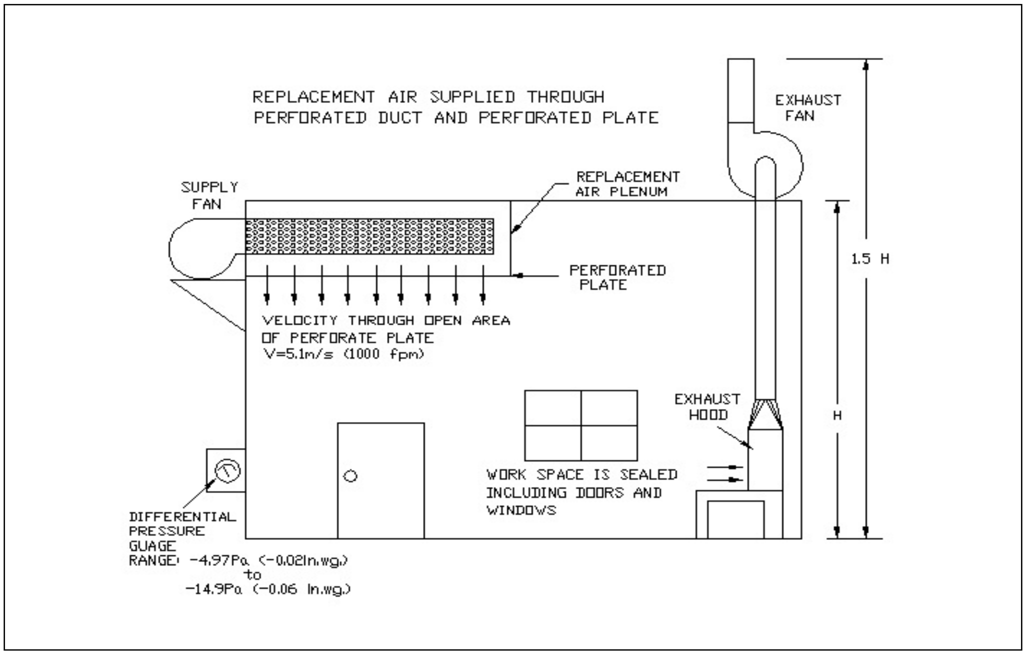
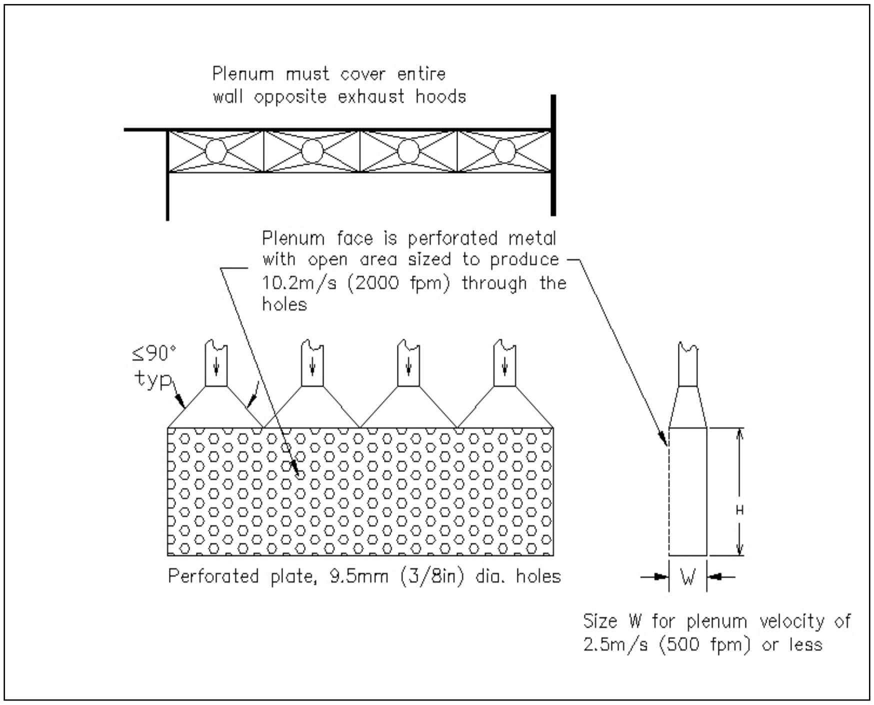


Figure 4-13. Horizontal Distribution Method.



4-3.5.1.1 Vertical Distribution Method.

Design a drop ceiling with perforated plate to form a plenum in accordance with the paragraph in Chapter 2 entitled “Plenum Design”.

4-3.5.1.2 Horizontal Distribution Method.

Design the wall plenum to cover the entire wall opposite the hoods. Size the open area of the perforated sheet for 2,000 fpm (10.16 m/s) through the holes. See Figure 4-13 for more details.

4-3.6 Heating and Air Conditioning.

Design heating, air conditioning, and humidity control according to UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems*. Temper the replacement air to provide a minimum winter design temperature of 65 degrees F (18 degrees C) and a maximum summer design temperature of 78° F (25.6° C), with a relative humidity of 50 percent +/- 10 percent. Do not separate the air conditioning system from the replacement air system. See the paragraph in Chapter 2 entitled, “Energy Conservation” for criteria on heat recovery systems. Do not re-circulate exhaust air.

4-4 SYSTEM CONTROLS.

Design system controls in accordance with the paragraph in Chapter 2 entitled, “Controls” and the following:

a. Position an annunciator panel at the entrance to the space with a potential for personnel exposure so operators can monitor operating gauges.

b. Install static pressure sensors at locations that are representative of average static pressure in each controlled space. This will ensure that desired differential pressures are maintained.

c. Trigger a timer if the pressure varies from the specified range. Select a timer that automatically resets if the problem is corrected within 60 seconds.

d. Trigger both visible and audible alarms if the system cannot correct the difficulty within the allotted time.

4-5 SAFETY AND HEALTH CONSIDERATIONS.

29 CFR 1910 requires specific criteria for the safety and health of operators. The physical nature of the work and the use of protective clothing increase the potential for heat stress. Consider cooling the replacement air to reduce this potential. Refer to NAVSEA S6340-AA-MMA-010, *Otto Fuel II Safety, Storage, and Handling Instructions* for complete operational considerations.

4-5.1 Emergency Shower and Eyewash Stations.

Provide combination emergency shower and eyewash stations in the immediate area of Otto Fuel II use. Design in accordance with UFC 3-420-01, *Plumbing Systems,* Appendix D.

CHAPTER 5 COMPOSITE FABRICATION AND REPAIR FACILITIES

5-1 FUNCTION.

Composite shops and facilities primarily fabricate and repair aircraft and shipboard components. Both include a shop area, a mechanical equipment area, and a decontamination area (for protective clothing).

5-2 OPERATIONAL CONSIDERATIONS.

Composite fabrication and repair operations include sanding, buffing, fabric cutting, grinding, lay up, and wet spray up. These operations produce dust and vapor that constitute health hazards. The protective clothing that the workers wear and the physical nature of the work creates a potential for heat stress.

a. Consider using airless spray equipment to reduce hazardous vapors in the shop. Initial cost for this equipment is greater than traditional compressed air systems. Benefits include overspray reduction and less accumulation of resin and fiberglass over the life of the equipment. A disadvantage of these systems is their limited pattern and flow adjustment capability.

b. Consider using low monomer polyester material, closed molding systems or low-VOC resin systems, and airless and air-assisted spray equipment to avoid the need for expensive air pollution devices.

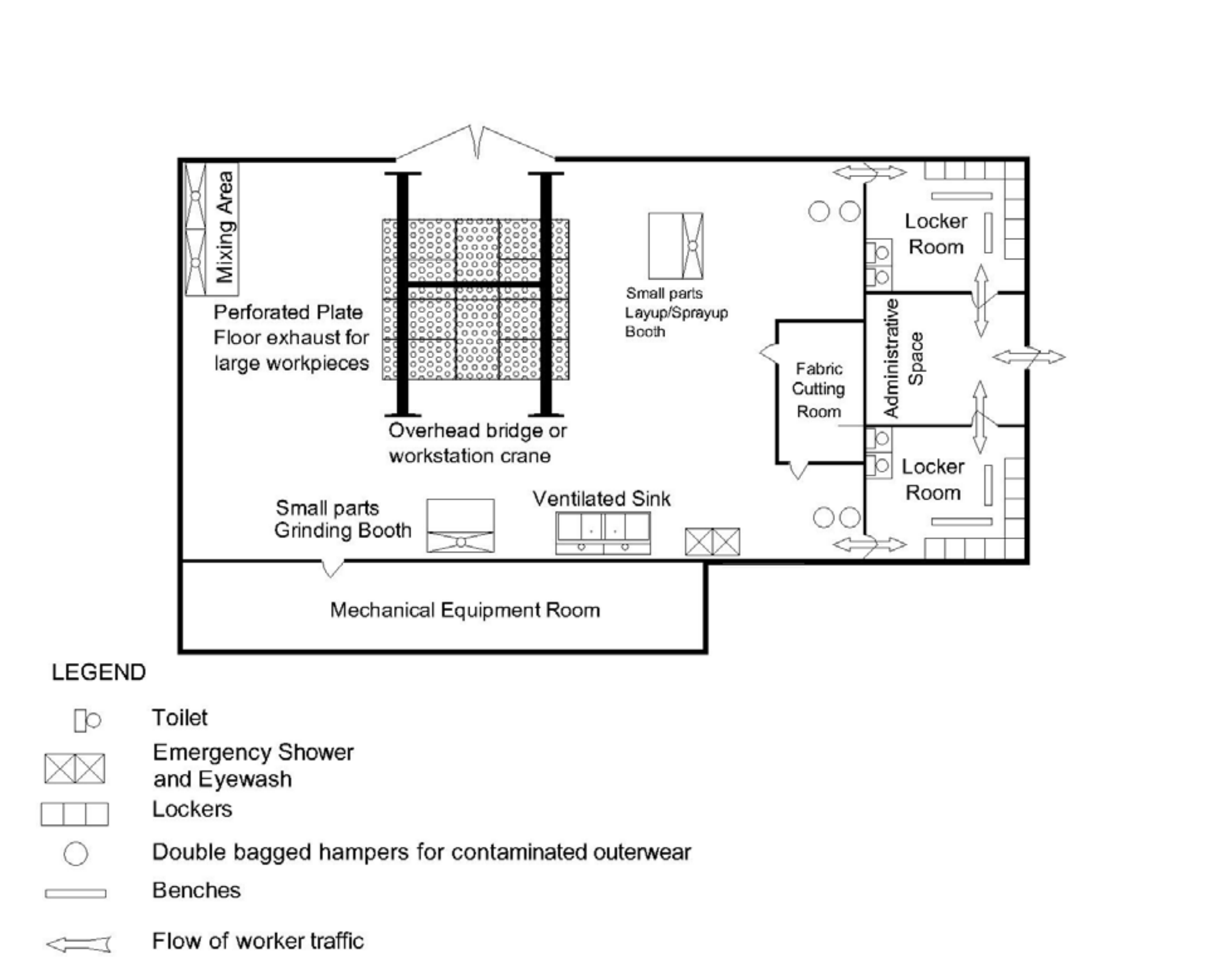
c. Isolate conventional grinding operations from the mixing areas and the lay up and spray up areas. The combined hazard of dust and flammable vapors is potentially explosive. Post signs in the lay up and spray up areas and the mixing area without low volume-high velocity (LVHV) connectors that read:

DANGER
DO NOT GRIND, CUT, OR SAW
FIBERGLASS IN THIS AREA

5-3 FLOOR PLAN.

Figure 5-1 shows typical floor plans for Composite fabrication and repair facility. The workers enter the clean locker rooms through the administrative area. They put on protective outerwear and proceed to the shop area. After performing their work, shop personnel vacuum, then discard their protective outerwear in containers near the entrances to the locker rooms. The workers then enter the locker rooms where they remove the remainder of their work garments.

Figure 5-1 Example Floor Plan for a Composite Facility.



5-4 DESIGN CRITERIA.

Design the facility using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

5-4.1 Exhaust Air System.

Provide an exhaust system that captures contaminated air generated during FRP fabrication and repair operations. Refer to Chapter 2 of this UFC; UFC 3-600-01, *Fire Protection Engineering For Facilities*; NFPA 33, *Standard Spray Application Using Flammable or Combustible Materials*; NFPA 68, *Standard on Explosion Protection by Deflagration Venting*; NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*; NFPA 654, and the specific requirements of this Chapter.

5-4.2 Hood Design.

The sizes and shapes of work pieces in FRP fabrication and repair facilities vary. Design separate hoods for processes producing only particulate and only vapor, and both particulate and vapor. Consider a molding system that completely encloses the work piece if the facility repeatedly manufactures the same work piece. Design exhaust hoods to enclose all processes to the greatest possible extent without inhibiting operations. Baffle all exhaust hoods to reduce cross drafts and improve hood efficiency. Table 5-1 summarizes recommended exhaust hoods, capture velocities, and air pollution control devices for each operation.

Table 5-1. Recommended Hood, Capture Velocity, and Air Pollution Device

Operation (expected contaminant)	Hood Type	Recommended Capture Velocity (fpm (m/s))	Air Cleaning Device (see notes)
Chemical Mixing (vapors)	Workbench (Figure 5-2)	100 (0.51 m/s)	1
Lay up (Vapors)	Workbench/Floor Exhaust (Figure 5-3)	100 (0.51 m/s)	1
Spray up (Vapors)	Spray up Booth (Figure 5-4)	100 (0.51 m/s)	1
Grind,Cut,Saw (Particulate)	Workbench/Floor Exhaust (Figure 5-3)	150 (0.76 m/s)	2
Cleanup (Vapors)	Ventilated Sink (Figure 5-5)	100 (0.51 m/s)	3 or 1
Hand Tools (Particulate)	LVHV Vacuum System	Not applicable	2

NOTES: (1) Determined by the local air pollution regulatory agency,
(2) fabric collector, and
(3) substitute an aqueous emulsion cleaner for acetone.

5-4.2.1 Plenum Velocity.

Design the plenum velocity at least one-half, but no greater than, the velocity through the perforated plate or layered prefilter to create an even airflow over the hood face. Design the hood-to-duct transition with an included angle of no more than 90 degrees.

5-4.2.2 Hood Length.

Specify that the length of the hood served by each exhaust plenum will not exceed 8 ft (2.44 m). For example, hoods between 8 and 16 ft (2.44 and 4.88 m) in length will have two exhaust takeoffs. Provide cleanout doors in the plenum to allow removal of accumulated particulate.

5-4.2.3 Portable Hand Tools.

Use portable hand tools with Low Volume High Velocity (LVHV) vacuum systems for sawing, cutting, and grinding on all work pieces. Ensure that the tools, with their vacuum hoses, are properly sized for the work piece internal angles and curvature. LVHV systems are described in the paragraph in Chapter 5 entitled, “Industrial Vacuum System”.

Figure 5-2. Workbench Hood.

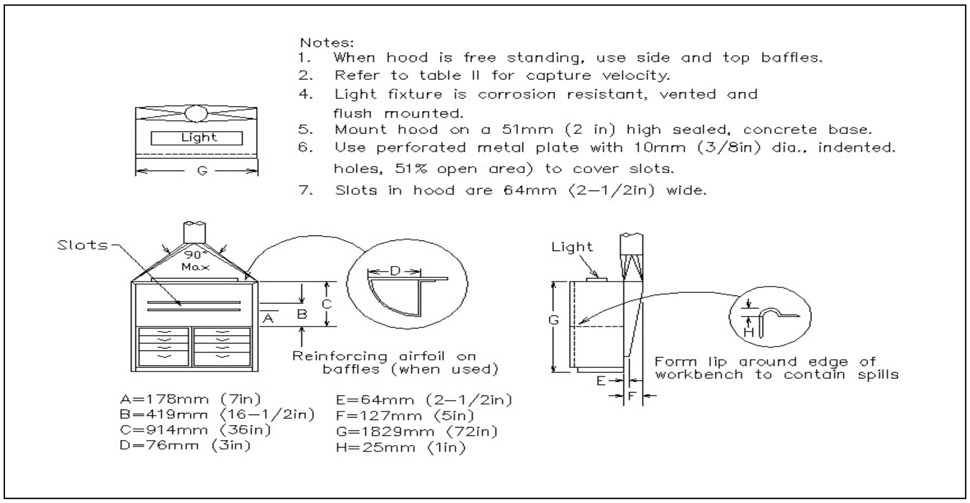
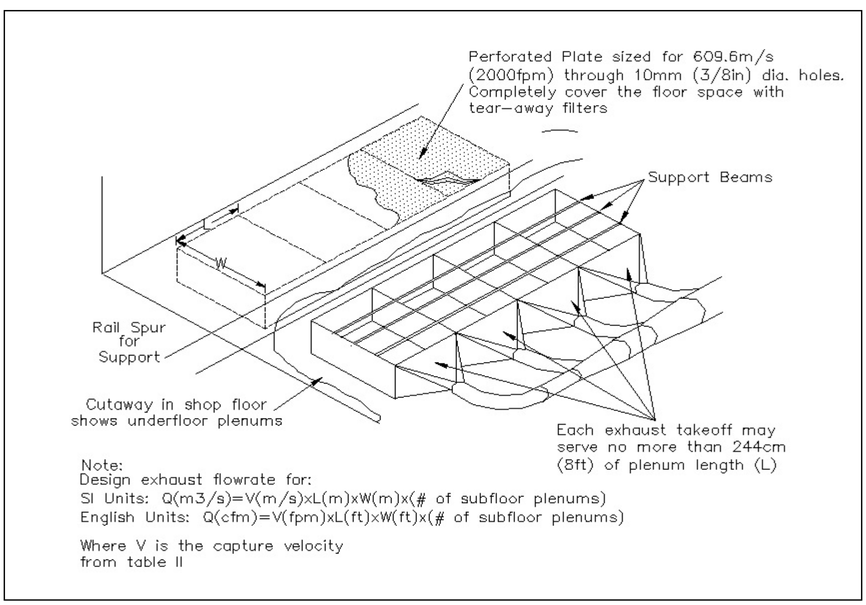


Figure 5-3. Floor Exhaust.



NOTE: Mount the work piece on a mechanism for easy rotation. This will reduce the dead air space that occurs when working on radomes, boat hulls, and other large objects.

Figure 5-4. Spray Up Booth.

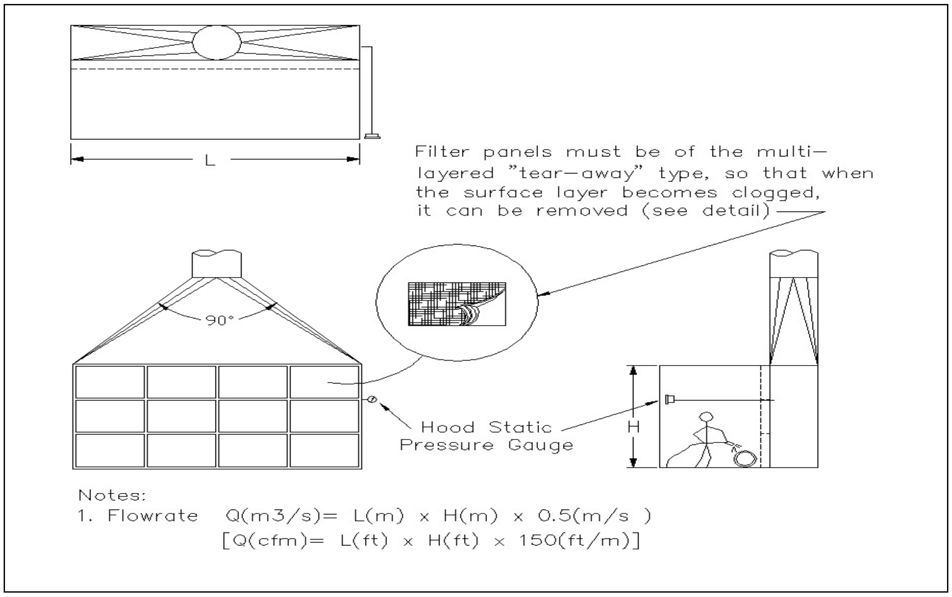
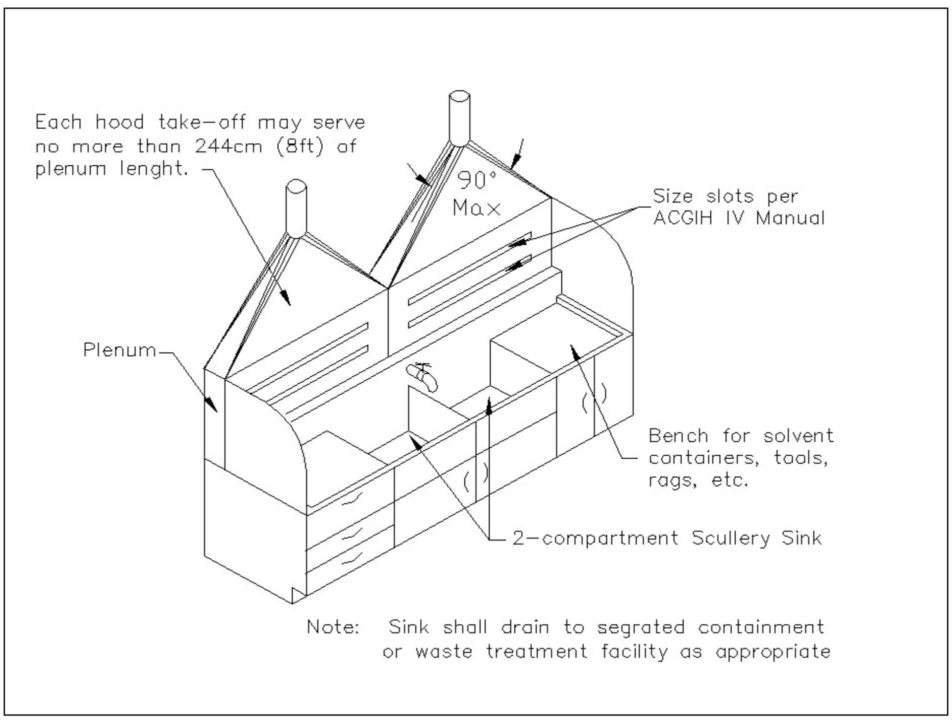


Figure 5-5. Ventilated Sink.



5-4.2.4 Spray Up Booths.

Design a spray up booth as shown on Figure 5-4. Use the spray up hood design in shops where spray up and lay up are performed in the same booth. Separate operations in this booth from any cutting, grinding, and sawing operations when conventional hand tools are used.

5-4.2.5 Ventilated Workbench and Sink.

Design a ventilated workbench as shown in Figure 5-2 for small work pieces. Use a similar workbench for resin preparation and mixing as shown on Figure 5-5. Eliminate the drawers and increase the size of the hood face by extending it to the floor if collection drums are used during resin preparation. Use aqueous emulsion cleaners to reduce styrene and acetone exposure.

5-4.3 Ductwork.

Design a 3,500 fpm (17.8 m/s) minimum transport velocity for LVHV hand tools, and grinding and spray up operations to prevent particulate material from collecting in the ductwork.

a. Size the ductwork carrying vapor generated during lay up and mixing operations for a minimum transport velocity of 2,500 fpm (12.7 m/s). Use sheet metal as duct material since it is non-combustible. Route the ductwork directly to fans located outdoors. See the paragraph in Chapter 2 entitled, “Ductwork” for further information on ductwork.

b. Consult with a fire protection engineer and use UFC 3-600-01, *Fire Protection Engineering For Facilities* to design a fire protection system for the ductwork when required. Condensation of flammable vapors, i.e. styrene and acetone, may occur and pool in the ductwork as it passes through an area with a lower temperature.

5-4.4 Fans.

See the paragraph in Chapter 2 entitled, “Fans” for general considerations.

5-4.5 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, “Exhaust Stacks” for exhaust stack design guidance.

5-4.6 Air Cleaning Devices.

Use separate air cleaning devices for grinding, buffing and polishing operations where particulate material is generated. Use separate air cleaning devices for lay up and mixing operations where flammable vapors are generated. Consult the air pollution control authorities for details on local requirement.

5-4.6.1 Grinding Operations and Hand Tools.

Use a fabric collector for grinding operations and LVHV hand tools. Consider using a disposal chute with a motor-driven rotary air lock in shops with a large particulate volume.

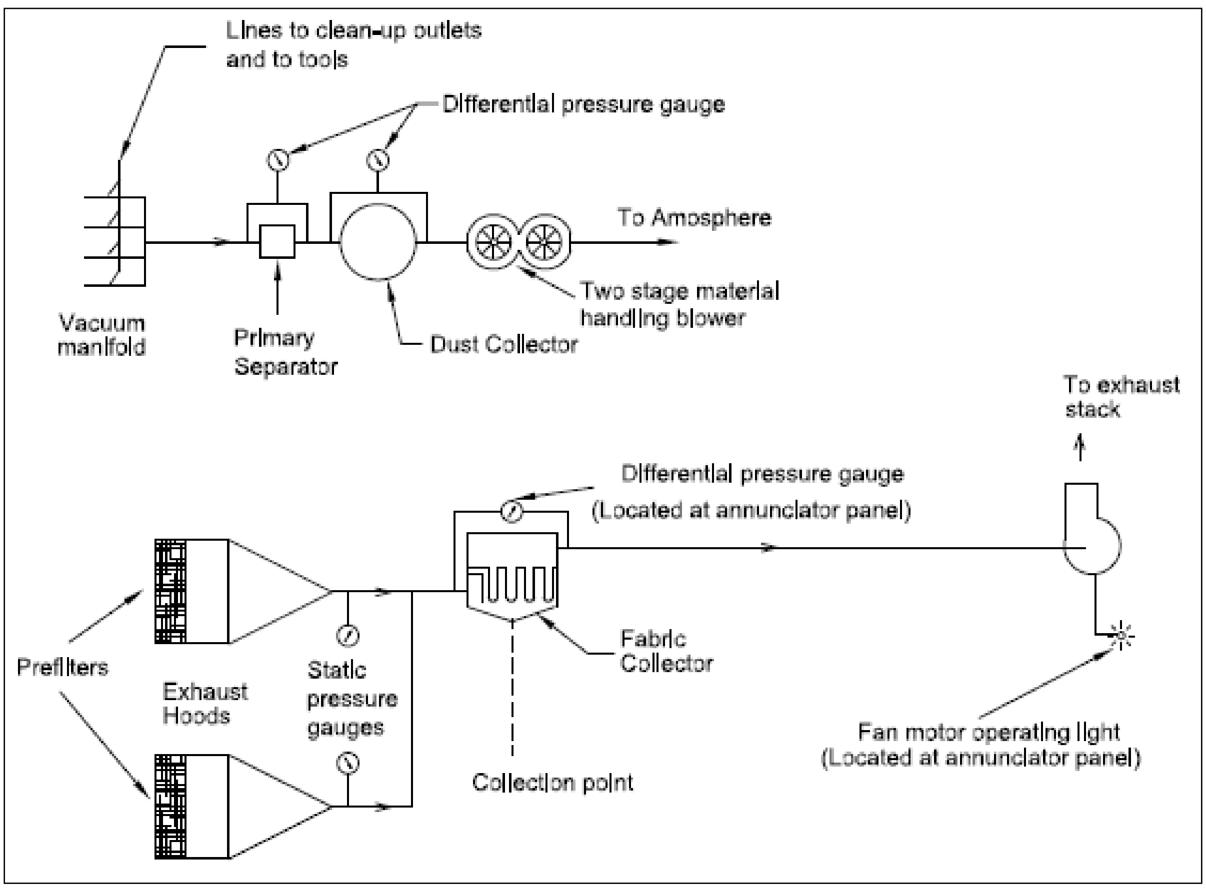
5-4.6.2 Spray Up Operations.

Spray-up operations release a combined contaminant of wet resin laden fiber and organic vapors. Therefore, separate spray up operations from all other operations. Install an air-cleaning device for vapors. Install layered prefilters on the spray up hood face instead of the perforated plate to prevent wet airborne resin from hardening in the ductwork and collectors. Peel off and discard a layer of the prefilter when its surface becomes loaded as indicated by the hood static pressure gauge. This continues until only the base filters remain. After that, replace the entire prefilter section. Specify a filter material that is not damaged by the styrene and acetone vapor produced in Composites facilities.

5-4.7 Industrial Vacuum System.

Install a vacuum system; see Figure 5-6, to exhaust fibers, dry resin and dust from LVHV hand tools when they are used. The vacuum system also allows workers to conduct shop cleanup and to decontaminate their protective outerwear. ACGIH IV Design Manual, Chapter 13, Section 13.40, Low Volume-High Velocity Exhaust Systems, gives design details and illustrates power tools using LVHV vacuum systems. The large size and high terminal velocity of the particulates produced by the hand tools requires a high velocity vacuum take-off hood for each tool. Generally, design the takeoff hood into the tool's safety guard.

Figure 5-6. Exhaust System Schematic.



5-4.7.1 Vacuum System Design.

Design the vacuum system in accordance with the following criteria:

a. Ensure each take-off hood produces the proper capture velocity. This is the most important consideration in designing the vacuum system. Design the hood to capture contaminants as close as possible to the point of generation. Design vacuum systems to capture contaminants within 1/2 inch (12.7 mm) of the source.

b. Design the capture air-stream to have a velocity of two to three times the generation velocity for particles of 20 to 30 micrometers (20 to 30 microns.) Design for an additional velocity of:

   1. Four to five times the generation velocity to pull the particles up through 300 U.S. standard mesh, or

   2. Six to eight times the generation velocity to pull particles up through 20 U.S. standard mesh.

c. Design the air volume for no less than two parts of air to one part of material to be captured by weight.

d. Design the vacuum hose length less than 25 ft (7.6 m). Locate inlet valves 30 to 35 ft (9 to 10.7 m) apart when a 25ft (7.6 m) length of hose is used. Locate the tool vacuum hose connection on the ends of the workbench underneath the stands. Size the hose based on the following:

   1. Air volume per hose.

   2. Number of hoses to be used simultaneously.

   3. Transport velocities.

e. Use either a multistage centrifugal or turbine blower, positive-displacement blower or a regenerative blower for the vacuum system. Size the blower according to the following:

   1. The total system pressure loss associated with the total number of hoses to be used simultaneously.

   2. The maximum exhaust flow-rate entering the inlet of the blower.

f. Place the primary separator and dust collector ahead of the vacuum exhaust blower to minimize wear to the blower.

g. Use the manufacturer's data to complete the design because the LVHV system design data is largely empirical.

5-5 REPLACEMENT AIR.

Design replacement air systems to maintain a pressure (relative to the atmosphere) ranging from -0.02 to -0.06 in wg (-4.97 to -14.9 Pa) in the shop space and the protective clothing decontamination areas. Maintain the clean spaces at a positive pressure differential relative to dirty spaces. See the paragraph in Chapter 2 entitled, “Replacement Air” for further details. Provide each ventilated space with a dedicated replacement air system. Conduct a study of the curing requirements of the resin before specifying temperature and humidity ranges. Do not re-circulate exhaust air.

5-6 SYSTEM CONTROLS.

Design system controls in accordance with the paragraph in Chapter 2 entitled, “Controls” and the following:

a. Position the annunciator panel at the entrance to the dirty space so operators can monitor operating gauges.

b. Install static pressure sensors at locations that are representative of the average static pressure in each controlled space. This will ensure that desired differential pressures are maintained.

c. Interlock the hand tool power supply with the main ventilation system's on/off switch and with the vacuum system. This will prevent the use of hand tools without ventilation controls.

5-7 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, “Safety and Health Considerations”. Provide combination emergency shower and eyewash stations in the workspace. Design in accordance with UFC 3-420-01, *Plumbing Systems,* Appendix D.

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CHAPTER 6 ABRASIVE BLASTING FACILITIES

6-1 FUNCTION.

Workers prepare the surface of aircraft, shipboard, mechanical, utility, and other equipment in abrasive blasting facilities for surface coating, welding, and other operations.

This Chapter does not apply to temporary blasting enclosures.

Criteria for the design of Dry Media Blast (DMB) Aircraft Depaint Hangars are contained in UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*.

6-2 OPERATIONAL CONSIDERATIONS.

Silica sand is prohibited from use in fixed location enclosures. Avoid using agricultural media (e.g. peach pits, rice hulls, walnut shells). They are particularly susceptible to explosions.

6-3 DESIGN CRITERIA.

Apply the general technical requirements of Chapter 2 and the specific requirements of this Chapter to ensure the proper function, operation and maintenance of an abrasive blasting facility. Use this information when assembling a specification package for an enclosure manufacturer or inspecting an enclosure already in place.

6-3.1 Exhaust Air.

Determine the type of dust hazard and the minimum average air velocity through the blasting enclosure in accordance with 29 CFR 1910.94(a), *Abrasive Blasting*; ANSI/AIHA/ASSE Z9.4, *Abrasive-Blasting Operations– Ventilation and Safe Practices for Fixed Location Enclosures*, sections 4, 5, 6 and A7; NFPA 68, *Standard on Explosion Protection by Deflagration Venting*; NFPA 69, *Standard on Explosion Prevention Systems*; NFPA 70; NFPA 91; NFPA 654; NFPA 484 *Standard for Combustible Metals* when blasting on materials containing aluminum, magnesium, titanium, zirconium and lithium, respectively.

6-3.2 Blasting Cabinets.

Install baffles around air inlets to prevent abrasive material from escaping from the cabinet. Use a minimum inward air velocity of 500 fpm (2.54 m/s) at all operating openings. Discharge the exhaust air outside the building.

6-3.3 Walk-in Blasting Enclosures.

Design the enclosure so that the air flows from either the ceiling to the floor (downdraft), Figure 6-1, or from one wall to the opposite wall (crossdraft), Figure 6-2, and the following:

a. Consider the geometry of the room and how work pieces are positioned within the room, and the number of workers and their locations when selecting a downdraft or a crossdraft design.

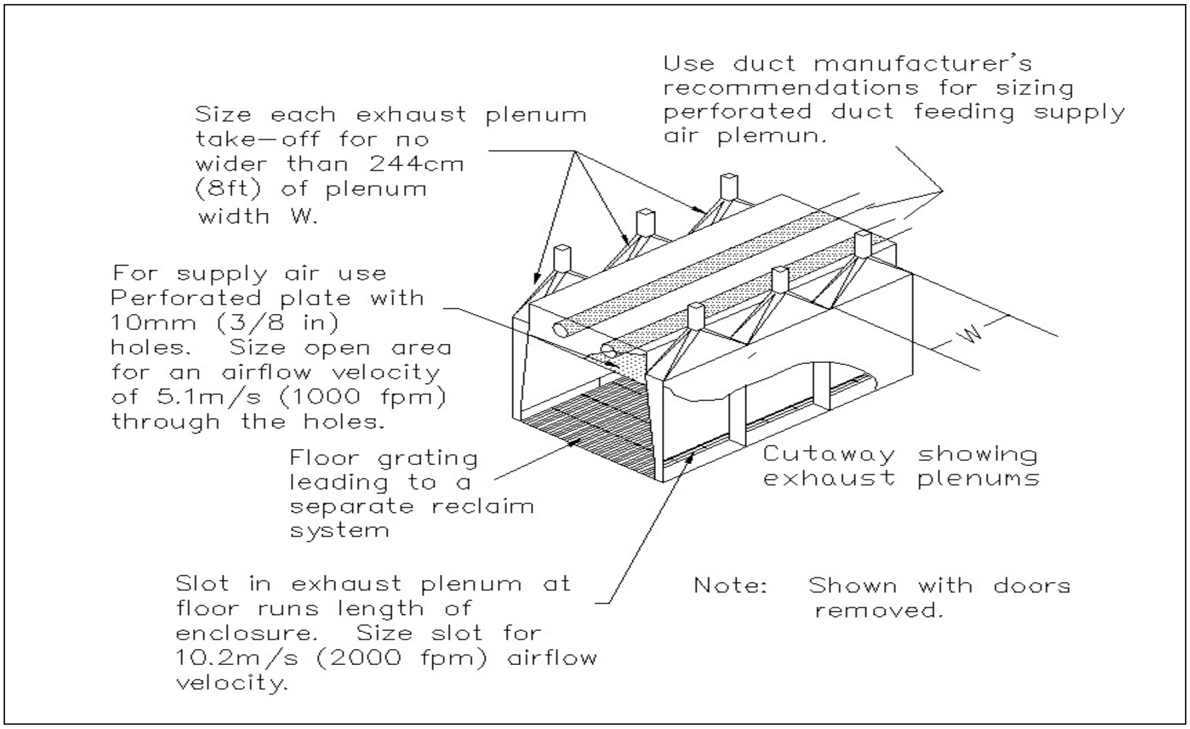
b. Minimize the area of a blasting room to reduce the volumetric airflow rate. Allow at least 4 ft (1.22 m) of clearance between the work piece and the ceiling, walls, and doors of the room. Add extra clearance to accommodate internal fixtures such as tables and hoists.

c. Isolate the abrasive blasting rooms from other processes, functions and activities, whenever possible. Place blasting rooms outside, away from administration and other spaces. Protect the blasting room and related equipment from rainwater and moisture intrusion. As a minimum, put a roof or cover over the blasting room.

6-3.3.1 Downdraft.

The downdraft design provides superior visibility. In addition, a downdraft design is preferred since contaminated air is usually drawn away from the worker's breathing zone. When more than one operator works in an enclosure, contaminated air generated from one operation is less likely to migrate into the other operator's breathing zone. Use a perforated plate with 3/8-in (9.53 mm) diameter holes, as shown in Figure 6-1, to uniformly distribute the airflow over the entire cross-section of the enclosure. Use a perforated duct inside the plenum to help evenly pressurize the plenum.

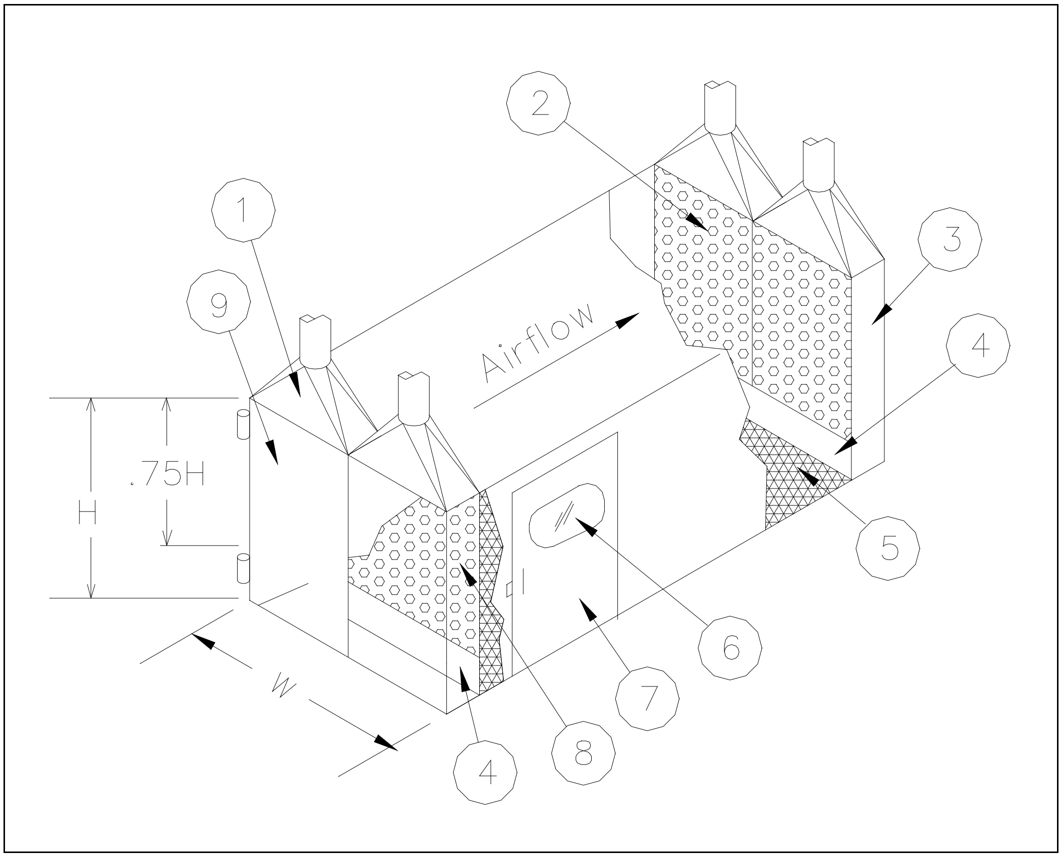
Figure 6-1. Downdraft Blast Enclosure.



6-3.3.2 Crossdraft.

Consider the work locations of operators when positioning the replacement and exhaust air plenums. Do not allow any operator to blast upstream of coworkers. Use a perforated plate with 3/8-in (9.53 mm) diameter holes; see Figure 6-2, to uniformly distribute airflow over the entire cross-section of the enclosure.

Figure 6-2. Crossdraft Blast Enclosure.



NOTES:
1. For mechanically supplied replacement air, use maximum plenum take-off width of 8 ft (2.44 m). Plenum serves as material door.
2. Perforated plate with 3/8-in (9.53 mm) holes. Size open area for an airflow velocity of 2000 fpm (10.16 m/s) through holes.
3. Size the exhaust plenum for a maximum plenum velocity of 1000 fpm (5.08 m/s). Size any supply plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
4. Lift up flap to remove material from behind plenum.
5. Floor grating.
6. Observation window.
7. Personnel door.
8. Perforated plate, from floor to ceiling and wall-to- wall, with 3/8-in (9.53 mm) holes. Size open area for an airflow velocity of 1000 fpm (5.080 m/s) through holes.
9. Hinged plenum equipment doors.

6-3.4 Access Doors and Observation Windows.

Provide an observation window and an access door in accordance with 29 CFR 1910.94(a)(3)(i)(d) and (e) and ANSI/AIHA/ASSE Z9.4 sections 5.3 and 5.4. Position the observation window in the blast room walls and door as necessary so workers inside the room can be seen from outside the room at all times. Use several doors and windows in large rooms. Provide emergency exits on opposing walls. Make personnel and equipment doors operable from both inside and outside of the room.

6-3.5 Air Cleaning Devices.

See the paragraph in Chapter 2 entitled, "Air Pollution Control Equipment". Design in accordance with 29 CFR 1910.94(a)(4)(iii) and ANSI/AIHA/ASSE Z9.4, section 6.3. Consider using a pulse-jet, pleated paper cartridge type dust collector and the following.

a. Replaceable explosion vents on the collector hoppers in accordance with NFPA 68.

b. Platforms leading to all elevated access hatches.

c. Fan located on the clean side of the collector.

d. Place dust collectors outside of the building for all blasting applications. NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*, specifically requires that the air pollution equipment be located outside when blasting on aluminum or aluminum alloys.

6-3.6 Recirculation.

Do not recirculate exhaust air when operations generate toxic materials. If exhaust air recirculation is permitted, design the system in accordance with the ACGIH IV Design Manual (Section 10.8), ANSI/AIHA/ASSE Z9.4 (section 6.3) and ANSI AIHA/ASSE Z9.7, 29 CFR 1910.1025 (lead), and 29 CFR 1910.1027 (cadmium). The outdoor air volumetric airflow rate must be sufficient to keep the contaminant below 25 percent of the MEC.

6-3.7 Media Reclamation.

Design in accordance with 29 CFR 1910.94(a)(4)(ii) and ANSI/AIHA/ASSE Z9.4, section 6.2. Do not integrate the exhaust ventilation system with the media recovery system.

a. Protect the media recovery system and ductwork from moisture and rainwater intrusion to keep the media from caking and plugging up the system.

b. Use mechanical recovery systems such as rotary screw conveyors for heavy media (steel shot).

c. Consider using pneumatic recovery system instead of mechanical recovery system for plastic media.

6-3.8 Ductwork.

See the paragraph in Chapter 2 entitled, “Ductwork”. Do not use spiral lock seam duct. Size the exhaust ductwork to maintain a minimum transport velocity of 3,500 fpm (17.8 m/s). Specify flat backed elbows per the ACGIH IV Design Manual, Chapter 5, Figure 5-16.

6-3.9 Fans.

See the paragraph in Chapter 2 entitled, “Fans”. Use centrifugal fans with backward curved blades, whenever possible. Centrifugal fans with radial blades are less efficient, but still acceptable. Place the exhaust fan and the outlet ductwork outside of the building.

6-3.10 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, “Exhaust Stacks” for design guidance.

6-3.11 Replacement Air Ventilation Systems.

See the paragraph in Chapter 2 entitled, “Replacement Air”. Design dedicated mechanically supplied replacement air systems to maintain room static pressures (relative to the atmosphere) ranging from -0.02 to -0.06 in wg (-4.98 to -14.9 Pa).

Blast booths often do not have mechanical replacement air. In this case, there is no control over the room static pressure for non-mechanical replacement air systems. The extra negative pressure reduces exhaust fan performance. If mechanically supplied replacement air is not feasible, ensure that the room static pressure and the resistance through filters and louvers are included when sizing the exhaust fan.

6-3.12 Heating and Air Conditioning.

For HVAC-related issues use UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems.*

6-3.13 System Controls.

Design system controls in accordance with the paragraph in Chapter 2 entitled, “Controls” and the following.

a. Install static pressure sensors at locations that represent the average static pressure in each blasting room. This will enhance monitoring and maintenance of desired blasting room pressures.

b. Interlock the blasting tool power supply with the ventilation system's on-off switch. This will prevent the use of blasting tools without ventilation controls.

6-4 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, “Safety and Health Considerations”, 29 CFR 1910.94(a)(5), and ANSI/AIHA/ASSE Z9.4, section 7, for general requirements. Consider the following.

6-4.1 Respiratory Protection.

Follow the guidelines in 29 CFR 1910.94(a)(5) for respiratory protection requirements. The operator must wear a continuous-flow, air-line respirator that covers the head, neck, and shoulders. Consider providing each respirator hood with an adjustable, vortex-type climate control system.

6-4.2 Air Supply and Air Compressors.

For large booths, consider providing multiple air hose connection points along the perimeter of the enclosure to accommodate work in various parts of the booth.

6-4.3 Noise.

See the paragraph in Chapter 2 entitled, “Noise”. Carefully select the blast nozzle. Nozzle noise generation depends greatly on the discharge velocity. Consider using sound barriers or dampening materials on enclosure walls. Protect the dampening material from abrasive blast as much as possible. Isolate the air compressor, media recirculation, and air pollution equipment to minimize noise exposure.

6-4.4 Hygiene Facilities.

Provide clean change rooms, shower facilities, and lunchroom facilities in accordance with OSHA regulations.

CHAPTER 7 WOOD SHOP FACILITIES

7-1 FUNCTION.

Wood shops differ in size and function. Use the design criteria in this chapter as a general guideline for developing ventilation systems for wood shops.

7-2 OPERATIONAL CONSIDERATIONS.

A properly designed ventilation system will control the dust level within the shop. Exposure to wood dust may lead to health problems. The accumulation of wood dust can create explosion and fire hazards. Even if a ventilation system is installed to collect most of the dust, manual cleaning at each machine and throughout the shop is still necessary. Restrict woodworking exhaust systems to handling only wood dust. Do not connect any other process that which could generate sparks, flames, or hot material to a woodworking exhaust system.

7-3 FLOOR PLAN LAYOUT.

Contact the shop personnel who will be working with the machinery to get their input on workflow and specific equipment. Design the ventilation system to complement equipment layout and minimize housekeeping.

7-4 DESIGN CRITERIA.

Design the facility using general technical requirements in Chapter 2 of this UFC, NFPA 664, *Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* and the specific requirements in this chapter.

7-4.1 Dust Collection System.

Calculate the system capacity on the basis that the system operates with all hoods and other openings, such as floor sweeps, open. Refer to the ACGIH IV Design Manual, Chapter 13, (Section 13.95), for determining the exhaust flow rate for specific wood shop machines.

7-4.1.1 System Layout.

Lay out the system to meet the shop requirements. Consider locating machines with the greatest hood resistance as close as possible to the fan. In most cases, ductwork is located along the ceiling and walls; however, running ductwork under removable grates or panels in the floor may reduce duct lengths and leave more working space around machinery. Refer to NFPA 650, *Pneumatic Conveying Systems for Handling Combustible Particulate Solids* and NFPA 664 for information on wall penetrations and clearances.

7-4.1.2 Plenum Exhaust System.

An alternative to the tapered system is a plenum system, described in the ACGIH IV Design Manual, Chapter 5. A plenum system allows equipment to be moved in the shop and may be more efficient. Ducts can be added or removed, as equipment needs change. See the ACGIH IV Manual Chapter 5 (Section 5.5) for further considerations.

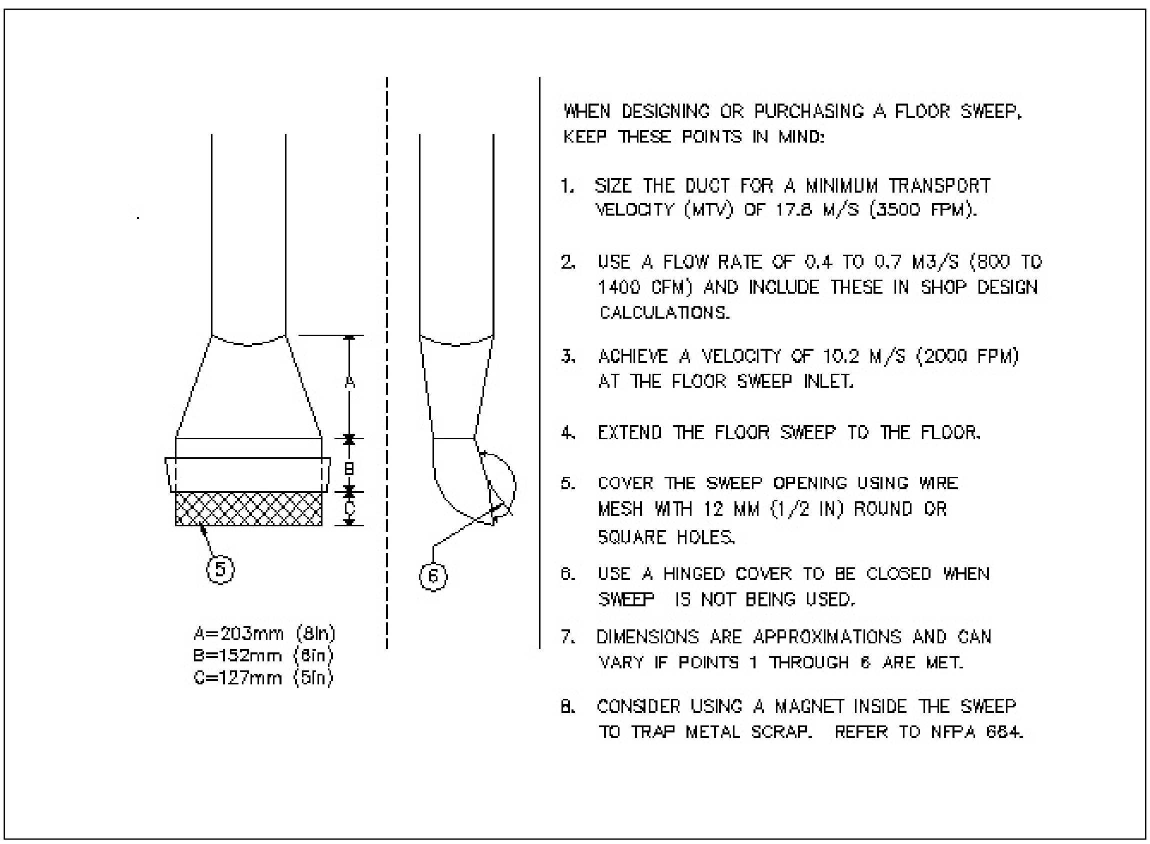
7-4.2 Hood Design.

Provide a hood for each operation that produces dust. This includes sawing, shaping, planing, and sanding operations. Design and position all hoods so the wood dust will fall, be projected, or be drawn into the hood in the direction of the airflow. Construct hoods of noncombustible materials. Ensure the hoods do not interfere with worker operations. In some cases, the exhaust hood may be utilized as a safety guard. Refer to the ACGIH IV Design Manual, Chapter 13 (Section 13.95) for woodworking hood designs. Modify the drawings as necessary to meet the specific equipment and process requirements.

7-4.3 Floor Sweeps.

If the design includes floor sweeps, include a means, such as magnetic separators, to prevent scrap metal from entering the system. Figure 7-1 shows a basic floor sweep design. The floor sweep is only opened during shop clean up. If the system design calculations indicate that, when opened, the floor sweep provides a transport velocity of less than 3,500 fpm (17.78 m/s), design the system to include floor sweeps in the normally opened position without a hinged cover.

Figure 7-1. Floor Sweep



7-4.4 Ductwork.

See the paragraph in Chapter 2 entitled, “Ductwork” for general ductwork design. See NFPA 664 for specific requirements on wood shop ductwork construction. Size the ductwork to maintain a minimum transport velocity as specified in the ACGIH IV Design Manual, Chapter 13.95, Woodworking. Use only metal ductwork and conductive flexible hose. Bond and ground all ductwork in accordance with NFPA 664. The ductwork must be designed on the basis that all hoods and other openings connected to the system are open.

7-4.5 Blast Gates.

Provide blast gates only for the specific purpose of balancing the airflow. Do not use blast gates to isolate equipment from the exhaust system with the intent to reduce the overall airflow requirement. When possible, install blast gates on horizontal runs and orient the gate so the blade is on the top half of the duct and opens by pulling the blade towards the ceiling. When possible, blast gates must be installed at a location not easily accessible to shop personnel. After final balancing and acceptance, secure the blade and mark its position so that it can be returned to the balanced position if inadvertently moved. When the blast gate cannot be placed out of the reach of shop personnel, then lock the blade in position. For example, drill a hole through the body and blade of the gate and then insert a bolt and tack weld it.

7-4.6 Duct Support.

If sprinkler protection is provided in the duct, horizontal ductwork must be capable of supporting the weight of the system, plus the weight of the duct half-filled with water or material being conveyed, whichever has the higher density.

7-4.7 Clean Out Panels.

See the paragraph in Chapter 2 entitled, “Ductwork”.

7-4.8 Exhaust Fans.

See the paragraph in Chapter 2 entitled “Fans”.

7-4.9 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, “Exhaust Stacks”.

7-4.10 Air Cleaning Devices.

See the paragraph in Chapter 2 entitled, “Air Pollution Control Equipment”. Locate the air-cleaning device outside the building.

7-4.11 Building Heating and Air Conditioning.

For HVAC-related issues use UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems.*

7-5 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, “Safety and Health Considerations” and the following items.

a. Refer to section 7.2.2 of ANSI O1.1, *Woodworking Machinery, Safety Requirements* for personal protective equipment.

b. Provide a means for separately collecting and disposing of any metal scrap such as nails, band iron, or any wood containing metal. Do not use the woodshop ventilation system to pick up these materials.

c. Avoid the use of wood painted with paints containing lead, hexavalent chromium, cadmium, or coated with wood preservatives. Otherwise, consult an industrial hygienist (IH) to determine the exposure level and the level of respiratory protection needed.

d. Use sharp and clean blades at the correct feed rate to generate less heat. The generated heat can raise the wood or wood-containing product to ignition temperature that could start a fire.

CHAPTER 8 BATTERY MAINTENANCE FACILITIES

8-1 FUNCTION.

Battery maintenance facilities contain space and equipment for receiving, cleaning, testing, charging, and issuing batteries. Sizes range from a small booth to a room with storage area. In these facilities, batteries are not in operation while being charged. Two types of electrochemical battery in general use are lead-acid and nickel-cadmium (NICAD). This chapter does not address battery-post repair operation. For stationary battery installations where batteries are operated on a continuous float charge and no battery maintenance is involved, use UFC 3-520-05 *Stationary and Mission Batteries*.

8-2 OPERATIONAL CONSIDERATIONS.

Batteries generate a small amount of hydrogen and other gases while they are being charged or discharged. Hydrogen build-up could lead to an explosion. Provide ventilation to keep the hydrogen concentration below 25 percent of the LEL (LEL = 4 percent) to prevent an accumulation of an explosive mixture.

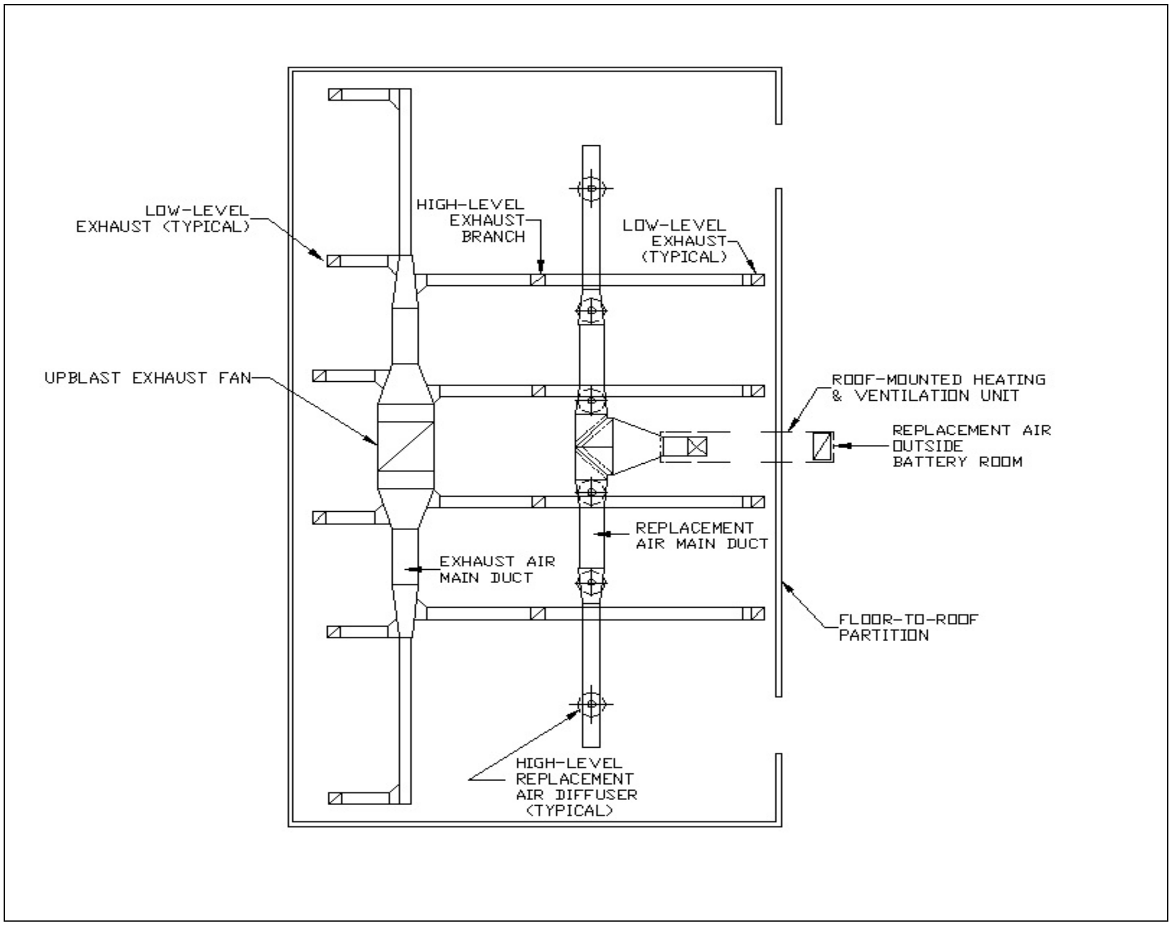
8-3 DESIGN CRITERIA.

Design the ventilation system using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

8-3.1 Exhaust System.

Design exhaust ventilation to have both high-level exhaust for hydrogen and low-level exhaust for electrolyte spills (acid mist and odors). Distribute one-third of the total exhaust flow rate to the high-level exhaust to ventilate all roof pockets. Locate low-level exhaust at a maximum of 1-ft (304.8-mm) above the floor. Do not re-circulate exhaust air back to the maintenance facility. Exhaust all air directly to the outdoors through a dedicated exhaust duct system. See Figure 8-1 for a floor plan of a battery maintenance room.

Figure 8-1. Ventilation System for Battery Maintenance Facilities.



8-3.1.1 Minimum Flow Rate Calculation.

To determine the amount of required volumetric airflow rate, the amount of hydrogen produced must be calculated for the total number of battery cells in the room. Hydrogen generation, heat generation and proximity factor into the ventilation calculation. The volume of hydrogen generated is governed by the amount of charging current (ampere) supplied to the fully charged battery by the charger. Significant amounts of hydrogen are evolved only as the battery approaches full charge. Refer to IEEE Standard 1635 / ASHRAE Guideline 21, “Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications”, Section on HVAC System Design for Ventilation.

8-3.2 Ductwork.

Design ductwork in accordance with the paragraph in Chapter 2 entitled, “Ductwork”. Use FRP or PVC ductwork.

8-3.3 Fans and Motors.

Select fans in accordance with the paragraph in Chapter 2 entitled, "Fans". Use AMCA 201, Type B spark resistant construction and explosion proof motors. Fans must have non-sparking wheel. Locate the motor outside of the air stream.

8-3.4 Weather Stack Design and Location.

Avoid re-entry of exhaust air by discharging the exhaust high above the roof line or by assuring that no window, outdoor intakes, or other such openings are located near the exhaust discharge. See the paragraph in Chapter 2 entitled, "Exhaust Stacks" for additional considerations.

8-3.5 Air Cleaning Device.

Due to the quantities and types of contaminants generated by this process, there is no requirement for air pollution control equipment.

8-3.6 Replacement Air.

Design a replacement air system in accordance with the paragraph in Chapter 2 entitled, "Replacement Air". Design the replacement (makeup) air volumetric flow rate equal to 95 percent of the exhaust airflow rate to maintain the space under a negative pressure and prevent the migration of fumes and gases into adjacent areas. Provide means for air flow to ensure a negative pressure relationship. duct system. Makeup air can be transferred from a Class 1 or Class 2 area in the facility as defined in ANSI/ASHRAE 62.1, Ventilation for Acceptable Indoor Quality, or supplied directly. If supplied directly, it must be filtered.

8-3.7 System Controls.

Design system control in accordance with the paragraph in Chapter 2 entitled, "Controls" and the following criteria:

a. Interlock the charging circuit and the exhaust fan in the shop to ensure chargers will not operate without ventilation.

b. Provide indicator light showing that the exhaust system is functioning properly.

8-4 SAFETY AND HEALTH CONSIDERATIONS.

In accordance with 29 CFR 1926.403, *Battery Rooms and Battery Charging*, provide the following.

a. Face shields, aprons, and rubber gloves for workmen handling acids or batteries.

b. Combination emergency shower and eyewash stations within 25 ft (7.6 m) of the work area. Design in accordance with UFC 3-420-01, *Plumbing Systems,* Appendix D.

c. Facilities for flushing and neutralizing spilled electrolyte, and for fire protection.

d. Non-slip rubber insulating matting in front of all charging benches to protect personnel from electric shock and slipping hazards

e. Warning signs, such as: “Hydrogen, Flammable Gas, No Smoking, No Open Flames.”

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CHAPTER 9 PAINT SPRAY BOOTHS

9-1 FUNCTION.

Paint spray booths provide surface finishing capabilities for a wide range of parts, equipment, and vehicles. Paint spray booth sizes range from bench type units for painting small parts, to large walk-in booths or rooms for painting vehicles, tractors or large equipment.

9-2 OPERATIONAL CONSIDERATIONS.

During paint spray operations, paint is atomized by a spray gun and then deposited on the object being painted. Depending on the application equipment and spray method used, transfer efficiencies vary greatly. Transfer efficiency is the amount of paint solids deposited on a surface divided by the total amount of paint sprayed, expressed as a percentage.

a. Use equipment with a high transfer efficiency, such as electrostatic or high volume low pressure (HVLP) spray guns, to reduce overspray. Overspray is the paint that is sprayed but not deposited on the surface being painted. This equipment not only saves in paint cost, but also reduces volatile organic compound (VOC) emissions and maintenance requirements.

b. Warm the paint before applying, whenever possible. This lowers the paint viscosity enabling spray painting at a lower pressure, thereby minimizing the amount of overspray generated. The lower viscosity also decreases the quantity of solvent used to thin the paint prior to spraying. This results in reduced solvent consumption and VOC emissions.

9-2.1 Painting Equipment Types.

Spray-painting equipment must conform to national, state, and local emission control requirements. One of these requirements is transfer efficiency. Five primary types of paint spraying equipment and their typical transfer efficiencies include:

1. Conventional air spray (25 percent transfer efficiency).
2. Airless spray (35 percent transfer efficiency).
3. Air-assisted airless spray (45 percent transfer efficiency).
4. Electrostatic spray (65 percent transfer efficiency).
5. High volume/low pressure (HVLP) spray (up to 75 percent transfer efficiency).

9-3 DESIGN CRITERIA.

Design or procure paint spray booths in accordance with the general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter. Design paint spray booths in accordance with the requirements of NFPA 33, *Standards for Spray Application Using Flammable or Combustible Materials*.

9-3.1 Walk-in Spray Paint Booths.

The ventilation system for a walk-in booth is mainly to prevent fire and explosion. A well-designed ventilation system will also reduce paint overspray, help control workers' exposure, and protect the paint finish. Workers must use appropriate respiratory protection irrespective of the airflow rate.

a. Ensure the ventilation system for a walk-in booth meets the requirements of 29 CFR 1910.94 and 29 CFR 1910.107 and the appropriate guidelines in the painting operations section ACGIH IV manual.

b. Do not re-circulate exhaust air while painting.

9-3.1.1 Exhaust Configurations.

The two main ventilation system configurations are downdraft and crossdraft. In a downdraft booth, air enters through filters in the ceiling of the booth and leaves through filters that cover trenches under a metal grate floor. In a crossdraft booth, air enters through filters in the front of the booth and leaves through filters in the back of the booth. Both configurations are commercially available.

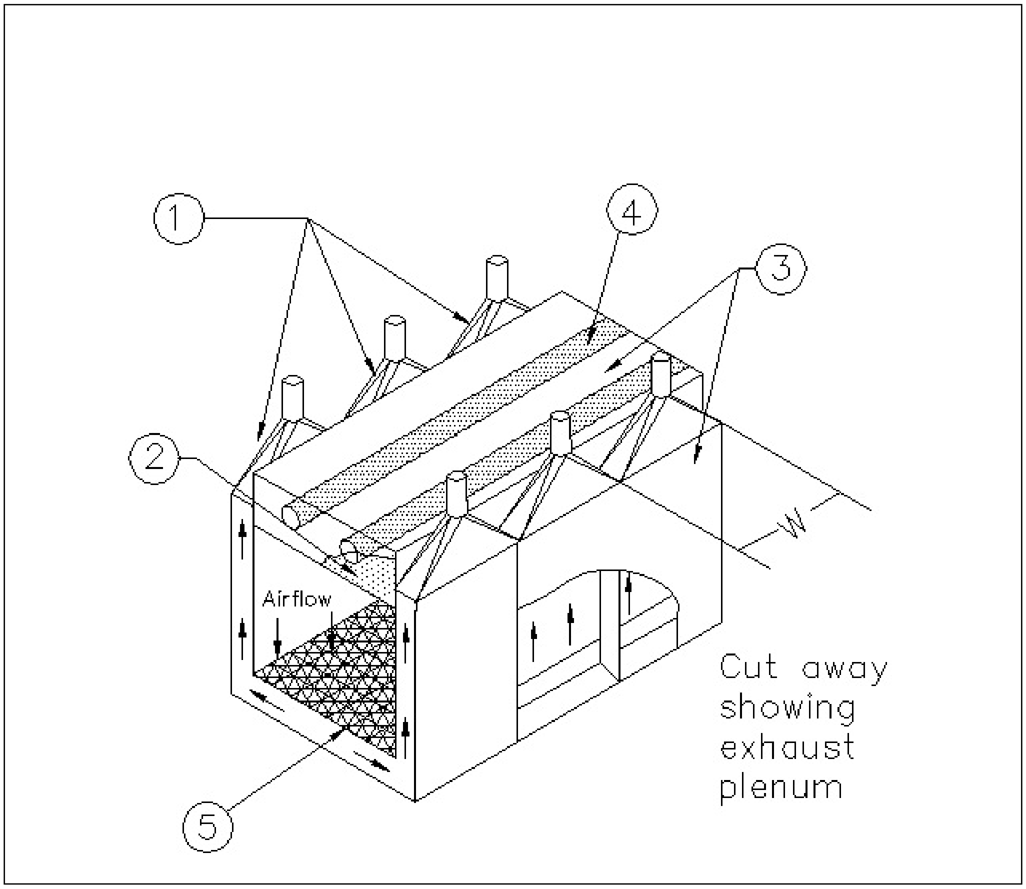
9-3.1.1.1 Downdraft Paint Spray Booths.

Downdraft booth configuration provides a cleaner paint job than the crossdraft booth configuration and controls exposures to workers better than crossdraft booth configuration. Figure 9-1 is an example of a downdraft configuration.

9-3.1.1.2 Crossdraft Paint Spray Booths.

The crossdraft paint spray booth usually requires less total volumetric airflow rate than the downdraft spray paint booth because the vertical cross-sectional area of the booth is often smaller than the booth footprint area. Figures 9-2 and 9-3 are examples of drive-through crossdraft paint spray booth configurations.

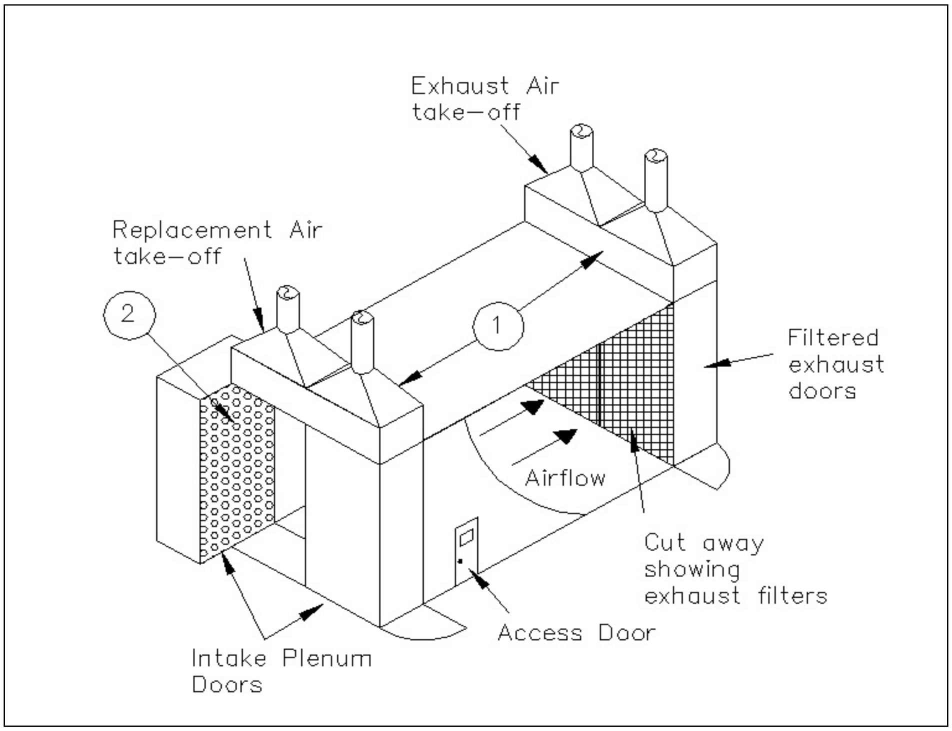
Figure 9-1. Walk-In Downdraft Paint Booth.



Drawing shown with doors removed

NOTES:
1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width (W).
2. Perforated plate with 3/8-in (9.53-mm) holes. Size open area for an airflow velocity of 1,000 fpm (5.08 m/s) through holes.
3. Size exhaust plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s). Size replacement air plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
4. Use manufacturer's recommendations for sizing perforated ductwork.
5. Removable filters and floor grating.

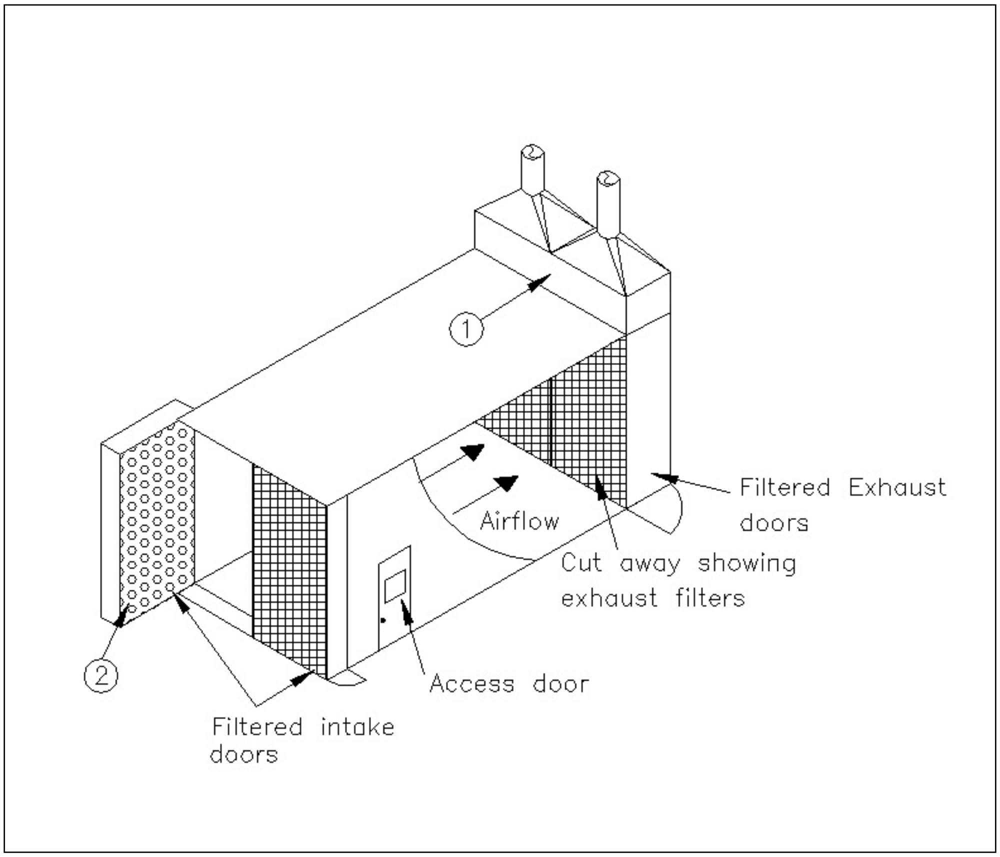
Figure 9-2. Drive-Through Cross Draft Paint Booth with Mechanical Replacement Air.



NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width. Size the exhaust plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s). Size replacement air plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
2. Perforated plate with 3/8-in (9.53-mm) holes. Size open area for an airflow velocity of 2,000 fpm (10.16 m/s) through holes.

Figure 9-3 Drive-Through Crossdraft Paint Booth With No Mechanical Replacement Air



NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width. Size the exhaust plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s). Size replacement air plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
2. Perforated plate with 3/8-in (9.53-mm) holes. Size open area for an airflow velocity of 2,000 fpm (10.16 m/s) through holes.

9-3.1.2 Paint Spray Booth Exhaust Filtration System.

There are two types of exhaust air filtration systems. The first type is a water wash system. A water curtain is created at the exhaust plenum by a pump providing continuous circulation of water. The second type is a dry filter system, where the exhaust air passes through filter media. Consider the following.

a. Do not design or purchase the water wash paint spray booths. The water wash system requires more energy to operate than the dry filter system. The wastewater must be treated and the hazardous constituents removed (often at great cost to the generating facility) before it may be discharged to a municipal treatment plant.

b. Neither water wash nor dry filter filtration systems can reduce the concentration of volatile organic compounds in the exhaust air stream. Consult the environmental department for controlling volatile organic compounds.

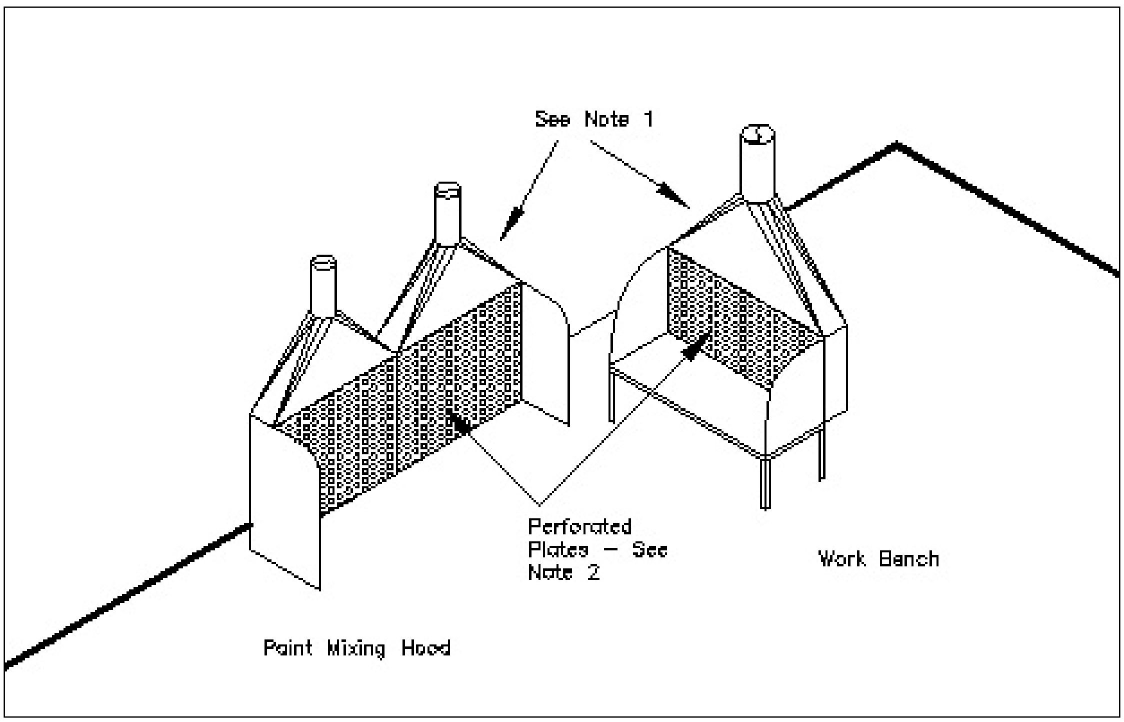
9-3.2 Storage and Mixing Room.

Refer to the ACGIH IV Manual, Paint Mix Storage Room, VS-75-30 for the design of ventilation system.

9-3.3 Small Spray Booths and Paint Mix Hoods.

Refer to the ACGIH IV Design Manual for the design of ventilation system. Figure 9-4 is an example of a workbench and a floor hood designed for paint mixing and small spray applications. ACGIH P.13-120 figure VS-75-02 states that Q=125cfm/ft2 for face area up to 4ft2 and Q=100cfm/ft2 for face area over 4 ft2.

Figure 9-4 Paint Mixing Hood and Work Bench



NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width. Size each plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s).
2. Perforated plate with 3/8-in (9.53 mm) holes. Size open area for an airflow velocity of 2,000 fpm (10.16 m/s) through holes.

9-4 FANS AND MOTORS.

Use explosion proof motor and electrical fixtures for exhaust fan. Do not place electric motors, which drive exhaust fans, inside booths or ducts. See Section 2-4.2 entitled, “Fans” for more detailed information about fan selection.

9-5 REPLACEMENT AIR.

There is no control over the room temperature or room static pressure for non-mechanical replacement air systems. Dust from outside often enters the paint spray booths through cracks and damages the paint finish. If painting operations require neutral air pressure inside the booth, provide a mechanical replacement air system to maintain a neutral air pressure inside the booth and prevent dust from entering the paint spray area. The neutral air pressure will also prevent paint overspray and vapors from escaping the booth and migrating into adjacent work areas.

9-5.1 Air Distribution.

Distribution of replacement air within the spray booth is as significant as the average air velocity through the booth. Distribute the replacement air evenly over the entire cross section of the booth to prevent turbulence or undesirable air circulation. The preferred means of distributing the replacement air is through perforated plate as shown in Figures 9-1, 9-2, and 9-3. See the paragraph in Chapter 2 entitled, “Replacement Air” for additional replacement air design criteria.

9-5.2 Heating and Air Conditioning.

See the paragraph in Chapter 2 entitled, “Replacement Air”. Most new paint spray booth ventilation systems have a painting mode and a curing mode. Do not re-circulate air during the painting mode. About 10 percent of the booth airflow is from outside the booth and 90 percent of the exhaust air is recycled during curing. Review the paint drying requirements before specifying temperature and humidity ranges. Refer to ANSI AIHA/ASSE Z9.7 for exhaust air re-circulation requirements.

9-6 SYSTEM CONTROLS.

Design system controls in accordance with the paragraph in Chapter 2 entitled, “Controls”.

9-7 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, “Safety and Health Considerations”. Provide combination emergency shower and eyewash stations in the workspace. Design in accordance with UFC 3-420-01, *Plumbing Systems,* Appendix D.

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APPENDIX A REFERENCES

DEPARTMENT OF THE AIR FORCE

AFOSH STD 91-501, *Air Force Consolidated Occupational Safety Standard*, http://static.e-publishing.af.mil/production/1/usafe/publication/afoshstd91-501_usafesup_i/afoshstd91-501_usafesup_i.pdf

AIR MOVEMENT AND CONTROL ASSOCIATION, INC.

http://www.amca.org/

AMCA 201, *Fans and Systems*

AMCA 99-2408, Standards Handbook: Operating Limits for Centrifugal Fans (Performance Classes)

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS, INC

http://www.acgih.org/

ACGIH IV *Design Manual, Industrial Ventilation; A Manual of Recommended Practice, For Design*

ACGIH IV *Manual, Industrial Ventilation; A Manual of Recommended Practice, For Operation and Maintenance*

AMERICAN NATIONAL STANDARDS INSTITUTE, INC.

http://www.ansi.org/

ANSI O1.1, *Woodworking Machinery, Safety Requirements*

ANSI/AIHA/ASSE Z9.4, *Abrasive-Blasting Operations– Ventilation and Safe Practices for Fixed Location Enclosures*

ANSI AIHA/ASSE Z9.7, *Recirculation of Air from Industrial Process Exhaust Systems*

AMERICAN SOCIETY OF HEATING, REFRIGERATION AND AIR CONDITIONING ENGINEERS, INC.

http://www.ashrae.org/

ASHRAE *Handbook, Fundamentals*

ASHRAE *Handbook, HVAC Systems and Equipment*

ASHRAE Standard 52.2, *Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size*

ASHRAE Guideline 1, *HVAC &R Technical Requirements for the Commissioning Process*

DEPARTMENT OF THE ARMY

Army EM 385-1-1, *Safety and Health Requirements*, http://140.194.76.129/publications/eng-manuals/

DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA PROGRAM

http://dod.wbdg.org/

UFC 1-200-01, *General Building Requirements*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 3-101-01, *Architecture*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-420-01, *Plumbing Systems*

UFC 3-450-01, *Noise and Vibration Control*

UFC 3-520-05, *Stationary and Mission Batteries*

UFC 3-600-01, *Fire Protection Engineering For Facilities*

UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*

UFC 4-216-02, *Design: Maintenance Facilities for Ammunition, Explosives, and Toxins (Inactive)*

U.S. ENVIRONMENTAL PROTECTION AGENCY

http://www.epa.gov

EPA-560-OPTS-86-001, *A Guide to Respiratory Protection for the Asbestos Abatement Industry*

DEPARTMENT OF LABOR

29 CFR 1910.94(a), *Abrasive Blasting*

NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION

http://www.nema.org

NEMA MG-1, *Standard for Motors and Generators*

NATIONAL FIRE PROTECTION ASSOCIATION

http://www.nfpa.org

NFPA 33, *Standard Spray Application Using Flammable or Combustible Materials*

NFPA 34, *Standard for Dipping Coating and Printing Processes Using Flammable or Combustible Liquids*

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

NFPA 69, *Standard on Explosion Prevention Systems*

NFPA 70, *National Electrical Code*

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*

NFPA 484, *Standard for Combustible Metals*

NFPA 650, *Pneumatic Conveying Systems for Handling Combustible Particulate Solids*

NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*

NFPA 664, *Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

DEPARTMENT OF THE NAVY

OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual,* http://doni.daps.dla.mil/OPNAV.aspx

DEPARTMENT OF THE NAVY, NAVAL SEA SYSTEMS COMMAND

http://www.navsea.navy.mil/

NAVSEA OP5, Volume 1, *Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation, and Shipping*

NAVSEA S6340-AA-MMA-010, *Otto Fuel II Safety, Storage, and Handling Instructions*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

http://www.osha.gov/

29 CFR 1910.107, *Spray Finishing Using Flammable and Combustible Materials*

29 CFR 1910.134, *Respiratory Protection*

29 CFR 1910.1000, *Air Contaminants*

29 CFR 1910.1001, *Asbestos, General Industry*

29 CFR 1910.1025, *Lead*

29 CFR 1910.1027, *Cadmium*

29 CFR 1915.1001, *Asbestos, Shipyards*

29 CFR 1926.403, *Battery Rooms and Battery Charging*

OSHA 3048, *Noise Control, A Guide for Workers and Employees*

SHEET METAL AND AIR CONDITIONING CONTRACTORS NATIONAL ASSOCIATION

http://www.smacna.org/

SMACNA GSSDC, *Guide for Steel Stack Design and Construction*

SMACNA RIDCS, *Round Industrial Duct Construction Standards*

SMACNA RTIDCS, *Rectangular Duct Construction Standards*

COMPRESSED GAS ASSOCIATION

http://www.cganet.com/

G-7.1, *Commodity Specification for Air*

APPENDIX B GLOSSARY

B-1 TERMS

Air cleaner	**A device designed for the purpose of removing atmospheric airborne impurities such as dusts, gases, vapors, fumes, and smoke. (Air cleaners include air washers, air filters, electrostatic precipitators and charcoal filters.)**
Air filter	**An air cleaning device to remove light particulate loadings from normal atmospheric air before introduction into the building. Usual range: loadings up to 3 grains per thousand ft^3 (0.0069 g/m^3). Note: Atmospheric air in heavy industrial areas and in-plant air in many collectors are then indicated for proper air cleaning.**
Air, standard	**Dry air at 70 degrees F, 21.11 degrees C, and 29.92 in. Hg barometer. This is substantially equivalent to 0.075 pounds per cubic feet (lb/ft^3). Specific heat of dry air = 0.24 Btu/lb-F (1.004 kJ/(kg.K).**
Aspect ratio (AR)	**Ratio of the width to the length; AR = W/L.**
Blast gate	**Sliding damper.**
Capture velocity	**Air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.**
Dust	**Small solid particles created by the breaking up of larger particles by processes crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, and sweeping.**
Dust collector	**Air cleaning device to remove heavy particulate loadings from exhaust systems before discharge to outdoors. Usual range: loadings 0.003 grains per cubic foot and higher.**
Fan class	**This term applies to the fan's performance abilities. The required fan class is determined according to the operating point of the ventilation system. AMCA 99-2408 provides a set of five minimum performance limit**

	standards (Class I through V) which manufactures use to apply the correct class to their fans.
FRP	Fiberglass reinforced plastic used in construction of such items as boats and airplanes. It is also used for ductwork in corrosive environments.
Fumes	Small, solid particles formed by the condensation of vapors of solid materials.
Gases	Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
Gravity, specific	Ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2 degrees F (4 degrees C) is the standard substance usually referred to for gases, dry air, at the same temperature and pressure as the gas is often taken as the standard substance.
Hood	A shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.
Humidity, relative	Ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.
Lower explosive limit (LEL)	Lower limit of flammability or explosiveness of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 degrees F (121 degrees C). Above these temperatures, it must be decreased by a factor of 0.7 since explosiveness increases with higher temperatures.
Manometer	An instrument for measuring pressure; essentially a U-tube partially filled with a liquid, usually water, mercury or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted in the instrument.
Micron	A unit of length; approximately 1/25,000 of an inch (the thousandth part of 1 millimeter or the millionth of a meter).
Mists	Small droplets of materials that are ordinarily liquid at normal temperature and pressure.

Plenum	**A pressure equalizing chamber.**
Pressure, static	**Potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapse the pipe.)**
Pressure, total	**The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).**
Replacement air	**Ventilation term used to indicate the volume of controlled outdoor air supplied to a building to replace air being exhausted. It may require heating, cooling, or humidity control.**
Slot velocity	**Linear flow rate of contaminated air through a slot. Usually measured in meters per second (m/s) [feet per minute (fpm)].**
Smoke	**An air suspension (aerosol) of particles, usually not solid, often originating in a solid nucleus, formed from combustion or sublimation.**
Threshold limit values	**Values, established by ACGIH, for airborne toxic materials (TLV) as guidelines in the control of health hazards and represent time-weighted concentrations to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects.**
Transport (conveying))	**Minimum air velocity required to move the particulates in the air stream, measured in fpm (m/s).**
Vapor	**The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature.**
Work piece	**The item being created or repaired using equipment or machinery that, while operating, generates a fume, gas, vapor, or particulate hazardous to the health of the operator. Landing gear, torpedo parts, cabinetry, lagged piping are examples of work pieces. Parts washers, wood saws, and degrease units are example equipment.**

B-2 ABBREVIATIONS AND ACRONYMS

A

ACGIH	American Conference Of Governmental Industrial Hygienists, Inc.
ACH	air changes per hour
AMCA	Air Movement and Control Association, Inc.
ANSI	American National Standards Institute, Inc.
AR	Aspect ratio
ASHRAE	American Society of Heating, Refrigeration And Air Conditioning Engineers, Inc.

C

C	Degrees Celsius
cfh	cubic feet per hour
cfm	cubic feet per minute
cfm/ft2	cubic feet per minute per square foot
CFR	Code of Federal Regulations
cm	centimeter
cms	cubic meters per second
CO	carbon monoxide

D

D	depth
dbA	decibels on the A-weighted scale
DDC	direct digital controls

E

EM	Engineering Manual

F

F	Degrees Fahrenheit
fpm	feet per minute
FRP	fiberglass reinforced plastic
Ft	feet

G

GSSDC	Guide for steel stack design and construction

H

H	Height
HEPA	high efficiency particulate air
HVAC	Heating, ventilation, and air conditioning
HVLP	High volume, low pressure

I

IH	industrial hygienist
IMC	International Mechanical Code
In	inch(es)
IV	Industrial ventilation

L

LEL	Lower Explosive Limit
LVHV	low volume, high velocity

M

m	meter
MEC	minimum explosive concentration
MERV	minimum efficiency reporting value
MILCON	Military Construction
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
mm	millimeter
m/s	meter per second
MSDS	Material Safety Data Sheet

N

NAVAIR	Naval Air System Command
NAVFAC	Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NICAD	nickel-cadmium
NIOSH	National Institute of Occupational Safety and Health

O

O/I	organization and intermediate
OPNAVINST	Chief of Naval Operations Instruction
OSHA	Occupational Safety and Health Administration

P

Pa	Pascal
PEL	permissible exposure limit
PPE	personal protective equipment
PVC	polyvinyl chloride

R

REO	Regional Engineering Office
RIDCS	Round industrial duct construction standard

S

SCBA	self-contained breathing apparatus
SMACNA	Sheet Metal And Air Conditioning Contractors National Association

T

TLV	Threshold Limit Value
TWA	time-weighted average

U

UFC	Unified Facilities Criteria
UPS	Uninterruptible Power Supply

V

VFD	variable frequency drive
VOC	Volatile Organic Compound

W

W	width
wg	water gage

UFC 3-420-01
01 April 2021

UNIFIED FACILITIES CRITERIA (UFC)

PLUMBING SYSTEMS

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UNIFIED FACILITIES CRITERIA (UFC)

PLUMBING SYSTEMS

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 3-420-01, dated 25 October 2004, with Change 10, dated 26 October 2015.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-420-01, *PLUMBING SYSTEMS*

Superseding: UFC 3-410-01, *PLUMBING SYSTEMS*, dated 25 October 2004, with Change 10, dated 26 October 2015.

Description: This UFC is the core document for plumbing design. It is intended as a reference for all plumbing work. It is organized to provide the top-level minimum mandatory plumbing design and analysis requirements and refers to other criteria as appropriate.

Reasons for Document:

- This UFC provides a central point reference for all plumbing design criteria.
- Establishes minimum design analysis and drawing requirements in support of design activities
- Helps direct designers to the appropriate plumbing discipline criteria document.

Impact:

- There are negligible cost impacts. Creation of a single-source reference for mechanical design discipline helps clarify requirements for the design of DoD facilities.

Unification Issues

- There are no unification issues.

TABLE OF CONTENTS

FIGURES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides guidance in the design of plumbing systems, together with the criteria for selecting plumbing materials, fixtures, and equipment and is applicable to all elements of the Department of Defense (DoD) charged with planning military construction. This UFC provides minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, installation, quality of materials, location, operation, and use of plumbing systems. It is not the intent of this manual to duplicate information contained in the standards cited herein, but to reference them as appropriate. See Chapter 4.

1-2 APPLICABILITY.

This UFC applies to all service elements and contractors involved in the design and construction of plumbing systems for use in facilities of all branches of service. A plumbing system consists of the water supply distribution system; fixtures, and fixture traps; soil, waste, and vent piping; storm water drainage; acid and industrial waste disposal systems; special gases (medical and oxygen) systems; and water heaters. The plumbing system extends from connections within a structure to a point 5 feet (1.5 m) outside the structure. Additions, alterations, renovations, or repairs to a plumbing system must conform to requirements for a new plumbing system without requiring the existing plumbing system to comply with all the requirements of this manual. Do not execute additions, alterations, or repairs that cause an existing plumbing system to become unsafe, hazardous, or overloaded.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

Service water heating systems must meet American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Refer to UFC 1-200-02, *High Performance and Sustainable Building Requirements* for publication year of ASHRAE.

1-3.1 Environmental Severity and Humid Locations.

In corrosive and humid environments, provide design detailing, and use materials, systems, components, and coatings that are durable and minimize the need for preventative and corrective maintenance over the expected service life of the component or system. Follow the guidance of UFC 1-200-01, Chapter 4 to address corrosion control and apply the requirements for the appropriate Environmental Severity

Classification (ESC) for the specific installation as identified in UFC 1-200-01 Appendix A.

1-4 SAFETY.

The Designer of Record must follow the concepts from the most current ANSI/ASSE Z590.3, *Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes*. Through the application of Prevention through Design (PtD) concepts, decisions pertaining to occupational hazards and risks can be incorporated into the process of design and redesign of work premises, tools, equipment, machinery, substances, and work processes, including their construction, manufacture, use, maintenance, and ultimate disposal or reuse. This standard also provides guidance for a life-cycle assessment and design model that balances environmental and occupational safety and health goals over the life span of a facility, process, or product.

All DoD facilities must comply with DoDI 6055.01 and applicable Occupational Safety and Health Administration (OSHA) safety and health standards.

1-5 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems* and as required by individual Service Implementation Policy.

1-6 NON-GOVERNMENT STANDARD MODIFICATION.

1-6.1 Primary voluntary consensus standard reference.

The DoD uses the International Code Council™ International Plumbing Code® as the primary voluntary consensus standard for DoD facility plumbing systems.

1-6.1.1 International Plumbing Code® copyright.

1-6.1.2 International Plumbing Code® modifications.

Chapter 4 modifies the IPC and is organized by the chapter of the IPC that each section modifies. The modifications are one of four actions, according to the following legend:

- [Addition] – Add new chapter or section, including new chapter or section numbers.
- [Deletion] – Delete chapter, section, paragraph, or sentence.
- [Replacement] – Delete chapter, section, paragraph, or sentence noted and replace it with the narrative shown.
- [Supplement] – Add narrative shown as a supplement to the narrative shown in the referenced chapter, section, or paragraph.

The format of Chapter 4, including English and metric unit references, does not follow the UFC format, but instead follows the format established in the IPC, to the extent possible.

When and if these supplemental technical criteria are adopted into the IPC, they will be removed from this document. When interpreting the IPC, the advisory provisions must be considered mandatory; interpret the word “should” as “shall”.

1-6.2 Conflicts in criteria.

Where, in any specific case, different sections of this guidance or referenced standards specify different materials, methods of construction, or other requirements, the most restrictive requirement will govern. In leased facilities where the local jurisdiction controlling the lessor has adopted a different plumbing code, the more restrictive requirement will govern.

1-7 GLOSSARY.

Appendix A contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

Appendix B contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

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CHAPTER 2 TECHNICAL CRITERIA

Not used.

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CHAPTER 3 GENERAL DESIGN REQUIREMENTS

3-1 GENERAL POLICY.

3-1.1 Energy Efficiency and Water Conservation.

Plumbing system energy usage and equipment efficiencies must comply with UFC 1-200-02. Employ strategies that in aggregate use a minimum of 20 percent less potable water than the indoor water use baseline calculated for the building after meeting the Energy Policy Act of 1992 and the IPC fixture performance requirements. Use ultra-water-efficient plumbing fixtures including low flow faucets, showerheads, and ultra-low consumption (e.g., 1/8 gallon (0.5 liters) per flush) flushing urinals or (if approved) waterless urinals, in accordance with UFC 1-200-02. Mission requirements and operating points to prevent Legionella will take priority over meeting energy and conservation targets.

3-1.2 Reliability.

Provide dual-fuel capability and/or redundant system components to Mission Critical facilities.

3-1.3 Piping Arrangement.

Conceal piping in permanent-type structures. In limited life structures, piping may be installed exposed, except when specific project criteria justify concealment or where concealment does not increase the cost of the project. Exposed piping attached to or near fixtures or equipment, or subject to high heat or frequent washing, must be copper, brass, or chromium plate. Prime other exposed piping with paint suitable for metal surfaces and finish-paint with color to match background. Arrange piping runs parallel or perpendicular to primary walls and to minimize interference with personnel and equipment. For critical piping services such as medical gas systems, route piping so that it is not on exterior walls or walls shared with mailrooms in accordance with UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*. Provide efficient piping designs. Efficient designs consist of, but are not limited to, minimized changes of direction of horizontal sanitary piping and reduced number of vents by use of venting methods that serve multiple fixtures.

3-1.4 Siting.

Whenever possible, site and design buildings, sewers, and water mains to avoid the need for sewage lifts or water booster pumps.

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CHAPTER 4 SUPPLEMENTAL IPC TECHNICAL CRITERIA

Note: Chapter, section and paragraph numbers reference IPC-2018.

4-1 GENERAL SUBSTITUTIONS.

- All references to “approved” materials must be materials allowed by the applicable Unified Facilities Guide Specification (UFGS).
- All references in the IPC to the IBC must be considered to be references to UFC 1-200-01.
- All references in the IPC to the International Fuel Gas Code must be considered to be references to NFPA 54, *National Fuel Gas Code* and NFPA 58, *Liquefied Petroleum Gas Code*.
- All references in the IPC to the International Mechanical Code must be considered to be references to UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*.
- All references in the IPC to the International Energy Conservation Code must be considered to be references to UFC 1-200-02.
- Where the IPC references the International Fire Code (IFC), the IFC must be replaced with NFPA 1, *Fire Code* except where superseded by UFC 3-600-01, *Fire Protection Engineering for Facilities*.
- All references in the IPC to NFPA 70, *National Electric Code* must be considered to be references to UFC 3-501-01, *Electrical Engineering*.

4-2 CHAPTER 1 - SCOPE AND ADMINISTRATION. [DELETION]

Delete chapter in its entirety. Scope administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) and by the authority granted to the Contracting Officer in administering the contract and this UFC.

4-3 CHAPTER 2 – DEFINITIONS.

4-3.1 Section 202 - GENERAL DEFINITIONS.

Code [Replacement]

Delete the code definition and replace it with the following:

The IPC, revision year approved by UFC 1-200-01 and subsequent amendments thereto, as modified by this UFC.

Code Official [Replacement]

Delete the code official definition and replace it with the following:

Refer to UFC 1-200-01, paragraph entitled Implementation, Administration, and Enforcement.

Owner or Owner's Representative [Addition]

Add the following definition:

OWNER OR OWNER'S REPRESENTATIVE. For Government-owned facilities, the Contracting Officer assigned by the Government to administer the construction contract. For leased facilities, the leaser of the facility.

Permit Holder [Addition]

Add the following definition:

PERMIT HOLDER. The contractor accomplishing the project.

4-4 CHAPTER 3 - GENERAL REGULATIONS.

4-4.1 Section 301 – GENERAL.

301.6 Prohibited Locations. [Supplement]

Insert the following before the first sentence:

No plumbing system components may be installed within any Air Handling Unit (AHU), ductwork, or room used as a plenum conveying supply air, return air, outside air, or mixed air. This will not prohibit connection of AHU components, such as humidifiers, to the water supply system, nor prohibit connection of trapped condensate pans and humidifier drains indirectly to the drainage system. This will also not prohibit plumbing system components in ceiling spaces used as return air plenums, nor prohibit drains in raised floor supply plenums.

301.8 Protection of Building Materials. [Addition]

Where the seasonal design temperature of the cold water entering a building is below the seasonal design dew point of the indoor ambient air, and where condensate drip will cause damage or create a hazard, insulate plumbing piping with a vapor barrier type of insulation to prevent condensation. All chilled water piping from a central drinking water cooling system should be insulated with vapor barrier type insulation to prevent condensation.

301.9 Protection of Computers, Telephone Switches, Terminal Equipment, Record Storage, and other Electronic Equipment from Water Damage. [Addition]

Neither water nor drainage piping shall be located over electrical wiring or equipment unless adequate protection against water (including condensation) damage has been provided. Insulation alone is not adequate protection against condensation. Locate these areas to minimize exposure to water and other listed hazards from adjoining areas and activities.

301.9.1 Prohibited piping. Water, sanitary, indirect waste, special waste, gas, fuel oil, condensate drain, roof drains, conductors, and other utility piping not serving these areas within building are prohibited.

301.9.2 Restricted piping. Utilities containing water or other fluids, which serve these areas within the building, must not pass directly over electronic equipment, telephone switches, or stored records, whether the utilities are installed over or below the finished ceiling.

301.9.3 Waterproof floor above. The floor above these areas should be waterproofed to prevent passage of accidental spillage. As an alternative, allow no prohibited pipe in the rooms above the electronic equipment and record storage areas.

4-4.2 Section 303 – MATERIALS.

303.3 Plastic pipe, fittings and components. [Supplement]

Add the following after the last sentence:

Installation procedure for plastic piping materials shall be in accordance with the Plastic Pipe Institute (PPI) *Handbook of Polyethylene Pipe*. Design parameters such as thermal movement, chemical resistance, flow characteristics, and pressure ratings are covered in PPI publications. The designer should be aware that some Schedule 40 plastic pipes do not have the strength of a Schedule 40 steel pipe; therefore, the desired working temperature and pressure ratings for any plastic piping specified must be indicated either in the specifications or on the drawings.

4-4.3 Section 305 – PROTECTION OF PIPES AND PLUMBING SYSTEM COMPONENTS.

305.4 Freezing. [Supplement]

Add the following after the last sentence:

Although insulating water pipes, tanks, and cooling towers may not prevent water from freezing, these devices are to be insulated and, if noted on the drawings, heat traced for protection against damage. The proper thickness or conductivity factor for this insulation and the watts/linear foot (watts/linear meter) for heat tracing are to be determined by the design engineer. Do not provide water or waste piping in exterior walls or attic spaces where there is danger of freezing where practicable. Provide proper design to prevent freezing when not practicable.

Section 308 – PIPING SUPPORT.

308.5 Interval Support. [Replacement]

Replace first sentence with the following:

Above ground piping and below ground piping shall be supported from structure in accordance with Table 308.5.

4-4.4 Section 313 – EQUIPMENT EFFICIENCIES.

313.2 Energy conservation. [Addition]

Design systems containing electric water heaters, gas water heaters, solar water heaters, air-to-water heat pump water heaters, and water-to-water heat pump water heaters in accordance with the ASHRAE Handbook Series (appropriate Chapters), ASHRAE Standard 90.1 and Department of Energy – Federal Energy Management Program (DOE-FEMP), *Buying Energy Efficient Products* (appropriate recommendations).

4-4.5 Section 316 – ALTERNATIVE ENGINEERED DESIGN.

316 Alternative engineered design. [Deletion]

Delete section its entirety.

4-5 CHAPTER 4 - FIXTURES, FAUCETS AND FIXTURE FITTINGS.

4-5.1 Section 401 – GENERAL.

401.2 Prohibited fixtures and connections. [Supplement]

Add the following after the last sentence:

Fixtures employing continuous flow devices and fixtures that are subject to backflow are prohibited. Continuous flow devices cannot be used for water conservation reasons.

401.3 Water conservation. [Supplement]

Add the following after the last sentence:

Water conservation fixtures conforming to the IPC shall be used except where the sewer system will not adequately dispose of the waste material on the reduced amount of water. DOE-FEMP water conservation recommendations are, for certain fixtures, more restrictive than Section 604.4. Designers have the option to design to DOE-FEMP water conservation recommendations for areas of the country that restrict water usage. The owner or owner's representative should be consulted before specifying water conservation fixtures that are more restrictive than Section 604.4.

4-5.2 Section 402 – FIXTURE MATERIAL.

402.1 Quality of fixtures. [Supplement]

Add the following after the last sentence:

Fixture materials are to be selected from those specified in UFGS 22 00 00, *Plumbing, General Purpose*. Porcelain-enameled cast-iron lavatories shall be provided in enlisted personnel barracks or dormitories or other gang toilet in similar facilities.

4-5.3 Section 403 – MINIMUM PLUMBING FACILITIES.

403.1 Minimum number of fixtures. [Replacement]

Delete the last sentence and replace with the following:

Use the actual number of occupants for whom each occupied space, floor or building is designed to calculate the design occupant load. The designer must document the calculations for the design occupant load. These calculations must be reviewed and approved for the project to ensure that the number of plumbing fixtures is appropriate.

Table 403.1 Minimum Number of Required Plumbing Fixtures. [Deletion]

Delete the last sentence:

“The number of occupants shall be determined by the *International Building Code*.”

Table 403.1 Minimum Number of Required Plumbing Fixtures. [Supplement]

For the business classification, add the following to the description:

training rooms, support areas (such as for the administrative and supervisory offices for industrial shops and warehouses), and locker rooms in coliseums, arenas, skating rinks, pools, and tennis courts for indoor sporting events and similar activities

4-5.4 Section 404 – ACCESSIBLE PLUMBING FACILITIES.

404.1 Where required. [Replacement]

Replace the first sentence with the following:

Accessible plumbing facilities and fixtures must be provided in accordance with the Architectural Barriers Act (ABA), *Accessibility Standards for Department of Defense Facilities* and the IBC, whichever is more stringent.

4-5.5 Section 405 – INSTALLATION OF FIXTURES.

405.3 Setting. [Supplement]

Add the following after the last sentence:

Lavatories and urinals in enlisted men's barracks or dormitories and in men's gang-toilet facilities (three or more water closets) are subject to heavy damage. Verify wall bolts are tight and properly installed.

405.3.1 Water closets, urinals, lavatories and bidets. [Supplement]

Add the following after the last sentence:

Lavatories provided in enlisted personnel barracks or dormitories or other gang toilet facilities shall be installed to prevent uplifting.

4-5.6 Section 410 – DRINKING FOUNTAINS.

410.6 Central drinking water systems. [Addition]

Central drinking water systems should be evaluated as an alternative to unitary water coolers in facilities where 15 or more drinking stations are required. Evaluation should include potential heat recovery from central condenser, addition of heat to building envelope by unitary condensers, differences in anticipated energy usage, and differences in first cost.

4-5.7 Section 411 – EMERGENCY SHOWERS AND EYEWASH STATIONS.

411.4 Design guidance for emergency shower and eyewash stations. [Addition]

Refer to Appendix C of UFC 3-420-01, *Design: Plumbing Systems* for additional requirements associated with emergency shower and eyewash stations.

4-5.8 Section 413 – FLOOR AND TRENCH DRAINS.

413.5 Required locations and construction. [Addition]

Floor drains are not required in service sink rooms and transformer rooms.

Provide floor drains to serve, but not be limited to, the following areas and equipment:

1. Gang toilets, which are those having three or more water closets; and gang shower drying rooms, which are those serving two or more showers.

2. Subsistence buildings, as follows:

   (a) Dishwashing, scullery or pot washing, and food-cart washing areas.
   (b) Vegetable peelers and vegetable preparation areas.
   (c) Steam table and coffee urn areas.
   (d) Soda fountain area.
   (e) Adjacent areas to ice chests, ice-making machines, and walk-in or reach-in, freezers and refrigerators.

(f) Steam cookers and steam-jacketed kettles.

3. Cold-storage buildings, as follows:

   (a) Fat-rendering, processing, salvage, and receiving rooms.
   (b) Receiving and issuing vestibules.
   (c) Adjacent areas to meat coolers and milk, butter, and egg rooms.

4. Mechanical rooms with steam, condensate, chilled ,or hot water systems.

5. Laundry rooms.

When automatic priming is through a device connected to the water system, ensure that device is equipped with a vacuum breaker.

412.6 Floor drains for emergency shower and eyewash stations. [Addition]

Refer to Appendix C of UFC 3-420-01 for additional requirements for use of floor drains associated with emergency shower and eyewash stations.

4-5.9 Section 416 – FOOD WASTE DISPOSER.

416.5 Food waste disposer design. [Addition]

Food waste disposers are authorized in DoD permanent quarters, hospitals, and dining facilities when the sewage treatment plant can handle the additional load. Design of new sewage treatment plants and additions to existing plants shall be based on the increase in load that will result from food waste disposers installed in hospital, dining facilities, and the ultimate projected number of family quarters to be constructed. Food waste disposers installed in hospital kitchens and dining facilities shall be sized as shown in Table 413.5. Food waste disposers will not discharge into a grease interceptor.

Table 413.5
SIZE OF FOOD WASTE DISPOSERS

PERSONS SERVED	POT WASHER HORSEPOWER	DISHWASHER HORSEPOWER
Up to 200	2	3
200 to 500	3	5
501 to 1,000	5	7-1/2
Over 1,000	7-1/2	10

4-5.10 Section 419 LAVATORIES.

419.6 Tempered water for private hand-washing facilities. [Addition]

Tempered water shall be delivered from lavatories located in private toilet facilities. *Tempered water* shall be delivered through an *approved* water-temperature limiting device that conforms to ASSE 1070/ASME A112.1070/CSA B125.70, *Water Temperature Limiting Devices* or CSA B125.3, *Plumbing Fittings*.

4-5.11 Section 422 - SINKS.

422.4 Tempered water for kitchen sinks. [Addition]

Tempered water shall be delivered from kitchen sinks located in break rooms. *Tempered water* shall be delivered through an *approved* water-temperature limiting device that conforms to ASSE 1070/ASME A112.1070/CSA B125.70 or CSA B125.3.

4-5.12 Section 424 – URINALS.

424.1 Approval. [Supplement]

Add the following after the last sentence:

Waterless/waterfree urinals must conform to American Society of Mechanical Engineers (ASME) A112.19.2, *Vitreous China Plumbing Fixtures and Hydraulic Requirements for Water Closets and Urinals*, but not conform to the hydraulic performance requirements.

Approval for the use of waterless/waterfree urinals is the responsibility of the Facilities Engineering Command (FEC) Technical Discipline Coordinator (TDC), Base Civil Engineer (BCE) or the Department of Public Works and Utilities (DPW) to ensure life cycle costs and operation and maintenance (O&M) requirements are acceptable.

4-6 CHAPTER 5 - WATER HEATERS.

4-6.1 Section 501 – GENERAL.

501.2 Water heater as space heater. [Replacement]

Replace the first sentence with the following:

Where a combination potable water heating and space heating system requires water for space heating at temperatures of 140°F (60°C) or higher, a master thermostatic mixing valve complying with ASSE 1017, *Temperature Activated Mixing Valves for Hot Water Distribution Systems,* must be provided to limit the water to the potable hot water distribution system. The valve must be set to deliver 131°F (55°C) water to the fixtures except where higher temperatures are required by specialized equipment as indicated in ASHRAE Handbook, *Applications*. If the master thermostatic mixing valve is near the point of use at the fixtures, then lower potable domestic hot water distribution temperatures, less than 131°F (54.4°C), may be acceptable.

501.9 Multiple water heaters. [Addition]

Provide hospitals, laundry buildings, subsistence buildings, bachelor officers' quarters with mess, and enlisted men's barracks with mess with multiple water heaters and storage tanks. Provide other facilities with a single water heater and storage tank. Multiple units, however, may be justified by circumstances such as:

1. facility configuration
2. space limitations
3. limited access to tank room
4. hot water requirements necessitating an unusually high capacity heating and storage unit.

When two units are provided for hospitals, laundry buildings, subsistence buildings, bachelor officers' quarters with mess, and enlisted men's barracks with mess, each will have a capacity equal to two thirds of the calculated load. When more than two units are provided, their combined capacity shall be equal to the calculated load.

501.10 Solar water heating. [Addition]

At least 30 percent of domestic hot water demand shall be provided by the use of solar water heating, if life cycle cost effective. Solar water heating systems must be in accordance with UFC 3-440-01, *Facility Scale Renewable Energy Systems*. Conventional back-up heating equipment shall be provided for periods when high demand or an extended period of cloudy days exceeds the capacity of the solar energy system."

4-6.2 Section 502 – INSTALLATION.

502.1 General. [Supplement]

Add the following after the last sentence:

The local Public Works/Base Civil Engineer should be contacted to determine if scale will be an issue based on the chemical analysis of the potable water or historical data. If so, provide a commercial scale prevention system.

4-6.3 Section 504 – SAFETY DEVICES.

504.2 Vacuum relief valve. [Supplement]

Add the following after the last sentence:

Provide a vacuum relief valve on each copper-lined storage tank to prevent the creation, within the tank, of a vacuum which could cause loosening of the lining.

4-6.4 Section 505 – INSULATION.

505.1 Unfired vessel insulation. [Supplement]

Add the following after the last sentence:

The insulation requirements stated in this section are minimum design requirements. The quality of insulation should be upgraded if the designer can show an improvement in the system performance or that insulation improvements are cost effective.

4-6.5 Section 507 – SIZING HOT WATER SYSTEMS.

507.1 Sizing Calculations. [Addition]

Design in accordance with ASHRAE Handbook, *HVAC Applications*, "Service Water Heating" chapter; and in accordance with ASHRAE Standard 90.1. In addition to criteria provided in the ASHRAE Handbook, consideration should be given to differences in costs of building area required to support systems when calculating life cycle costs. For low-rise residential buildings, design in accordance with the ICC International Residential Code. Size domestic hot water system and set service water heater (SWH) storage temperature set point for not less than 140°F (60°C) to limit the potential for growth of *Legionella pneumophila*. Provide temperature control (master mixing valve) to lower temperature to 131°F (55°C) immediately downstream of the SWH storage tank in accordance with ASSE 1017. Where a recirculation pump is required the hot water temperature shall be at least 122°F (50°C) throughout the recirculation piping. Deliver a minimum of 122°F (50°C) water to the fixtures and drop the temperature at the fixture through a water-temperature limiting device in accordance with Section 424, except where higher temperatures are required by specialized equipment as indicated in ASHRAE Handbook, *Applications.*

Take steps to both limit the risk of Legionella bacteria growth and scalding in the domestic water system. Therefore, if the master mixing valve is near the point of use at the fixtures, then lower domestic hot water distribution temperatures, less than 131°F (55°C), and lower recirculation loop temperatures, less than 122°F (50°C), may be acceptable. On existing systems take necessary steps to avoid scalding occupants when distributing at 131°F (55°C). For example, existing lavatories may have to add ASSE 1070 temperature reducing devices at all applicable existing fixtures and shower valve limit stops on all existing showers may have to be adjusted.

507.1.1 Sizing central service water heater systems. [Addition]

Use ASHRAE Handbook, HVAC Applications, “Service Water Heating” chapter, “Hot-Water Demand per Fixture for Various Types of Buildings” table to size central SWH systems, except revise the numbers in row “9. Showers” by multiplying by the correction factor (CF) calculated in Section 507.1.3. The revision reflects Public Law 102-486 maximum fixture flow of 2.5 gpm (9.5 L/s), ASHRAE recommended service water storage temperature minimum of 140°F (60°C), personnel safety maximum fixture delivery temperature of 110°F (43°C), and the appropriate supply design cold water temperature, which varies according to location and season. Use the Hotel column to size central SWH systems for Navy bachelor housing and lodges, due to occupant’s schedules resembling those of hotel and motel occupants – the rooms are inhabited mostly between 5 p.m. and 7 a.m. Use Appendix D of UFC 3-420-01 for sizing the domestic water heaters in Army barracks.

507.1.2 Hot water mixing equation. [Addition]

Conversion Factors: 1 gpm = 3.8 L/s; °F = 9/5 °C + 32

Let:

Q_f = Fixture flow in gpm = 2.5 gpm per Public Law 102-486
Q_s = Flow from SWH storage tank in gpm
Q_c = Flow from cold water supply in gpm
T_f = Temperature at fixture in °F = 110°F for personnel safety
T_s = Temperature at SWH storage tank in °F, 140°F minimum for Legionella
T_c = Temperature at cold water supply in °F, varies due to location and season

Mixing Equation:

$$(Q_f \times T_f) = (Q_s \times T_s) + (Q_c \times T_c)$$

Substituting $Q_c = Q_f - Q_s$ gives the following:

$$\begin{aligned}
(Q_f \times T_f) &= (Q_s \times T_s) + \left((Q_f - Q_s)T_c\right) \\
(Q_f \times T_f) &= (Q_s \times T_s) + (Q_f - T_c) - (Q_s \times T_c) \\
(Q_f \times T_f) - (Q_f \times T_c) &= (Q_s \times T_s) - (Q_s \times T_c) \\
Q_f \times (T_f - T_c) &= Q_s(T_s - T_c) \\
Q_s &= Q_f \times \left(\frac{T_f - T_c}{T_s - T_c}\right)
\end{aligned}$$

Substituting Q_f = 2.5 gpm, T_f = 110°F, T_s = 140°F, and T_c = 50°F gives the following:

$$Q_s = 2.5 \times \left(\frac{110 - 50}{140 - 50}\right)$$

$Q_s = 1.667\ gpm$ of hot water from storage tank

$Q_c = Q_f - Q_s = 2.5\ gpm - 1.667\ gpm = 0.833\ gpm$ of cold water from supply

The mixing equation may be used to evaluate the effect of variation of T_c temperatures on Q_s. At T_s = 140°F, for T_c = 40°F, Q_s = 1.75 gpm; and for T_c = 80 F, T_c = 1.25 gpm.

The mixing equation may also be used to evaluate the required size of SWH storage tanks as T_s varies. Higher storage temperatures allow smaller tank sizes to deliver equal water to fixtures.

507.1.3 ASHRAE Handbook, *HVAC Applications*, "Service Water Heating" chapter, "Hot-Water Demand per Fixture for Various Types of Buildings" table. [Supplement]

Row 9, Showers, indicates 225 gallons per hour (gph) per fixture for hot water flow in Gymnasiums, Industrial Plants, Schools, and YMCA's. Assume this represents continuous flow of shower fixture, what is the design fixture flow rate?

Since 225 gph/60 minutes per hour = 3.75 gpm of hot water flow = Q_s, calculate the fixture flow Q_f from the mixing equation, using T_f = 110°F, T_s = 140°F, and T_c = 50°F. Observe that $Q_f = Q_s + Q_c$, therefore $Q_c = Q_f - Q_s$. Substituting:

$$\begin{aligned} Q_f \times T_f &= (Q_s \times T_s) + (Q_c \times T_c) \\ Q_f \times T_f &= (Q_s \times T_s) + \left((Q_f \times Q_s)T_c\right) \\ Q_f \times T_f &= \left(Q_f \times T_c\right) + \left(Q_f \times T_c\right) - (Q_s \times T_c) \\ \left(Q_f \times T_f\right) - \left(Q_f \times T_c\right) &= (Q_s \times T_s) - (Q_s \times T_c) \\ Q_f \times \left(T_f - T_c\right) &= Q_s(T_s - T_c) \\ Q_f &= Q_s\left(\frac{T_s - T_c}{T_f - T_c}\right) \\ &= 3.75\left(\frac{(140-50)}{(110-50)}\right) \\ &= 5.625 \text{ gpm} \end{aligned}$$

Therefore, the proper CF for Chapter 50, Table 10, Row 9 is equal to 2.5 gpm per fixture (per Public Law 102-486) divided by 5.625 gpm (calculated above), which results in CF = 0.444 for T_c of 50°F. This may also be calculated as Q_s = 1.667 divided by Q_s = 3.75 equals CF = 0.444.

Thus, the gymnasium shower at 225 gph x CF corrects to 225 gph x 0.444 = 100 gph for T_c of 50°F.

507.1.4 Domestic hot water recirculation pumps. [Addition]

See Appendix E-3.2.5 of UFC 3-420-01, *Design: Plumbing Systems*.

507.2 Life cycle cost analysis. [Addition]

Evaluate alternative energy source options, such as electric, steam, oil-fired, and gas-fired SWH. Evaluate SWH storage tank capacity and electric heater element sizing to minimize electric demand charges to the government. Larger storage tanks with smaller heater elements may be cost effective due to reduced demand charges, although the longer storage recovery time and the additional costs for providing non-standard tank and element selections should also be considered. Do not exceed the ASHRAE recommended 8-hour maximum recovery time. Also consider the incremental cost of additional electric service capacity versus the incremental costs of providing steam or gas service or providing fuel oil storage and delivery. Include the costs of providing combustion air and flue gas exhaust for fuel-fired water heaters. Do not consider the cost of the tempering valve in the life cycle costs analysis, it is required by the 140°F (60°C) storage temperature to avoid Legionella. However, since it is required, consider the life cycle cost advantages of storing hot water at higher temperatures, if the source is electric, steam, or natural gas, and the tank insulation is increased to maintain equal total heat loss. A smaller SWH storage tank may reduce the size of the mechanical room and the building, which will reduce the energy and capital costs of the facility. Consider a pre-heat tank upstream of the SHW storage tank for applications recovering heat from refrigerant hot gas, steam condensate, process waste cooling, solar collectors, and diesel engines. Provide a tempering valve for all heat recovery SWH systems to limit the supply temperature, because the recovered heat can heat the storage tank above the normal storage temperature. A pre-heat tank may increase the amount of heat usably recovered prior to allowing the water to be heated by prime energy. Consider sealed combustion chambers for natural gas-fired SWH's, with combustion air ducted directly from and flue gases ducted directly to the outside air. This may reduce the possibility of carbon monoxide poisoning within the occupied spaces. Ensure adequate clearances of inlet and outlet during snow, icing, flood, and heavy wind-driven rain conditions.

507.3 Minimizing the risk of Legionellosis in building water systems [Addition]

The following are suggested references that provide guidance on minimizing the risk of Legionellosis: U.S. Army Corps of Engineers Engineering Manual (EM) 200-1-13, *Environmental Quality: Minimizing the Risk of Legionellosis Associated with Building Water Systems on Army Installations*; ASHRAE Guideline 12-2000, *Minimizing the Risk of Legionellosis with Building Water Systems;* and ANSI/ASHRAE Standard 188-2015, *Legionellosis: Risk Management for Building Water Systems.*

For **Navy** projects only:

For projects that meet the scope as defined by Section 2 "Scope" of the ASHRAE Guideline 12-2000, designs must incorporate the design recommendations in the "Recommended Treatment" paragraphs and the Public Works Department must provide the services to meet the maintenance recommendations in the “Recommended Treatment” paragraphs, for the applicable systems.

For projects that meet the scope as defined by Section 2 “Scope” of the ANSI/ASHRAE Standard 188-2015 designs must incorporate the requirements in Section 4.1 “Building Designer Requirements” and the Public Works Department must provide the services to meet the requirements in Section 4.2 “Building Owner Requirements.”

4-7 CHAPTER 6 - WATER SUPPLY AND DISTRIBUTION.

4-7.1 Section 601 – GENERAL.

601.6 Storage tank materials. [Addition]

Storage tanks shall be constructed of one of the following combinations of materials and methods:

1. Ferrous metals lined with nonferrous metals and provided with cathodic protection.
2. Ferrous metals lined with glass and provided with cathodic protection.
3. Ferrous metals lined with cement and provided with cathodic protection.
4. Fiberglass reinforced plastic for atmospheric pressure applications.

4-7.2 Section 602 - WATER REQUIRED.

602.2 Potable water required. [Supplement]

Add the following after the last sentence:

Exception: A nonpotable water supply, when used in an entirely separate system and when approved by the local health department, may be used for flushing water closets and urinals and for other approved purposes where potable water is not required.

602.2.1 Water for landscaping. [Addition]

Wall faucets, wall hydrants, lawn faucets, and yard hydrants shall be located so that, with 100 feet (30 m) of garden hose, the area can be watered without crossing the main entrance of public buildings or barracks. The branch to the lawn faucets and yard hydrants shall be equipped with stop and waste valves. The means of watering lawn areas, flowerbeds, and gardens shall be provided as follows:

1. Wall faucets with vacuum breaker backflow preventer on outside walls in nonfreezing climates.
2. Non-freeze wall hydrants with vacuum breaker backflow preventer on outside walls in freezing climates.
3. Lawn faucets with vacuum breaker backflow preventer for garden and lawn areas in nonfreezing climates.

4. Yard non-freeze hydrants for garden and lawn areas in freezing climates. Yard non-freeze hydrants have an automatic drain feature that can allow ground water to enter the service line. To protect the water supply the designer can either isolate the supply to the yard non-freeze hydrants with a double check valve backflow preventer, or specify sanitary yard hydrants. Sanitary yard hydrants are self-contained and do not drain to the surrounding ground, eliminating the possibility of cross-contamination. The designer should select the most cost effective option; sanitary yard hydrants are about three times the cost of standard non-freeze yard hydrants.

4-7.3 Section 604 – DESIGN OF BUILDING WATER DISTRIBUTION SYSTEM.

604.1 General [Supplement]

Add the following after the last sentence:

Service lines will enter the building in accessible locations. Large and mission critical facilities shall be provided with two or more water services to ensure constant delivery to all fixtures and equipment. Coordinate with user. A drain valve must be installed inside the building and downstream of both the building backflow preventer and the building service valve. Drain valve must be placed in a location with access to waste drains.

604.3 Water distribution system design criteria [Supplement]

Add the following after the last sentence:

Provide piping water velocities not to exceed 10 feet per second (3.28 m/s).

604.9 Water hammer [Supplement]

Add the following after the last sentence:

Only specify commercial-type water hammer arresters; vertical capped pipe columns are not permitted. Size and locate commercial water hammer arresters in accordance with PDI WH 201, *Water Hammer Arresters Standard* and manufacturer's recommendations. Provide access doors or removable panels when water hammer arresters are concealed.

4-7.4 Section 606 – INSTALLATION OF THE BUILDING WATER DISTRIBUTION SYSTEM.

606.5.11 Sizing booster systems and pumps [Addition]

Water pressure may be increased by using a hydro-pneumatic system consisting of a tank, pumps, compressed air system, and associated control devices.

606.5.11.1 Tank Pressure. The minimum pressure maintained within the tank is at low-water level and is equal to the pressure required to meet the fixture demands. The high pressure at high water level depends on the operating pressure differential selected for the system. A reasonable and most commonly selected pressure differential is 20 psi (138 kPa).

606.5.11.2 Pumps. Provide factory prefabricated pump package. Use variable speed pumping unless approved by the Authority Having Jurisdiction. For mission critical projects or for contingency operations provide triplex pumps, otherwise provide duplex pumps. . Each pump is sized to meet the requirements of the facility. Pump capacities in gallons per minute (L/s) shall be in accordance with Table 606.5.11.2. Pump head is to be equal to the high pressure maintained within the hydro-pneumatic tank.

606.5.11.3 Tank Capacity. For constant speed pumping, tank capacity is to be based upon a withdrawal, in gallons (liters), of 2-1/2 times the gallon per minute (L/s) capacity of the pump and a low water level of not less than 10 percent of total tank capacity or 3 inches (76 mm) above top of the tank outlet, whichever is greater. Table 606.5.11.3 indicates high water levels and withdrawals for efficient operation of tanks with bottom outlets and a 10 percent residual. Using this table, the tank capacity may be determined as per Example 1. Pressure ranges are given in pounds per square inch (psi) and kilopascals (kPa)

Example 1: Determine the tank capacity when pump capacity is 150 gpm and tank operating pressure range is 40 to 60 psi. (Referring to Table 606.5.11.3, the withdrawal from the tank is 24 percent of the tank capacity.)

Total tank capacity = 2.50 x 150 gpm / 0.24 = 1,563 gallons

or

Total tank capacity = 2.50 x 568 L/s / 0.24 = 5916 liters

For variable speed pumping, follow manufacturer's recommendations for tank size or calculate tank size based on 4% minimum flow and a 5-minute minimum off time.

606.5.11.4 Compressed Air. Compressed air is supplied for tank operation according to the tank capacities. Satisfactory operation has been attained by providing 1.5 cubic feet per minute (cfm) for tank capacities up to 500 gallons (1893 L) and 2 cfm (0.0566 cubic meters/min.) for capacities from 500 to 3,000 gallons (1893 to 11 355 L). For each additional 3,000 gallons (11 355 L) or fraction thereof, add 2 cfm (0.0566 cubic meters/min.). (Quantities are expressed in cubic feet (cubic meter) per minute free air at pressure equal to the high pressure maintained within the hydro-pneumatic tank.)

606.5.11.5 Controls. The controls of a hydro-pneumatic system are to maintain the predetermined pressures, water levels, and air-water ratio within the tank. Specify manufacturer's packaged controls. Specify commissioning of booster pump systems to ensure proper on/off set points and pump ramp speed settings under various conditions i.e. high demand/low incoming pressure and low demand/high incoming pressure.

606.5.11.6 Booster Pumps. Booster pumps must be the "on-off".

606.5.11.6.1 On-Off Type. The installation of an "on-off" type of pumping system should be considered when relatively long periods of pump-on or pump-off are anticipated. Pumps are to be activated, only when pressure is inadequate. Flow normally is through a single full-size pump bypass with check valve and two normally open (N.O.) isolating valves, whether the installation has one pump or multiple pumps. Provide each pump with a check valve on the discharge and two N.O. isolating valves.

Table 606.5.11.2
TANK FILL PUMPS

LOCATION	NUMBER OF FIXTURES	FLOW RATE PER FIXTURE gpm (L/s)	MIN. PUMP CAPACITY gpm (L/s)
Administration Building	1-25	1.23 (0.08)	25 (1.5)
	26-50	0.9 (0.06)	35 (2.2)
	51-100	0.7 (0.045)	50 (3.2)
	101-150	0.65 (0.04)	75 (4.7)
	151-250	0.55 (0.03)	100 (6.3)
	251-500	0.45 (0.03)	140 (7.8)
	501-750	0.35 (0.02)	230 (15.0)
	751-1,000	0.3 (0.02)	270 (17.0)
	1,000-up	0.275 (0.02)	310 (20.0)
Apartments	1-25	0.6 (0.04)	10 (0.6)
	26-50	0.5 (0.03)	15 (0.9)
	51-100	0.35 (0.02)	30 (1.9)
	101-200	0.3 (0.02)	40 (2.5)
	201-400	0.28 (0.02)	65 (4.1)
	401-800	0.25 (0.015)	120 (7.6)
	801-up	0.24 (0.015)	210 (13.0)
Hospitals	1-50	1.0 (0.06)	25 (1.6)
	51-100	0.8 (0.05)	55 (3.5)
	101-200	0.6 (0.04)	85 (5.4)
	201-400	0.5 (0.03)	135 (7.9)
	401-up	0.4 (0.025)	210 (13.0)
Industrial Buildings	1-25	1.5 (0.10)	25 (1.6)
	26-50	1.0 (0.06)	40 (2.5)
	51-100	0.75 (0.05)	60 (3.8)
	101-150	0.7 (0.045)	80 (5.0)
	151-250	0.65 (0.04)	110 (7.0)
	251-up	0.6 (0.04)	165 (10.5)
Quarters And Barracks	1-50	0.65 (0.04)	25 (1.6)
	51-100	0.55 (0.03)	35 (2.2)
	101-200	0.45 (0.03)	60 (3.8)
	201-400	0.35 (0.20)	100 (6.3)
	401-800	0.275 (0.02)	150 (9.5)

	801-1200	0.25	(0.015)	225	(14.5)
	1,200-up	0.2	(0.01)	300	(19.0)
Schools	1-10	1.5	(0.09)	10	(0.06)
	11-25	1.0	(0.06)	15	(0.9)
	26-50	0.8	(0.05)	30	(1.9)
	51-100	0.6	(0.04)	45	(2.8)
	101-200	0.5	(0.03)	65	(4.1)
	201-up	0.4	(0.025)	110	(7.0)

Table 606.5.11-3
HYDRO-PNEUMATIC TANK HIGH WATER LEVELS AND WITHDRAWALS
(Based on bottom outlet tanks and a 10 percent residual)

PRESSURE RANGE psi (kPa)	HIGH WATER LEVEL (percent of total tank capacity)	WITHDRAWAL (96% of total tank capacity)
20-40 (140-275)	43	33
30-50 (205-345)	38	28
40-60 (275-415)	34	24
50-70 (345-480)	32	22
60-80 (415-550)	28	18
20-45 (140-310)	48	38
30-55 (205-380)	42	32
40-65 (275-450)	37	27
50-75 (345-520)	35	25
60-85 (415-590)	32	22

4-7.5 Section 607 – HOT WATER SUPPLY SYSTEM.

607.1.3 *Legionella pneumophila* (Legionnaires' disease) [Addition]

The bacterium that causes Legionnaires' disease when inhaled has been discovered in the service water systems of various buildings in the United States and abroad. It has been determined that *Legionella pneumophila* can colonize in hot water systems maintained at temperatures of 115°F (46°C) or lower. Service water segments subject to stagnation (e.g., faucet aerators, shower heads and certain portions of storage–type water heaters) could provide an ideal location for bacteria to breed. Service water temperatures in the range of 140°F (60°C) are recommended in order to limit the growth potential of the bacteria. However, care must be taken to avoid scalding. Anti-scald devices must be incorporated in designs in which the service water temperature is in the range described above. For hospital and health care facilities, periodic supervised flushing of fixture heads with water at or above 170°F (77°C) are recommended.

607.2 Hot or tempered water supply to fixtures [Replacement]

Remove the last sentence and replace with the following:

Recirculating system piping shall be considered to be sources of *hot* and *tempered water*.

Size hot water recirculation pump in accordance with ASHRAE Handbook, *HVAC Applications*.

A water distribution system having one or more recirculation pumps that pump water from a heated water supply pipe back to the heated water source through a cold water supply pipe is prohibited.

607.2.1 Circulation systems and heat trace systems for maintaining heated water temperature in distribution systems. [Replacement]

Delete the first paragraph and replace with the following:

Provide recirculating systems for temperature maintenance. Heat trace systems are not permitted for temperature maintenance.

In buildings operated on a nominal 40-hour week or on a nominal two-shift basis (either a 5- or a 7-day week), a clock or other automatic control will be installed on domestic hot-water circulating pumps to permit operation only during periods of occupancy plus 30 minutes before and after.

607.2.1.2 Demand recirculation controls for distribution systems [Deletion]

Delete section in its entirety.

607.5 Insulation of piping [Supplement]

Add the following after the last sentence:

Insulate service hot water piping to meet the more restrictive minimum requirements of the following:

1. IPC.
2. ASHRAE Standard 90.1
3. UFGS 23 07 00, *Thermal Insulation for Mechanical Systems*.

The insulation requirements are minimum design requirements. The quality of insulation should be upgraded if the designer can show an improvement in the system performance or that insulation improvements are cost effective.

4-7.6 Section 608 – PROTECTION OF POTABLE WATER SUPPLY.

608.1 General [Supplement]

Add the following after the last sentence:

Single check valves are not considered adequate protection against backflow. Backflow prevention devices must be approved by the State/local regulatory agencies. If there is no State/local regulatory agencies requirements, all backflow prevention devices must be listed by the Foundation for Cross-Connection Control & Hydraulic Research, or any other approved testing laboratory having equivalent capabilities for both laboratory and field evaluation of backflow prevention devices and assemblies. Testing frequencies will follow the requirements set forth by the State/local regulatory agencies or DoD policy, whichever is more stringent.

4-7.7 Section 611 – DRINKING WATER TREATMENT UNITS.

611.2 Reverse osmosis systems [Supplement]

Add in front of the first sentence:

Reverse osmosis water treatment systems shall be installed when water of a higher purity than that produced by the domestic water is required, such as for deionized or distilled water systems used in hospitals. A water quality analysis shall be performed and water treatment design shall proceed based on that analysis. Reverse osmosis is a general term covering equipment that can have various types of filter elements and membranes and polishing components. The reverse osmosis membrane selection is critical and the operating pressure depends upon the membrane selected. Pump pressures can range from 80 to 800 psi (552 to 5516 kPa). The reverse osmosis unit is only part of the required treatment systems, which may include pretreatment facilities and organic filters. In some cases, booster pumps may be required for final water distribution. Materials for piping, pumps, valves, and other components must be carefully selected due to the corrosive nature of the high-purity water produced.

4-7.8 Section 614 – ION EXCHANGE WATER SOFTENING TREATMENT EQUIPMENT [ADDITION].

614.1 Ion exchange

Softening requirements are application-specific; it is typically required where precipitation of calcium carbonate can damage boiler/water heating equipment, block conduits or for aesthetic reasons. Ion exchange water softening is a suitable process for these purposes. However, each category has its own recommended limits for maximum hardness. Water hardness for laundries should not exceed 2.5 grains per gallon (43 ppm) and water hardness is usually reduced to zero. Large mess halls should have a water hardness not exceeding that provided for laundries; whereas, hospitals can utilize water of up to 3 grains per gallon (51 ppm) water hardness. Ion exchange water softening equipment consists of a softener unit and a regeneration brine tank utilizing common salt (NaCl) for regeneration of the softener exchange material. Softening units can be multiple units where two or more units utilize the same regenerating brine tank to provide for continuity of treatment during regeneration of a softening unit.

4-8 CHAPTER 7 - SANITARY DRAINAGE.

4-8.1 Section 704 – DRAINAGE PIPING INSTALLATION

704.5 High efficiency water closets [Addition]

For both new construction and renovations, high efficiency flushometer valve water closets with flush valves less than 1.28 gpf must be installed downstream of additional long-duration flows from other water-consuming appliances, plumbing fixtures, (e.g., lavatory faucets, flushing urinals, showerheads), and other devices that are able to assist with the drain line transport of solid wastes. For new construction, drain line slopes of greater than 1% must be provided.

704.6 Waterless/waterfree urinals [Addition]

When multiple waterless/waterfree urinals are ganged together, the most upstream urinal shall not be a waterless/waterfree urinal to assure flushing of the sanitary drain line.

4-8.2 Section 712 - SUMPS AND EJECTORS.

712.3.1 Sump pump [Supplement]

Add the following after the last sentence:

Sump pumps shall be installed in pits below the lowest floor. Subsoil drains may discharge into this pit. Provide a single pump unit where the function of the equipment is not critical, and provide duplex pump units where the function of the equipment is mission critical. When duplex pump units are provided, the capacity of each pump is to be sufficient to meet the requirements of the facility..

712.3.2 Sump pit [Supplement]

Add the following after the last sentence:

Sumps are to contain, in gallons, between the high level and low level operating switch settings approximately twice the capacity of the sump pump, in gallons per minute. The depth of the pit, below the finished floor, shall be in even feet to conform to standard lengths of submerged pump shafts.

712.3.4 Maximum effluent level [Supplement]

Add the following after the last sentence:

A high water alarm actuator is to be installed within sump and operate an audible or visual alarm when the normal high-water level within sump has been exceeded.

712.3.6 Controls [Addition]

Automatic controls are to be provided for each pump. Duplex pump units are to be equipped with controls to alternate the operation of the pumps under normal conditions and to operate pumps simultaneously when one pump cannot handle the flow.

712.4 Sewage pumps and sewage ejectors [Supplement]

Add the following after the last sentence:

Detailed requirements for pumps and ejectors shall be in accordance with the standards of the Hydraulic Institute. Where sewers are not of sufficient depth to drain the lower floor fixtures by gravity, the main toilet rooms should be located on higher floors. Sewage ejectors shall be of the duplex pneumatic type and shall be located in a concrete pit below the lowest floor. Ejectors will utilize a high-velocity steam, air, or water jet for ejecting the sewage. When the sewage must be pumped, duplex units shall be provided below the lowest floor in a concrete sump protected by a safety railing. Duplex sewage pumps shall be installed in a separate pump house when the sewage from a group of buildings must be pumped and where it is not possible to install sewage pumps in the buildings. Pump motors shall be located so as not to become submerged by an electrical service interruption. Packaged pumping systems installed in vertical dry or wet basins with non-clog centrifugal pumps are acceptable, if the influent line leads directly to the discharge line of both pumps and all incoming sewage passes through self-cleaning screens. Auxiliary screens shall be installed in influent lines within wet wells, since built-in, self-cleaning screens of the pump discharge lines may not be able to handle extreme peak flow conditions. Combination "T" and check valve arrangements shall be provided in the influent line to each pump to prevent raw sewage from backing into incoming sewer lines, when pumps are operating.

712.4.2 Capacity [Supplement]

Add the following after the last sentence:

The capacity shall be determined by the fixture unit method described in Section 710.

4-8.3 Section 715 - BACKWATER VALVES.

714.3 Location [Supplement]

Add the following after the last sentence:

A gate valve must be installed on the sewer side of each backwater valve, and both shall be installed in a manhole.

4-8.4 Section 716 – VACUUM DRAINAGE SYSTEMS [DELETE]

Delete section in its entirety.

4-9 CHAPTER 8 - INDIRECT/SPECIAL WASTE.

4-9.1 Section 802 - INDIRECT WASTES.

802.1.5 Nonpotable clear-water waste [Supplement]

Add the following after the last sentence:

Clear water discharge from hydraulic elevator sump pumps shall be connected to the sanitary sewer drainage system through an indirect waste pipe by means of a 2-inch (50 mm) air gap or directly through an oil/water separator to storm sewer, or to grade outside the building, each in accordance with discharge permits, regulations, and statutes.

802.1.9 Arms vault and storage areas [Addition]

Through-the-wall drains with discharge to grade shall be provided in arms vaults and storage areas requiring dehumidification, to dispose of condensate water from dehumidifiers. When such drains are not practicable, floor drains shall be installed inside the vaults or storage areas to provide for water removal.

4-10 CHAPTER 9 – VENTS.

4-10.1 Section 901 – GENERAL.

901.1 Scope [Supplement]

Add the following after the last sentence:

A Philadelphia (one pipe), engineered vent system, or a sovent (aerator) type system are not be permitted.

901.3 Chemical waste vent systems [Replacement]

Replace with the following:

The vent system for a chemical waste system must be independent of the sanitary vent system and must terminate separately through the roof to the open air.

4-10.2 Section 917 - SINGLE STACK VENT SYSTEM [DELETE].

Delete section in its entirety.

4-10.3 Section 918 - AIR ADMITANCE VALVES [SUPPLEMENT].

Add the following before the first sentence:

Air admittance valves may be used on a limited basis for renovation projects only after approval from the FEC, TDC, BCE, or DPW

4-10.4 Section 919 - ENGINEERED VENT SYSTEM [DELETE].

Delete section in its entirety.

4-11 CHAPTER 10 – TRAPS, INTERCEPTORS AND SEPARATORS.

4-11.1 Section 1002 - TRAP REQUIREMENTS.

1002.4 Trap Seals [Supplement]

Add the following after the last sentence:

Where a trap seal is subject to loss by evaporation, the trap seal shall be protected by a deal seal trap consisting of a 4-inch (100 mm) seal and one of the other trap seal protection methods listed in Sections 1002.4.1.1 through 1002.4.1.4.

4-11.2 Section 1003 - INTERCEPTORS AND SEPARATORS.

1003.1 Where required [Supplement]

Add the following after the last sentence:

Interceptors shall be installed underground outside the building. The area surrounding interceptors shall be paved and provided with suitable drainage facilities. Where design temperatures are less than 0°F (–18°C), interceptors should be located within the building, remote from the kitchen area.

4-12 CHAPTER 11 - STORM DRAINAGE.

4-12.1 Section 1101 – GENERAL.

1101.1 Scope [Supplement]

Add the following after the last sentence:

Storm drainage will include roof drains, leaders, and conductors within the building and to a point 5 feet (1.5 m) outside the building.

4-12.2 Section 1104 - CONDUCTORS AND CONNECTIONS.

1104.3 Insulation of rainwater conductors [Addition]

To prevent condensation, insulate horizontal piping runs, roof drains, and roof drain sumps inside the building with a minimum of 1-inch (25 mm) thick insulation.

4-12.3 Section 1107 – SIPHONIC ROOF DRAINAGE SYSTEMS [DELETE]

4-13 CHAPTER 12 - SPECIAL PIPING AND STORAGE SYSTEMS.

1201.1 Scope [Supplement]

Add the following before the last sentence:

Refer to UFC 4-510-01, *Design: Military Medical Facilities,* for additional medical gas systems requirements.

4-14 CHAPTER 15 - REFERENCED STANDARDS.

Delete the last sentence of the first paragraph.

4-15 APPENDIX A.

4-15.1 PLUMBING PERMIT FEE SCHEDULE [DELETE].

Delete appendix in its entirety.

4-16 APPENDIX C.

4-16.1 STRUCTURAL SAFETY [DELETE].

Delete appendix in its entirety.

4-17 APPENDIX D.

4-17.1 DEGREE DAY AND DESIGN TEMPERATURES [SUPPLEMENTAL].

Where data conflicts with UFC 3-400-02, *Engineering Weather Data*, UFC 3-400-02 takes precedence.

CHAPTER 5 DESIGN ANALYSIS

5-1 DESIGN ANALYSIS.

The Design Analysis must be submitted at a preliminary design stage equivalent to 35% design for concurrence of the results. The Design Analysis must consist of a Basis of Design Narrative and Calculations. The analysis must be updated as necessary as the design progresses. The results of this analysis are used for design decision-making in reducing total life cycle cost, while meeting mission objectives.

5-1.1 Basis of Design.

5-1.2 Provide a Basis of Design Narrative.

Include the following:

- Building population (number of males and number of females)
- Plumbing fixture determination, listing quantity and types of fixtures
- Fixture units for drainage, venting, cold and hot water piping
- Roof areas used in determining storm drainage pipe sizes
- Capacities of all equipment and tanks

5-1.2.1 Criteria/Codes.

Identify the governing codes and criteria utilized for the design. Include the titles and the date of the applicable edition or publication.

5-1.2.2 Site Conditions.

Conduct detailed field investigation and interview the appropriate field personnel. Do not rely solely on the as-built drawings.

Determine energy sources available at the project site. Describe the source of thermal energy that will be used (i.e. extension of central high pressure steam, natural gas, or standalone heat source with the type of fuel utilized).

5-1.2.3 System Selection.

Provide a narrative description of all system alternatives considered. Describe in detail all systems and components selected at a preliminary design stage equivalent to 35% design to include the results of the LCCA and modeled energy use.

5-1.2.4 Special Plumbing Systems.

Provide a description of special plumbing systems such as compressed air, medical gas, etc.

5-1.3 Calculations.

Show calculations and assumptions supporting equipment selections in a clear and organized manner. When charts or tables are used in the design analysis, cite the source and date of the publication.

5-1.3.1 Sizing Calculations.

Provide calculations for sizing equipment, piping, and all accessories which includes pressure calculations. Provide the model number and manufacturer of each major piece of equipment used as the basis for the design.

5-1.3.2 LCCA.

Provide LCCA on optimized system level alternatives modeled in accordance with UFC 1-200-02. Provide energy model, including model inputs and outputs, on optimized system level alternatives by energy type in accordance with UFC 1-200-02.

5-1.3.3 Energy Compliance Analysis (ECA).

If required by UFC 1-200-02, provide a computerized Energy Compliance Analysis. The ECA is a building level analysis which takes into account the interaction between architectural, electrical and mechanical components of the facility design and confirms compliance with the energy reduction goals.

5-2 FINAL DRAWING REQUIREMENTS.

The drawings will be accurate, to scale and follow the Tri-Service A/E/C CADD Standard. Drawings must show equipment and piping sufficiently to indicate all aspects of installation. Provide each set of drawings with a legend covering symbols and abbreviations as indicated in ASHRAE Handbook, *Fundamentals*. Where practical, group all notes, legends, and schedules at the right of the drawings above the title block.

5-2.1 Drawing Units.

Unless otherwise authorized, the IP System of measurement must be used on CONUS projects and the SI system of measurement must be utilized on OCONUS projects.

5-2.2 Legend.

Provide legends to clarify all symbols and abbreviations used on the drawings.

5-2.3 Seismic and ATFP Bracing

Show all pertinent seismic and ATFP bracing details for the plumbing systems on the contract drawings.

5-2.4 Demolition Plans.

Demolitions plans must be separate and distinct from new work plans.

5-2.5 Floor and Site Plans.

Exercise judgment to avoid overly congested drawings. Provide north arrows an all building and site plans. The orientation of drawings must be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans must be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation must be maintained with all disciplines. Provide drawings with dimensions locating all work relative to structural features of the building. For floor plans show fixtures, equipment, and piping in their proper locations. For site plans show connections to existing systems, location of propane and oil tanks, and layout of ground coupled heat pump well fields. Calculate the grade of drain lines and show established invert elevations.

5-2.6 Enlarged Floor Plans.

Provide large-scale details of congested area on the drawings, with dimensions locating all work relative to structural features of the building. Provide separate waste/vent and domestic water enlarged floor plans. Enlarged floor plans must be drawn at no less than 1/4” = 1’-0” (1:50).

5-2.7 Sections and Elevations.

Provide as required to supplement plan views.

5-2.8 Access Space.

Identify space necessary to access and replace items that require maintenance, such as heat exchangers, on the drawings.

5-2.9 Riser Diagrams

Show riser diagrams of soil, waste, drain, and vent stacks. Indicate cleanouts. Show water risers for all buildings in excess of one story. Indicate shutoff valve and water hammer arrester locations. Indicate pipe sizes.

5-2.10 Water Service.

Unless directed otherwise, place the following note on the applicable drawing: "Water pipe sizes are based on a minimum working pressure of ___ [psig (kPa)] at a flow rate of ___ [gpm (L/s)] at the location where the main service enters the building." When water pressure is not known, it must be measured.

5-2.11 Equipment Schedules.

Unless directed otherwise, include equipment schedules on the drawings. The following are typical schedules and data provided on these schedules:

5-2.11.1 Hot water circulating pump.

Provide a hot water circulating pump schedule. Include as a minimum:

- Capacity in gpm (L/s)
- Total head in feet (m)
- Minimum horsepower
- Volts, phase, hertz
- RPM

5-2.11.2 Ejector or sump pump.

Provide an ejector or sump pump schedule. Include as a minimum:

- Capacity in gpm (L/s)
- Total dynamic head in feet (m)
- Minimum horsepower
- Volts, phase, hertz
- RPM

5-2.11.3 Water heater.

Provide a water heater schedule. Include as a minimum:

- Heating capacity in gph (L/s)
- Temperature rise in degrees Fahrenheit (°F) (Celsius (°C))
- Storage capacity in gallons (liters)
- Energy Factor (defined by Gas Appliance Manufacturers Association (GAMA))

5-2.11.4 Hot water storage tank.

Provide a water heater storage tank schedule. Include as a minimum:

- Dimensions
- Capacity in gallons (liters)
- Minimum insulation

5-2.11.5 Hot water generator.

Provide a hot water generator schedule. Include as a minimum:

- Dimensions
- Storage capacity in gallons (liters)

- Heating surface area
- Design pressure
- Heat source (i.e. steam, HTHW, natural gas, electric)
- GPH @ entering water temperature and leaving water temperature

5-2.11.6 Drinking water dispenser:

Provide a drinking water dispenser schedule. Include as a minimum:

- Cafeteria: Type, size
- Electric drinking water cooler: Type, size (Note: Water coolers must use HFC refrigerants.)

5-2.11.7 Grease interceptor.

Provide a grease interceptor schedule. Include as a minimum:

- Fat capacity in pounds (kilograms)
- Flow rating in gpm (L/s)
- Maximum leaving water grains (ppm)

5-2.11.8 Reverse osmosis water treatment equipment.

Provide a reverse osmosis water treatment equipment schedule. Include as a minimum:

- Minimum flow rating in gpm (L/s)
- Design and operating temperature in °F (°C)
- Maximum leaving water grains (ppm)

5-2.11.9 Water softening treatment equipment.

Provide a water softening treatment equipment schedule. Include as a minimum:

- Minimum flow rating in gpm (L/s)
- Grains (grams) hardness to which water is to be softened
- Amount of water metered in gallons (liters) to start automatic regeneration of a softener unit

5-2.11.10 Booster pump.

Provide a booster pump schedule. Include as a minimum:

- Capacity in gpm (L/s)
- Total head in feet (m)
- Minimum horsepower
- Volts, phase hertz
- RPM

5-2.12 Details.

Details must be edited to reflect the configurations and construction materials shown on the plans.

5-2.13 Access Panels.

Indicate location and size of access panels in floors, walls, and ceilings (except in lay-in tile applications) as required to access valves, wall cleanouts, etc. on drawings. Sufficiently sized, safe access must be provided for the maintenance of valves and other components.

APPENDIX A GLOSSARY

A-1 ACRONYMS

A/E	Architect and Engineer
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASSE	American Society of Safety Engineers
ASSE	American Society of Sanitary Engineering
ASTM	American Society of Testing and Materials
CFR	Code of Federal Regulations
DoD	Department of Defense
ES/EWS	Emergency Shower and Eyewash Station
FCCHR	Foundation for Cross-Connection Control and Hydraulic Research
FM	Factory Mutual Corporation
ICC	International Code Council
IPC	International Plumbing Code®
ISEA	International Safety Equipment Association
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PDI	Plumbing and Drainage Institute
PPI	Plastic Pipe Institute
SWH	Service Water Heater
UEPH	Unaccompanied Enlisted Personnel Housing
UFC	Unified Facilities Criteria

UL Underwriter's Laboratory

UOPH Unaccompanied Officers Personnel Housing

APPENDIX B REFERENCES

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.ansi.org

ANSI/ASHRAE/IES 90.1 (ASHRAE 90.1), *Energy Standard for Buildings Except Low-Rise Residential Buildings*

ANSI/ASHRAE Standard 188-2015, *Legionellosis: Risk Management for Building Water Systems.*

ANSI/ASSE Z590.3, *Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes.*

ANSI/ISEA Z358.1, *Emergency Eyewash and Shower Equipment*

AMERICAN SOCIETY OF SAFETY ENGINEERS (ASSE)

http://www.asse.org

ASSE 1017, *Temperature Activated Mixing Valves for Hot Water Distribution Systems*

ASSE 1070/ASME A112.1070/CSA B125.70, *Water Temperature Limiting Devices*

ASSE Z87.1, *Occupational Eye and Face Protection (formerly ANSI Z87.1)*

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

http://www.ashrae.org

Handbook, *Fundamentals*

Handbook, *HVAC Applications*

ASHRAE Guideline 12-2000, *Minimizing the Risk of Legionellosis with Building Water Systems*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

http://www.asme.org

ASME A112.19.2, *Vitreous China Plumbing Fixtures and Hydraulic Requirements for Water Closets and Urinals*

CSA GROUP

http://www.csagroup.org

CSA B125.3, *Plumbing Fittings*

DEPARTMENT OF ENERGY

https://energy.gov/eere/femp/downloads/how-buy-energy-and-water-efficient-products-federal-government

Federal Energy Management Program (DOE-FEMP), *Buying Energy Efficient Products*

ENVIRONMENTAL PROTECTION AGENCY (EPA)

http://www.epa.gov

40 CFR 261, *Identification and Listing of Hazardous Waste*

INTERNATIONAL CODE COUNCIL (ICC)

http://www.iccsafe.org

International Plumbing Code®

International Plumbing Code® Commentary

INTERNATIONAL SAFETY EQUIPMENT ASSOCIATION (ISEA)

http://www.iccsafe.org

The National Standard Plumbing Code

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

http://www.nfpa.org

NFPA 1, *Fire Code*

NFPA 54, *National Fuel Gas Code*

NFPA 58, *Liquefied Petroleum Gas Code*

NFPA 70, *National Electric Code*

PLASTIC PIPE INSTITUTE (PPI)

http://plasticpipe.org/index.html

Handbook of Polyethylene Pipe

PLUMBING AND DRAINAGE INSTITUTE (PDI)

http://www.pdionline.org

PDI WH 201, *Water Hammer Arresters Standard*

UNITES STATES ACCESS BOARD

http://www.access-board.gov

Architectural Barriers Act, *Accessibility Standards for Department of Defense Facilities*

UNITED STATES ARMY CORPS OF ENGINEERS

http://www.usace.army.mil/

Engineering Manual (EM) 200-1-13, *Environmental Quality: Minimizing the Risk of Legionellosis Associated with Building Water Systems on Army Installations*

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA (UFC)

http://dod.wbdg.org

UFC 1-200-01, *DoD Building Code (General Building Requirements)*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 3-230-02, *O&M: Water Supply Systems*

UFC 3-230-03, *Water Treatment*

UFC 3-400-02, *Engineering Weather Data*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-440-01, *Facility-Scale Renewable Energy Systems*

UFC 3-501-01, *Electrical Engineering*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UFC 4-440-01, *Warehouses and Storage Facilities*

UFC 4-510-01, *Design: Military Medical Facilities*

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

http://dod.wbdg.org

UFGS 22 00 00, *Plumbing, General Purpose*

UFGS 23 03 00.00 20, *Basic Mechanical Materials and Methods*

UFGS 23 07 00, *Thermal Insulation for Mechanical Systems*

APPENDIX C DESIGN GUIDANCE FOR EMERGENCY SHOWER AND EYEWASH STATIONS

C-1 EMERGENCY SHOWER AND EYEWASH STATION (ES/EWS).

Provide ES/EWS meeting ANSI/ISEA Z358.1, *Emergency Eyewash and Shower Equipment,* where required by Occupational Safety and Health Administration (OSHA) regulations or by other competent authority, such as UFC's, Military Handbooks, or Design Manuals. Consult with the local station and engineering authorities, including the process, environmental, and safety engineers, and the Industrial Hygienist about ES/EWS locations, materials present, waste treatment systems available, and permits required. Locate ES/EWS as close to the hazard as possible, within 10 to 20 feet (3 to 6 m) for highly corrosive chemicals, but not more than 10 seconds or 100 feet (30 m) of unobstructed travel away, whichever is lesser.

For personnel protection within water-reactive hazardous materials storage and handling areas, provide ASSE Z87.1, *Occupational Eye and Face Protection* chemical splash goggles. Consider providing portable ANSI/ISEA Z358.1 personal eyewash protection for use within the water-reactive area. Provide ES/EWS immediately outside the water-reactive area, but not more than the 10 seconds or 100 feet (30 m) away from the work location. Ensure water from ES/EWS will not enter the water-reactive area; this may require provision of partitions, walls, berms, trenches, or curbs. The personal eyewash must be of the smallest reasonable volume necessary to enable initial flushing on the way to the ES/EWS, to minimize the water-reactive hazard due to spillage of the flushing fluid. A water-reactive material spill is the most probable cause of the need for flushing, and the spillage of the flushing fluid provides the other chemical needed to initiate the reaction. Carefully consider whether to provide personal eyewash or not, and document the decision analysis. Personal eyewash fluid presence may increase the risk of a water-reactive chemical event due to risk of accidental personal eyewash fluid spill, and due to valid usage of personal eyewash. Water-reactive materials are defined in UFC 4-440-01, *Warehouses and Storage Facilities*.

C-2 ALARMS.

Provide a water flow-initiated alarm for each ES/EWS. For locations where potable water is not available, provide personal eyewash protection and a manually initiated alarm. Provide a local audible signal device, a silencing switch, and a flashing strobe light for each ES/EWS and for each manual alarm, and optionally provide central reporting of the alarm to a 24 hour per day manned location. Alarm installations must be waterproof per National Electrical Manufacturers Association (NEMA) Class 3. ES/EWS alarm systems in hazardous (classified) locations, per National Electric Code, must be listed and labeled for that purpose. Alarm audible signal devices must have a distinct sound, different from other alarms in this and adjacent facilities. Mount alarm audible signal device, silencing switch, and strobe light on wall or ES/EWS column, immediately above the level of the showerhead.

Alarms protect people by promptly summoning help, and protect stored materials, equipment, and facilities by indicating or reporting ES/EWS activation, with its attendant water flow.

C-3 FLOOR DRAINS.

Floor drains for ES/EWS are not required by the IPC. See Section 411.

C-3.1 Occupant Preference.

Owners and occupants prefer floor drains, for housekeeping and for material and facility protection reasons.

The floor drain may become a source of illicit disposal of prohibited substances. Careful supervision will be necessary.

C-3.2 De Minimis Losses.

Floor drains may be provided. The Environmental Protection Agency regulation, 40 CFR 261, *Identification and Listing of Hazardous Waste*, describes “ ...the following mixtures of solid wastes and hazardous wastes listed in Subpart D are not hazardous wastes...” “...“de minimis” losses include ...” “...discharges from safety showers and rinsing and cleaning of personal safety equipment;...”. Therefore, ES/EWS discharges may be drained to the sanitary sewer system, as they are “de minimis” losses.

C-3.3 Sizing.

C-3.3.1 Capacity.

Minimum capacity 45 gpm (2.8 L/s) water flow, based upon 1.5 times the ANSI/ISEA Z358.1 standard water flow minimum requirement.

The floor drain must accommodate the full flow of the ES/EWS to avoid spilling water over the containment curb, into the hazardous material storage area, and to avoid damage to the material and the facility in case of continuous ES/EWS operation.

C-3.3.2 Traps.

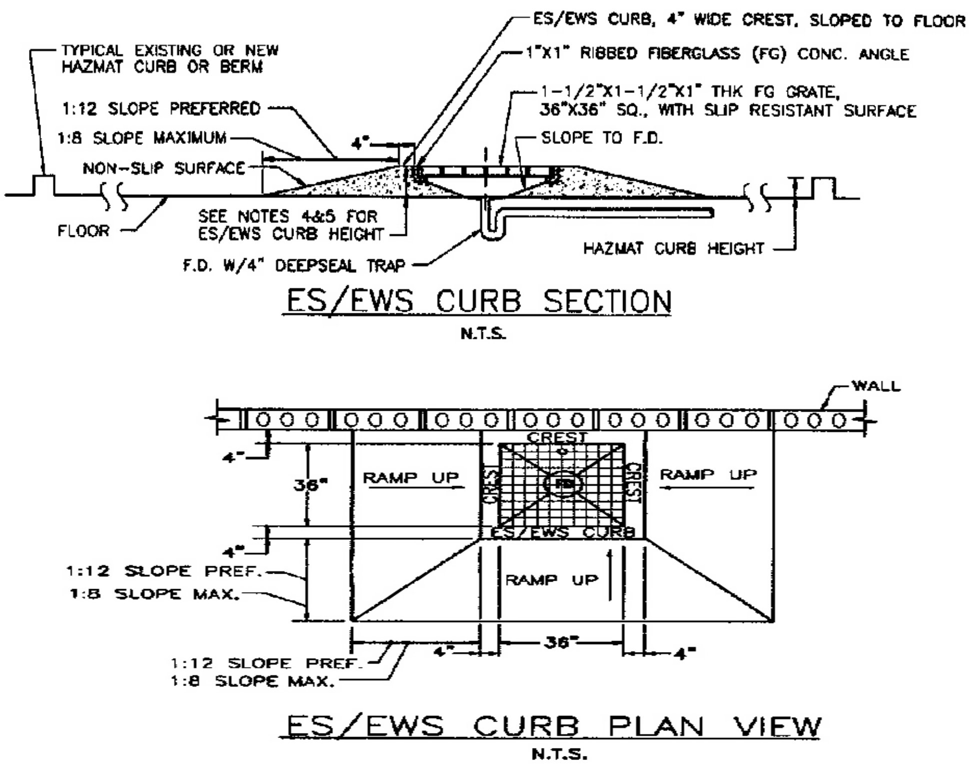
Floor drains must be provided with 4-inch (100 mm) deep seal traps. Frequent testing of the ES/EWS, as required by ANSI/ISEA Z358.1, will refill the trap seal.

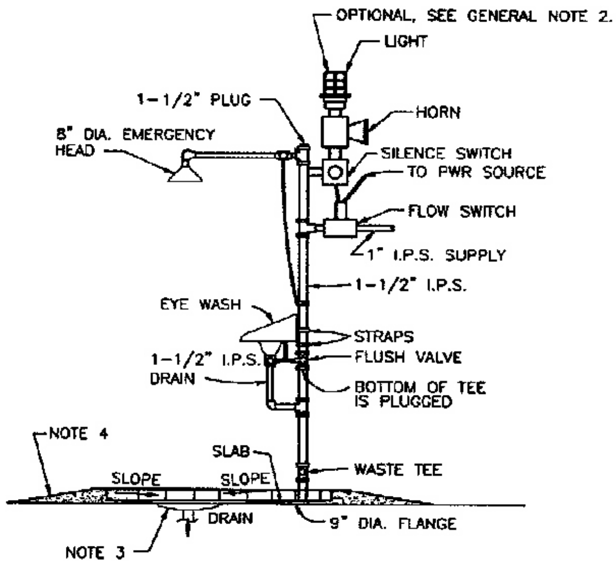
The deep seal trap is provided to reduce the problem of the unused trap drying out and allowing the back flow of sewer gases, fumes, and vermin into the space. Weekly testing of the ES/EWS will be usage enough to refill the trap seal; otherwise, provide an automatic trap priming valve connected to the cold water supply to maintain the trap seal.

C-3.3.3 Containment Curb.

For hazardous material (HAZMAT) areas, provide a 1.5 inch (37 mm) high ES/EWS containment curb completely around the ES/EWS, slope the exterior (approach) face of the curb up at a slope of 1/12 rise, but not more than 1/8 rise per *ABA Accessibility Standards for DoD Facilities*, mark the ES/EWS curb as a trip hazard per OSHA regulations, and inform the personnel that the ES/EWS curb exists. Where ES/EWS with floor drains are located within hazardous material (hazmat) spill containment bermed or curbed areas, provide the crest of the ES/EWS curb to be 1.5 inch (37 mm) higher than the surrounding HAZMAT area curb, to ensure spills do not enter the floor drain. See Figure D-1.

Figure C-1 Emergency Eyewash and Shower Details





EMERGENCY SHOWER & EYE WASH (ES/EWS) DETAIL
N.T.S.

The ES/EWS containment curb protects the floor drain from accidental spills in the surrounding HAZMAT area. The ES/EWS curb also protects the stored HAZMAT materials and facility from accumulated ES/EWS water flow by directing the flow into the floor drain.

C-3.3.4 Placard.

In HAZMAT areas, post a placard at each ES/EWS stating: “NO DUMPING. This drain discharges untreated into the sanitary sewer, contact Activity Environmental Office for proper disposal of spilled material or waste.”

The placard provides the occupants with sufficient information to avoid inadvertent “spills” caused by using the floor drain as a convenient sink for cleanup of spilled materials. Revise the wording to correctly indicate the discharge destination and any treatment system it passes through, such as a neutralization tank or an oil-water separator.

C-3.4 Connection.

All drain connections must comply with all national, State, local, and DoD regulations.

C-3.4.1 Extraordinary hazard materials.

Extraordinary hazard materials - such as poisons, must not discharge into a drain system. Utilize the HAZMAT spill containment curb system to contain the ES/EWS water flow. Provide remote alarm reporting to a central manned station. Immediate action is required to prevent poison contaminated water from spreading throughout the facility.

The floor drain is omitted to prevent inadvertent exposure of persons downstream of the floor drain from unknowingly contacting the potentially poisonous runoff. The hazardous material spill response team answering the alarm will be aware of the hazards and capable of taking appropriate measures for self-protection. If the HAZMAT spill containment curbed area has insufficient volume to hold a minimum of 30 minutes of ES/EWS water flow, provide a floor drain to an above ground holding tank sized to hold at least 30 minutes of flow. Properly label the piping and the tank as holding poisonous fluids. Provide a HAZMAT spill containment berm around the holding tank. Provide an ES/EWS containment curb around the floor drain to preclude fire protection water from flooding the floor drain holding tank and tank berm. ES/EWS curb to be 1.5 inches (37 mm) higher than the HAZMAT curb.

C-3.4.2 Plating shops.

Drain to the proper industrial waste treatment system. Segregate cyanide wastes, including ES/EWS drainage, from all acid wastes. Segregate hexavalent chromium wastes, including ES/EWS drainage, from all caustics and cyanides. Where the shower is located in a multiple use area, such as a material handling or shipping/receiving area, drain to the proper industrial waste treatment system.

C-3.4.3 Battery rooms or shops.

Drain to the proper neutralization tank, if provided; otherwise, drain to the sanitary sewer system. Segregate caustics from the Nickel- Cadmium-Alkali battery area, including ES/EWS drainage, from acids. Segregate acids from the Lead- Acid battery area, including ES/EWS drainage, from caustics. Do not allow mixing of acid and alkali wastes in the drains.

C-3.4.4 Oily waste shops.

Drain to the oil/water separator, if provided; otherwise, drain to the sanitary sewer system. Typical oily waste shops include the following: paint shops and hangers, paint mix rooms, paint equipment rooms, engine shops, ground support equipment shops, refueler shops, Public Works automotive shops, locomotive and crane shops.

C-3.4.5 Miscellaneous materials.

Drain to the sanitary sewer system.

C-3.4.6 Exterior ES/EWS in HAZMAT areas.

Slope impervious-surfaced grade to drain to a bermed or curbed impervious-surfaced area to allow cleanup without “spillage” to the environment; or provide a floor drain connected to an appropriate drain system, and an enclosure with roof to preclude storm water entry into the floor drain. Provide the ramp, curb, and grate around the floor drain, to preclude surface drainage into the floor drain.

C-4 PIPED DRAINS.

Piped drains for eyewash stations (EWS) are not required by the IPC. See Section 411.

C-4.1 Occupant Preference.

Owners and occupants prefer piped drains for EWS for housekeeping purposes.

C-4.2 De Minimis Losses.

Piped drains for EWS may be provided. The Environmental Protection Agency regulation, 40 CFR 261, describes " ...the following mixtures of solid wastes and hazardous wastes listed in Subpart D are not hazardous wastes..." "..."de minimis" losses include ..." "...discharges from safety showers and rinsing and cleaning of personal safety equipment;...". Therefore, EWS discharges may be drained to the sanitary sewer system, as they are "de minimis" losses.

C-4.3 Sizing.

Pipe full size from waste tee. See Figure D-1.

C-4.3.1 Traps.

Piped drains must be provided with 4 inch (100 mm) deep seal traps. Frequent testing of the EWS, as required by ANSI/ISEA Z358.1, will refill the trap seal.

The deep seal trap is provided to reduce the problem of the unused trap drying out and allowing the back flow of sewer gases, fumes, and vermin into the space. Weekly testing of the EWS will be usage enough to refill the trap seal; otherwise, provide an automatic trap priming valve connected to the cold water supply to maintain the trap seal.

C-4.4 Connection.

All drain connections must comply with all national, State, local, and DoD regulations.

C-4.4.1 Extraordinary hazard materials.

Extraordinary hazard materials - such as poisons, must not discharge into a drain system. Utilize the HAZMAT spill containment curb system to contain the EWS water flow. Provide remote alarm reporting to a central manned station. Immediate action is required to prevent poison contaminated water from spreading throughout the facility.

The piped drain is omitted to prevent inadvertent exposure of persons downstream of the piped drain from unknowingly contacting the potentially poisonous runoff. The hazardous material spill response team answering the alarm will be aware of the hazards and capable of taking appropriate measures for self-protection. If the HAZMAT spill containment curbed area has insufficient volume to hold a minimum of 30 minutes of EWS water flow, provide a piped drain to an above ground holding tank sized to hold at least 30 minutes of flow. Properly label the piping and the tank as holding poisonous fluids. Provide a HAZMAT spill containment berm around the holding tank.

C-4.4.2 Plating shops.

Drain to the proper industrial waste treatment system. Segregate cyanide wastes, including EWS drainage, from all acid wastes. Segregate hexavalent chromium wastes, including EWS drainage, from all caustics and cyanides. Where the EWS is located in a multiple use area, such as a material handling or shipping/receiving area, drain to the proper industrial waste treatment system.

C-4.4.3 Battery rooms or shops.

Drain to the proper neutralization tank, if provided; otherwise, drain to the sanitary sewer system. Segregate caustics from the Nickel- Cadmium-Alkali battery area, including EWS drainage, from acids. Segregate acids from the Lead- Acid battery area, including EWS drainage, from caustics. Do not allow mixing of acid and alkali wastes in the drains.

C-4.4.4 Oily waste shops.

Drain to the oil/water separator, if provided; otherwise, drain to the sanitary sewer system. Typical oily waste shops include the following: paint shops and hangers, paint mix rooms, paint equipment rooms, engine shops, ground support equipment shops, refueler shops, Public Works automotive shops, locomotive and crane shops.

C-4.4.5 Miscellaneous materials.

Drain to the sanitary sewer system.

C-4.4.6 Exterior EWS in HAZMAT areas.

Slope impervious-surfaced grade to drain to a bermed or curbed impervious-surfaced area to allow cleanup without “spillage” to the environment; or provide a piped drain connected to an appropriate drain system.

Note: All drain connections must comply with all national, State, local, and DoD regulations. Coordinate this issue with the local authorities per paragraph 1 above.

C-5 ELECTRICAL.

Provide ground fault circuit interrupter (GFCI) protection for dedicated heat tape circuits and for all electrical power outlets within 6 feet (1.8 m) of an ES/EWS and below the elevation of the showerhead.

For heat tape systems, provide a ground fault equipment protection (GFEP) device on each heating cable branch circuit. Conventional circuit breakers may not prevent arcing from damaged or improperly installed heat trace cables. Coordinate heat tape system requirements with electrical engineer.

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APPENDIX D DOMESTIC WATER HEATER FOR ARMY BARRACKS

D-1 PURPOSE.

This appendix provides basic design guidance for the sizing of domestic water heaters for barracks buildings at Army installations.

D-2 BACKGROUND.

There have been questions regarding the sizing for domestic water heaters for barracks. Designers have often used ASHRAE design criteria for motels or dormitories with some over sizing. However the peak demand for domestic hot water in barracks is significantly larger than motels or dormitories due to the concentrated shower pattern of the occupants. This appendix provides a uniform approach to determine domestic water heating requirements for Army barracks, and will be used for the planning, design and construction of new and renovated facilities.

D-3 GUIDANCE.

D-3.1 General.

D-3.1.1 Storage Temperature.

As with any domestic water heating system, storage tank temperature must be maintained at a minimum of 140°F (60°C) to reduce the potential for *Legionella pneumophila* (Legionnaires' disease). Note that higher storage temperatures will result in a lower recovery rate to satisfy the peak demand. Include a cross connection with a mixing valve between the domestic water supply and hot water supply lines (leaving the storage tank) to control the temperature of water distributed to plumbing fixtures to a minimum of 131°F (55°C). Require a strainer upstream of the thermostatic mixing valve on both the hot- and cold-water connections to protect the small orifice in the mixing valve from debris that may be in either line. Where a recirculation pump is required, the minimum hot water return temperature shall be 122°F (50°C) at the connection to the cold water inlet of the water heater/storage tank, at the master mixing valve. The water temperature shall be reduced at the fixture as required through a water temperature limiting device in accordance with Section 424, except where higher temperatures are required by specialized equipment as indicated in ASHRAE Handbook, *Applications* or Table 506.1.

D-3.1.2 Thermal Expansion.

If a backflow preventer is installed in the domestic water main entering a building or in the line supplying the domestic hot water system, include provisions to accommodate thermal expansion. In barracks this can be critical as occupants often shower at the same time and after this peak usage event, the hot water loop will be at a relatively low temperature. During the subsequent recovery phase the water temperature will rise causing the water to expand. If little hot water is being used, this expansion will cause a pressure increase that may activate a relief valve or rupture the storage tank. The best method to alleviate this excess pressure is to install an expansion tank, sized in accordance with "Hydronic

Heating and Cooling" chapter in the ASHRAE Handbook, *Systems and Equipment*.

D-3.1.3 Central Plant.

Normally if a central energy plant is available it will be life cycle cost effective (an analysis must be performed) to generate domestic hot water using distributed media as the heat source. If there is no central plant or if the plant does not operate during the non-heating season, provide a separate domestic hot water source. If the site consists of several barracks buildings, evaluate the life cycle cost of these alternatives:

- A single boiler to provide low temperature hot water, 200°F (94°C) to heat exchangers in each barracks for domestic hot water generation.
- A single heating source for domestic hot water in each individual barracks separately.

If the barracks building is not part of a building complex and there is no central plant or distribution system available then a single heating source must be provided.

D-3.2 Calculations.

The following information applies to all types of domestic water heating systems for barracks.

D-3.2.1 Peak Demand.

Design for the case where all occupants are taking showers at essentially the same time. Public law limits the maximum flow from of each showerhead and private lavatory faucet to 2.5 gpm (0.16 L/s). It is assumed during peak demand that the shower runs for 7.5 minutes and the lavatory runs for 2 minutes. As a result, the peak domestic hot water demand (at T_s) can be found by the following equation:

$$V_p = (h)(occ)(P)\left(\frac{T_d - T_c}{T_s - T_c}\right)$$ **(Equation E-1)**

where:

V_p = volume of domestic hot water required at peak, L (gal).
h = number of shower heads, ea.
occ = number of occupants using each shower, ea.
T_d = temperature of water delivered to shower valve, 43°C (110°F).
T_s = temperature of water in storage tank, °C (°F).
T_c = temperature of cold water supply.
P = amount of water used per occupant during peak demand, 90.0 L/occupant (23.75 gal/occupant).

Note that there is no diversity in the number of occupants in the building. The peak volume of domestic hot water is calculated assuming 100 percent building occupancy. Also note that Equation E-1 does not take laundry or dining facilities into account. Add additional hot water requirements if laundry or dining facilities will be requiring hot water during the peak demand period.

D-3.2.2 Tank Size.

Once the peak demand is known, the tank capacity and corresponding recovery rate can be determined. Since space in the mechanical room is frequently limited, select the desired tank capacity first. An initial estimate of tank size can be determined by using 12.5 gal per occupant (50 L per occupant). Normally a selection of 12.5 gal (50 L) will provide acceptable operation at a reasonable cost but it must be noted that other factors including larger tank sizes and higher storage temperatures will reduce amount of recovery required. Larger tank sizes and increased storage temperatures will also result in greater heat loss from the storage tank. Compare selected tank size to standard tank capacities available commercially and with the space available in the mechanical room.

D-3.2.3 Recovery Rate.

Once the tank capacity is known, the recovery rate can be calculated. The recovery rate is the quantity of water to be heated from the inlet temperature to the desired storage temperature. The difference between the inlet water temperature and the water storage temperature is often assumed to be 100°F (55°C). However, this temperature difference must be coordinated with local conditions and revised as necessary. The required recovery rate can be found using the following equation:

$$R = \left(\frac{V_p - (MS_t)}{d}\right) \qquad \textbf{(Equation E-2)}$$

where:

R = recovery rate at the required temperature, L/s, (gph).

M = ratio of usable water to storage tank capacity, 60-80%.

S_t = storage tank capacity (initial estimate), L (gal) = $(h)(occ)\frac{50\ L}{occupant}$.

d = duration of the peak, (hours) = $\frac{9.5\ min}{occupant}\ (occ)\ \frac{1\ hour}{60\ min}$.

The duration is calculated assuming that the peak usage period will be 9.5 minutes per occupant. Therefore, if two occupants share a bathroom the duration is 19 minutes, 3 occupants would be 28.5 minutes, etc.

The recovery rate is an output condition. Insure that manufacturer's data for the hot water generation unit indicates sufficient input capacity to satisfy the recovery rate with actual design inlet water and storage temperatures.

The tank size may be adjusted up or down to accommodate available tank sizes or available recovery capacities. A smaller tank size yields a higher recovery rate. Simply enter the desired tank size into Equation E-2 and solve for the required recovery rate. Verify that the combination of tank size and recovery rate is commercially available.

D-3.2.4 Pipe Sizes.

The next component to be sized in the system is the domestic hot water distribution piping. Appendix A of *The National Standard Plumbing Code*, “Service Water Heating” chapter of the ASHRAE Handbook, *Applications,* and “Pipe Sizing” chapter of the ASHRAE Handbook, *Fundamentals* provide an ample set of resources on this topic. Therefore, this appendix will not discuss this process.

D-3.2.5 Domestic Hot Water Circulation Pump.

After the domestic hot water distribution piping has been sized, the domestic hot water circulation pump can be sized. This pump is used to circulate the domestic hot water through the distribution piping system. Size the pump using equation below:

$$Q_p = \frac{q}{c\ \rho\ c_p\ \Delta T}$$ **(Equation E-3)**

where:

Q_p = pump capacity, L/s (gpm).

q = heat loss in the piping system, kW (Btuh).

c = constant, $1\ \frac{kW \cdot sec}{kJ}\left(60\frac{min}{hr}\right)$.

ρ = density of water, $0.9971\frac{kg}{L}\left(8.33\ \frac{lb}{gal}\right)$.

c_p = specific heat of water, $4.18\ \frac{kJ}{kg \cdot K}\left(1\ \frac{Btu}{lb \cdot °F}\right)$.

ΔT = allowable temperature drop through the system, K (°F).

Equation E-3 can be simplified to:

$$Q_p = \frac{q}{\left(4.1679\frac{kW \cdot sec}{L \cdot K}\right)\Delta T}$$ **(Equation E-4 (SI))**

$$Q_p = \frac{q}{\left(500\frac{Btuh}{gpm \cdot °F}\right)\Delta T}$$ **(Equation E-4 (IP))**

Heat loss in the piping system (q) can be calculated using ASHRAE Handbook, *Applications*. However, a common rule of thumb is 0.032 kW/m (30 Btuh/ft.).

The allowable temperature drop through the piping system (ΔT) is usually 2 to 5K (5 to 10°F). It is recommended to use 2K (5°F) to assure that sufficient hot water is provided for all occupants under peak conditions.

D-3.3 Separate Storage Tank.

Systems using a separate hot water generation unit and storage tank: The following information applies to systems using a separate storage tank and forced circulation type water heater, boiler or heat exchanger to generate and store domestic hot water. A forced circulation type water heater is similar to a boiler in that it is designed to heat domestic water as it passes through a series of coils rather than heating water in a storage tank but is designed for generating domestic hot water only.

D-3.3.1 Tank Location

Locate the storage tank and hot water generation unit in the same mechanical room whenever possible. This keeps the head requirements at a minimum for the pump circulating water between the hot water generation unit and the storage tank.

D-3.3.2 Connection

Require the domestic water supply be connected in the line supplying hot water to the storage tank. This allows the cold water to mix with the warmer water in the storage tank before entering the boiler, minimizing problems associated with condensation and thermal stress and improving overall system efficiency. Require a submittal from the manufacturer addressing whether a thermostatically controlled bypass line between the boiler supply and return lines or other means are needed to preclude the possibility of thermal shock to the boiler.

D-3.3.3 Forced Circulation

If a forced circulation type water heater or boiler is used, Equation E-3 again can be used to size the circulation pump between the heater and the storage tank. In this case limit the temperature differential to no greater than 30°F (16K) to minimize problems with condensation and thermal stress and improve overall system efficiency. Also note that the sizing of the circulation pump must account for the heating of the domestic cold water being provided. Therefore, the value of q required to use Equation E-3 can be found using the following equation:

$$q = q_{pipe} + (R\ c\ \rho\ c_p\ \Delta T) \quad \textbf{(Equation E-5)}$$

where:

q_{pipe} = heat loss in the piping between the boiler and the storage tank, kW (Btuh)

ΔT_t = temperature difference between the tank water and the make-up water, K (°F)

Determine actual storage tank and domestic water supply temperatures based on local requirements. If the water in the tank is assumed to be 60°C (140°F) and the make-up water is 4°C (40°F), Equation E-5 can be simplified to:

$$q = q_{pipe} + \left(R \times 233.402 \frac{kW \cdot sec}{L}\right) \qquad \text{(Equation E-6 (SI))}$$

$$q = q_{pipe} + \left(R \times 50{,}000 \frac{Btuh}{gpm}\right) \qquad \text{(Equation E-6 (IP))}$$

The new value of q can then be inserted into Equation E-3 to determine the required flow rate for the pump. Compare this flow rate with the minimum flow rates required for boiler or water heater operation and require the larger of the two values. Once the required flow rate is known, the pressure drop for the circulation pump can be determined. The resources listed in E-3.2.4 (Pipe Sizes) give adequate information on calculating the pressure drop through the piping. However, several manufacturers must be contacted to determine the pressure drop through the water heater or boiler. This value will vary widely between different manufacturers. Therefore, the circulation pump must be sized to overcome the highest pressure drop.

However, flow rates over or under those required by the boiler or water heater manufacturer can reduce the efficiency of the unit. As a result, the drawings must indicate the pump characteristics used for the design. Then add a note indicating that the pump is to be sized by the boiler or water heater manufacturer with the horsepower requirements not to exceed those listed in the schedule.

D-3.3.4 Heat Exchanger.

If a heat exchanger is used, size the circulation pump based on the flow required for the heat exchanger to meet the recovery calculated in Equation E-3 and the heat lost through the piping.

D-3.4 Sample Calculations.

D-3.4.1 Given.

h = 36 shower heads
occ = 2 occupants per shower
T_d = 43°C (110°F)
T_s = 60°C (140°F)
T_c = 4.4°C (40°F)
M = 75% useable tank capacity
ΔT = 5K (9°F) Maximum temperature drop through distribution system.
ΔT_t = 54K (97°F)

Piping system consists of:

- 9 meters of DN50 pipe
- 6 meters of DN25 pipe
- 15 meters of DN20 pipe

A separate tank and hot water boiler will be used.

q_{pipe} = 0.10 kW = 341.18 Btuh

D-3.4.2 Find.

(a) Peak domestic hot water demand, L (gal).
(b) Storage tank size, L (gal).
(c) Recovery rate required given the tank size selected, L/s (gph).
(d) Flow rate required for domestic hot water circulation pump.
(e) Flow rate required for boiler circulation pump.

D-3.4.3 Solution.

(a) Peak Domestic Hot Water Demand:

$$V_p = (h)\ (occ)\ \left(\frac{90}{occupant}\right)\left(\frac{T_d - T_c}{T_s - T_c}\right)$$

$$= (36\ heads)\left(\frac{2\ occupants}{head}\right)\left(\frac{90\ L}{occupant}\right)\left(\frac{43°C - 4.4°C}{60°C - 4.4°C}\right)$$

$$= 4499\ L\ (1{,}188\ gal)$$

(b) Initial Storage Tank Size:

$$S_t = (36\ heads)\left(\frac{2\ occupants}{head}\right)\left(\frac{50\ L}{occupant}\right)$$

$$= 3600\ L\ (951\ gal)$$

Use 2 tanks of 1893 L (500.0 gal) each to fit into the available space.

(c) Initial Recovery Rate:

$$d = \left(\frac{9.5\ min}{occupant}\right)(2\ occupants)\left(\frac{60\ sec}{min}\right)$$

$$= 1140\ sec$$

$$R = \frac{4499L - (75\% \times 2\ each \times 1893L)}{1140\ sec}$$

$$= 1.46\ Lps\ (1{,}388\ gph\ or\ 23\ gpm)$$

(d) Flow rate for domestic hot water circulation pump (heat loss through piping is 0.629 kW):

$$Q_p = \frac{0.629\ kW}{\left(4.1679\ \frac{kW\ \cdot sec}{L\ \cdot K}\right)\ 5K}$$

$$= 0.0302\ L/s\ (0.48\ gpm)$$

(e) Flow rate for boiler circulation pump:

$$q = q_{pipe} + \left(R \times 233.402 \frac{kW\ \cdot sec}{L}\right)$$

$$= 0.1\ kW + \left(1.46 \frac{L}{sec} \times\ 233.402 \frac{kW\ \cdot sec}{L}\right)$$

$$= 340.87\ kW$$

$$Q_p = \frac{340.87\ kW}{\left(4.1679 \frac{kW\ \cdot sec}{L\ \cdot K}\right) 16K}$$

$$= 5.11\ L/s\ (81.0\ gpm)$$

UFC 3-420-02
8 November 2022

UNIFIED FACILITIES CRITERIA (UFC)

COMPRESSED AIR

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UNIFIED FACILITIES CRITERIA (UFC)

COMPRESSED AIR

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-420-02FA, dated MAY 2003.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 REISSUES AND CANCELS

This UFC reissues and cancels UFC 3-420-02FA, 15 May 2003.

1-2 PURPOSE AND SCOPE.

The intention of this UFC is to provide criteria to achieve economical, durable, efficient, and dependable compressed air systems to support Tri-Service facilities. Utilize industry standard practices for sizing and selecting equipment, components, fittings, piping, etc. except as otherwise noted in this UFC. Non-Government standards form the foundation of criteria requirements as represented in MIL-STD-3007G (General Requirements, figure 1). Refer to MIL-STD-3007G as DoD policy authority to adopt non-government standards (NGS).

1-3 APPLICABILITY.

This UFC provides criteria for the provision and design of low pressure compressed air systems with a maximum design operating pressure of 125 psig (8.62 barg), including piping, compressors, aftercoolers, separators, air receivers, and air dryers. For medium and high pressure compressed air systems, refer to CAGI and the ASME Piping Series (B31.1 and B31.3) for further guidance.

This UFC is applicable to all service elements and contractors involved in the planning, design, and construction of DoD facilities worldwide. Where conflicts in requirements appear between sections of any mechanical UFC or applicable codes or laws, the most restrictive requirement will govern.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4.1 Additional Requirements.

Use this UFC in conjunction with UFC 3-401-01 and the UFCs and government criteria referenced therein. This includes, but is not limited to, taking the following into consideration: maintainability; site location (weather, elevation, air cleanliness, etc.); conflicts in design criteria; and control system integration. Please refer to UFC 4-510-01 for Medical Gas Systems, including Dental Compressed Air and Medical Compressed Air.

1-4.2 Environmental Severity and Humid Locations.

In corrosive and humid environments, provide design detailing, and use materials, systems, components, and coatings that are durable and minimize the need for preventative and corrective maintenance over the expected service life of the component or system. UFC 1-200-01, section titled “Corrosion Prone Locations” identifies corrosive environments and humid locations requiring special attention. UFC 1-200-01, section titled “Requirements for Corrosion Prone Locations” provides examples of necessary actions. To determine Environmental Severity Classifications (ESC) for specific project locations refer to UFC 1-200-01 Appendix titled “Environmental Severity Classifications (ESC) for DoD Locations”.

1-5 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

Cybersecurity is implemented to mitigate vulnerabilities to all DoD real property facility-related control systems to a level that is acceptable to the System Owner and Authorizing Official. UFC 4-010-06 provides requirements for integrating cybersecurity into the design and construction of control systems.

1-6 DESIGN GUIDANCE.

The leading compressed air standards organization in the USA is the Compressed Air and Gas Institute (CAGI). Utilize CAGI's Compressed Air and Gas Handbook for design guidance, best practices, and calculation procedures in conjunction with this UFC. Figure 4-1 illustrates the arrangement of a typical compressed air system. As an additional resource of technical information on compressed air systems, please refer to the Army Technical Manual TM-5-810-4/Airforce Manual 88-8, Chapter 3 which can be found on the Whole Building Design Guide (https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-420-02).

1-7 BEST PRACTICES.

APPENDIX A contains information that is considered best practice based on experience and lessons learned.

1-8 GLOSSARY.

APPENDIX B contains acronyms and abbreviations.

1-9 REFERENCES.

APPENDIX C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 BASIC PRINCIPLES.

2-1.1 Life Cycle Consideration.

Energy and water-efficient and sustainable design attributes for military construction must be based on the cost-benefit analysis, return on investment, total ownership costs, and demonstrated payback. Provide mechanical systems based on achieving the lowest life cycle cost of the approved alternatives. Ensure that all operation and maintenance costs are included in any life cycle cost analysis.

Follow procedures for Life Cycle Cost Analysis (LCCA) stated in UFC 1-200-02. In selecting alternatives for analysis, give preference to features and systems with lower complexity and maintenance burden. Do not include alternatives for which it is clear, prior to LCCA that the cost exceeds the potential savings based on historic information or engineering judgment. Where such alternatives were considered, but not analyzed, identify those alternatives and provide an explanation.

2-1.2 Energy Conservation.

Utilize Life Cycle Cost Effective (LCCE) strategies in design and operation of compressed air systems. Energy Conservation Best Practices are discussed further in APPENDIX A.

2-1.3 HVAC Considerations.

Provide heating, ventilating, and air conditioning systems to maintain space temperatures within acceptable ranges for the compressed air systems. Refer to APPENDIX A for design considerations.

2-1.4 Electrical Considerations.

Provide electrical systems for compressed air systems and components thereof in accordance with UFC 3-501-01 & UFC 3-520-01.

2-1.5 Noise and Sound Considerations.

Determine the sound power levels for each piece of equipment used for compressed air systems. Use this information to predict the acoustic characteristics and the resulting ambient noise level. Refer to UFC 3-101-01 and appropriate facility-type UFCs for sound transmission requirements (STCs) into adjacent building spaces.

For additional information on noise control refer to UFC 3-450-01.

2-1.6 Breathing Air Systems

Breathing Air systems must deliver Grade D breathable air in accordance with CGA G-7.1-2018. Table 2-1 is derived from OSHA Standard 29 CFR 1910.134(i)(1) which lists minimum criteria of Grade D air. Coordinate Breathing Air System design with the stakeholders to ensure equipment, materials, design, and configuration comply with local regulations and requirements (for example, Tinker Air Force Base INSTRUCTION 48-103 “RESPIRATORY PROTECTION PROGRAM”).

Table 2-1 Minimum Grade D Breathing Air Characteristics

Component	**Criteria**
Oxygen Content (volume/volume)	19.5% - 23.5%
Hydrocarbon (condensed)	<= 2-gr/ft^3 (5 mg/m^3)
Carbon Monoxide (CO)	<= 10 parts per million (ppm)
Carbon Dioxide (CO2)	<= 1,000 ppm
Odor	Lack of a noticeable odor

CHAPTER 3 COMPRESSED AIR SYSTEM COMPONENTS

3-1 INTRODUCTION.

Compressed air systems are comprised of multiple components, including but not limited to air intakes, intake filters, compressors, aftercoolers, wet receivers, dry receivers, valves, air dryers, condensate removal, regulators, oil separators, and lubricators.

3-1.1 Redundant Systems.

When a system failure would result in unusually high repair costs, or replacement of process equipment, or when activities are disrupted that are mission critical, the designer must provide redundancy requirement analysis to support the justification of redundancy.

3-1.2 Air Intakes.

The intake for a compressor will be located either outdoors or indoors, whichever provides better air quality. All air compressors are sensitive to dust and airborne vapors which can form adhesive, abrasive, and corrosive mixtures within the compressor. These contaminants build up in rotating parts and can induce excessive wear and mechanical unbalance, thereby damaging the compressor.

- Locate air intakes outside of the building where practicable (save for breathing air systems which must always be located outside of the building). Locate the air intake at least 6-feet (2 m) above the ground or roof level. Position intake pipes to prevent entrance of snow or rainwater. If the intake would be subject to adverse weather conditions, provide a hood or louver for protection therefrom. Locate intakes far enough away from steam, gas, or oil engine exhaust pipes to ensure that the intake air is free of moisture or pollution.
- Locate intakes for reciprocating compressors at least 3-feet (1 m) away from any wall to minimize the pulsating effect on the structure. Provide an intake filter silencer or a pulsation damper.
- Do not locate compressor air intakes within an enclosed courtyard.

3-1.2.2 Intake Pipe Materials.

Provide plastic, copper, stainless steel, aluminum, or galvanized steel for air intake pipes. Utilize mechanical couplings for metallic pipe. Welded joints are prohibited.

3-1.2.3 Intake Air Filter.

Select air filters based on manufacturer’s recommendations for the type of compressor (for example, lubricated or non-lubricated) and based on the ambient air quality. Provide the necessary stages of filtration required to ensure the air entering the compressor is within the compressor manufacturer's recommendations, accounting also for the purpose of the compressor (for example, breathing air versus shop air).

3-1.2.4 Pressure Drop.

Provide a means to monitor the pressure drop across the inlet air filters. Coordinate with end user as to the level of detail required (for example, a binary input dirty filter switch versus directly measuring the pressure drop).

3-2 COMPRESSORS.

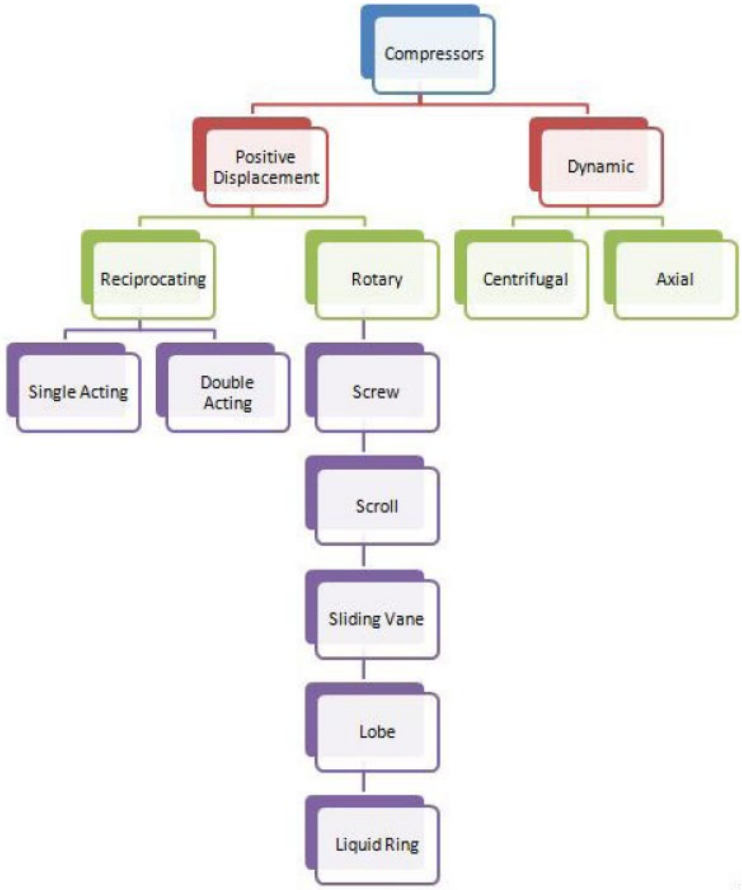
Utilize a central compressed air system whenever it is economically feasible as determined via a Life Cycle Cost Analysis. Compressors and all accessories must conform to ANSI/CAGI B19.1 and ASME B19.3, ASME BPVC Section VIII, PTC-9 & PTC-10, and ISA 7.0.01-1996, as applicable.

Where lubricating oils cannot be tolerated at the point of use, oil-free air compressors must be used. Oil-free air is required for such end uses as food handling, medical and dental application, chemical processing, and instrument air for pneumatic controls. Breathing air must be oil-free unless otherwise permitted by the end-user (for example, Contingency Operations).

3-2.1 Compressor Types.

Perform an analysis for each compressor to ensure that the best value is obtained by comparing such items as brake horsepower (bhp) per 100 cubic feet per minute (cfm) (kilowatt (kW) per cubic meter per minute (m^3/min)), unloaded horsepower (kilowatt), expected compressor life, and expected operation and maintenance costs. See Figure 3-1 for type of compressors. Typical applications for each type of compressor can be found in TM 5-810-4.

Figure 3-1 Types of Compressors



Courtesy of the Compressed Air and Gas Institute (CAGI)

3-2.2 Capacity.

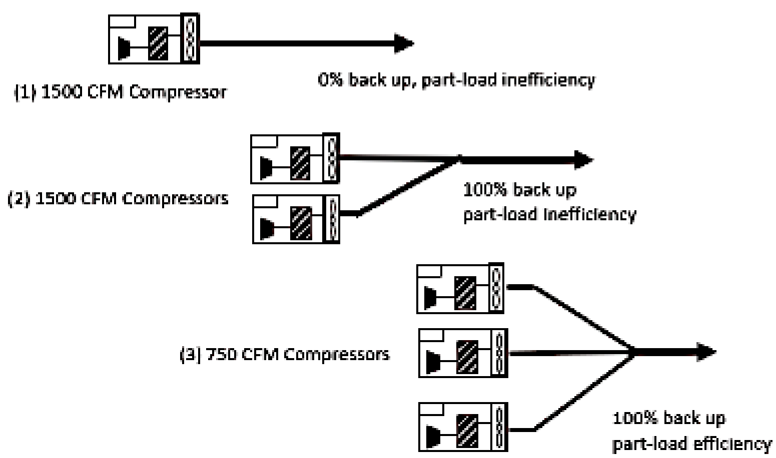
Size compressor based on the sum of the average air consumption of the end use devices, not the sum of the maximum air consumption (that is to say, utilize a load factor in determining compressor capacity). Utilize the CAGI Handbook, along with user input, to determine load factors.

Add an additional 10% to the estimated consumption to account for system leakage.

3-2.3 Multi-staging.

Multistage compressors may be used; however, only if LCCE. If multistage compressors are used, intercoolers must be used. An economic evaluation is necessary to determine whether a central compressed air distribution system or a system of separate compressors located near the point of usage is most cost-effective. Selection of the number of compressors for either situation must be based upon economics and other factors such as system reliability. Seasonal or operational load variations must also be considered. The efficiency of larger compressors is generally higher than that of smaller units but use of smaller air-cooled units permits savings on water, water piping, and system losses. Multiple units with interconnecting piping give flexibility for maintenance shutdown of one compressor. A smaller air compressor to handle requirements for weekends, holidays and other low usage times may also be economical (see Figure 3-2).

Figure 3-2 Multiple Compressor Installation



Courtesy of the Compressed Air and Gas Institute (CAGI)

3-2.4 Location.

Locate compressor(s) in a clean, well-lit, and ventilated area of sufficient size to permit easy access for cleaning, inspection, and any necessary dismantling (for example, removal of pistons, wheels, crankshafts, intercoolers, motors, and drivers). Provide aisle space between equipment for normal maintenance as well as for equipment removal and replacement as recommended by the manufacturer and code.

The temperature of the room in which air-cooled compressors are located must not exceed 100°F (38°C) or the maximum inlet air temperature specified by the compressor manufacturer, whichever is lower.

3-2.5 Automatic Warning and Shutdown.

Protect air compressor systems against high temperature, high pressure, and low oil pressure. In the case of centrifugal compressors, provide protection against excessive vibration. Protective controls will include a fault indicator and a manual reset device.

3-2.6 Vibration Limits.

To obtain guidance for establishing centrifugal compressor vibration levels, please contact manufacturers.

Flexible connectors, such as flexible metal hose, must be used to connect the discharge piping system to the air compressors.

3-2.7 Lubrication System.

System design will be in accordance with the manufacturer's recommendations. Lubricant type will depend on the compressor application:

- Gravity, splash, or pressure petroleum oil must be used where oil contamination of the compressed air at the point of use is not a problem.
- Synthetic liquid lubricants must be used where there is a danger of fire, where the carbonaceous deposits must be reduced, or where lubricant is provided for extended maintenance periods
- Solid lubricants, such as carbon or Teflon piston rings, must be used for oil-free reciprocating compressed air applications.

3-3 AIR DISCHARGE PIPE.

3-3.1 Critical Pipe Length.

Determine critical pipe lengths of the air discharge pipe by coordinating with air compressor manufacturers. Critical pipe lengths must be avoided to prevent resonance.

3-3.2 Surge Volume.

Provide pulsation dampers or surge bottles at the discharge of reciprocating compressors if LCCE.

3-3.3 Safety Provision.

Provide a safety valve between a positive displacement compressor discharge and any isolation valve or other flow restricting device, as well as between the compressor and an internally finned tube aftercooler. The safety valve or valves will have a total capacity sufficient to handle the entire output of the compressor. Connect safety valves directly into the piping without unnecessary additional piping or tubing. Direct safety valve discharge away from personnel areas and traffic lanes.

3-4 AFTERCOOLER AND SEPARATOR.

3-4.1 Circulating Water.

When water-cooling is provided or required, provide the required waterflow through the intercooler, cylinder jacket, and aftercooler for cooling the compressor, cooling the compressed air, and for moisture removal. Provide controls and components to prove waterflow (for example, flow switch or differential pressure sensor) to ensure that sufficient cooling water is flowing before the compressor is allowed to start. Water for the aftercooler for liquid seal rotary compressors must be piped in series with the compressor. Waterflow for rotary screw compressors and rotary lobe compressors is not required prior to startup. Design the pipes to conform to the manufacturer's recommendations. Use a strainer or filter in the piping system to reduce fouling of the cooler system components.

Ensure cooling water temperature entering compressor cylinder jackets is at least 15°F (8.3°C) above the inlet air dew point to prevent condensation from forming in the cylinder inlet ports. Consult with a compressor manufacturer to verify the cooling water requirements for cooling compressor cylinder jackets.

3-5 AIR DRYER.

Provide air dryers where required. Coordinate the required air dew point temperature with customer and as required by the application (for example, very low dew point air for piping exposed to freezing where heat tracing is not practicable.).

3-5.1 Dryer Types.

In determining the type of dryer to be used for a given application, drying requirements, flow pressure, inlet temperatures, and the pressure dew point must be accurately determined. Select the dryer that meets these requirements most economically and efficiently. The various drying methods are as follows:

a. Refrigeration. Refrigeration dryers remove moisture from compressed air by cooling the air in a heat exchanger. This condenses and removes the moisture from the airstream and produces an operating pressure dew point at the dryer outlet in the range of 35°F to 39°F (2°C to 4°C). By adjusting the refrigeration unit operating parameters, these units can produce pressure dew points of 50°F (10°C). Higher dew points are available in either direct refrigeration or chiller-type design. The temperature of the room in which an air-cooled refrigerated dryer is located must not exceed 100°F (38°C) or the maximum inlet air temperature specified by the compressor manufacturer, whichever is lower.

b. Twin-tower regenerative. Regenerative dryers utilize non-consumable desiccants to remove moisture form the inlet air while the other is being regenerated (typical dew point ranges from -150°F up to 33°F (-101°C up to 1°C)). This method of regeneration includes the following dryer classifications:

    (1) Heatless desiccant regeneration passes a quantity of dried (purge) air through the off-stream bed. No external heat is applied. This type, with a field-adjustable purge control must be selected so that purge rate (and therefore pressure dew point) can be adjusted to accommodate seasonal variation in ambient temperatures, thereby reducing operating costs. Provide prefiltering to remove oil from the air stream to minimize future desiccant replacement.

(2) Heat regenerative dryers utilize heat from an external source (either electric or steam) in conjunction with purge air to regenerate the off-stream tower.

c. Deliquescent. Deliquescent (salt pellet) dryers and ethylene glycol stills are mentioned here for general information purposes only and must not be used.

A summary of typical applications for the above dryers are illustrated in Figure 3-3.

Figure 3-3 Air Dryer Types

Type of Dryer	Pressure Dew Point Range	Typical Applications	Initial Cost	Operating Cost	Remarks
DELIQUESCENT					
	12-20°F below inlet temperature	Protection against condensation in indoor air lines.	Lowest	Low to moderate	Causes high maintenance of downstream equipment due to salt solution in air lines.
REFRIGERATED					
	Above 33° F	General plant air, air-operated tools, instruments; materials conveying.	Low	Lowest	Most widely used type of air dryer because of its inherent reliability and low cost factor.
TWIN-TOWER REGENERATIVE					
Heatless Desiccant	Below 33°F (down to minus 150°F)	Outside air lines; chlorine padding; manufacturing processes requiring very dry air such as assembling electronic components and making urethane foam.	Low to moderate	Highest	Inefficient operation due to high purge rate.
Heat Regenerative	Below 33°F (down to minus 150°F)	Outside air lines; chlorine padding; manufacturing processes requiring very dry air such as assembling electronic components and making urethane foam.	Moderate to high	Moderate to high	Minimum air waste for high flow, low dew point applications.

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3-5.2 Prefilters and After-Filters.

Consideration must be given to providing a prefilter upstream of the air dryer. A prefilter may be required to remove compressor carry-over oil and other undesirable particles from the air prior to the air entering the air dryer. This filter can extend the life of the air dryer and reduce air dryer maintenance costs. An air filter must be considered to protect the downstream piping system and equipment from impurities and undesirable particles added to the air as a result of passing through the air dryer. Consult the air dryer manufacturers for recommendations and selection of prefilters and after filters for specific air quality requirements.

3-6 AIR RECEIVER.

Air receivers must be constructed in accordance with ASME BPVC Section VIII. Provide both a wet receiver and a dry receiver for applications that require dry air. Tank mounted compressors do not require wet and dry storage.

3-6.1 Determining Receiver Size.

Determine the appropriate receiver size after establishing the air compressor capacity. Size the receiver in accordance with the recommendations of the CAGI Handbook or the compressor manufacturer's recommendations. If the compressor manufacturer's literature recommends a larger air receiver, then provide the larger receiver.

3-6.2 Installation.

Install each receiver on a dry equipment pad. Provide space around each unit to facilitate draining, inspection, and maintenance. When a receiver is located outside, install the safety valve and pressure gauge indoors to prevent freezing. Heat trace the associated outdoor piping and arrange piping to drain back to the receiver. Where an automatic condensate trap is used with a receiver located outdoors, locate the trap indoors and heat trace the outdoor piping, or provide the outdoor trap and piping with electric heat tape to protect them from freezing.

3-7 PIPING.

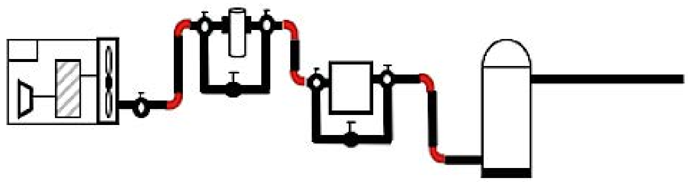
3-7.1 Materials.

- Steel compressed air piping must be a minimum of Schedule 40 and be galvanized, black, or stainless steel. Pipe fittings will be galvanized, black, or stainless steel, to match piping used. Fittings must be threaded, flanged, or welded type. Grooved fittings may only be used if permission is received by the Authority Having Jurisdiction.
- Copper compressed air piping or tubing will be Type K or Type L with brazed joints. Brazing filler metals with melting temperatures between 1,000°F (537.8°C) and 1,600°F (871.1°C) will be used.
- Thermoplastic piping system for transport or storage of compressed air will not be allowed. Safety records show that leaks in this type of pipe (when used for compressed air service) have caused the pipe to rupture, causing serious injury to personnel and/or property damage.

3-7.2 Loss of Air Pressure Due to Friction.

The maximum allowable pressure drop from the compressor to the most distant point of use must not exceed 5 percent. Utilize equivalent lengths of pipe to account for fittings, valves, and other minor losses.

Figure 3-4 Piping Loss Calculation



Pipe length calculation

	Piping and Equivalent Length Fitting Adjustment	
	2" piping and components	3" piping and components
Piping	500'	500'
5 Gate Valves	6.05 equivalent feet 1.21 x 5	8.95 equivalent feet 1.79 x 5
6 Long Radius Elbows	12.42 equivalent feet 2.07 x 6	18.42 equivalent feet 3.07 x 6
Total Piping	**518.47 feet**	**527.37 feet**

Pressure drop calculation

	pressure drop @ 500 cfm with 2" piping and components	pressure drop @ 500 cfm with 3" piping and components
Piping	9.95 psid 518.47/1000 x 19.2 psid	1.23 psid 527.37/1000 x 2.34 psid
Filter	2 psid	2 psid
Dryer	3 psid	3 psid
System Total	**14.95 psid**	**6.23 psid**

System conditions and assumptions

- 500 cfm compressor, fully loaded
- 50' of pipe in compressor room
- 450' of pipe in distribution header
- 5 open gate valves
- 6 long radius elbows
- Pipe is schedule 40 steel
- Filter pressure drop is 2 psid
- Dryer pressure drop is 3 psid

Courtesy of the Compressed Air and Gas Institute (CAGI)

3-7.3 Piping Layout.

Arrange piping system in a closed loop or “ring main” where possible. Provide dedicated main air lines to services requiring heavy air consumption and that are long distances from the compressor unit. Install piping parallel with the lines of the building, with main and branch headers sloping down toward a dead end. Install traps in airlines at all low points and dead ends to remove condensed moisture.

- Branch headers from compressed air mains, and all other takeoffs, must be taken off at the top to avoid picking up moisture.
- A strainer or filter and a lubricator must be provided in piping that serves tools.
- Provide all end points with a filter/strainer, pressure regulator, and dryer/lubricator (depending on end use application). Provide pressure gauges upstream and downstream of pressure regulator if a pressure gauge is not integral to the regulator. Provide filters and dryers with automatic drains.

- Provide service drops with isolation ball valves.
- Provide end point quick connect couplings compatible with end user equipment.
- Coordinate service drop locations and configurations with end user.

3-8 CONTROL SYSTEM.

Compressed air system controllers must be integrated into the building automation system (BAS) where a BAS is available; to the extent of which the compressor controls are capable; and to the extent of the user’s needs. For example, a rotary screw compressor may be provided with web-based controls from the manufacturer that can display operating conditions and permit remote modification and control; however, manufacturers might only offer auxiliary contacts and relays to facilitate remote monitoring for tank mounted reciprocating compressors. Integrate air dryers into the BAS to monitor operating status, faults, alarms, and leaving compressed air dry bulb temperature and dew point.

- Align the control features and needs provided with a compressed air system with the end-user and Installation during design development.
- If a BAS is not available, provide the compressor with the means to facilitate future integration. Compressor controller must natively communicate using open protocols (BACnet, LON, or MODBUS) using standard objects and services, or provide a gateway to facilitate the aforementioned communication.
- Refer to UFC 3-410-02 and UFC 4-010-06 for additional control requirements.
- These requirements do not apply to portable air compressor units.

3-9 SOUND TESTS.

After installation, perform a sound test on all compressors and accessories in accordance with UFGS 22 05 48.00 20. Sound reading test results must not exceed limitations set by OSHA Standard 1910.95.

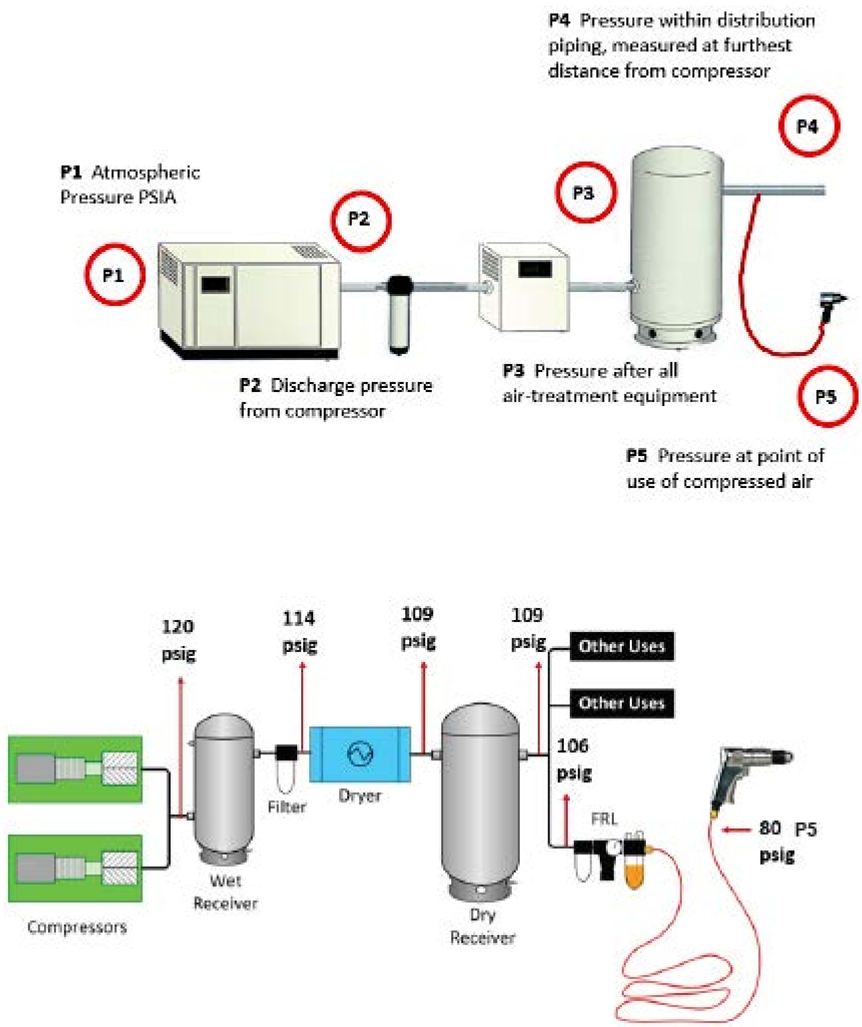
CHAPTER 4 GENERAL DESIGN AND EQUIPMENT SCHEDULES

4-1 DESIGN ANALYSIS.

The following items must be included in the design analysis:

- Equipment redundancy requirements for critical system operation.
- Application (hospital, industrial, etc.)
- Maximum operating pressure required
- Location of air requirement in buildings
- Total compressed air flow and compressor sizing calculation including, but not limited to adjustments for altitude, moisture, temperature, and additional environmental factors that impact the compressed air system design.
- Heat Rejection Rates and rejection methods (for example, heat rejected to space, remote radiator, or other)
- Makeup/intake air system(s) design, including calculations.
- Air usage continuous or intermittent demand
- Operating pressure dew point requirement
- Dryer type selection and justification
- Air filtration needs at points of use
- Need for oil-free air
- Life Cycle Cost Analyses performed in accordance with UFC 1-200-02.
- Pressure drop calculations due to components, fittings, and piping from compressor outlet to end point devices (see Figure 4-1).
- List end point air consumption rates with corresponding minimum operating pressure requirements. If used, provide diversity factors for each corresponding end point load.
- Consider the Best Practices enumerated in APPENDIX A and document in the design narrative/analysis the best practices incorporated into the design. Include justification/rationale in the design narrative when a best practice is not incorporated into the design.

Figure 4-1 Design with the End in Mind



Courtesy of the Compressed Air and Gas Institute (CAGI)

4-2 EQUIPMENT SCHEDULES.

Equipment schedules will be shown on the drawings, including the following:

4-2.1 Air Compressor.

a. Capacity in standard cubic feet of air per minute (SCFM) (standard cubic meters per minute (Standard m^3/min))

b. Inlet air pressure in psia (bar)

c. Discharge pressure in psia (bar)

d. Ambient air temperature range with coincident humidity in gr/lb (g/kg)

e. Heat rejection type (water/oil/air cooled)

f. Heat Rejection characteristics (for example, for air-cooled: btu/h (kW), CFM (m^3/min), and temperature difference).

g. Minimum motor power in horsepower (kW)

h. Volts, phase, frequency

i. Minimum Circuit Ampacity

j. Maximum Overcurrent Protection Device in Amps

k. Type of Compressor

l. Number of Compressors

m. Oil-free or not oil-free

n. Accessory list

o. Spare parts list

4-2.2 Air Receiver.

a. Type (wet or dry)

b. Capacity in ft^3 (m^3)

c. Design Pressure in psia (bar)

d. Orientation: horizonal or vertical

e. Diameter in feet and inches (mm)

f. Length in feet and inches (mm)

g. Accessory list

h. Spare parts list

i. Drain type

j. Accessories

4-2.3 After Cooler-Separator.

a. Water-cooled

  i. Capacity in cfm (m^3/min) and psig (barg)

  ii. Dew point temperature entering and leaving in °F (°C)

  iii. Length in inches (mm)

  iv. Diameter in inches (mm)

  v. Cooling water

    1. Flow rate in gpm (L/s)

    2. Inlet Temperature in °F (°C)

    3. Outlet Temperature in °F (°C)

4. Fluid Type (for example, water, glycol, etc.)
5. Percentage of Glycol or level of freeze protection required

vi. Accessory list

vii. Spare parts list

b. Air-cooled

i. Capacity in cfm (m^3/min) and psig (barg)

ii. Compressed air inlet temperature entering after cooler in °F (°C)

iii. Approach temperature in °F (°C)

iv. Ambient air temperature in °F (°C)

v. Minimum fan motor power in horsepower (kW)

vi. Volts, phase, hertz,

vii. Minimum Circuit Ampacity

viii. Maximum Overcurrent Protection Device in Amps

ix. Accessory list

x. Spare parts list

4-2.4 Air Dryer.

a. Type (for example, refrigerated)

b. Capacity (cfm (m^3/min)) and operating pressure in psig (barg)

c. Dew point temperature entering and leaving in °F (°C)

d. Ambient temperature in °F (°C)

e. Volts, phase hertz (if applicable)

f. Refrigerant Type (if applicable)

g. Approx. Refrigerant Charge (if applicable)

h. Regeneration air flow in cfm (m^3/min)

i. Regeneration air temperature in °F (°C)

j. Regeneration Heater Input in btu/h (W) (if applicable)

k. Accessory list

l. Spare parts list

m. Drain type

APPENDIX A BEST PRACTICES

The Best Practices Appendix is considered to be guidance and not requirements. Its main purpose is to communicate proven facility solutions, systems, and lessons learned, but may not be the only solution to meet the requirement.

A-1 ENERGY CONSERVATION MEASURES.

To the extent practicable and LCCE, consider the following energy conservation measures:

A-1.1 Compressors.

a. Variable speed compressor(s).

b. Multiple compressors versus a single compressor (for example, if demand differs significantly on nights and weekends versus during weekday daytime demand, then multiple small compressors may be a LCCE solution than a single large single speed compressor).

c. Shut down idling compressors.

d. Utilize heat from compressors to provide compressor room heating in winter.

e. Select an air compressor with a pneumatic load- unload feature that, when fully unloaded, consumes approximately 15 percent of the base load horsepower.

f. Use waste heat from the oil cooler to heat makeup air or for building space heating during the heating season.

g. When economically justifiable, use multistage compression with intercoolers.

h. Integral size motors must be the premium efficiency type in accordance with NEMA MG 1.

i. Provide a dedicated room for air compressors.

A-1.2 Aftercooler with Separator.

a. Aftercooler selection must be based on degree of drying required downstream of the aftercooler. Final discharge air temperature of the aftercooler will affect dryer sizing and can reduce both the initial and operating costs of compressed air dryers.

b. Duct air from air cooled aftercoolers to provide space heating in winter and to remove heat form the plant in summer. Pipe coolant water to recycle waste heat.

A-1.3 Filters and Dryers.

a. Improve air quality only to the degree required at the point of use. If air quality requirements differ at various points of use, specify appropriate filters or dryers in applicable branch lines.

b. Accurately determine the dew point required at each point of use since that affects the selected type(s) and size(s) of dryer(s).

c. Room air temperatures will affect drying efficiency. If practicable, locate dryers where ambient temperature will not exceed 100°F (38°C).

d. Select dryer in conjunction with aftercooler so inlet air temperature to the dryer can be as low as feasible. Keep inlet pressure as high as possible. Accurately determine operating temperature and pressure, since even minor changes in either can result in substantial operating costs.

A-1.4 Air Leakage.

a. Maximum acceptable air leakage rate for a compressed air system must not exceed 10 percent of the installed system flow rate. Air leaks occur most often at pipe joints. Hose connections, and equipment connections; and are usually a result of poor maintenance practices and/or inadequately trained maintenance personnel.

b. Specification of quality materials and workmanship are a major contribution the designer of a compressed air system can provide for a safe and relatively leak-free air system. In addition, designing the compressed air system with minimum piping and pipe joints, will reduce potential leakage sources.

A-2 AIR INTAKES.

It is desired that the intake air filter be located on the compressor and piped from the enclosed filter hood to the outside. This method prevents ingestion of foreign material to the internals of the compressor should the piping have a poor joint or other leak upstream of the intake filter.

A-3 AIR COMPRESSORS.

Oil-free air can be obtained by using a centrifugal compressor, which is not lubricated due to its configuration; a water-sealed rotary compressor: or a reciprocating nonlubricated air compressor using carbon or Teflon for piston and packing rings. For isolated cases where oil-free air is required on a compressed air system coalescing filters may be used to remove solids, moisture, and oil from the air stream.

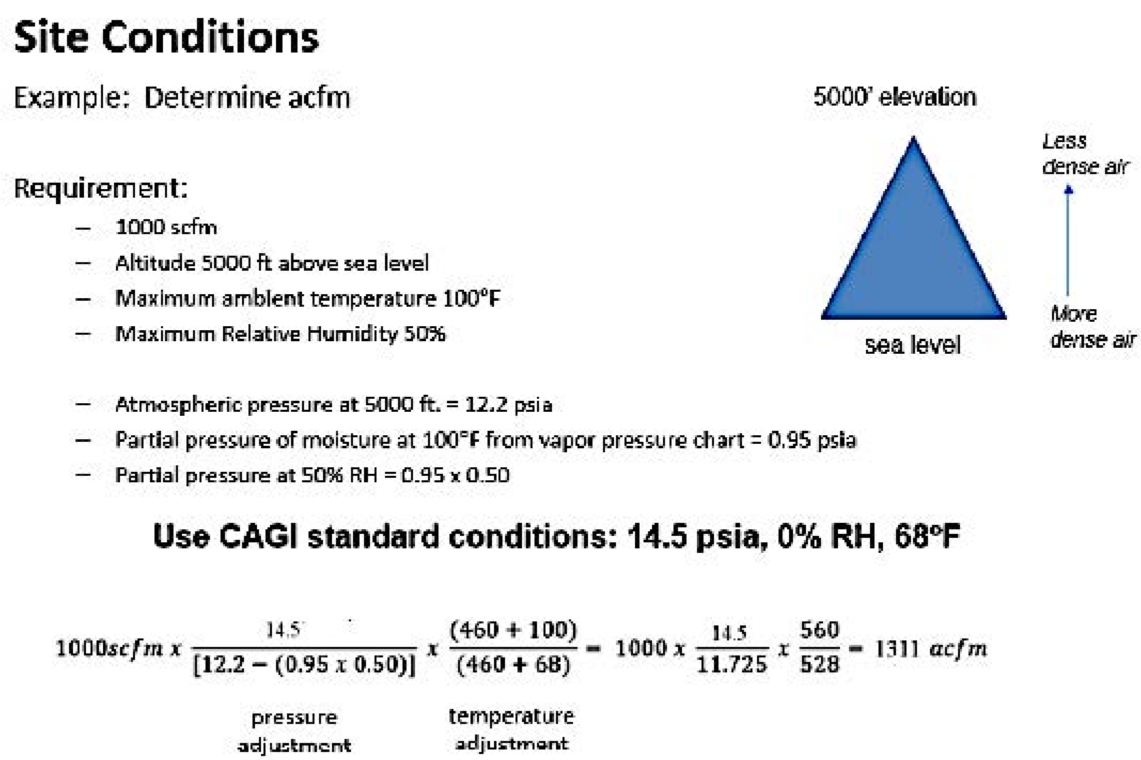
A-4 AIR PRESSURE ADJUSTMENTS.

Converting between actual cubic feet per minute (ACFM) and standard cubic feet per minute (SCFM) can be accomplished using the following equation which is illustrated in Figure A-1 utilizing I-P units of measure.

$$Flow_{act} = (Flow_{std})\left(\frac{P_{std,abs}}{P_{act,abs} - (P_v RH)}\right)\left(\frac{T_{act,abs}}{T_{std,abs}}\right)$$

Where:
$Flow_{act}$ = Actual Flow Rate in CFM (m³/minute)
$Flow_{std}$ = Standard Flow Rate in CFM (m³/minute)
$P_{std,abs}$ = Standard Pressure (Absolute) in PSIA (bar)
$P_{act,abs}$ = Actual Pressure (Absolute) in PSIA (bar)
P_v = Partial Pressure of Moisture in Air at Actual Temperature in PSIA (bar)
RH = Actual Relative Humidity
$T_{act,abs}$ = Actual Temperature (Absolute) in Rankine (Kelvin)
$T_{std,abs}$ = Standard Temperature (Absolute) in Rankine (Kelvin)

Figure A-1 Flow Rate Adjustments



Courtesy of the Compressed Air and Gas Institute (CAGI)

A-5 AIR RECEIVER SIZING.

Oversizing dry receivers by at least 10% may reduce the risk of running out of dry air if an unusual period of high demand exceeds the amount of usable storage.

A-6 AUTOMATIC BLOW DOWNS & DRAINS.

Blow downs and drains must be the automatic type to conserve energy. Typical locations include, but are not limited to, air receivers, filters, and dryers.

APPENDIX B GLOSSARY

B-1 ACRONYMS.

ACFM	Actual Cubic Feet per Minute
AFCEC	Air Force Civil Engineer Center
ASME	American Society of Mechanical Engineers
BACnet	Building Automation and Control network
BARG	Bar (Gauge)
BAS	Building System Automation
BIA	Bilateral Infrastructure Agreement
CAGI	Compressed Air and Gas Institute
CFM	Cubic Feet per Minute
DoD	Department of Defense
DN	Diametre Nominal (Nominal Diameter)
ER	Engineering Regulation
ESC	Environmental Severity Classifications
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilation, and Air Conditioning
ISA	Instrument Society of America
LCCA	Life Cycle Cost Analysis
LCCE	Life Cycle Cost Effective
LON	Lonmark® LONtalk
m	Meter
mm	Millimeter
NEMA	National Electrical Manufacturers Association
OSHA	Occupational Safety and Health Administration

PSIA	Pounds per Square Inch, Absolute
PSIG	Pounds per Square Inch, Gauge
RH	Relative Humidity
SCFM	Standard Cubic Feet per Minute
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria
U.S.	United States

B-2 DEFINITION OF TERMS.

Actual Cubic Feet Per Minute (Actual Cubic Meters Per Minute): The flow rate of air expressed in terms of actual conditions, that is at non-standard conditions.

Standard Conditions: For the purposes of this UFC, standard conditions are taken to be those of CAGI: Standard Pressure of 14.5 psia (1 bar); Standard Dry Bulb Temperature of 68°F (20°C); Standard Humidity of 0% Relative Humidity.

Standard Cubic Feet Per Minute (Standard Cubic Meters Per Minute): The flow rate of air expressed in terms of standard conditions.

APPENDIX C REFERENCES

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B19.3, *Safety Standard for Compressors for Process Industries*

ASME *Boiler and Pressure Vessel Code Section VIII*, 2021

ASME PTC-9, *Performance Test Code on Displacement Compressors, Vacuum Pumps, and Blowers*, 1997

ASME PTC-10, Performance Test Code on Compressors and Exhausters, 1997

COMPRESSED AIR AND GAS INSTITUTE (CAGI)

CAGI *Compressed Air and Gas Handbook*, 7th Ed., 2016

ANSI/CAGI B19.1, *Safety Standard for Compressor Systems*

COMPRESSED GAS ASSOCIATION (CGA)

CGA G-7.1-2018, *Commodity Specification for Air - Seventh Edition*

INSTRUMENT SOCIETY OF AMERICA

ANSI/ISA-7.0.01-1996, *Quality Standard for Instrument Air*

INTERNATIONAL STANDARDS ORGANIZATION

ISO 2151-2004, *Acoustics - Noise Test Code for Compressors and Vacuum Pumps-Engineering Method (Grade 2)*

OCCUPATIONAL SAFETY AND HEALTH AGENCY (OSHA)

OSHA (29 CFR) 1910.95, *Occupational Noise Exposure*

OSHA (29 CFR) 1910.134(i), *Breathing Air Quality and Use*

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 1-200-01, *DoD Building Code*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 3-101-01, *Architecture*

UFC 3-401-01, *Mechanical Engineering*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-410-02, *Direct Digital Control for HVAC and Other Building Control Systems*

UFC 3-450-01, *Noise and Vibration Control*

UFC 3-501-01, *Electrical Engineering*

UFC 3-520-01, *Interior Electrical Systems*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UFC 4-510-01, *Design: Military Medical Facilities*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

UFGS 22 05 48.00 20, *Mechanical Sound, Vibration, and Seismic Control*

US ARMY CORPS OF ENGINEERS

Engineering Regulation No. 1110-1-8173, *Energy Modeling and Life Cycle Cost Analysis*

UFC 3-430-01FA
25 July 2003

UNIFIED FACILITIES CRITERIA (UFC)

HEATING AND COOLING DISTRIBUTION SYSTEMS

UNIFIED FACILITIES CRITERIA (UFC)

HEATING AND COOLING DISTRIBUTION SYSTEMS

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes TI 810-32 dated 10 January 2002. The text of this UFC is the text of TI 810-32. The format of this document does not conform to UFC 1-300-01; however, it will be reformatted at the next revision.

FOREWORD

\1\
The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

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- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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US Army Corps
of Engineers®

TI 810-32
10 January 2002

Technical Instructions

HEATING AND COOLING DISTRIBUTION SYSTEMS

Headquarters
U.S. Army Corps of Engineers
Engineering Division
Directorate of Military Programs

CEMP-E

TI 810-32
10 January 2002

TECHNICAL INSTRUCTIONS

HEATING AND COOLING DISTRIBUTION SYSTEMS

This document reissued 10 January 2002.

Record of Changes (changes indicated \1\…/1/)

No.	Date	Location
1	7 March 2002	Pages 4-1, 4-2, 5-1, and C-1 Table 4-2 Figures (editorial – changes not marked) 3-1 thru 3-28, 4-1, and 4-3
2	30 Sept 2002	Page 1-1 Figures (editorial – changes not marked) 3-14, 3-28, 4-4, 4-5, 4-17, and 7-7

CEMP-E **TI 810-32**
30 August 1999
Reissued 10 January 2002

FOREWORD

These technical instructions (TI) provide design and construction criteria and apply to all U.S. Army Corps of Engineers (USACE) commands having military construction responsibilities. TI will be used for all Army projects and for projects executed for other military services or work for other customers where appropriate.

TI are living documents and will be periodically reviewed, updated, and made available to users as part of the HQUSACE responsibility for technical criteria and policy for new military construction. CEMP-ED is responsible for administration of the TI system; technical content of TI is the responsibility of the HQUSACE element of the discipline involved. Recommended changes to TI, with rationale for the changes, should be sent to HQUSACE, ATTN: CEMP-ED, 20 Massachusetts Ave., NW, Washington, DC 20314-1000.

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FOR THE COMMANDER:

DWIGHT A. BERANEK, P.E.
Chief, Engineering and Construction Division
Directorate of Military Programs

HEATING AND COOLING DISTRIBUTION SYSTEMS

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CHAPTER 1

GENERAL INFORMATION

1-1. PURPOSE AND SCOPE. This document provides criteria and guidance for the design and construction of heating and cooling distribution systems and supplements information in the "Notes to the Designer" of the guide specifications. These distribution systems include Heat Distribution Systems in Concrete Trenches, Pre-engineered Underground Heat Distribution Systems, Prefabricated Underground Heating/Cooling Distribution Systems, and Aboveground Heat Distribution Systems. The mediums used in these distribution systems, as defined by the Department of Defense (DoD), include:

a. High temperature hot water (HTHW) (251 deg. F to 450 deg. F)

b. Low temperature hot water (LTHW) (150 deg. F to 250 deg. F)

c. Low pressure steam systems (up to 15 psig)

d. High pressure steam systems (over 15 psig)

e. Condensate return systems (up to 200 deg. F)

f. Chilled water systems.

1-2. APPLICABILITY. These instructions are applicable to all **\2** DoD agencies **/2/** and their contractors involved in the design and construction of heating and cooling distribution systems.

1-3. REFERENCES. Appendix A contains a list of references used in these instructions.

1-4. EXCEPTIONS. Generally, this document covers heating and cooling distribution systems most typically installed on United States military installations. However, deviations from the recommendations of this manual may be necessary when unusual site conditions are present or specific using service requirements are encountered. For example, the manual does not discuss design problems associated with arctic and subarctic construction, in which case, the designer should refer to the "Cold Climate Utilities Manual", 1986, Canadian Society of Civil Engineers, Montreal, Quebec.

1-5. DEFINITIONS. The term "designer" used throughout this manual refers to the person or persons responsible for preparing contract drawings and specifications for a heating or cooling distribution design. The main engineering discipline areas of the "designer" are:

a. Mechanical. Includes expansion compensation, stress analysis, piping system design (fittings, valves, insulation), equipment selection and sizing, and pipe sizing and routing.

b. Structural. Includes reinforced concrete design, pipe supports, and valve manhole cover design.

c. Electrical. Includes cathodic protection, electrical service and controls (e.g. sump pumps).

d. Civil. Includes earth work, road crossings (for buried systems), system plans and profiles, and area drainage designs.

CHAPTER 2

SYSTEM SELECTION

2-1. GENERAL. When designing a heating or cooling distribution system, the designer must first select two critical items: media type and system type.

2-2. DISTRIBUTED MEDIA SELECTION.

a. Connecting to an existing system. Almost all heating and cooling distribution systems will be connected to an existing central distribution system. In this case, the designer most often designs for the media to which it is being connected-HTHW, LTHW, steam/condensate, or chilled water.

b. Installation of new system. When no existing system is present, the designer must select the system that is most appropriate for the end user. High temperature hot water and steam/condensate systems are the most common types of distribution systems currently used on military installations. However, a new system should only use the temperatures and pressures necessary to meet the requirements of the installation. For example, the use of high pressure steam sterilizers or steam kettles at several facilities may require the use of a high pressure steam or HTHW system. However, it is usually much more cost effective (on a first cost and life cycle cost basis) to use a low or medium temperature hot water distribution systems whenever possible and to incorporate stand alone high pressure/temperature systems where required. The lower maintenance costs, safer operation, longer life of systems, and simpler system controls for hot water systems often offset the costs of larger piping required. For further assistance for selecting the system type, refer to ASHRAE Handbook, "HVAC Systems and Equipment."

2-3. SYSTEM TYPES. When selecting a distribution system, the designer must determine which system types apply to a particular medium. The designer must also exclude systems which are not appropriate for a particular site or for which the customer has no interest. Examples of this are locating aboveground systems in non-industrial areas where the installation is sensitive to the aesthetic appearance of the area or routing concrete shallow trench systems through drainage swales or flood plains.

a. Heat Distribution Systems in Concrete Trenches (chapter 4). This system is a buried system with its removable concrete cover installed at grade and will typically be used for HTHW and steam/condensate systems. In rare instances, it may also be used for chilled water and LTHW in the event no plastic piping is installed in the same trench as high temperature (greater than 250 degrees F) piping systems. Experience has shown that if insulation of a high temperature system is compromised, temperatures can increase to such a level and cause damage to the plastic piping.

b. Pre-engineered Underground Heat Distribution Systems (chapter 5). This system is designed for higher pressure and temperature applications. The two types of pre-engineered systems are the drainable-dryable-testable (DDT) type which is used for high pressure steam/condensate and HTHW at all sites, and high temperature hot water at any type of site, and the water spread limiting (WSL) type which is used only for steam/condensate systems in bad and moderate sites. HTHW supply and return lines may be provided in a single casing; however, steam and condensate lines must always be provided in separate casings because condensate lines typically last less than half as long as the steam line and are easier to replace when in a separate casing.

c. Prefabricated Underground Heating/Cooling Distribution System (chapter 6). This system is designed for lower temperature and pressure applications. It is typically used for LTHW, chilled water, or combination LTHW/chilled water systems.

d. Aboveground Heat Distribution System (chapter 7). This system may be used for HTHW, steam/condensate, and LTHW systems, and for chilled water systems where freezing is not a concern.

2-4. SYSTEM SELECTION. The system type selected will be based on the type of media that is distributed.

a. High Temperature Water and Steam/condensate Systems. The order of preference for system types for high temperature and high pressure systems are:

(1) Aboveground Heat Distribution System. This is the least expensive system and historically requires the lowest maintenance and operating costs. However, the safety and aesthetics of an aboveground system are not always desirable and must be accepted by the end user.

(2) Heat Distribution Systems in Concrete Trenches. This is the most dependable of the buried distribution systems. The piping is totally accessible through removable concrete covers, the piping does not come in contact with the soil, and ground water is drained away from the piping system to low point drains. Except in rare instances, this is the system that should be selected if aboveground is not acceptable with the end user.

(3) Pre-engineered Underground Heat Distribution System. This type of buried distribution system should be selected as the last option due to very short system lives which are typically caused by poor drainage, poor corrosion protection, and improper installation. Instances where it would be used would be when aboveground is not acceptable with the end user or when drainage swales and high ground water prevent the installation of a concrete trench system.

b. Low Temperature and Chilled Water Systems. The order of preference for system types for hot water, chilled water or combination hot/chilled water are:

(1) Aboveground Heat Distribution System. This is the least expensive system and historically requires the lowest maintenance and operating costs. However, the aesthetics of an aboveground system are not always desirable and must be accepted by the end user. In addition, aboveground systems are typically not used for chilled water because of potential freezing problems in colder climates and heat gain in warmer areas.

(2) Prefabricated Underground Heating/Cooling Distribution System. This buried distribution system is relatively inexpensive and dependable. The non-metallic casing materials provide excellent protection from corrosion and the lower temperatures and pressures allow the system to operate for extended periods of time. It is an excellent application for chilled water since the system is installed underground, limiting the amount of heat gain to the system.

CHAPTER 3

GENERAL DISTRIBUTION SYSTEM DESIGN

3-1. GENERAL. Some aspects of a heating or cooling distribution system design are similar regardless of the system type. These aspects are covered in this chapter.

3-2. SITE SOIL SURVEY. After general routing has been proposed and before specific design has begun, a detailed soil survey will be conducted for all distribution systems.

a. The survey will be made after the general layout of the system has been determined, will cover the entire length of the proposed system, and will be made by a geotechnical engineer. The geotechnical engineer will be a registered professional engineer with a minimum of three years of experience in the field of soil mechanics and foundation design. This engineer must also be familiar with the local soil conditions.

b. If at all possible, the survey should be conducted during the time of the year when the ground-water table is at its highest point; if this is not possible, water table measurements will be corrected, on the basis of professional judgement and local knowledge, to indicate conditions likely to exist at the time of year when the water table is at its highest point. It may be necessary to dig test pits at the worst locations to investigate the soil for evidence of high water table.

c. As a minimum, information on ground-water conditions, soil types, terrain, and precipitation rates and irrigation practices in the area of the system will be collected. This information will be obtained from available records at the installation. In addition, soil resistivity will be determined for the cathodic protection system design for Pre-Engineered Underground Heat Distribution Systems.

d. Information on ground-water conditions and soil types (in most cases not necessary for Prefabricated Underground Heating and Cooling Distribution Systems and Aboveground Heat Distribution Systems) will be obtained through borings, test pits, or other suitable exploratory means. Generally, a boring test pit will be made at least every 100 feet along the line of the proposed system within areas of prior construction. In open undisturbed natural areas the spacing of borings may be increased. Each exploratory hole will extend to a level at least five feet below the anticipated elevation of the bottom of the proposed system. If a significant difference in underground conditions is found at adjacent exploratory points, additional explorations will be made between those points in order to determine more precisely where the change occurs. Upon completion of the survey, each exploration point will be classified on the basis of the criteria presented in the guide specification for Pre-Engineered Underground Heat Distribution Systems or in the guide specification for Heat Distribution Systems in Concrete Shallow Trenches. The classification criteria is different for each system. Note that although classification is not a requirement for design of Prefabricated Underground Heating and Cooling Distribution Systems or Aboveground Heat Distribution Systems, the site survey, except for borings or test pits, must be conducted to ensure that actual site characteristics have been identified so that accurate plan and profile drawings can be generated.

3-3. UTILITY INVESTIGATION. All existing, concurrently constructed and new utilities will be identified if within 25 feet of the proposed distribution system routing. If the proposed routing crosses any utilities, burial depths will be determined. Utility locations and depths can be verified through base personnel familiar with utilities, base/post utility maps and by site visits. The designer is responsible for these site visits to verify locations of utility interferences and to coordinate all other construction items with the user. In the event utility information is not available, utility location consultants may be procured who specialize in the location, identification and depth determination of utilities. If interferences exist, details will be provided in the design to relocate utilities or modify system routing to avoid the interference.

3-4. SYSTEM LAYOUT PLAN/PROFILE. All distribution systems require a layout plan and profile be provided by the designer.

a. Layout plans will include, but not be limited to:

(1) system routing (including expansion loops and bends, manhole locations and anchor locations).

(2) stationing numbering for the system (one dimensional coordinates from the point of origin of the distribution system).

(3) all utilities within 25 feet of the system.

(4) all roads and buildings clearly labeled.

(5) types of surface conditions (asphalt, concrete, seeding, gravel, etc.).

(6) grade contour lines (new and existing).

(7) all dimensions and clearances to ensure accurate routing.

b. A profile of the system will also be drawn and, as a minimum, show:

(1) all system stationing numbering.

(2) system slope drawn to scale (1-inch to 20 feet minimum for all systems) to all low points.

(3) new and existing grade.

(4) all existing or new utilities shown at their actual burial depths.

3-5. EXPANSION COMPENSATION. All expansion systems, loops, and bends, will be sized in order to prevent excessive pipe stresses (due mainly from thermal expansion) from exceeding those allowed by the Power Piping Code, ASME B31.1. Mechanical expansion joints are not recommended for absorbing system expansion. Mechanical expansion joints greatly increase the maintenance requirements of the distribution systems. In the unlikely event that expansion joints must be used, they must be placed in an adequately sized valve manhole. The designer is responsible for expansion calculations for Heat Distribution Systems in Concrete Trenches, Prefabricated Underground Heating/Cooling Distribution Systems, and Aboveground Heat Distribution Systems. The designer is also responsible for the expansion and stress determinations in all the valve manholes, including the location of the equipment/pipe support locations. Even though the manufacturer is responsible for the expansion calculations for Pre-Engineered Underground Heat Distribution Systems, the calculations will be thoroughly reviewed by the designer at the shop drawing review. It is recommended that a three dimensional finite element computer program be used for determining system stresses. Many finite element software packages are available which operate on desktop computers. The temperature differential used in the stress analysis will be the maximum temperature of the media less the minimum temperature the system will encounter during a shutdown. All loops and bends will be sized based on zero percent cold springing. Cold springing effects lessen over time and are difficult to maintain in the event the system is ever cut, and shall therefore not be included in the analysis. However, loops may be installed with cold springing as an added conservative measure.

3-6. VALVE MANHOLES. For all distribution systems, valve manholes will be designed by the project designer. A valve manhole is required for all buried system lateral connections, all below to above ground system transitions, all drain points (low points), all below ground valving, all trap stations, high points for vents of buried systems, and to minimize depth of buried systems. Distance between valve manholes varies with different applications. However, spacing shall never exceed 500 feet with Pre-Engineered Underground Heat Distribution Systems or Prefabricated Underground Heating/Cooling Distribution Systems to minimize excavation when searching for failures and to minimize effects of a failure. To enhance maintainability, avoid valve manholes deeper than 6 feet.

a. Manhole internals. Layout of each manhole will be designed on a case by case basis.

(1) Equipment/valve locations. It is important to first layout, to scale, all manhole piping, insulation, valving (with stems upright 90 degrees or less from vertical), and equipment and then locate the manhole walls around these appurtenances to ensure adequate manhole size and room for maintenance personnel. One line diagrams of piping and equipment are unacceptable. See figure 3-1 for a typical manhole plan. Note that all valve manhole layouts have certain designer requirements in common. The designer will:

(a) Provide main line isolation valves in valve manholes to most efficiently minimize outages to buildings served by the distribution system. When installed, main line isolation valves will be located downstream of the building's service laterals.

(b) Provide lateral isolation valves within the valve manholes for all laterals runs.

(c) Locate all carrier pipe vents and drains needed within the manhole for proper system drainage of the main and lateral lines.

(d) Layout all valve manhole internals (valves and valve stems, pipe w/insulation, access ladders, isolation flanges, and equipment) to scale to ensure adequate clearance has been provided for operation and maintenance within the manhole.

(e) Ensure no non-metallic piping is routed in the manholes (i.e., as allowed with chilled water or condensate return systems) which also serves high temperature mediums that could damage the non-metallic piping. Damage to non-metallic piping is caused when manholes flood and the hot piping boils the flood water. Boiling water can exceed the temperature allowables of many nonmetallic piping materials. Because of this, the designer must transition to steel piping at the manholes (see figure 8-4).

(2) Clearances. Design will provide for clearance around piping and equipment in the manhole in accordance with table 3-1.

(3) Access Ladders. Access ladders will be required on all valve manholes greater than 3 feet in depth. Ladders will be welded steel and will consist of uprights and nonslip steps or rungs. Uprights will be not less than 16 inches apart and steps or rungs will be spaced no greater than 12 inches apart. Ladders will extend not less than 6 inches from the manhole wall and will be firmly anchored to the wall by steel inserts spaced not more than three 3 feet apart vertically. All parts of the ladders will be hot-dipped galvanized after fabrication in conformance with ASTM A 123. The top rung of the ladders shall be not more than 6 inches from the top of the manhole. A typical valve manhole access ladder detail is shown in figure 3-2.

(4) Insulation. Insulation for valves, fittings, field casing closures, and other piping system accessories in valve manholes will be of the same types and thicknesses as those provided in the distribution systems' guide specification. All insulation will be premolded, precut, or job fabricated to fit and will be removable and reusable. Insulation jackets will be provided for all pipe insulation in manholes and will comply with the requirements of the particular distribution system guide specification.

(5) Isolation flanges. Isolation flanges will be provided when connecting to an existing cathodically protected heating or cooling distribution system or to prevent a new system's cathodic protection system from contacting an existing system. The isolation flanges will be installed in the valve manhole and a typical flange detail is shown in figure 3-3.

(6) Valve/piping supports. Piping in valve manholes often will need supports within the manhole especially when larger valves or equipment are attached to the piping. These supports will be located on the manhole plans as determined by the designer's expansion compensation calculations for each manhole valving and equipment layout. Typical valve/piping support details are shown in figure 3-4.

b. Valve manhole construction. Valve manholes will be field constructed of reinforced concrete conforming to the current criteria. Valve manholes will be constructed of 4,000 psi minimum compressive strength concrete. Reinforcing bars will conform to ASTM A 615, grade 60. Typical reinforcing steel details and sizing are shown in figure 3-5 and table 3-2 respectively. Concrete floor slabs and walls will be of sufficient weight to prevent flotation in high water table areas. Floor slabs will be sloped to the drain which will be installed in the floor slab. Concrete wall sections will be not less than 8 inches thick and must meet anticipated load and soil conditions. Side walls will be constructed in a monolithic pour. Water stops will be provided at all construction joints. Do not locate valve manholes in roads or parking areas which create an inadequate amount of manhole ventilation and poor access.

c. Valve manhole covers. The valve manhole cover types discussed here are: raised solid plate, supported cover, and concrete.

(1) Raised solid plate covers. Raised solid plate covers are preferred for HTHW and steam/condensate systems installed in Pre-Engineered Underground Heat Distribution Systems. For shallow concrete trench systems, the raised solid plate cover's raised feature will interfere with the trench's walkway function. When the valve manhole cover must remain flush with the trench top, the supported cover is the preferred type. For the raised solid plate cover, ventilation openings are provided around the entire perimeter below the raised top. The height of the valve manhole wall above grade (6 inches, minimum) shall be sufficient to prevent surface water entry. The solid plate cover assembly is removable. The cover, constructed of aluminum, also provides sectionalized access for inspection and maintenance. The solid plate cover raised frame design and section, lifting lug, and handle details are shown in figure 3-6 through 3-12. Figure 3-13 contains notes for raised solid plate cover figures.

(2) Supported covers. Supported covers may be used for any distribution system covered in this manual. For Pre-engineered Underground or Prefabricated Underground Heat Distribution Systems, design the cover to be at least 6 inches above the surrounding grade. When used for concrete shallow trench systems, the finished top will be flush with the concrete trench top. Required grates or other structural members used for supporting covers to be made of corrosion resistant material such as aluminum or galvanized steel. Details for the supporting cover are shown in figures 3-14 through 3-18. These details are designed for loadings up to 150 psf and must be re-evaluated for larger loadings. Other structural solutions for supporting the checkered plate are acceptable. The checkered plate cover (also referred to as diamond or embossed plate) as shown in figure 3-18, will be installed over grating or other structural supports in most locations to minimize the influx of leaves and other debris. The checkered plate is attached to the grating and is removable.

(3) Concrete covers. The use of concrete covers is discouraged, but, if used, they must be used with 4 x 4 ft. aluminum doors for any distribution system covered in this manual. Concrete covers should only be used if desired by the user or if specific design conditions exist, such as below to aboveground system transitions. When used for Pre-engineered Underground or Prefabricated Underground Heat Distribution Systems, design the top of the concrete cover to be a minimum of 6 inches above the surrounding grade. When used for concrete shallow trenches, design the cover to be flush with the trench top. Concrete requirements for this cover are similar to those required for valve manhole construction. Concrete cover will be designed to support anticipated loadings. Figure 3-19 shows a typical concrete cover plan and figure 3-20

provides construction details for this cover. The concrete cover detailed is designed for loadings up to 150 psf. For greater loadings, the design must be re-evaluated. A disadvantage of concrete covers is the difficulty in providing ventilation. For concrete shallow trench systems, a single 6 inch gooseneck pipe will be used, as detailed in figure 3-21, to allow steam to exit the valve manhole if a leak or excessive heat loss is present. Note that for shallow trench systems, the gooseneck will be installed off to one side of the valve manhole concrete top to minimize pedestrian traffic interference. For Pre-engineered Underground Heat Distribution Systems, two 6 inch goosenecks will be used. One will extend below the top as detailed in figure 3-21. The other will be similar but will extend to within 8 inches of the valve manhole floor on the opposite side of the manhole.

d. Valve manhole drainage. Drainage of water from the valve manhole is mandatory for the successful operation and longevity of buried heating or cooling distribution systems. There are three types of valve manhole drainage systems described in this manual: gravity drainage, pumped drainage from a sump basin, and pumped drainage from the valve manhole.

(1) Gravity drainage. The most cost effective and lowest maintenance system is gravity drainage to a storm drain when location, depth of existing storm drains, and local regulatory requirements allow this possibility. Drainage lines will be 6 inches in diameter minimum and will conform to the latest storm drain criteria and will be sloped at one percent, minimum. Valve manhole outlet will be a floor drain with backflow preventer to prevent storm water inflow from the storm drain (see figure 3-22). Note that valve manhole drain outlets shall be covered with a "hat type" cast iron pipe screen to minimize the accumulation of trash over the drain inlet. Also, the manhole floor will be sloped toward the drain.

(2) Pumped drainage from sump basin. For pumped drainage, a duplex submersible pump system installed in a remote sump basin may be provided as indicated in figures 3-23 and 3-24. The sump basin will be located no more than 10 feet from the valve manhole. Drainage from the valve manhole to the sump basin will be similar to drainage to a storm drain including the valve manhole floor drain (fig 3-22). Discharge from the pumps can be routed to a splashblock at grade or to an adjacent storm sewer. Design of the surrounding grade must ensure drainage away from the sump basin, valve manhole and concrete shallow trench (if used) when discharging to grade. A power pedestal complete with failure warning light will be provided with each basin as shown in figure 3-25. A typical wiring diagram and sequence of operation are shown in figure 3-26. A specification for the sump basin system can be included in the applicable manhole or heat distribution section of the contract specification. The sump basin design has proven to operate well even in the colder climates of the upper tier states in the continental United States. It is also an excellent method to retrofit existing manholes that currently do not drain properly. The remote sump basin increases the life of the systems by removing the sump pump and pump controls from the hot, humid environment of the manhole. Also, pump maintenance will be done outside of the manhole. The pumps are easily disconnected and lifted to grade. The sump pumps used in the sump basin must incorporate the design characteristics listed in table 3-3.

(3) Pumped drainage from valve manhole. Another means to pump water from the manhole is to locate the duplex sump pumps in the valve manhole. Typically, a 2'0" by 2'0" by 1'0" (deep) sump will be provided in a corner of the valve manhole. The duplex sump pumps will be installed to pump out of this sump. Valve manhole sump pump electrical arrangement should be installed as shown in figure 3-27. The control panel with high level warning light will be mounted adjacent to the valve manhole at grade. This keeps the electrical panel out of the hot, humid environment of the manhole. The sequence of operation and wiring diagrams will meet the requirements of figure 3-26. Pump discharge can be routed to a splashblock at grade (similar to the sump basin discharge piping arrangement on figure 3-23) or to an adjacent storm drain. Electric sump pumps used in the valve manholes must incorporate the design characteristics listed in table 3-3. Note that life of the pumps are typically shortened when installed in the hot and humid valve manhole environment.

e. General.

(1) Valve manhole wall penetrations. A design must be provided for the distribution system wall

penetrations. For a shallow trench system, the wall penetrations will typically be the same size as the inside dimension of the shallow trench connecting to the valve manhole. For shallow trench dimensions, refer to chapter 4 of this manual. Structural reinforcement must be designed around this opening. Drainage from the trench will then flow into the manhole. For Pre-engineered or Prefabricated Underground Heat Distribution Systems, sleeved openings will typically be provided with an expandable seal between the casing and the pipe sleeve as indicated on figure 3-28. Structural reinforcement must be designed to avoid contact with the pipe sleeve and water stop to prevent grounding of the system's cathodic protection.

(2) Waterproofing. Waterproof membranes will be placed in or below the concrete bottom slab and continued up the outer sides to the top of the sidewalls in accordance with the valve manhole guide specification.

(3) Pipe anchoring adjacent to valve manholes. Regardless of the buried distribution system, pipe anchors should be provided between 2 to 5 feet of a manhole wall to minimize movement through the manhole. For piping which passes through valve manholes, anchoring on one side only is typically adequate. Anchoring piping on more than one side may restrict piping movement and overstress the piping in the valve manhole. Anchors will typically be provided as part of the distribution system and will not be embedded in the manhole wall. However, if the manhole is used to support an anchor, the manhole must be designed to withstand the forces exerted by the system. Expansion compensation stress calculation will always be conducted to ensure proper anchor locations throughout the distribution system. These calculations must also account for the expansion in the valve manholes.

(4) Piping materials in valve manholes. Nonmetallic piping must not be used in the same valve manholes as piping carrying higher temperature media that could cause the temperature around the non-metallic piping to exceed the allowables and potentially cause permanent damage to the non-metallic piping. In addition, chilled water systems with PVC carrier piping must never be installed in the same valve manhole with any heating system.

CHAPTER 4

HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES

4-1. GENERAL. The concrete shallow trench (CST) is a system, which allows insulated carrier pipes to be routed underground but yet not have the piping in contact with the soil. The system also provides comparatively easy access for maintenance and repair by means of removable concrete tops. These exposed tops can be used as sidewalks since the system is installed at grade.

4-2. SYSTEM DESIGN. The designer is responsible for conducting a site investigation, designing the distribution system plan and profiles, and designing the valve manholes, as described in chapter 3 of this manual. In addition, the designer will use details and descriptions presented here to design a concrete shallow trench system at a particular site.

a. Trench Systems - General.

(1) Piping and fittings. All carrier piping and pipe fittings will be carbon steel and will be designed to satisfy the temperature and pressure requirements of the system. Materials will conform to the requirements in the guide specification.

(2) Pipe supports. Pipe supports will typically consist of three types: free, guided, and anchor. These supports are detailed in figure 4-1, figure 4-2, and figure 4-3. All of these pipe supports will be mounted on channel supports mounted to the trench walls as detailed in figure 4-4. Supports may be mounted by other means, such as on concrete pedestals, provided that paths for water flow are maintained. Table 4-1 provides guidance for the sizing of the channel supports. Note that the channels for anchor supports in the table are designed for more substantial loads than required for free and guided supports. The anchor support channel in this table is adequate for approximately 1,000 pounds force axially. The designer will determine axial force requirements at all anchor points and design the channels to accommodate these forces. **\1** Maximum distance between support channels shall be as listed in table 4-2. **/1/** These spacings are applicable to long, straight runs of piping only and must be reduced at elbows, vertical risers, valving, and equipment. The actual spacings, in these instances, will be determined by analyzing the pipe stresses with the pipe stress analysis, as described in chapter 3 of this manual. The designer should note that there are other types of supports (such as roller type) that may also be used. However, all supports must be capable of withstanding the thermal stresses and forces exerted on them.

(3) Clearances. Clearances in the trench will be adequate to provide room for expansion, air movement, and a sufficient amount of access for cleaning and maintenance. There must also be a minimum of 4 inches clearance under the support channels to ensure ground water drainage along the trench floor. Figure 4-5 provides a trench cross-section, which corresponds to the table 4-3 trench dimension schedule, which must be filled in by the designer.

(4) Insulation and jacketing. Insulation will be selected in accordance with insulation thickness tables in the guide specification. These insulation thicknesses were developed using a life cycle cost analysis. All insulations used have passed the Federal Agency Committee's boiling test and are listed in the guide specifications. All insulation in the trench will be covered with jacketing material in conformance to the guide specification.

b. Trench System - Structural. The concrete trench will be field constructed of reinforced concrete conforming to the current criteria. Trench walls and floors will be poured in place-they will not be precast. Trench tops will be poured in place or precast. Walls, floors, and tops will be constructed with 4,000 psi minimum compressive strength concrete. Reinforcing bars will conform to ASTM A 615, grade 60. Wall, floor, and top thicknesses shall be 6 inches, minimum. However, thicker sections may be required to accommodate site specific loadings or to prevent flotation. Concrete trench floors shall be sloped at a 1 inch in 20 feet slope toward all low points to ensure proper drainage. Doweled or keyed joints and water stops shall be provided at all construction joints and shall be detailed as shown in figure 4-6. Trench reinforcing details will be provided and will be similar to the section shown in figure 4-7. Note that actual concrete thicknesses and reinforcing bar sizes will be verified by the designer for each project. Trench corners will be constructed as detailed in figure 4-8. Trench tops will be no longer than eight feet to allow easy removal and placement.

c. Trench Top Removal Devices. The most common type of removal devices for the trench tops will be the sling type as detailed in figure 4-9. Four lifting devices are required to lift a trench top. One set of lifting devices will accommodate all trench tops for each contract. In some instances, sling type lifting devices will not be convenient to use (eg. when the trench top butts up against a parallel sidewalk or when the trench is routed through a parking area). In these instances, the designer shall require coil inserts to be cast into the trench cover in four locations that will accommodate threaded lifting eye bolts. When not being used, threaded plugs are inserted into the coil inserts. The lifting devices are also detailed in figure 4-9.

d. Road and Parking Lot Crossings. Road crossing requirements will be designed on a case by case basis and must take into account pavement materials, soils, and frost characteristics of the design site. A typical road crossing is shown in figure 4-10. Figure 4-11 details a concrete trench to curb and gutter system transition and figure 4-12 details a concrete trench to drain pan system transition. In all instances, the crown of the road crossing will be matched and the thickness of the trench top will be designed to accommodate worst case loadings. Parking lot crossings typically will have the trench top exposed at grade as shown in figure 4-13. Exposed tops allow for easier trench top removal over extended lengths of paved areas. If appearance of the crossing is critical, black pigments may be added to the concrete tops at the road crossing to match the surrounding pavement. In rare instances, the trench tops may be covered with asphalt surfacing, as detailed in figure 4-14.

e. Sidewalk Intersections. In the event the trench system intersects an existing sidewalk, the trench system will match the sidewalk as detailed in figure 4-15.

f. Expansion Compensation. Expansion loop and bend design is the responsibility of the designer, and is covered in chapter 3 of this manual. The expansion loop design is critical. Sufficient space needs to be provided in the expansion loop area to ensure that no pipe or insulation interference will occur due to pipe movement as shown in figure 4-16. This detail indicates location of supports and also shows how the piping system will be offset to allow for expansion movement in the trench. Table 4-4 is a typical loop schedule, which corresponds to figure 4-16. The locations of the supports in the expansion loops will be determined from the designer's piping stress analysis and then entered in Table 4-4. All piping stresses will be less than ASME B31.1 allowables for each application. The designer will require inspection ports be provided in the trench tops at each bend in the trench system routing for the purpose of observing pipe movement at the bends during system startup. The inspection port is similar to the access cover detailed in figure 4-18, except the nominal diameter of the lid will be 12 inches.

g. Sealants. The trench will be sealed to minimize the influx of ground water. A 1/4 inch thick neoprene pad will be used between trench tops and tops of trench walls. The pad will have a minimum width of 2 inches. All trench joints must be sealed with elastomeric sealants, which are available as a one or two component system. Asphaltic sealants have not performed as reliably for this application. The elastomeric sealant should be able to resist 50 percent total joint movement. The nonsagging type must be used for vertical joints. The self-leveling type must be used for trench top butt joints as shown in figure 4-17. Other horizontal joints may be sealed with either type of elastomeric sealant, but the sealant used in trench bottoms must finish flush with the floor.

h. Vents and drains. Piping vents and drains will be located at all high and low points, respectively **\1** (see figure 4-19) **/1/**. Piping drains will be provided in valve manholes only where access can be achieved and where system drainage is provided. Piping vents may be located anywhere in the trench piping system with an access cover provided in the trench top, as detailed in figure 4-18 or with an aluminum access door shown in figure 3-19.

4-3. GENERAL CONSIDERATIONS. The designer will address these key areas to ensure a satisfactory shallow trench design.

a. The grading design will ensure ground water will not pond or sit over the trench. The trench will not be routed through existing flood plains, swales, or in areas where seasonal water accumulates. Another distribution system, preferably an Aboveground Heat Distribution System (chap 7), should be used in these areas. In areas where seasonal ground water will cause a trench flotation problem, the design will include a subdrainage system along the trench if thickening of system walls and floor slabs to offset the buoyancy effect is not practical.

b. The trench floors will slope a minimum of 1 inch in 20 feet toward valve manholes and the piping will parallel the trench floor. This will allow the trench to drain off all water that may enter. Drainage will then be provided from the valve manholes as described in chapter 3 of this manual.

c. Valve manholes should be spaced to minimize the depth of the trench system. Additional manholes may be less expensive than excessive trench depths to accommodate the slope while still keeping the trench tops at grade.

Table 4-1. Channel Support Schedule *

LOCATION	PLATE	ANCHOR STUDS	ANGLE	CHANNEL	BOLTS
Free and Guided Supports	1/2" x 10" x 10"	4-1/2" x 4"	2" x 2" x 1/4" x 6" long	MC 6" x 15.3"	1/2"
Anchor Supports	3/4" x 10" x 10"	6-5/8" x 4"	2" x 2" x 1/4" x 6" long	MC 8" x 22.4"	3/4"

* Schedule for channel detailed in Figure 4-4.

NOTE TO THE DESIGNER:
Channels exceeding loadings indicated in manual shall be designed for vertical and axial loadings encountered.

Table 4-2. Support spacing schedule

\1\ MAXIMUM HORIZONTAL PIPE SUPPORT SPACING FOR STEEL /1/ DISTRIBUTION PIPING	
PIPE SIZE (INCHES)	SPACING (FEET)
1	7
1-1/4	7
1-1/2	9
2	10
2-1/2	11
3	12
2-1/2	13
4	14
5	16
6	17
8	19
10	22
12	23
14	25
16	27
18	28
20	30
24	32
30	33

NOTES TO THE DESIGNER: These spacings are maximum for horizontal, straight runs. More closely spaced supports must be provided for bends and risers and at equipment.

Table 4-3. Trench dimension schedule.

TRENCH DIMENSION SCHEDULE											
STANDARD TRENCH INTEM NO.	[PIPE SIZES (INCHES)	A	B_1	B_2	C*	D_1	D_2	E*	F MIN.	H_W MIN.	W
					6”		6”				
					6”		6”				
					6”		6”				
					6”		6”				

NOTES TO THE DESIGNER:

1. CLEARANCES BASED ON THE THICKEST INSULATION, IF LESS INSULATION (LOWER “k”) IS PROVIDED. DIMENSIONS C, D, E AND F WILL BE DIFFERENT THAN SCHEDULED. HOWEVER, OVERALL TRENCH DIMENSIONS SHSALL REMAIN THE SAME. C* & E* DIMENSIONS MUST BE MAINTAINED THROUGHOUT ALL STRAIGHT SECTIONS OF TRENCH TO ALLOW PROPER CLEARANCES FOR EXPANSION.

2. SCHEDULE DESIGNATIONS ARE ASSOCIATED WITH TRENCH DIMENSION SECTION, FIGURE 4-5.

Table 4-4. Expansion Loop Schedule*

Loop Name	Line Sizes	X	Y	YY	Z	ZZ	W	H	U	REMARKS

*See Expansion Loop Detail for Designations (Figure 4-16).

NOTE TO THE DESIGNER:
If only one support is required along parallel leg of loop, ZZ =0. If only one support is required along perpendicular legs of loop, YY = 0.

CHAPTER 5

PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM

5-1. GENERAL. Unlike Heat Distribution Systems in Concrete Trenches, which are totally designed by the designer, Pre-engineered Underground Heat Distribution Systems are designed by the system manufacturer. These pre-engineered systems are factory fabricated in lengths, which are transported to the site for field assembly. Other types of systems and materials are continuously being evaluated and will be included in guide specifications and this manual when deemed acceptable. There are two types of these systems. The DDT type is allowed for severe, bad and moderate site conditions. In severe sites allow only drainable-dryable-testable type systems. In bad and moderate sites allow DDT and water spread limiting systems. These **\1** site **/1/** conditions (or classifications) are described in detail in the guide specifications. Although the manufacturer is responsible for the pre-engineered system design, the project designer also has design responsibilities which include establishing the site, soil, and groundwater conditions, pipe sizes, proposed routing (including construction limits) estimated length, elevations, profiles of the system along with existing and finished earth surfaces and obstructions **\1** within **/1/** 8m (25 feet) of the system centerline including adjacent or crossing utilities. The project designer also provides information on location and design of manholes and entrances to buildings and manholes.

5-2. MANUFACTURER'S RESPONSIBILITY.

a. Pre-engineered Underground Heat Distribution System design. The manufacturer is responsible for the Pre-engineered Underground Heat Distribution System. This responsibility includes any or all of the following: insulation types, guided and anchor supports, end seals, casing and piping joint closure, casing type and thickness, and carrier pipe depending on the type of Pre-engineered Underground Heat Distribution System provided. There are two types of Pre-Engineered Underground Heat Distribution Systems. The drainable-dryable-testable system is a factory fabricated system, which includes a water-tight outer protective casing of steel, an air space, and an insulated carrier steel pipe. Casing drains and vents are provided in end plates, which are installed in valve manholes. DDT systems can be used for any heating medium including HTHW, high and low pressure steam, and condensate return and in any site condition (severe, bad or moderate). The water spread limiting systems is also a factory fabricated system, which includes an outer protective casing and an insulated carrier pipe. The system is fabricated in sections, which are independent from each other. Ground water or condensate, which leaks from or into one section, cannot travel into the next section. Field-assembly of the sections requires no welding; the sections are pushed together and are sealed with a system of couplings and seals. WSL systems can be used only in bad and moderate site conditions. The designer must determine the site conditions before a system type is selected. The site conditions will be considered severe, bad or moderate based on the site investigation results. For DDT and WSL systems, steam and condensate lines must always be installed in separate casings, as shown for a DDT system in figure 5-1, due to the corrosion problems associated with condensate return systems. Water systems may use just one casing for both supply and return pipes as detailed for a DDT system in figure 5-2, although installing the pipes in separate casings is preferred by most users because it is less difficult to isolate leaks. The tops of the casings will typically be buried between 2 and 6 feet below grade. However, note that excessive burial depths increase the installation and repair costs and should be avoided where possible.

b. Expansion compensation. The manufacturer is responsible for the system expansion compensation. A detailed stress analysis will be submitted for review as part of the contract requirements. The manufacturer will normally make use of expansion loops and bends to absorb system expansion in DDT systems. For WSL systems, field joints may be used to accommodate expansion. Except in rare instances, expansion joints will not be permitted.

c. Pre-engineered system's representative. The manufacturer is required to ensure that a qualified direct employee of the system manufacturer is present to guarantee proper installation when the following types of work are performed:

(1) inspection, unloading and storage of materials.

(2) inspection of trench prior to laying of casing.

(3) inspection of concrete thrust blocks.

(4) hydrostatic test of all service lines.

(5) field joint closure work.

(6) air test of casing.

(7) coating patch work.

(8) holiday test of casing coating.

(9) initial backfill up to 10 inches above the top of the casing.

(10) radiographic weld examination.

(11) startup and operation tests.

5-3. PROJECT DESIGNER'S RESPONSIBILITY.

a. Site information. As with all buried distribution systems, the site investigation is the responsibility of the designer. As described in chapter 3 of this manual, the designer will obtain soil borings, be responsible for designing the grading in the area, investigate all utilities for possible conflicts, and design for utility relocation as necessary. The designer must then determine the site conditions (severe, bad, or moderate) before a system type (DDT or WSL) is selected. The designer will then provide plans and profiles of the Pre-engineered system routing. The designer will show approximate slope of the system (1 inch in 20 feet is required to ensure drainage). This slope must be maintained in the entire system including through each leg of each expansion loop to ensure proper system drainage.

b. Valve manholes. The designer will design all valve manholes for the system as described in chapter 3 of this manual. The manholes will be no further apart than 500 feet to minimize excavation if a leak in the system must be found. The manholes will also be provided at all high (vent) points and low (drain) points in the system. The valve manholes will include ground water drainage capabilities as explained in chapter 3. Casing vents and drains will be included for maintenance of the casing air space in DDT systems as shown in figure 5-3.

c. Insulation. The insulation types used on the Pre-engineered Underground system will only be those that are listed in the guide specification. The insulation thickness tables in the guide specification will be used in determining required insulation thickness. These insulation thicknesses were developed using life cycle cost analyses.

d. Cathodic protection. The designer will be responsible for the cathodic protection design for all systems with coated steel casings. The designer shall also require that dielectric flanges be provided to isolate the system's cathodic protection system from non protected systems. These dielectric flanges shall always be installed inside valve manholes.

e. Review. The designer will provide a detailed review of the manufacturer's shop drawings to ensure the system meets the requirements of the contract. As a minimum, the following items are required in this review process:

(1) carrier pipe size and thickness.

(2) insulation thickness, type and K-value.

(3) casing material and thickness.

(4) casing coating material and thickness.

(5) verification of constant system slope to all low points (proposed elevations at all casing joints on submitted shop drawing layouts).

(6) cathodic protection design.

(7) manufacturer’s system stress analysis.

CHAPTER 6

PREFABRICATED UNDERGROUND HEATING/COOLING DISTRIBUTION SYSTEM

6-1. GENERAL. This system is similar to Pre-engineered Underground Heat Distribution System (chapter 5) because it is factory fabricated in lengths, which are transported to the site for field assembly. However, the system is not allowed for any high temperature water (greater than 200 deg. F) or steam/condensate systems. The project designer is also responsible for more of the overall design.

6-2. SYSTEM DESIGN.

a. Site information. As with all heat distribution systems, the site investigation is the responsibility of the designer. The designer will obtain soil borings, be responsible for designing all grading in the area, and investigate all utilities for possible conflicts with the system. The designer will provide detailed design plans and profiles of the distribution system routings. The design will ensure a minimum slope of 1 inch in 20 feet is maintained between valve manholes. The site information requirements are covered in detail in chapter 3 of this manual.

b. Valve manholes. The designer will design all valve manholes for the system as covered in chapter 3 of this manual. As with valve manholes for the Pre-engineered Underground Heat Distribution System, manhole spacing will not exceed 500 feet and all manholes will have drainage capabilities. Also, all valves, flanges, unions, and couplings shall be located within the manholes.

c. System Material Selections. Although this system is manufactured in sections in a factory, the designer will specify all materials.

(1) Piping. The piping materials allowed are steel, copper tubing, reinforced thermosetting resin plastic (RTRP), or polyvinyl chloride (PVC). RTRP piping can not be routed through valve manholes with heating systems that could damage the RTRP. PVC piping can not be routed in any valve manhole with any other heating system piping due to its comparatively low temperature tolerance.

(2) Casing. Allowed casing materials are PVC, polyethylene (PE), or RTRP. Because these casing materials are susceptible to damage from high temperatures, they must be installed a minimum of 15 feet from buried HTHW or steam systems to avoid plastic deformation and failures of the casing materials.

(3) Insulation. Insulation type for these systems is typically polyurethane foam. Open cell type insulations, such as fiberglass, mineral wool or calcium silicate, are unacceptable for use with chilled water systems due to the tendency of condensation forming in these insulations. Insulation thickness will be specified in the guide specification.

d. Expansion compensation. The designer will perform expansion compensation calculations as covered in chapter 3 of this manual. When required, based on these calculations, sizes and locations of all expansion loops and bends, and any other expansion-compensating device, will be clearly shown on the contract drawings. The designer shall provide expansion loop details.

CHAPTER 7

ABOVEGROUND HEAT DISTRIBUTION SYSTEMS

7-1. GENERAL. Aboveground distribution systems have the lowest first cost and lowest maintenance costs of any distribution system described in this manual and are completely designed by the project designer. This system is a good application for industrial areas and where water tables are high. Many installations, however, do not desire to have distribution piping above ground for aesthetic reasons.

7-2. SYSTEM DESIGN.

a. Site information. The designer will determine information on the site. The designer will design all grading for the area and investigate all utilities for conflicts. The designer will provide detailed plans and profiles of the above ground distribution system routing. Although this system is aboveground, profiles will indicate system drain and vent points and also potential interferences between the concrete support piers and any buried utilities.

b. Piping and fittings. All carrier piping and pipe fittings will be carbon steel and will be designed to satisfy the temperature and pressure requirements of the system. Materials will conform to the requirements of the guide specification.

c. Pipe supports. The two most common types of aboveground distribution systems are low profile and high profile.

(1) Low profile system. A typical low profile support is shown in figure 7-1. In this system, the distribution piping is mounted to concrete piers by means of pipe supports. Typically, the bottoms of the pipes are mounted no more than 4 feet above grade except at road crossings, which usually incorporate high profile supports. Typical anchor, free, and guided pipe supports mounted to the concrete piers are detailed in figure 7-2, figure 7-3, and figure 7-4. Spacing of supports in straight runs of piping will conform to the support spacing schedule in table 4-2. Provide extra supports, as necessary, at pipe bends and risers. Requirements for concrete piers and pipe supports are included in the guide specification.

(2) High profile systems. High profile systems are routed high enough to cross roads and avoid obstructions. Typically the piping will be installed 14 to 16 feet above grade. The system presented in this manual uses 6-inch concrete-filled pipes embedded in concrete footings as detailed in figure 7-5. The pipe guides are mounted on channels at the top of the support pipe as detailed in figure 7-6. The pipe anchors are also mounted to channels and then stabilized with guy cables as shown in figure 7-7. Structural design for the structural members on these high profile supports in figure 7-6 and 7-7 are for water filled, schedule 40 steel pipes up to 10-inch nominal size. Conditions outside these constraints must be designed on a case-by-case basis. The designer for each anchor application will also size the guy cables. Spacing of supports in straight runs of piping will conform to the support spacing schedule in table 4-2. Extra supports will be added, as necessary, at pipe bends and risers. Concrete footings and high profile supports will conform to the requirements of the guide specification.

c. Insulation and jacketing. All piping on aboveground systems shall be insulated and jacketed. Insulation thicknesses will be determined by insulation tables provided in the guide specification. These insulation thicknesses were developed using life cycle cost analyses. All insulation will be covered with a jacketing material in conformance with the guide specification.

e. Expansion Compensation. Expansion loops and bends will be designed as described in chapter 3 of this manual. Expansion loops will be located to minimize impacts to ground level interferences such as trees and sidewalks. For horizontal expansion loops, pipe supports will be spaced less than the maximums listed in table 4-2 because of the extra bends and associated movement in the loops. In low profile systems, vertical expansion loops may be used as road crossings. Details will be provided indicating support types and locations throughout the loops and bends.

f. Vents and Drains. Provide venting of all piping high points and draining of all low points to allow total drainage of the system. Vent and drain locations will be indicated on the profile drawings. Vents and drains are similar to those used for the concrete shallow trench system, figure 4-15.

g. Transition to Buried Systems. When a buried system transitions to an aboveground system a valve manhole will be provided at that point. A manhole top penetration will be provided to allow expansion of the distribution piping in the man-hole top yet keep rain and ground water out of the manhole. Figure 7-8 shows such a transition in a valve manhole with a concrete cover. The valve manhole used for this transition must be large enough to be accessible and will be designed in accordance with chapter 3 of this manual.

CHAPTER 8

SPECIAL CONSIDERATIONS

8-1. GENERAL. Although it is impractical to cover all special considerations, which arise in heating and cooling distribution designs, this chapter presents typical design problems and solutions associated with steam, high temperature hot water, low temperature hot water and chilled water systems.

8-2. STEAM SYSTEMS.

a. Trap Selection. Steam traps are used to separate the condensate and non-condensable gases from the steam. Many types of traps are used on drip legs for steam distribution systems. Those trap types include float and thermostatic (F&T), inverted bucket, thermostatic and thermodynamic (disc). However, for buried heat distribution drip leg applications, inverted bucket or thermostatic (bimetallic type) should be the trap types selected. For drip leg applications where freezing is a consideration, thermodynamic type (installed vertically) or bimetallic thermostatic type should be selected.

b. Trap Sizing and Location. Trap sizing is important for obtaining an efficient steam distribution system. Condensation in the steam line is caused by heat loss from the steam line. Trap life will be shortened, function affected and excessive energy will be wasted if traps are oversized to handle the higher initial startup condensate flows. Therefore, the traps should be sized for the condensate load seen during the distribution system normal operation. Because the traps are not sized for startup loadings, the bypass must be opened at startup to allow condensate to pass until the steam line has reached normal operating temperatures (see figure 8-1). The designer will calculate heat loss and condensate flow for that particular design using the methods presented in appendix D for determining condensate loads during normal operation. It is critical that the designer calculate trap capacity using the Appendix D method for each trap station in the design to ensure proper steam system operation. In addition to trap capacity, steam trap type, differential pressures, and inlet pressure must always be provided on the contract documents. Do not locate steam drip legs, with associated traps, more than 500 feet apart.

c. Drip Leg Sizing. Drip legs, installed vertically down from the steam pipe, are used to collect condensate. Design all steam lines to slope at 1 inch in 20 feet minimum toward these drip legs. It is preferable to slope the steam lines in the direction of steam flow whenever possible. The steam trap line and bypass line are connected to the drip leg as indicated in figure 8-1. The drip leg will be the same nominal pipe size as the main line (up to a 12-inch line) and will provide a storage capacity equal to 50% of the startup condensate load (no safety factor, one-half of an hour duration) for line sizes 4 inches in diameter and larger and 25% of the startup condensate load (no safety factor, one-half of an hour duration) for line sizes less than 4 inches. In no case will the drip leg be less than 18 inches in length or larger than 12 inches in diameter for all steam line sizes. The designer will calculate startup loads for drip leg sizing using the methods presented in appendix D.

d. Trap Station Layout. All trap stations will be piped as indicated in figure 8-1, as a minimum. Valve and strainer sizes will match the line sizes on which they are installed. Pipe lines to and from the steam trap will be sized based on calculated trap capacity but will be no less than 3/4-inch nominal size (line size "A" on figure 8-1). If reducing fittings are needed at the trap inlet and outlet, eccentric reducers must be used. The bypass line will be sized to accommodate warm-up condensate loads. For steam systems with an operating pressure of 150 psig or less and pipe sizes 12 inches or less, provide a ¾-inch bypass line. If the condensate return main is a low pressure or gravity flow type, the trap discharge line will be routed through an accumulator, as indicated in figure 8-2. The accumulator will lower the trap discharge temperature and minimize flashing when the condensate is introduced into sloped condensate lines which are routed to receiver/pump sets located in valve manholes. The pumps push the condensate back to the central plant in a separate pressurized condensate line. See figure 8-3 for a duplex condensate pump set connection detail.

This type of condensate return system is referred to as a "three pipe" or a "pumped return" system. If the steam pressure is sufficiently high, it may be used to force the condensate through the condensate return system to the central plant as shown in figure 8-1. No accumulator is required for this type system, which is referred to as a "two pipe" system. Sizing of the lines for both of these systems is presented later in this chapter.

e. Condensate Cooling System. Fiberglass reinforced plastic (FRP) piping is usually allowed for most condensate return systems. Since internal corrosion is a frequent problem in steel condensate lines, FRP eliminates this problem. However, the FRP materials cannot withstand as high of pressures or temperatures as steel and often fail when exposed to these conditions. A common temperature in an FRP distribution piping system where damage will occur is 250 deg. F. Condensate temperatures may exceed 250 deg. F. at the outlet of steam drip leg traps on steam systems that have pressures greater than 15 psig. In order to use FRP condensate lines in this case, a condensate cooling system will be employed, as detailed in figure 8-4. In this system, the high temperature condensate is discharged into a cooling tank where it blends with the system condensate. The blended condensate is then routed to the condensate main. Note that the detail shows the FRP (or non-metallic) pipe transitioning to steel inside the valve manhole to avoid burying the transition point. Also, note that nonmetallic piping will not be allowed in a manhole with high temperature hot water or high pressure steam systems due to the potential for this pipe being exposed to damaging temperatures within the manhole if the manhole floods or the carrier pipe on the heating system leaks.

f. Non-metallic Pipe Anchors in Valve Manholes. If anchoring of a non-metallic piping system is required at the valve manhole wall to comply with the distribution system stress analysis, a typical method is as detailed in figure 8-5. If the system is to be anchored at both of the valve manhole wall penetrations, provide adequate piping bends in the manhole to accommodate the expansion between the two anchors. Steel straps and bolts will be sized to accommodate the axial force of that particular piping layout. These sizes will be entered on the detail. Also, valve manhole sizes must be large enough to accommodate the anchors and still allow for maintenance access.

g. Pipe Sizing. Pipe sizing is critical to proper operation of both the steam and the condensate return systems.

(1) Steam. There are several methods to size steam lines. One of the quickest and most popular methods is using pressure drop versus flow rate charts, which provide steam velocities based on the required flow and pressure drops. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Fundamentals Handbook, Chapter "Pipe Sizing", is a good source for these steam sizing tables. Recommended velocities for various system pressure ranges are:

0 - 10 psig, saturated - 1,000 to 4,000 fpm
10 - 50 psig, saturated - 4,000 to 8,000 fpm
50 - 150 psig, saturated - 8,000 to 12,000 fpm

In addition, ensure the total pressure drop in the system will not be excessive. Steam pressure must be high enough at the end users to meet all special process requirements.

(2) Condensate. As described previously in this chapter, there are basically two types of condensate return systems used on central heating systems: the two pipe system (which uses steam pressure to force condensate back to the plant) and the three pipe, or pumped return, system. When sizing lines for these condensate return systems, table 8-1 will be used for guidance.

h. Steam System Material Selection.

(1) Valves. For high-pressure steam systems (125 psig or greater), valves will be 300-pound class and

will have welded ends. Steam and condensate valves at lower pressures will be 150-pound class with welded ends. Valves on trap stations, including the bypass valve, will be 150-pound class with threaded ends. Shutoff valves will be gate type.

(2) Fittings. All fittings in the steam distribution system, except as discussed for valves, will be welded except at equipment, traps, strainers, and items which require frequent removal. These items will be threaded or flanged.

(3) Piping. Steam and condensate piping will usually be carbon steel conforming to ASTM A 53, Grade B, Type E or S. Steam piping will be schedule 40. Condensate lines will be schedule 80 as will all welded piping less than 1-1/2 inches. Condensate lines in a pre-engineered underground heat distribution system may be FRP as discussed in chapter 5.

i. Field Joints. Radiographic examination of all carrier pipe field joints is required.

8-3. HTHW SYSTEMS.

a. Pipe Sizing. Sizing lines for HTHW systems is similar to any water system, except at high temperatures water becomes less dense and less viscous, and, therefore, the mass flow rate of the system must be calculated considering the lower density (usually temperatures are around 400 deg. F for HTHW).

$$m = q \times 60 \text{ min/hr} \times 0.1335 \text{ ft}^3\text{/gal} \times ?$$

where

q = system flow in gal/min

m = mass flow rate in lbm/hr

? = density of water at maximum system temperature in lbM/ft^3

Pressure drop versus flow charts may be used to determine line size, such as the chart included in appendix B. This chart takes into account the characteristics of higher temperature water systems. Recommended velocities for various HTHW flows are as follows:

Up to 10,000 lbm/hr	-	1 to 2 feet/sec
10,000 to 30,000 lbm/hr	-	2 to 3 feet/sec
30,000 to 200,000 lbm/hr	-	3 to 5 feet/sec
200,000 lbm/hr on up	-	(use velocity to accommodate 0.50 psi/100 ft., maximum)

b. HTHW System Material Selection

(1) Valves. All valves on HTHW systems will be 300-pound class with welded ends. Shutoff (isolation) valves will be gate type. Valve packings must be capable of handling the pressures and temperatures associated with HTHW systems.

(2) Fittings. All fittings on HTHW systems will be welded. The only exceptions will be specialty equipment such as dielectric flanges used to isolate the piping system from a cathodically protected system.

(3) Piping. HTHW piping will be carbon steel conforming to ASTM A53, Grade B, Type E or S. All piping will be schedule 40 except for welded pipe less than 1-1/2 inches, which will be schedule 80.

8-4. LTHW and CW systems.

a. Pipe Sizing. The most efficient method of determining pipe size for LTHW and CW systems is to use head loss vs. flow rate charts such as those found in ASHRAE Fundamentals, Chapter "Pipe Sizing". These tables are based on 60 deg. F water so for chilled water pipe sizing there is little error introduced using these charts. For LTHW systems, the use of the charts does introduce some error. However, the error is on the conservative side (the charts overstate the pressure drop of LTHW).

b. LTHW and CW Material Selection.

(1) Valves. Typically, valves on either LTHW or CW systems will be 150-pound class and will be located in the valve manholes. Ball valves provide a good means for line isolation. Although nonmetallic valves are sometimes allowed for these systems, metallic valves should be used for durability.

(2) Piping. The most common piping materials used for LTHW and CW systems are steel, copper tubing, reinforced thermosetting resin pipe (fiber- glass) and, for CW only, polyvinyl chloride and polyethylene. However, do not include nonmetallic piping in the same valve manholes with HTHW and steam systems. Chilled water lines using PVC piping must be installed in separate valve manholes since PVC can be thermally damaged at relatively low temperatures. Outside the valve manholes, a separation of 15 feet (minimum) must be maintained between pre-engineered underground HTHW and steam systems and PVC encased, prefabricated underground heating/cooling distribution systems to avoid thermal degradation of the PVC.

Table 8-1. Pipe sizing guidelines for condensate return systems.

TWO-PIPE SYSTEM SIZING GUIDELINES

- ?? DETERMINE CONDENSATE LINE PRESSURE (AS OBSERVED FROM ON-SITE PRESSURE GAGES).
- ?? DETERMINE CONDENSATE LOAD (lbm/hr) FROM CENTRAL PLANT LOGS AND OTHER INPUT.
- ?? ASSUME CONDENSATE AT TRAP DISCHARGE IS A COMBINATION OF CONDENSATE AND FLASH STEAM.
- ?? SIZE LINE TO ACCOMMODATE 5,000 ft/min STEAM AND CONDENSATE MIXTURE VELOCITY AND TO ENSURE MIXTURE PRESSURE IS HIGH ENOUGH TO OVERCOME LINE LOSSES.

THREE-PIPE SYSTEM SIZING GUIDELINES

GRAVITY LINE
- ?? SLOPE AT 1 inch/20 feet (MINIMUM) TOWARD RECEIVER.
- ?? TOTAL PRESSURE DROP LESS THAN 0.25 psi.
- ?? LINE SIZE WILL BE TWO (2) INCHES.

PUMPED LINE
- ?? SIZE PUMPS TO MOVE CONDENSATE TO THE CENTRAL PLANT AT THE REQUIRED HEAD AT 200 deg. F.

APPENDIX A

REFERENCES

Government Publications

Department of the Army
TM 5-802-1 Economic Studies for Military Construction Design-Applications
TM 5-809-1 Load Assumption for Buildings

Non-government Publications

American National Standards Institute (ANSI)
1430 Broadway, New York, NY 10018
H35.1 (1990) Alloy and Temper Design System for Aluminum

American Society for Testing and Materials (ASTM)
1916 Race Street, Philadelphia, PA 19103
A 36 (1991) Structural Steel
A 53 (1988a) Pipe, Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless
A 123 (1989a) Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A 615 (1990) Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

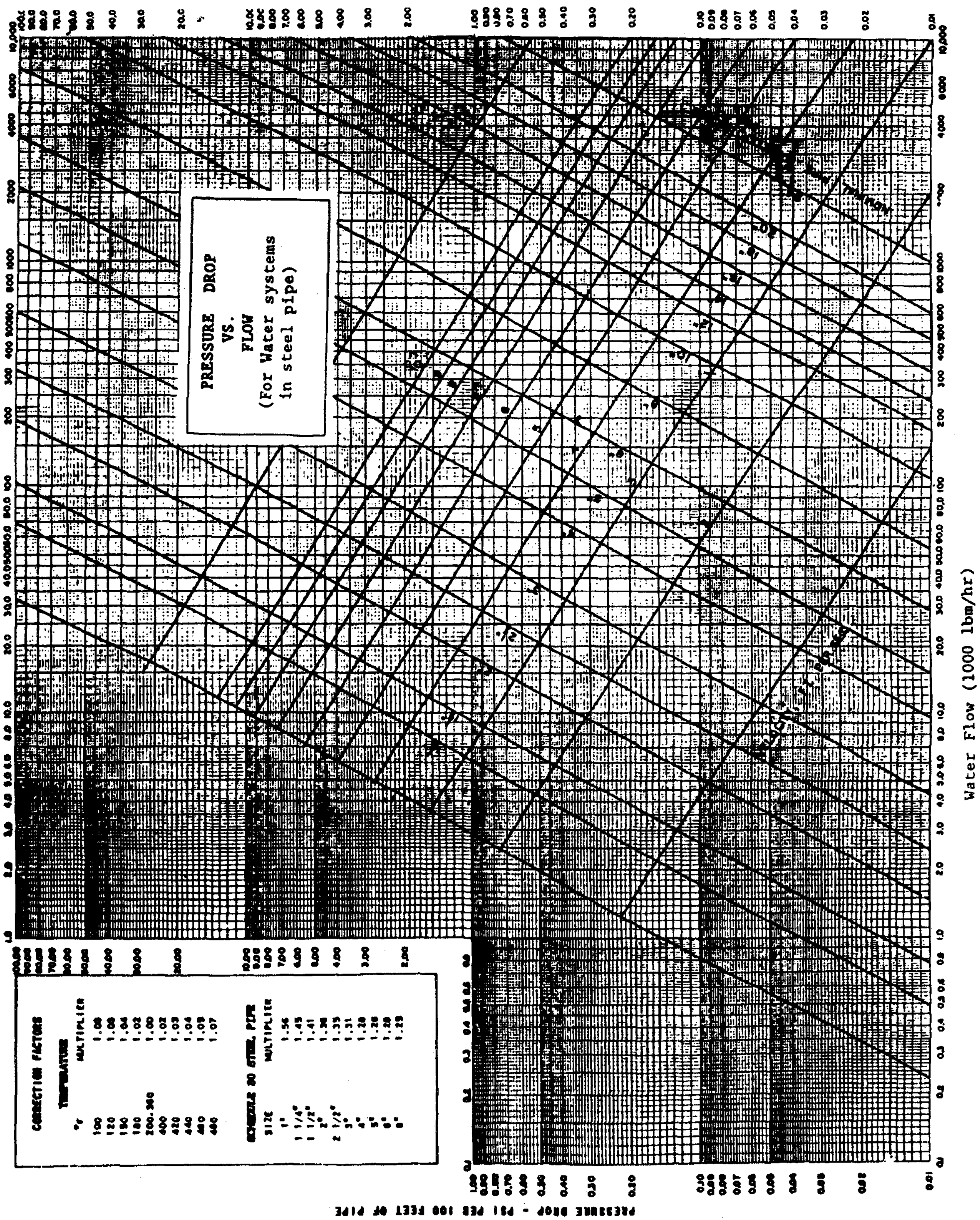
American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.,
1791 Tullie Circle, N.E., Atlanta, GA 30329
ASHRAE Handbook Fundamentals
ASHRAE Handbook HVAC Systems and Applications

American Society of Mechanical Engineers (ASME),
22 Law Drive, Box 2300, Fairfield, NJ 07007-2300
B31.1 (1989) Power Piping

Canadian Society of Civil Engineers,
Montreal, Quebec, Canada
(1986) Cold Climate Utilities Manual

APPENDIX B

PRESSURE DROP VERSUS FLOW CHART



APPENDIX C

CONDENSATION LOAD CALCULATIONS (NORMAL)

Step #1 Determine the heat loss per foot of line.

$$Q = 2? \ (T_{st} - T_{out})/(\ln(r_o/r_i)/k_p + \ln(r_{io}/r_o)/k_{in} + 1/3r_{io})$$

Assumptions. This equation models an insulated pipe surrounded by air. The convective resistance between the insulation and the outside of the pipe is assumed to be negligible. Also, the convective heat transfer coefficient outside of the insulation is assumed to be 3 BTU/hr-ft^2 deg. F.

Step #2 Determine the flow of condensate from the heat loss calculated in step #1.

$$m = Q/(h_{st} - h_{con})$$

Step #3 Multiply the flow rate per foot, calculated in step #2, by the total number of feet of steam line that slopes toward the trap in question. The result is the minimum flow capacity of the trap.

where:

- Q = heat loss per foot of pipe; Btu/hr-ft
- T_{st} = temperature of steam; deg. F
- T_{out} = temperature of ambient conditions; deg. F
- r_o = outside pipe radius; feet
- r_i = inside pipe radius; feet
- r_{io} = outside insulation radius; feet
- k_p = thermal conductivity of pipe; Btu/hr-ft- deg. F; (26 Btu/hr-ft-deg. F for steel)
- k_{in} = thermal conductivity of insulation; Btu/hr-ft- deg. F * (see table below)
- m = mass flow rate of condensate; lbm/hr-ft
- h_{st} = enthalpy of saturated steam; Btu/lbm
- h_{con} = enthalpy of condensate; Btu/lbm

\1\ *K-value (Btu/hr-ft-deg. F /1/

Insulation Type	400 deg. F	300 deg. F	200 deg. F
Mineral Fiber	0.034	0.029	0.024
Calcium Silicate	0.042	0.038	0.035

APPENDIX D

CONDENSATION LOAD CALCULATIONS (STARTUP)

Step #1 Determine the heat loss per foot of line.

The startup load can be calculated by determining the amount of heat that is required to heat the steam pipe from an ambient temperature to the saturation temperature of the steam the pipe is to carry. This is done by using the following equation:

$$Q = (v_p * c_p * ?_p \ (t_{st} - T_{out}))/t;\ \text{Btu/ft}$$

where:

$$v_p = ? \ (r_o^2 - r^2);\ \text{in ft}^3/\text{ft}$$

Step #2 Determine the pounds of condensate per foot from the heat loss calculated in step #1.

$$m = Q/(h_{st} - h_{con});\ \text{lbm/ft}$$

Step #3 Multiply the condensate per foot, calculated in step #2, by the total number of feet of steam line that slopes toward the drip leg in question. Then convert the total pounds of condensate to gallons assuming 200 F condensate:

$$\text{Total Condensate Volume (gallons)} = \frac{(m*L)*7.49\ \text{gallons/ft}^3}{60.1\ \text{lbm/ft}^3}$$

where:

Q = heat loss per foot of pipe; Btu/hr-ft
T_{st} = temperature of steam; deg. F
T_{out} = temperature of ambient conditions; deg. F
r_o = outside pipe radius; feet
r_i = inside pipe radius; feet
m = mass flow rate of condensate; lbm/hr-ft
h_{st} = enthalpy of saturated steam; Btu/lbm
h_{con} = enthalpy of condensate; Btu/lbm
c_p = specific heat of pipe (steel); (0.10 to 0.11) Btu/lbm/degrees F
$?_p$ = density of pipe (steel); (489) lbm/ft_3

t = length of time for startup; hrs (typically 0.5 hrs.)

L = total length of pipe draining to drip; ft
v_p = volume of pipe material per foot; ft^3/ft

US Army Corps
of Engineers®

TI 810-32
10 January 2002

Technical Instructions

HEATING AND COOLING DISTRIBUTION SYSTEMS

Headquarters
U.S. Army Corps of Engineers
Engineering Division
Directorate of Military Programs

TECHNICAL INSTRUCTIONS

HEATING AND COOLING DISTRIBUTION SYSTEMS

This document reissued 10 January 2002.

Record of Changes (changes indicated \1\…/1/)

No.	Date	Location
1	7 March 2002	Pages 4-1, 4-2, 5-1, and C-1 Table 4-2 Figures (editorial – changes not marked) 3-1 thru 3-28, 4-1, and 4-3
2	30 Sept 2002	Page 1-1 Figures (editorial – changes not marked) 3-14, 3-28, 4-4, 4-5, 4-17, and 7-7

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FOREWORD

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FOR THE COMMANDER:

DWIGHT A. BERANEK, P.E.
Chief, Engineering and Construction Division
Directorate of Military Programs

HEATING AND COOLING DISTRIBUTION SYSTEMS

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CHAPTER 1

GENERAL INFORMATION

1-1. PURPOSE AND SCOPE. This document provides criteria and guidance for the design and construction of heating and cooling distribution systems and supplements information in the "Notes to the Designer" of the guide specifications. These distribution systems include Heat Distribution Systems in Concrete Trenches, Pre-engineered Underground Heat Distribution Systems, Prefabricated Underground Heating/Cooling Distribution Systems, and Aboveground Heat Distribution Systems. The mediums used in these distribution systems, as defined by the Department of Defense (DoD), include:

a. High temperature hot water (HTHW) (251 deg. F to 450 deg. F)

b. Low temperature hot water (LTHW) (150 deg. F to 250 deg. F)

c. Low pressure steam systems (up to 15 psig)

d. High pressure steam systems (over 15 psig)

e. Condensate return systems (up to 200 deg. F)

f. Chilled water systems.

1-2. APPLICABILITY. These instructions are applicable to all **\2** DoD agencies **/2/** and their contractors involved in the design and construction of heating and cooling distribution systems.

1-3. REFERENCES. Appendix A contains a list of references used in these instructions.

1-4. EXCEPTIONS. Generally, this document covers heating and cooling distribution systems most typically installed on United States military installations. However, deviations from the recommendations of this manual may be necessary when unusual site conditions are present or specific using service requirements are encountered. For example, the manual does not discuss design problems associated with arctic and subarctic construction, in which case, the designer should refer to the "Cold Climate Utilities Manual", 1986, Canadian Society of Civil Engineers, Montreal, Quebec.

1-5. DEFINITIONS. The term "designer" used throughout this manual refers to the person or persons responsible for preparing contract drawings and specifications for a heating or cooling distribution design. The main engineering discipline areas of the "designer" are:

a. Mechanical. Includes expansion compensation, stress analysis, piping system design (fittings, valves, insulation), equipment selection and sizing, and pipe sizing and routing.

b. Structural. Includes reinforced concrete design, pipe supports, and valve manhole cover design.

c. Electrical. Includes cathodic protection, electrical service and controls (e.g. sump pumps).

d. Civil. Includes earth work, road crossings (for buried systems), system plans and profiles, and area drainage designs.

CHAPTER 2

SYSTEM SELECTION

2-1. GENERAL. When designing a heating or cooling distribution system, the designer must first select two critical items: media type and system type.

2-2. DISTRIBUTED MEDIA SELECTION.

a. Connecting to an existing system. Almost all heating and cooling distribution systems will be connected to an existing central distribution system. In this case, the designer most often designs for the media to which it is being connected-HTHW, LTHW, steam/condensate, or chilled water.

b. Installation of new system. When no existing system is present, the designer must select the system that is most appropriate for the end user. High temperature hot water and steam/condensate systems are the most common types of distribution systems currently used on military installations. However, a new system should only use the temperatures and pressures necessary to meet the requirements of the installation. For example, the use of high pressure steam sterilizers or steam kettles at several facilities may require the use of a high pressure steam or HTHW system. However, it is usually much more cost effective (on a first cost and life cycle cost basis) to use a low or medium temperature hot water distribution systems whenever possible and to incorporate stand alone high pressure/temperature systems where required. The lower maintenance costs, safer operation, longer life of systems, and simpler system controls for hot water systems often offset the costs of larger piping required. For further assistance for selecting the system type, refer to ASHRAE Handbook, "HVAC Systems and Equipment."

2-3. SYSTEM TYPES. When selecting a distribution system, the designer must determine which system types apply to a particular medium. The designer must also exclude systems which are not appropriate for a particular site or for which the customer has no interest. Examples of this are locating aboveground systems in non-industrial areas where the installation is sensitive to the aesthetic appearance of the area or routing concrete shallow trench systems through drainage swales or flood plains.

a. Heat Distribution Systems in Concrete Trenches (chapter 4). This system is a buried system with its removable concrete cover installed at grade and will typically be used for HTHW and steam/condensate systems. In rare instances, it may also be used for chilled water and LTHW in the event no plastic piping is installed in the same trench as high temperature (greater than 250 degrees F) piping systems. Experience has shown that if insulation of a high temperature system is compromised, temperatures can increase to such a level and cause damage to the plastic piping.

b. Pre-engineered Underground Heat Distribution Systems (chapter 5). This system is designed for higher pressure and temperature applications. The two types of pre-engineered systems are the drainable-dryable-testable (DDT) type which is used for high pressure steam/condensate and HTHW at all sites, and high temperature hot water at any type of site, and the water spread limiting (WSL) type which is used only for steam/condensate systems in bad and moderate sites. HTHW supply and return lines may be provided in a single casing; however, steam and condensate lines must always be provided in separate casings because condensate lines typically last less than half as long as the steam line and are easier to replace when in a separate casing.

c. Prefabricated Underground Heating/Cooling Distribution System (chapter 6). This system is designed for lower temperature and pressure applications. It is typically used for LTHW, chilled water, or combination LTHW/chilled water systems.

d. Aboveground Heat Distribution System (chapter 7). This system may be used for HTHW, steam/condensate, and LTHW systems, and for chilled water systems where freezing is not a concern.

2-4. SYSTEM SELECTION. The system type selected will be based on the type of media that is distributed.

a. High Temperature Water and Steam/condensate Systems. The order of preference for system types for high temperature and high pressure systems are:

(1) Aboveground Heat Distribution System. This is the least expensive system and historically requires the lowest maintenance and operating costs. However, the safety and aesthetics of an aboveground system are not always desirable and must be accepted by the end user.

(2) Heat Distribution Systems in Concrete Trenches. This is the most dependable of the buried distribution systems. The piping is totally accessible through removable concrete covers, the piping does not come in contact with the soil, and ground water is drained away from the piping system to low point drains. Except in rare instances, this is the system that should be selected if aboveground is not acceptable with the end user.

(3) Pre-engineered Underground Heat Distribution System. This type of buried distribution system should be selected as the last option due to very short system lives which are typically caused by poor drainage, poor corrosion protection, and improper installation. Instances where it would be used would be when aboveground is not acceptable with the end user or when drainage swales and high ground water prevent the installation of a concrete trench system.

b. Low Temperature and Chilled Water Systems. The order of preference for system types for hot water, chilled water or combination hot/chilled water are:

(1) Aboveground Heat Distribution System. This is the least expensive system and historically requires the lowest maintenance and operating costs. However, the aesthetics of an aboveground system are not always desirable and must be accepted by the end user. In addition, aboveground systems are typically not used for chilled water because of potential freezing problems in colder climates and heat gain in warmer areas.

(2) Prefabricated Underground Heating/Cooling Distribution System. This buried distribution system is relatively inexpensive and dependable. The non-metallic casing materials provide excellent protection from corrosion and the lower temperatures and pressures allow the system to operate for extended periods of time. It is an excellent application for chilled water since the system is installed underground, limiting the amount of heat gain to the system.

CHAPTER 3

GENERAL DISTRIBUTION SYSTEM DESIGN

3-1. GENERAL. Some aspects of a heating or cooling distribution system design are similar regardless of the system type. These aspects are covered in this chapter.

3-2. SITE SOIL SURVEY. After general routing has been proposed and before specific design has begun, a detailed soil survey will be conducted for all distribution systems.

a. The survey will be made after the general layout of the system has been determined, will cover the entire length of the proposed system, and will be made by a geotechnical engineer. The geotechnical engineer will be a registered professional engineer with a minimum of three years of experience in the field of soil mechanics and foundation design. This engineer must also be familiar with the local soil conditions.

b. If at all possible, the survey should be conducted during the time of the year when the ground-water table is at its highest point; if this is not possible, water table measurements will be corrected, on the basis of professional judgement and local knowledge, to indicate conditions likely to exist at the time of year when the water table is at its highest point. It may be necessary to dig test pits at the worst locations to investigate the soil for evidence of high water table.

c. As a minimum, information on ground-water conditions, soil types, terrain, and precipitation rates and irrigation practices in the area of the system will be collected. This information will be obtained from available records at the installation. In addition, soil resistivity will be determined for the cathodic protection system design for Pre-Engineered Underground Heat Distribution Systems.

d. Information on ground-water conditions and soil types (in most cases not necessary for Prefabricated Underground Heating and Cooling Distribution Systems and Aboveground Heat Distribution Systems) will be obtained through borings, test pits, or other suitable exploratory means. Generally, a boring test pit will be made at least every 100 feet along the line of the proposed system within areas of prior construction. In open undisturbed natural areas the spacing of borings may be increased. Each exploratory hole will extend to a level at least five feet below the anticipated elevation of the bottom of the proposed system. If a significant difference in underground conditions is found at adjacent exploratory points, additional explorations will be made between those points in order to determine more precisely where the change occurs. Upon completion of the survey, each exploration point will be classified on the basis of the criteria presented in the guide specification for Pre-Engineered Underground Heat Distribution Systems or in the guide specification for Heat Distribution Systems in Concrete Shallow Trenches. The classification criteria is different for each system. Note that although classification is not a requirement for design of Prefabricated Underground Heating and Cooling Distribution Systems or Aboveground Heat Distribution Systems, the site survey, except for borings or test pits, must be conducted to ensure that actual site characteristics have been identified so that accurate plan and profile drawings can be generated.

3-3. UTILITY INVESTIGATION. All existing, concurrently constructed and new utilities will be identified if within 25 feet of the proposed distribution system routing. If the proposed routing crosses any utilities, burial depths will be determined. Utility locations and depths can be verified through base personnel familiar with utilities, base/post utility maps and by site visits. The designer is responsible for these site visits to verify locations of utility interferences and to coordinate all other construction items with the user. In the event utility information is not available, utility location consultants may be procured who specialize in the location, identification and depth determination of utilities. If interferences exist, details will be provided in the design to relocate utilities or modify system routing to avoid the interference.

3-4. SYSTEM LAYOUT PLAN/PROFILE. All distribution systems require a layout plan and profile be provided by the designer.

a. Layout plans will include, but not be limited to:

(1) system routing (including expansion loops and bends, manhole locations and anchor locations).

(2) stationing numbering for the system (one dimensional coordinates from the point of origin of the distribution system).

(3) all utilities within 25 feet of the system.

(4) all roads and buildings clearly labeled.

(5) types of surface conditions (asphalt, concrete, seeding, gravel, etc.).

(6) grade contour lines (new and existing).

(7) all dimensions and clearances to ensure accurate routing.

b. A profile of the system will also be drawn and, as a minimum, show:

(1) all system stationing numbering.

(2) system slope drawn to scale (1-inch to 20 feet minimum for all systems) to all low points.

(3) new and existing grade.

(4) all existing or new utilities shown at their actual burial depths.

3-5. EXPANSION COMPENSATION. All expansion systems, loops, and bends, will be sized in order to prevent excessive pipe stresses (due mainly from thermal expansion) from exceeding those allowed by the Power Piping Code, ASME B31.1. Mechanical expansion joints are not recommended for absorbing system expansion. Mechanical expansion joints greatly increase the maintenance requirements of the distribution systems. In the unlikely event that expansion joints must be used, they must be placed in an adequately sized valve manhole. The designer is responsible for expansion calculations for Heat Distribution Systems in Concrete Trenches, Prefabricated Underground Heating/Cooling Distribution Systems, and Aboveground Heat Distribution Systems. The designer is also responsible for the expansion and stress determinations in all the valve manholes, including the location of the equipment/pipe support locations. Even though the manufacturer is responsible for the expansion calculations for Pre-Engineered Underground Heat Distribution Systems, the calculations will be thoroughly reviewed by the designer at the shop drawing review. It is recommended that a three dimensional finite element computer program be used for determining system stresses. Many finite element software packages are available which operate on desktop computers. The temperature differential used in the stress analysis will be the maximum temperature of the media less the minimum temperature the system will encounter during a shutdown. All loops and bends will be sized based on zero percent cold springing. Cold springing effects lessen over time and are difficult to maintain in the event the system is ever cut, and shall therefore not be included in the analysis. However, loops may be installed with cold springing as an added conservative measure.

3-6. VALVE MANHOLES. For all distribution systems, valve manholes will be designed by the project designer. A valve manhole is required for all buried system lateral connections, all below to above ground system transitions, all drain points (low points), all below ground valving, all trap stations, high points for vents of buried systems, and to minimize depth of buried systems. Distance between valve manholes varies with different applications. However, spacing shall never exceed 500 feet with Pre-Engineered Underground Heat Distribution Systems or Prefabricated Underground Heating/Cooling Distribution Systems to minimize excavation when searching for failures and to minimize effects of a failure. To enhance maintainability, avoid valve manholes deeper than 6 feet.

a. Manhole internals. Layout of each manhole will be designed on a case by case basis.

(1) Equipment/valve locations. It is important to first layout, to scale, all manhole piping, insulation, valving (with stems upright 90 degrees or less from vertical), and equipment and then locate the manhole walls around these appurtenances to ensure adequate manhole size and room for maintenance personnel. One line diagrams of piping and equipment are unacceptable. See figure 3-1 for a typical manhole plan. Note that all valve manhole layouts have certain designer requirements in common. The designer will:

(a) Provide main line isolation valves in valve manholes to most efficiently minimize outages to buildings served by the distribution system. When installed, main line isolation valves will be located downstream of the building's service laterals.

(b) Provide lateral isolation valves within the valve manholes for all laterals runs.

(c) Locate all carrier pipe vents and drains needed within the manhole for proper system drainage of the main and lateral lines.

(d) Layout all valve manhole internals (valves and valve stems, pipe w/insulation, access ladders, isolation flanges, and equipment) to scale to ensure adequate clearance has been provided for operation and maintenance within the manhole.

(e) Ensure no non-metallic piping is routed in the manholes (i.e., as allowed with chilled water or condensate return systems) which also serves high temperature mediums that could damage the non-metallic piping. Damage to non-metallic piping is caused when manholes flood and the hot piping boils the flood water. Boiling water can exceed the temperature allowables of many nonmetallic piping materials. Because of this, the designer must transition to steel piping at the manholes (see figure 8-4).

(2) Clearances. Design will provide for clearance around piping and equipment in the manhole in accordance with table 3-1.

(3) Access Ladders. Access ladders will be required on all valve manholes greater than 3 feet in depth. Ladders will be welded steel and will consist of uprights and nonslip steps or rungs. Uprights will be not less than 16 inches apart and steps or rungs will be spaced no greater than 12 inches apart. Ladders will extend not less than 6 inches from the manhole wall and will be firmly anchored to the wall by steel inserts spaced not more than three 3 feet apart vertically. All parts of the ladders will be hot-dipped galvanized after fabrication in conformance with ASTM A 123. The top rung of the ladders shall be not more than 6 inches from the top of the manhole. A typical valve manhole access ladder detail is shown in figure 3-2.

(4) Insulation. Insulation for valves, fittings, field casing closures, and other piping system accessories in valve manholes will be of the same types and thicknesses as those provided in the distribution systems' guide specification. All insulation will be premolded, precut, or job fabricated to fit and will be removable and reusable. Insulation jackets will be provided for all pipe insulation in manholes and will comply with the requirements of the particular distribution system guide specification.

(5) Isolation flanges. Isolation flanges will be provided when connecting to an existing cathodically protected heating or cooling distribution system or to prevent a new system's cathodic protection system from contacting an existing system. The isolation flanges will be installed in the valve manhole and a typical flange detail is shown in figure 3-3.

(6) Valve/piping supports. Piping in valve manholes often will need supports within the manhole especially when larger valves or equipment are attached to the piping. These supports will be located on the manhole plans as determined by the designer's expansion compensation calculations for each manhole valving and equipment layout. Typical valve/piping support details are shown in figure 3-4.

b. Valve manhole construction. Valve manholes will be field constructed of reinforced concrete conforming to the current criteria. Valve manholes will be constructed of 4,000 psi minimum compressive strength concrete. Reinforcing bars will conform to ASTM A 615, grade 60. Typical reinforcing steel details and sizing are shown in figure 3-5 and table 3-2 respectively. Concrete floor slabs and walls will be of sufficient weight to prevent flotation in high water table areas. Floor slabs will be sloped to the drain which will be installed in the floor slab. Concrete wall sections will be not less than 8 inches thick and must meet anticipated load and soil conditions. Side walls will be constructed in a monolithic pour. Water stops will be provided at all construction joints. Do not locate valve manholes in roads or parking areas which create an inadequate amount of manhole ventilation and poor access.

c. Valve manhole covers. The valve manhole cover types discussed here are: raised solid plate, supported cover, and concrete.

(1) Raised solid plate covers. Raised solid plate covers are preferred for HTHW and steam/condensate systems installed in Pre-Engineered Underground Heat Distribution Systems. For shallow concrete trench systems, the raised solid plate cover's raised feature will interfere with the trench's walkway function. When the valve manhole cover must remain flush with the trench top, the supported cover is the preferred type. For the raised solid plate cover, ventilation openings are provided around the entire perimeter below the raised top. The height of the valve manhole wall above grade (6 inches, minimum) shall be sufficient to prevent surface water entry. The solid plate cover assembly is removable. The cover, constructed of aluminum, also provides sectionalized access for inspection and maintenance. The solid plate cover raised frame design and section, lifting lug, and handle details are shown in figure 3-6 through 3-12. Figure 3-13 contains notes for raised solid plate cover figures.

(2) Supported covers. Supported covers may be used for any distribution system covered in this manual. For Pre-engineered Underground or Prefabricated Underground Heat Distribution Systems, design the cover to be at least 6 inches above the surrounding grade. When used for concrete shallow trench systems, the finished top will be flush with the concrete trench top. Required grates or other structural members used for supporting covers to be made of corrosion resistant material such as aluminum or galvanized steel. Details for the supporting cover are shown in figures 3-14 through 3-18. These details are designed for loadings up to 150 psf and must be re-evaluated for larger loadings. Other structural solutions for supporting the checkered plate are acceptable. The checkered plate cover (also referred to as diamond or embossed plate) as shown in figure 3-18, will be installed over grating or other structural supports in most locations to minimize the influx of leaves and other debris. The checkered plate is attached to the grating and is removable.

(3) Concrete covers. The use of concrete covers is discouraged, but, if used, they must be used with 4 x 4 ft. aluminum doors for any distribution system covered in this manual. Concrete covers should only be used if desired by the user or if specific design conditions exist, such as below to aboveground system transitions. When used for Pre-engineered Underground or Prefabricated Underground Heat Distribution Systems, design the top of the concrete cover to be a minimum of 6 inches above the surrounding grade. When used for concrete shallow trenches, design the cover to be flush with the trench top. Concrete requirements for this cover are similar to those required for valve manhole construction. Concrete cover will be designed to support anticipated loadings. Figure 3-19 shows a typical concrete cover plan and figure 3-20

provides construction details for this cover. The concrete cover detailed is designed for loadings up to 150 psf. For greater loadings, the design must be re-evaluated. A disadvantage of concrete covers is the difficulty in providing ventilation. For concrete shallow trench systems, a single 6 inch gooseneck pipe will be used, as detailed in figure 3-21, to allow steam to exit the valve manhole if a leak or excessive heat loss is present. Note that for shallow trench systems, the gooseneck will be installed off to one side of the valve manhole concrete top to minimize pedestrian traffic interference. For Pre-engineered Underground Heat Distribution Systems, two 6 inch goosenecks will be used. One will extend below the top as detailed in figure 3-21. The other will be similar but will extend to within 8 inches of the valve manhole floor on the opposite side of the manhole.

d. Valve manhole drainage. Drainage of water from the valve manhole is mandatory for the successful operation and longevity of buried heating or cooling distribution systems. There are three types of valve manhole drainage systems described in this manual: gravity drainage, pumped drainage from a sump basin, and pumped drainage from the valve manhole.

(1) Gravity drainage. The most cost effective and lowest maintenance system is gravity drainage to a storm drain when location, depth of existing storm drains, and local regulatory requirements allow this possibility. Drainage lines will be 6 inches in diameter minimum and will conform to the latest storm drain criteria and will be sloped at one percent, minimum. Valve manhole outlet will be a floor drain with backflow preventer to prevent storm water inflow from the storm drain (see figure 3-22). Note that valve manhole drain outlets shall be covered with a "hat type" cast iron pipe screen to minimize the accumulation of trash over the drain inlet. Also, the manhole floor will be sloped toward the drain.

(2) Pumped drainage from sump basin. For pumped drainage, a duplex submersible pump system installed in a remote sump basin may be provided as indicated in figures 3-23 and 3-24. The sump basin will be located no more than 10 feet from the valve manhole. Drainage from the valve manhole to the sump basin will be similar to drainage to a storm drain including the valve manhole floor drain (fig 3-22). Discharge from the pumps can be routed to a splashblock at grade or to an adjacent storm sewer. Design of the surrounding grade must ensure drainage away from the sump basin, valve manhole and concrete shallow trench (if used) when discharging to grade. A power pedestal complete with failure warning light will be provided with each basin as shown in figure 3-25. A typical wiring diagram and sequence of operation are shown in figure 3-26. A specification for the sump basin system can be included in the applicable manhole or heat distribution section of the contract specification. The sump basin design has proven to operate well even in the colder climates of the upper tier states in the continental United States. It is also an excellent method to retrofit existing manholes that currently do not drain properly. The remote sump basin increases the life of the systems by removing the sump pump and pump controls from the hot, humid environment of the manhole. Also, pump maintenance will be done outside of the manhole. The pumps are easily disconnected and lifted to grade. The sump pumps used in the sump basin must incorporate the design characteristics listed in table 3-3.

(3) Pumped drainage from valve manhole. Another means to pump water from the manhole is to locate the duplex sump pumps in the valve manhole. Typically, a 2'0" by 2'0" by 1'0" (deep) sump will be provided in a corner of the valve manhole. The duplex sump pumps will be installed to pump out of this sump. Valve manhole sump pump electrical arrangement should be installed as shown in figure 3-27. The control panel with high level warning light will be mounted adjacent to the valve manhole at grade. This keeps the electrical panel out of the hot, humid environment of the manhole. The sequence of operation and wiring diagrams will meet the requirements of figure 3-26. Pump discharge can be routed to a splashblock at grade (similar to the sump basin discharge piping arrangement on figure 3-23) or to an adjacent storm drain. Electric sump pumps used in the valve manholes must incorporate the design characteristics listed in table 3-3. Note that life of the pumps are typically shortened when installed in the hot and humid valve manhole environment.

e. General.

(1) Valve manhole wall penetrations. A design must be provided for the distribution system wall

penetrations. For a shallow trench system, the wall penetrations will typically be the same size as the inside dimension of the shallow trench connecting to the valve manhole. For shallow trench dimensions, refer to chapter 4 of this manual. Structural reinforcement must be designed around this opening. Drainage from the trench will then flow into the manhole. For Pre-engineered or Prefabricated Underground Heat Distribution Systems, sleeved openings will typically be provided with an expandable seal between the casing and the pipe sleeve as indicated on figure 3-28. Structural reinforcement must be designed to avoid contact with the pipe sleeve and water stop to prevent grounding of the system's cathodic protection.

(2) Waterproofing. Waterproof membranes will be placed in or below the concrete bottom slab and continued up the outer sides to the top of the sidewalls in accordance with the valve manhole guide specification.

(3) Pipe anchoring adjacent to valve manholes. Regardless of the buried distribution system, pipe anchors should be provided between 2 to 5 feet of a manhole wall to minimize movement through the manhole. For piping which passes through valve manholes, anchoring on one side only is typically adequate. Anchoring piping on more than one side may restrict piping movement and overstress the piping in the valve manhole. Anchors will typically be provided as part of the distribution system and will not be embedded in the manhole wall. However, if the manhole is used to support an anchor, the manhole must be designed to withstand the forces exerted by the system. Expansion compensation stress calculation will always be conducted to ensure proper anchor locations throughout the distribution system. These calculations must also account for the expansion in the valve manholes.

(4) Piping materials in valve manholes. Nonmetallic piping must not be used in the same valve manholes as piping carrying higher temperature media that could cause the temperature around the non-metallic piping to exceed the allowables and potentially cause permanent damage to the non-metallic piping. In addition, chilled water systems with PVC carrier piping must never be installed in the same valve manhole with any heating system.

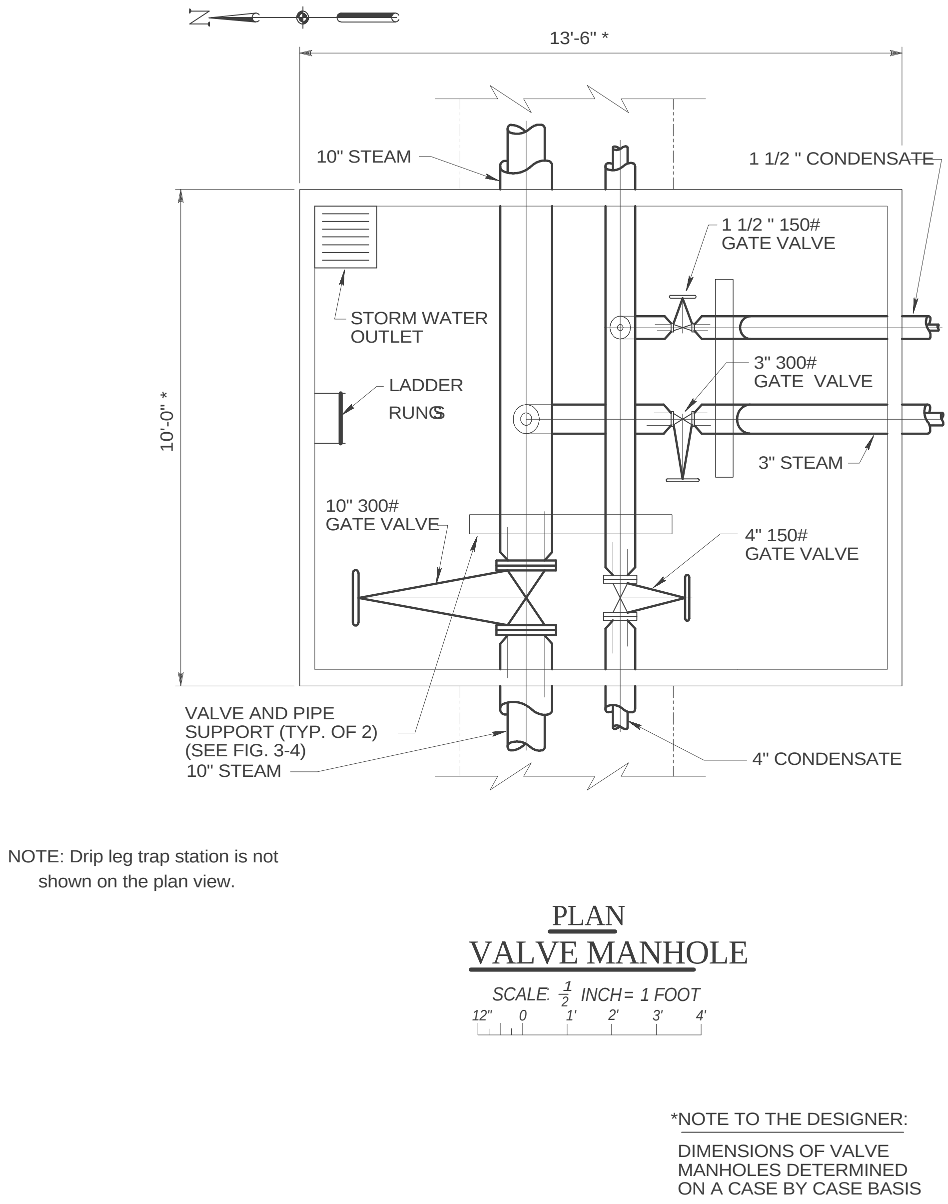


Figure 3-1. Typical Valve Manhole Plan.

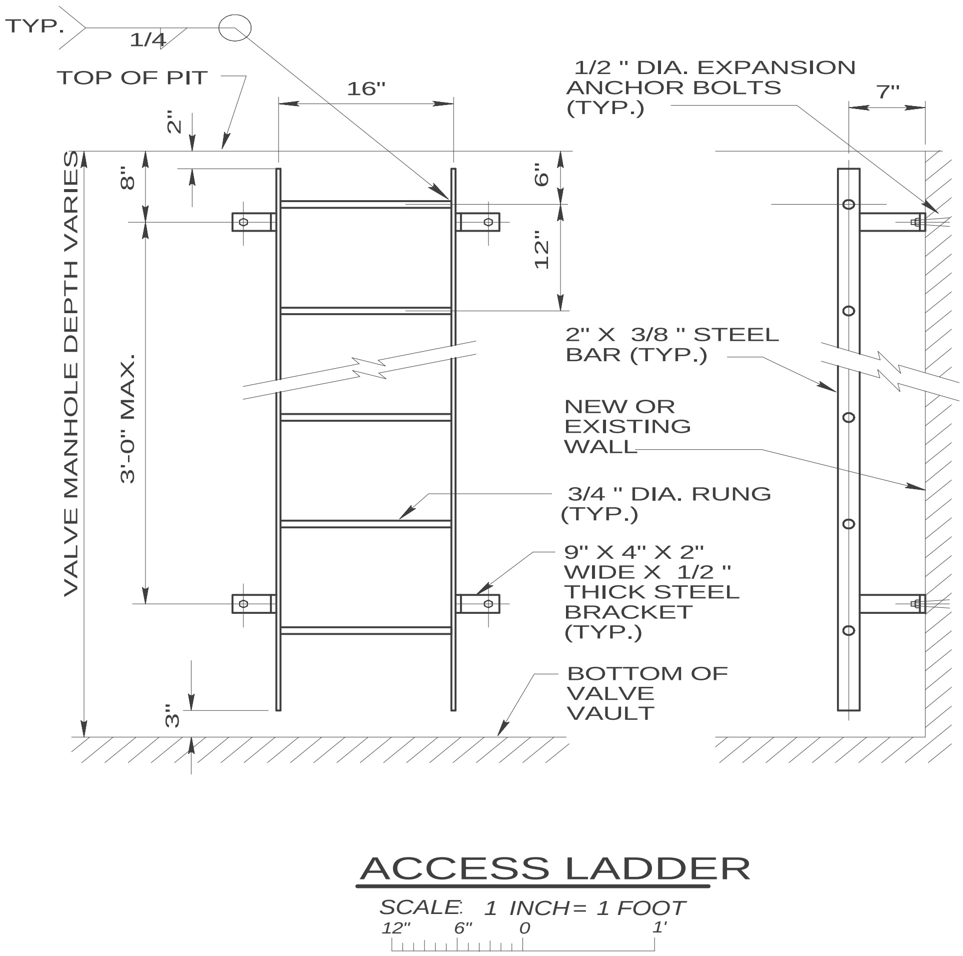


Figure 3-2. Access Ladder Detail.

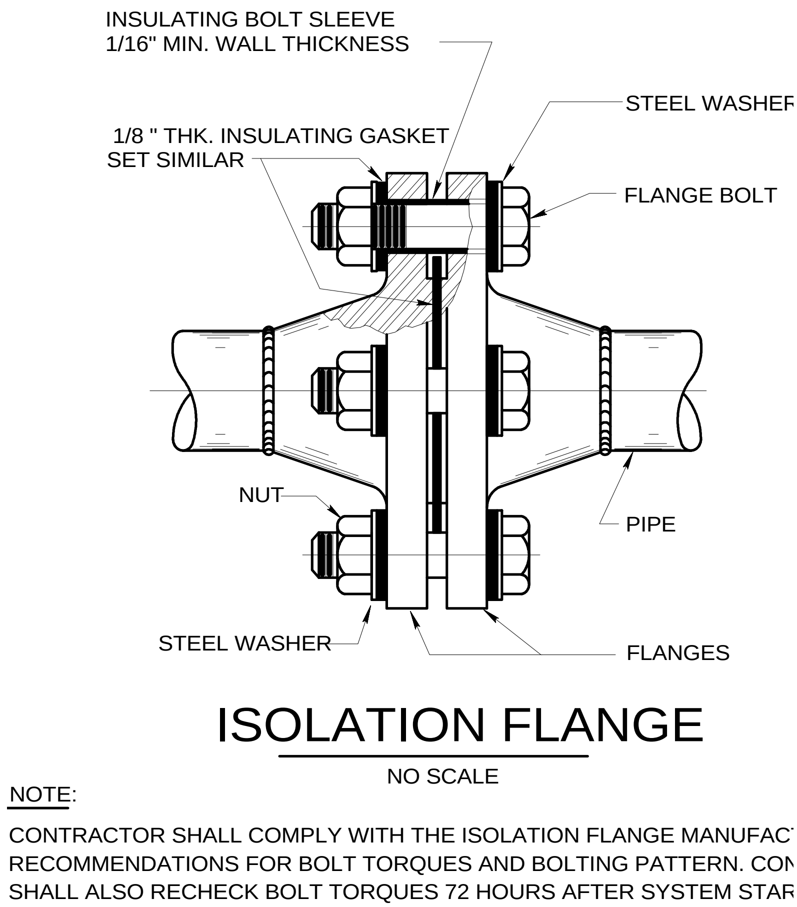


Figure 3-3. Typical Isolation Flange Detail.

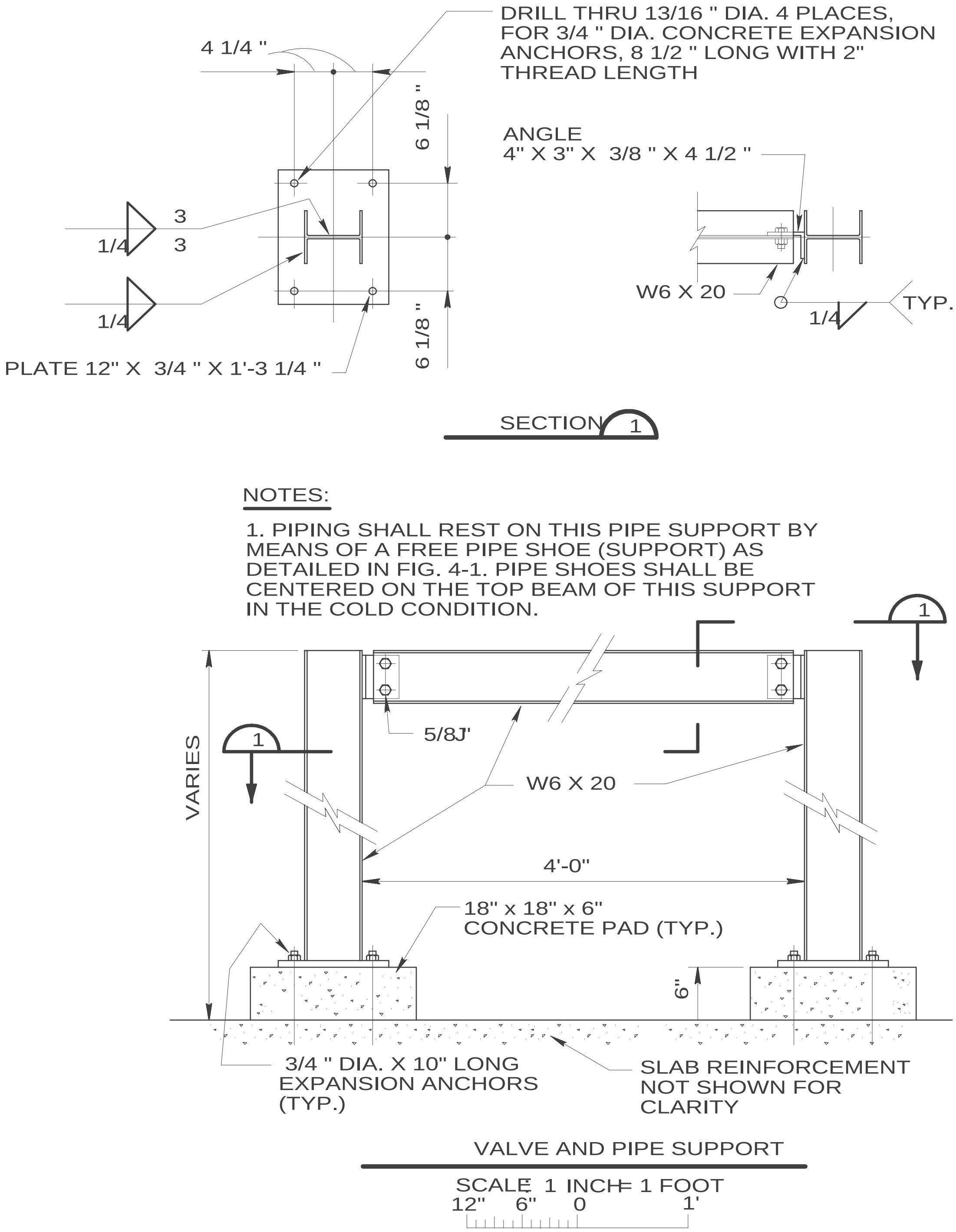
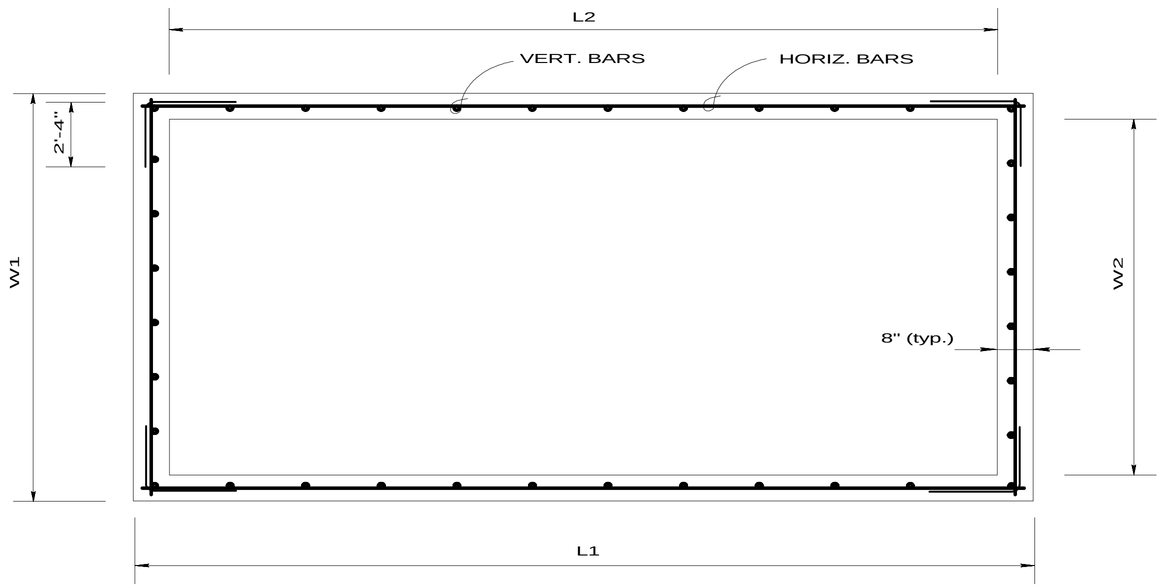
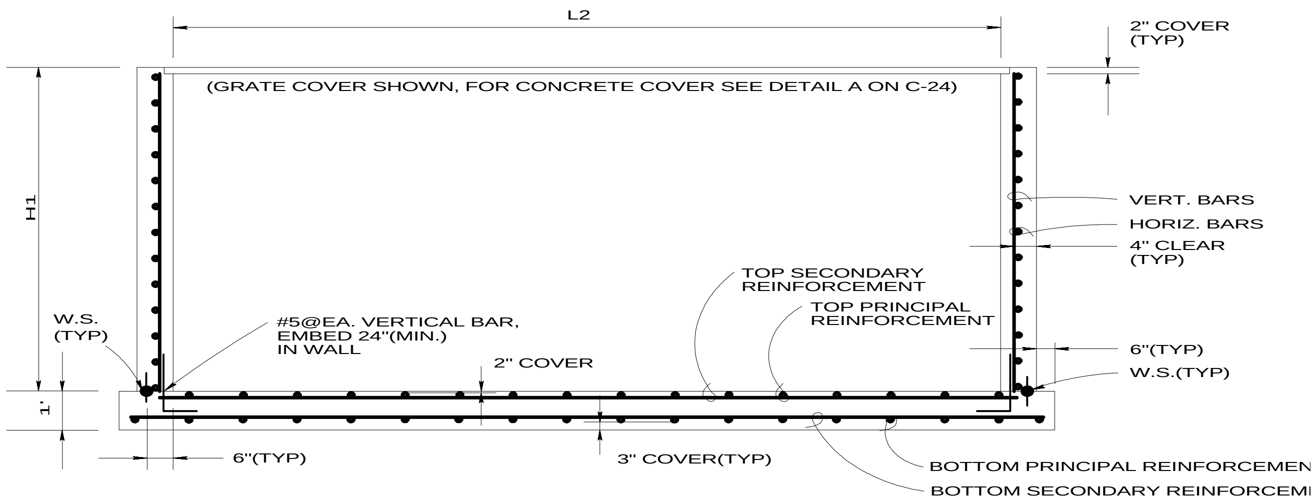


Figure 3-4. Typical Valve/Piping Support Detail.



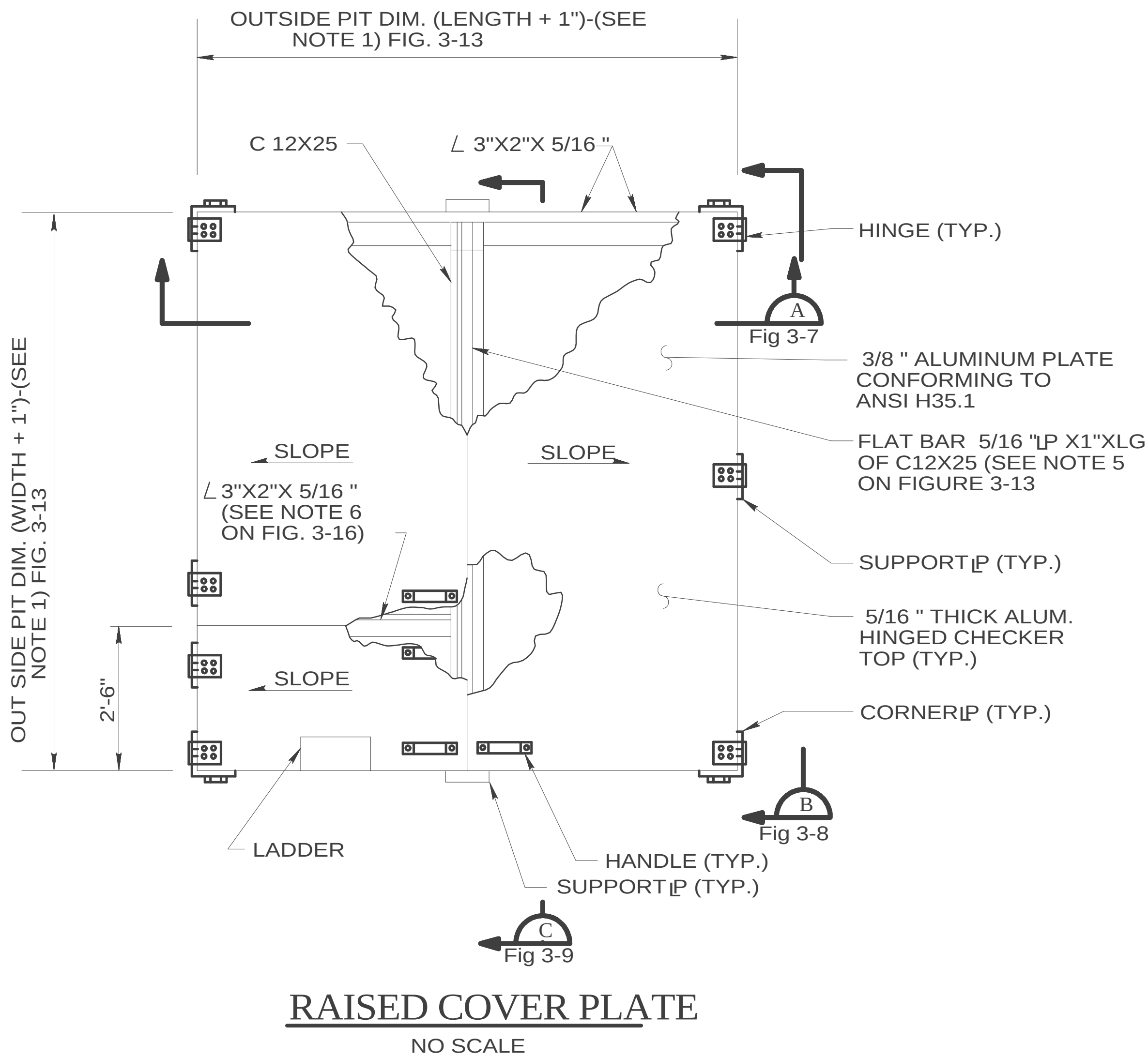
PLAN IN SECTION
NO SCALE



VALVE MANHOLE SECTION*
NO SCALE

NOTE
SEE TABLE 3-2
FOR REINFORCEMENT
BAR SIZES.

Figure 3-5. Valve Manhole Elevation and Section.



NOTE TO DESIGNER:

PLATE COVER SHOWN IS DESIGNED FOR LOADINGS UP TO 40 psf WHEN SPACING BETWEEN SIDWALL AND CENTER SUPPORTS IS LESS THAN 3'6". LOADINGS OR SPACINGS GREATER THAN THESE MUST BE DESIGNED FOR ON A CASE BY CASE BASIS.

Figure 3-6. Raised Cover Plate Design.

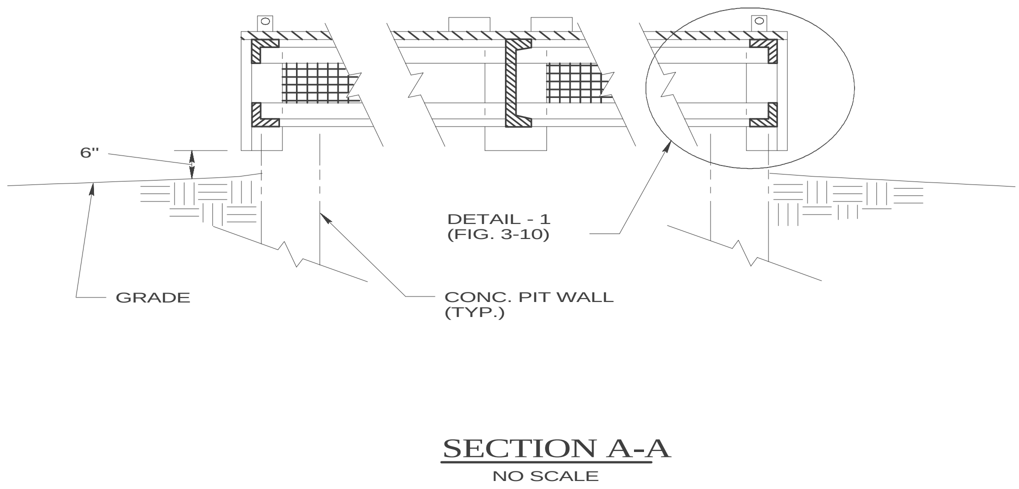


Figure 3-7. Section A-A of Raised Cover Plate.

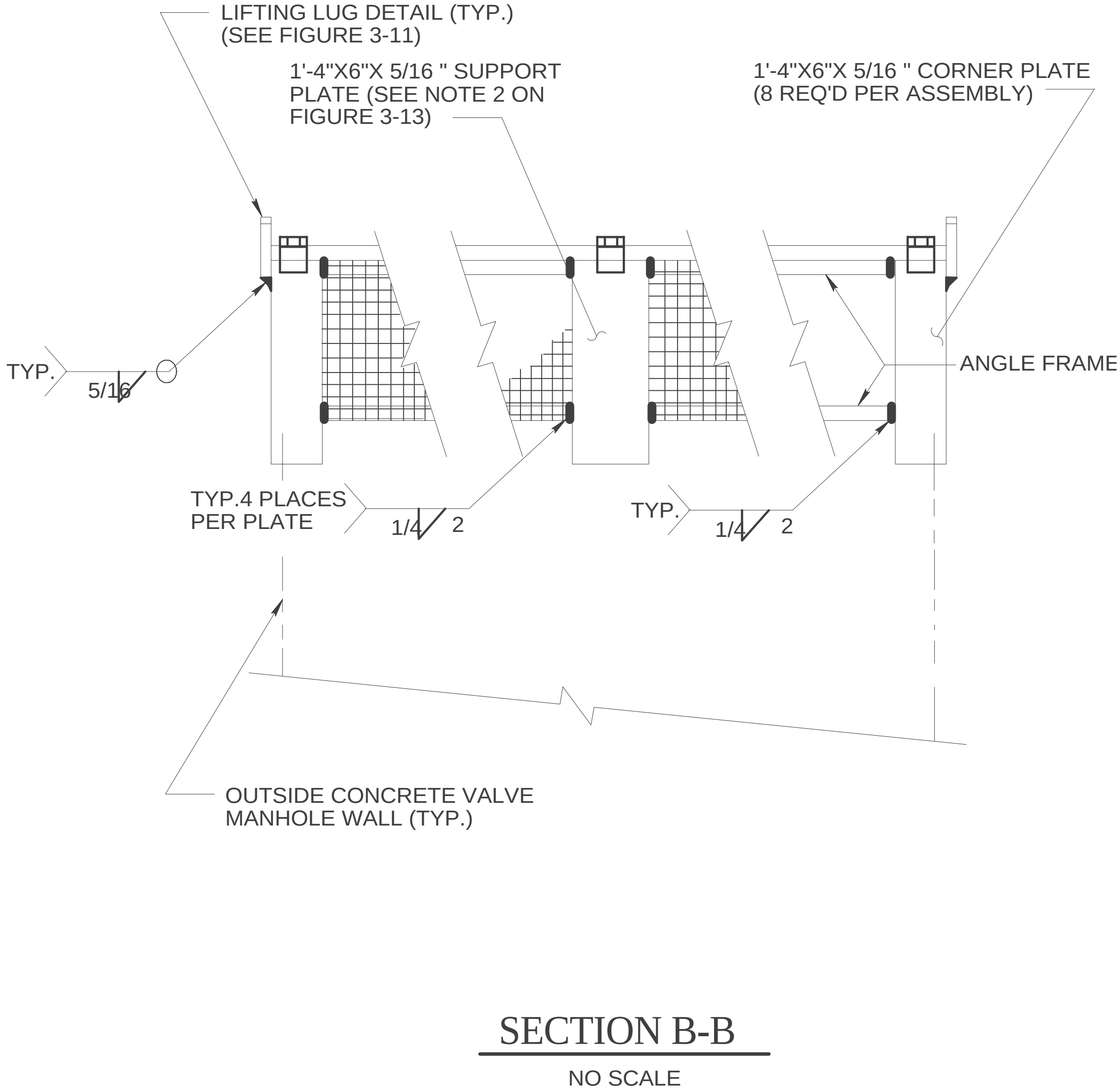
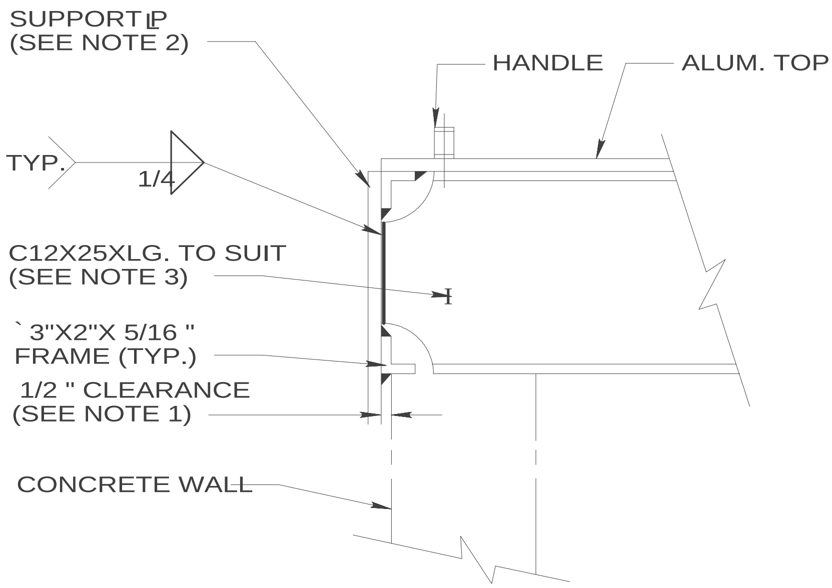


Figure 3-8. Section B-B of Raised Cover Plate.

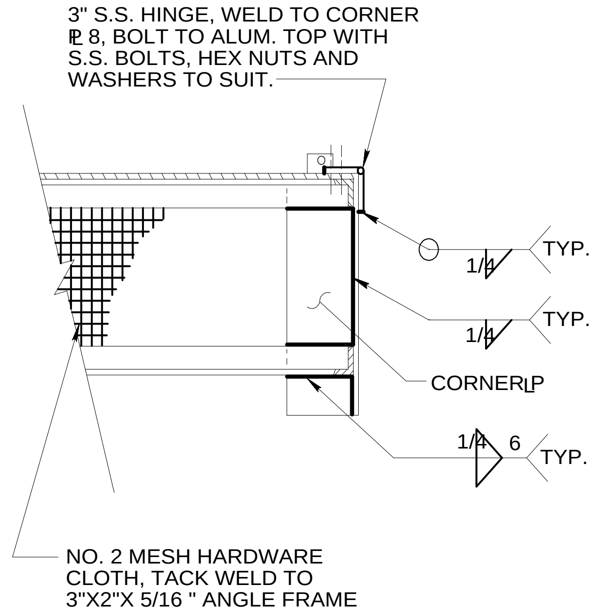


NOTE:

NOTES ARE LOCATED ON FIG. 3-13.

SECTION C-C
NO SCALE

Figure 3-9. Section C-C of Raised Cover Plate.



DETAIL - 1
NO SCALE

Figure 3-10. Detail of Raised Cover Plate.

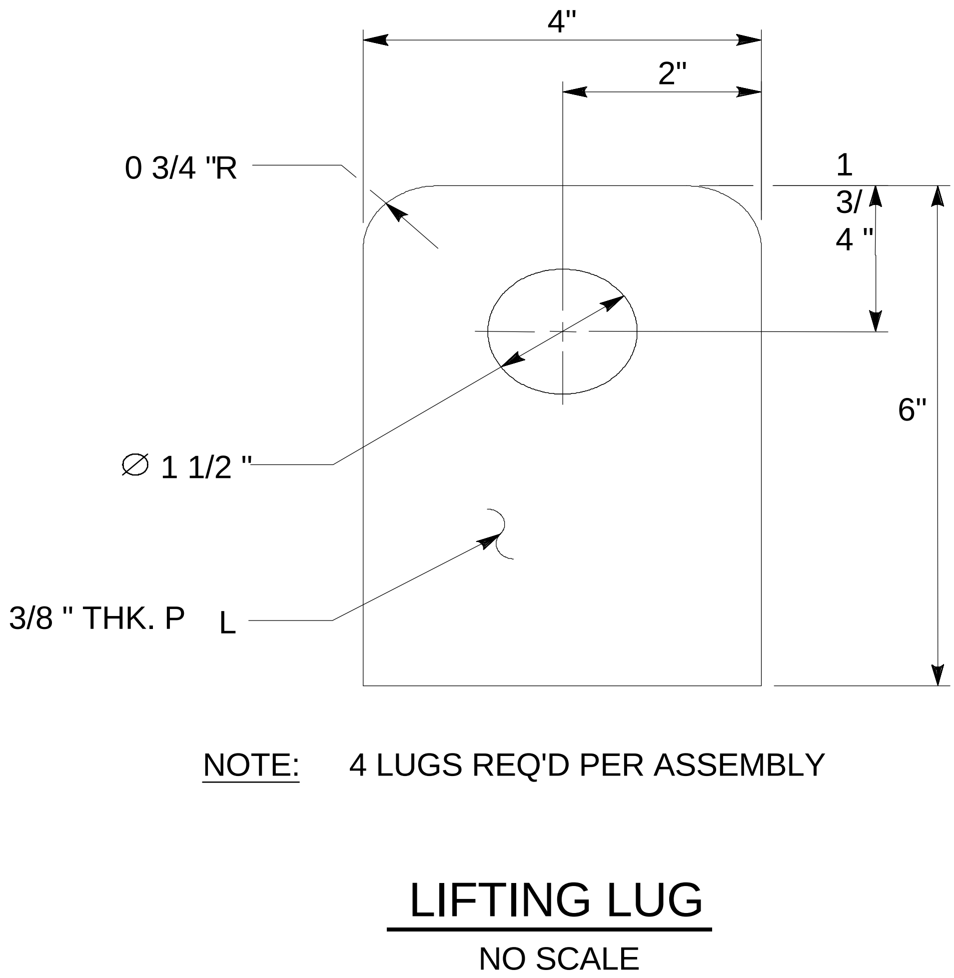


Figure 3-11. Lifting Lug Detail.

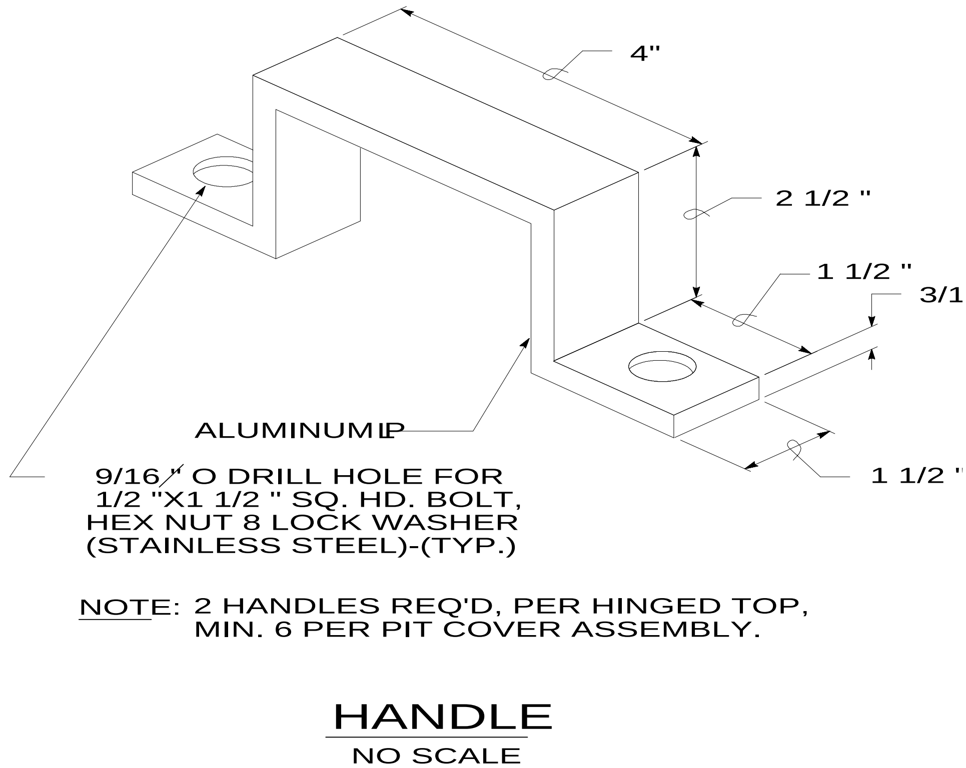


Figure 3-12. Handle Detail.

GENERAL NOTES: (FOR RAISED COVER PLATE)

1. FIELD VERIFY OUTSIDE DIMENSIONS OF NEW MANHOLE BEFORE CONSTRUCTING MANHOLE COVER ASSEMBLY. ADD 1" TO OUTSIDE MANHOLE DIMENSIONS (TO ALLOW FOR CLEARANCE) TO DETERMINE INSIDE ASSEMBLY DIMENSIONS.

2. EACH SUPPORT PLATE SHALL BE LOCATED HALFWAY BETWEEN CORNER PLATES AT 3 SIDES OF MANHOLE. 2 SUPPORT PLATES SHALL BE LOCATED BETWEEN 2 SPLIT ALUM. CHECKER TOP AT ONE SIDE OF MANHOLE.

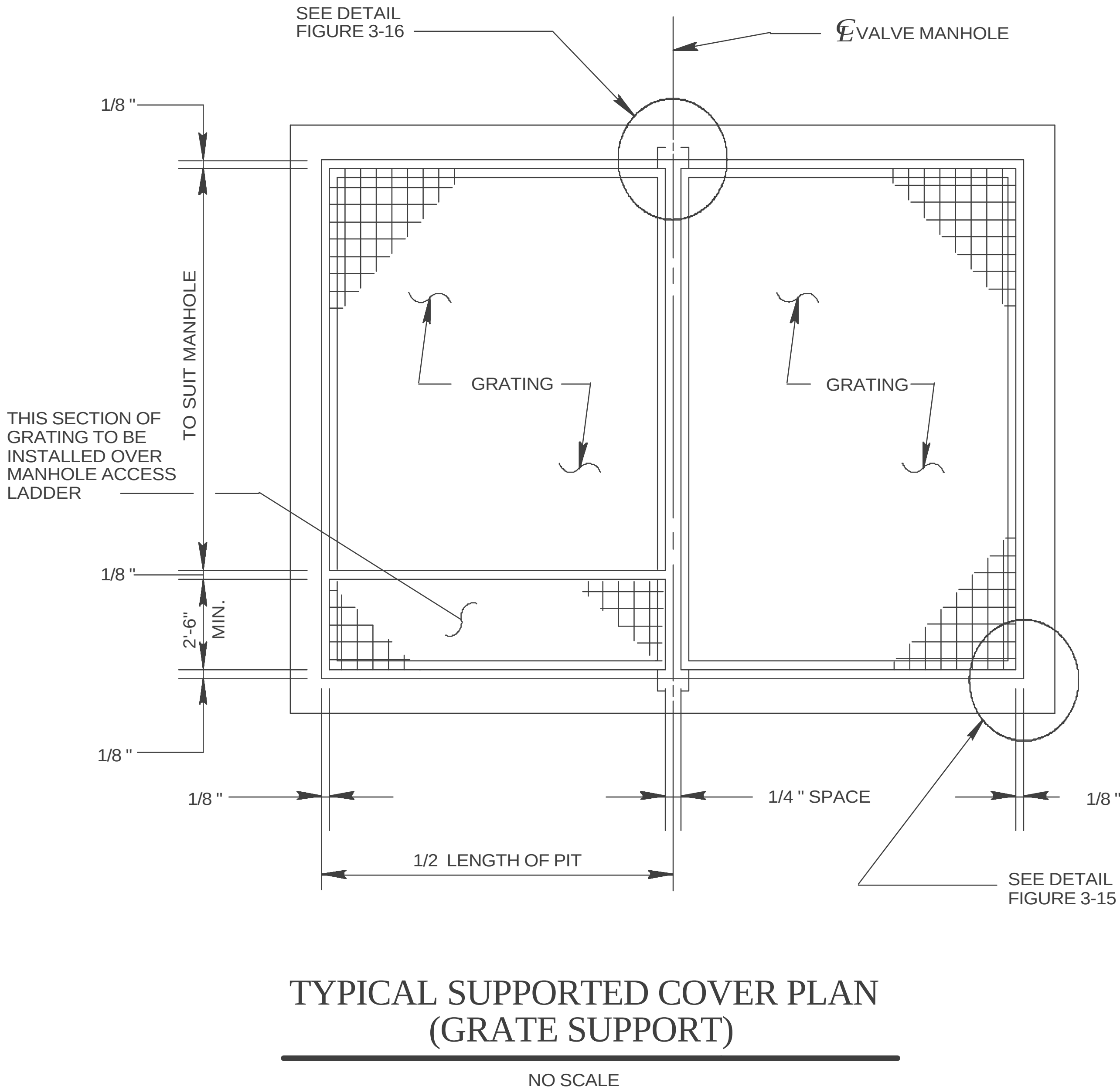
3. SUPPORT CHANNELS SHALL BE C12X25XLG, TO EQUAL WIDTH OR LENGTH DIM. PLUS 1" TO SUIT INSIDE ASSEMBLY DIM. THE CHANNEL SHALL REST ON THE CONCRETE MANHOLE TOP AND THE ALUM. TOP SHALL REST ON THE FLAT BAR PLATE.

4. CHANNEL SUPPORT, CORNER PLATES, SUPPORT PLATES, ANGLE FRAME HARDWARE CLOTH, AND LIFTING LUGS SHALL BE HOT-DIPPED GALVANIZED BEFORE INSTALLATION ON VALVE MANHOLES.

5. FLAT BAR 5/16 " THK. WELDED TO TOP OF C12X25 TO MAKE ALUM. CHECKER TOP SLIGHTLY SLOPED AS INDICATED. LOCATE FLAT BAR TO MATCH CHANNEL BEFORE WELDING.

6. ANGLE 3"X2"X 5/16 " WELDED TO C12X25 8 3"X 2"X5/16" AT EACH END LENGTH SHALL EQUAL HALF OF LENGTH OR WIDTH OF VALVE MANHOLE.

Figure 3-13. Notes for Raised Cover Plates.



NOTE TO DESIGNER:

GRATES IN FIGURES 3-14 THRU 3-16 ARE FOR LOADINGS UP TO 150 psf.
LOADINGS GREATER THAN THESE MUST BE DESIGNED FOR ON A CASE BY CASE BASIS.

Figure 3-14. Typical Supported Cover Plan (Grate Support).

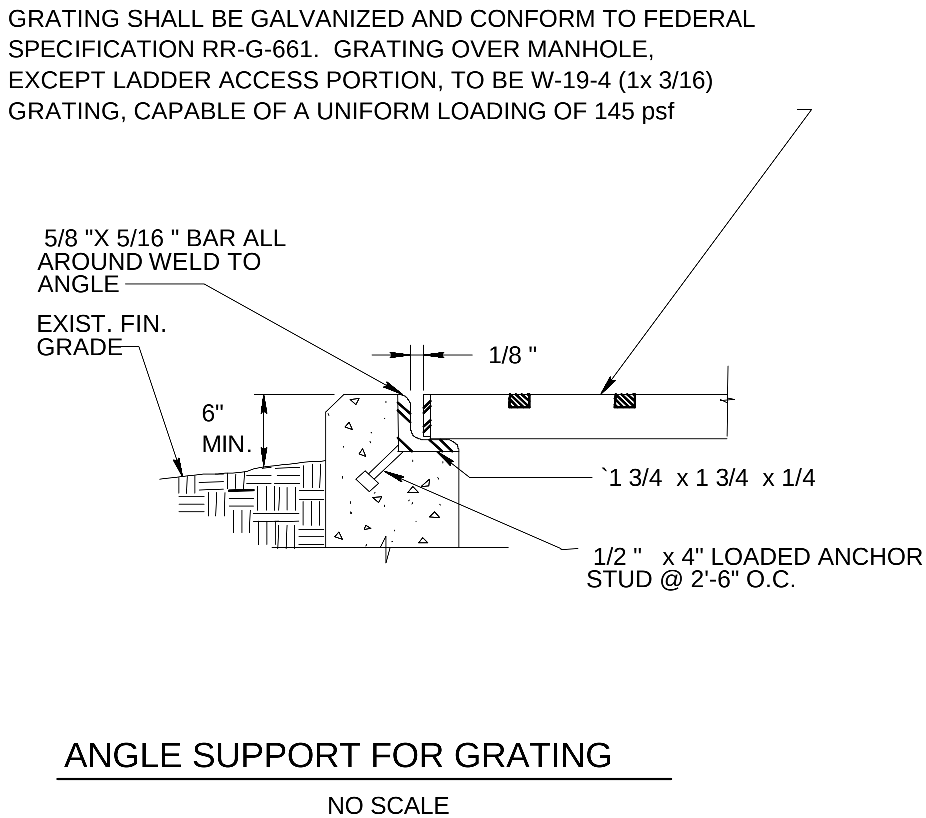


Figure 3-15. Detail of Angle Support for Grating.

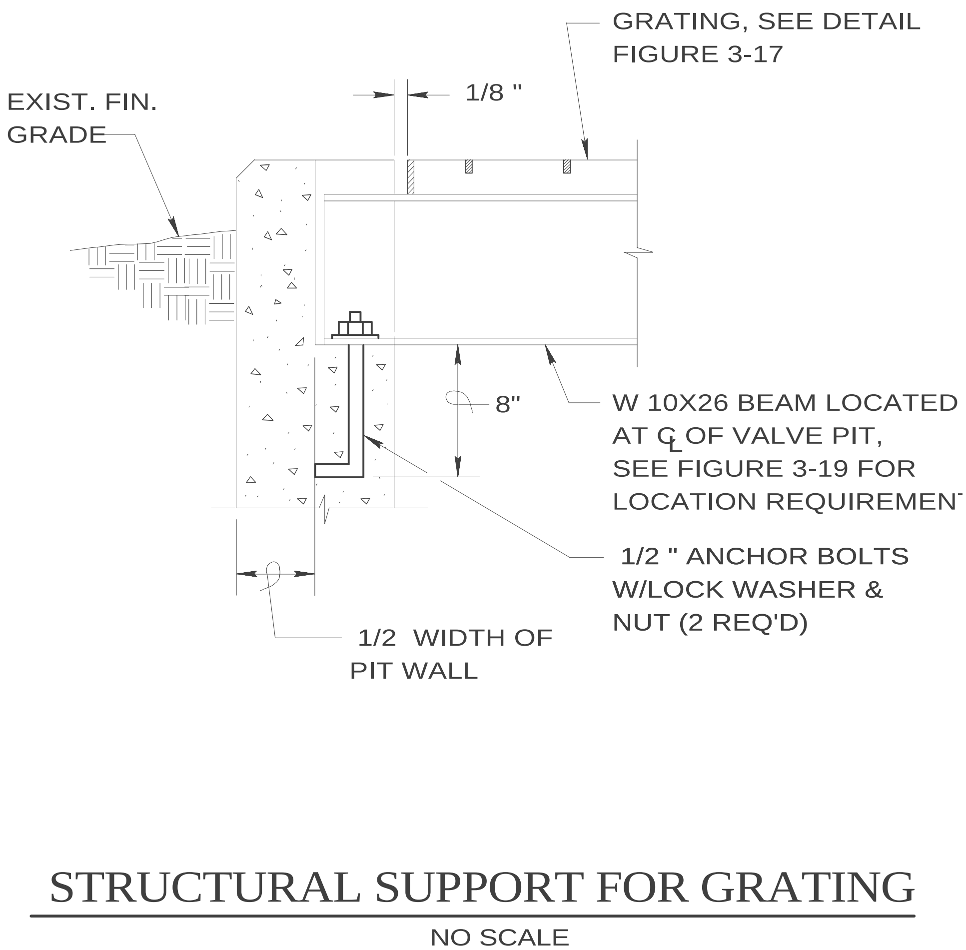
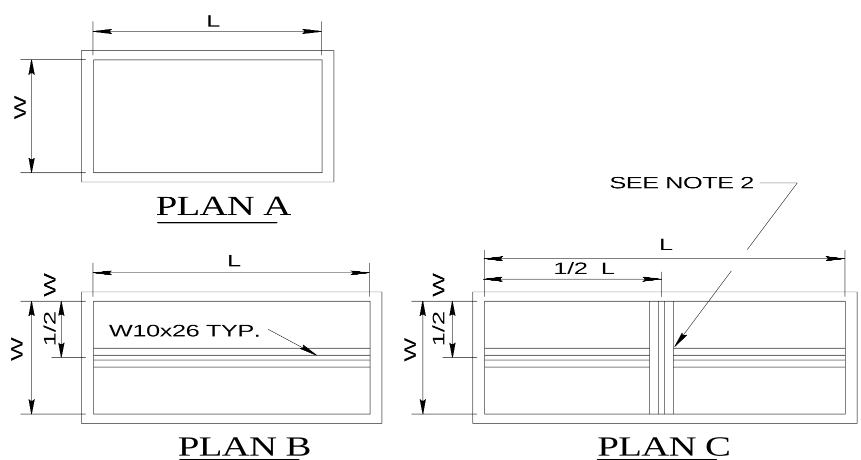


Figure 3-16. Detail of Structural Support for Grating.

GRATING SUPPORT STEEL			
VALVE M.H.PLAN	W-WIDTH (FT.)	L-LENGTH (FT.)	REMARKS
A	4 OR LESS	AS REQ'D	NO MEMBER REQ'D
B	GREATER THAN 4 NOT TO EXCEED 12	AS REQ'D NOT TO EXCEED 12	ONE MEMBER REQ'D
C	GREATER THAN 12 NOT TO EXCEED 16	GREATER THAN 12 NOT TO EXCEED 16	THREE MEMBERS REQ'D

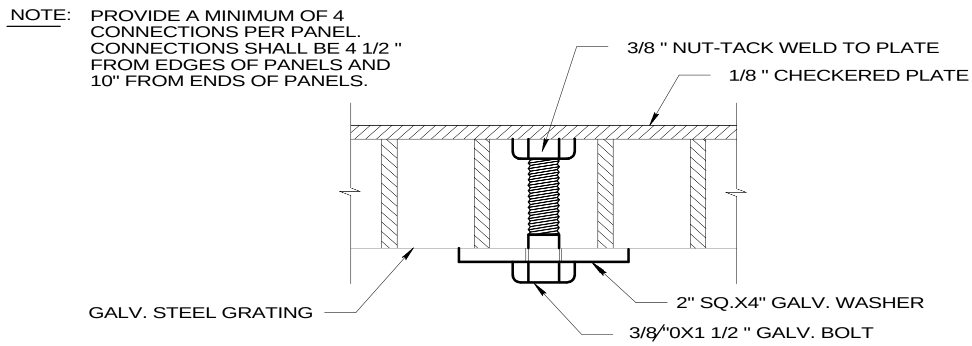
NOTE: 1. FOR VALVE MANHOLE WITH DIMENSIONS L & W GREATER THAN 16 FEET REQUIRES STEEL MEMBERS AND GRATING TO BE DESIGNED FOR UNIFORM LOADING OF 145 psf.
2. INTERSECTION OF STEEL MEMBERS MUST BE DESIGNED FOR LOADING AND DIMENSIONS INDICATED.



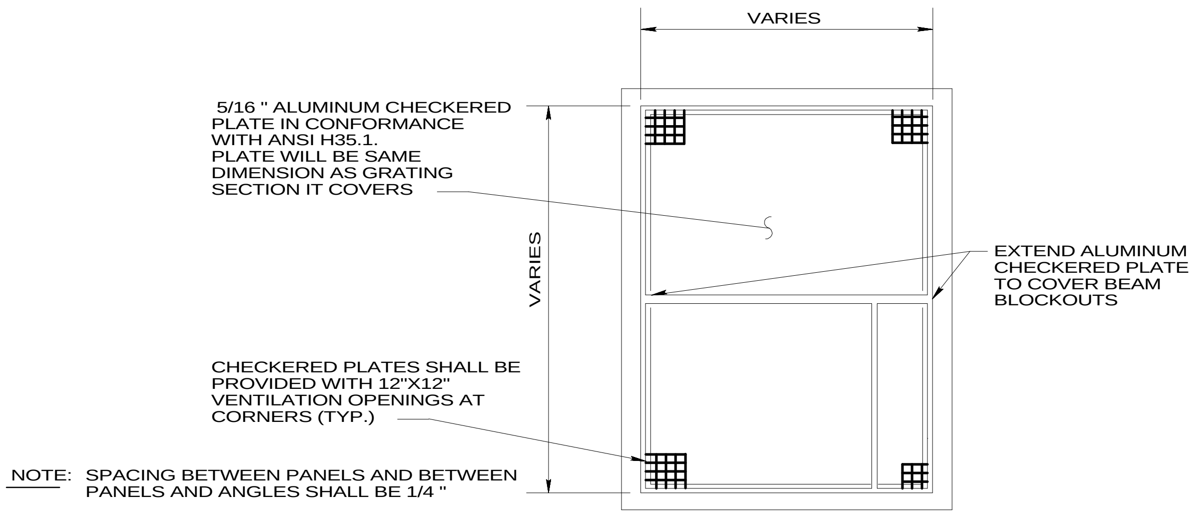
GRATING SUPPORT STEEL LOCATION

NO SCALE

Figure 3-17. Grating Support Steel Locations.



CONNECTION FOR ATTACHING CHECKERED PLATE TO GRATING



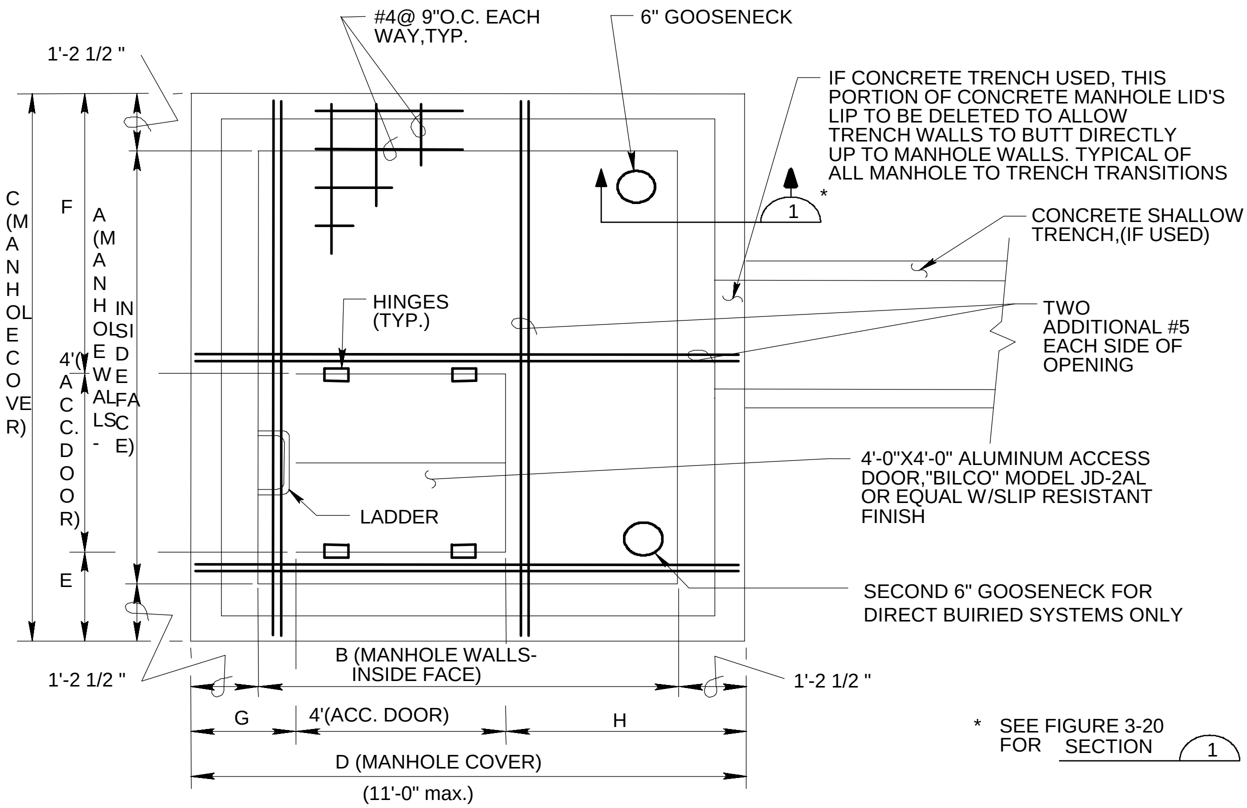
OPEN GRATE COVER W/CHECKER PLATE

CHECKER PLATE COVER DETAILS

NO SCALE

DESIGNER NOTE: CHECKERED PLATE TO BE USED TO COVER GRATING IN COLD CLIMATES AND AREAS WHERE TRASH ACCUMULATION IS A CONCERN.

Figure 3-18. Detail of Checker Plate Cover.



CONCRETE COVER PLAN

NO SCALE

NOTE TO DESIGNER:

CONCRETE COVER DETAILED IS DESIGNED FOR LOADINGS UP TO 150 psf.
LOADINGS GREATER THAN THESE MUST BE DESIGNED FOR ON A CASE BY CASE BASIS.

Figure 3-19. Typical Concrete Cover Plan.

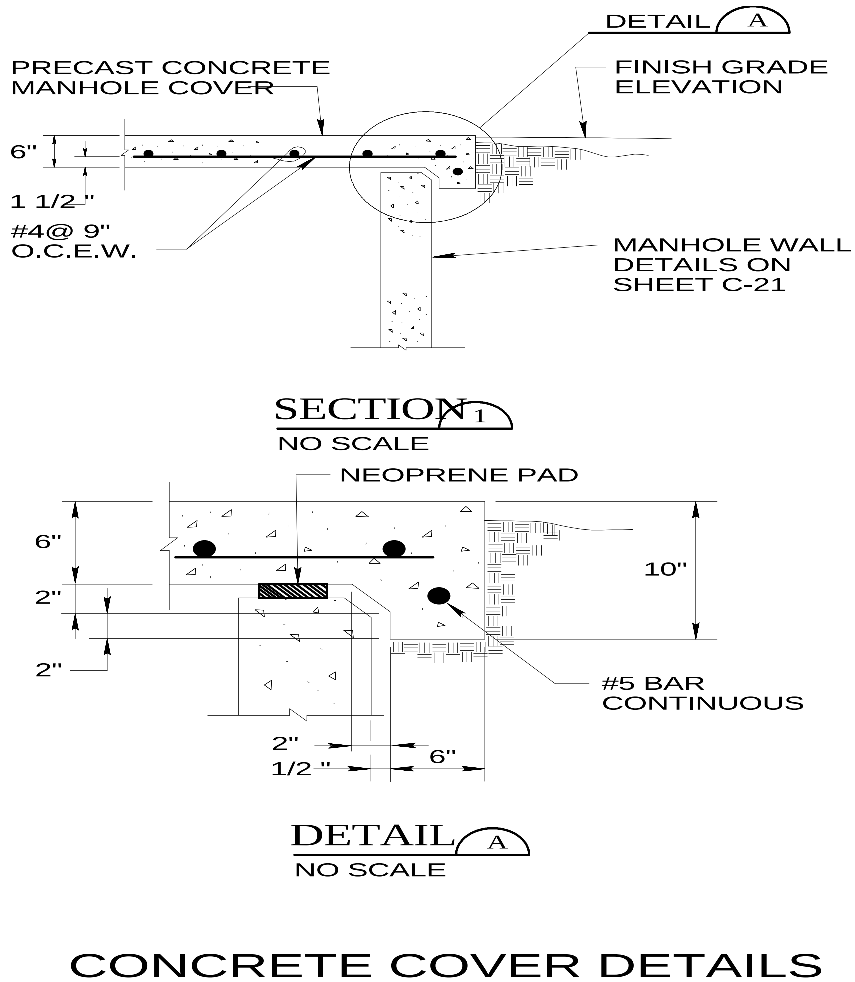


Figure 3-20. Concrete Cover Details.

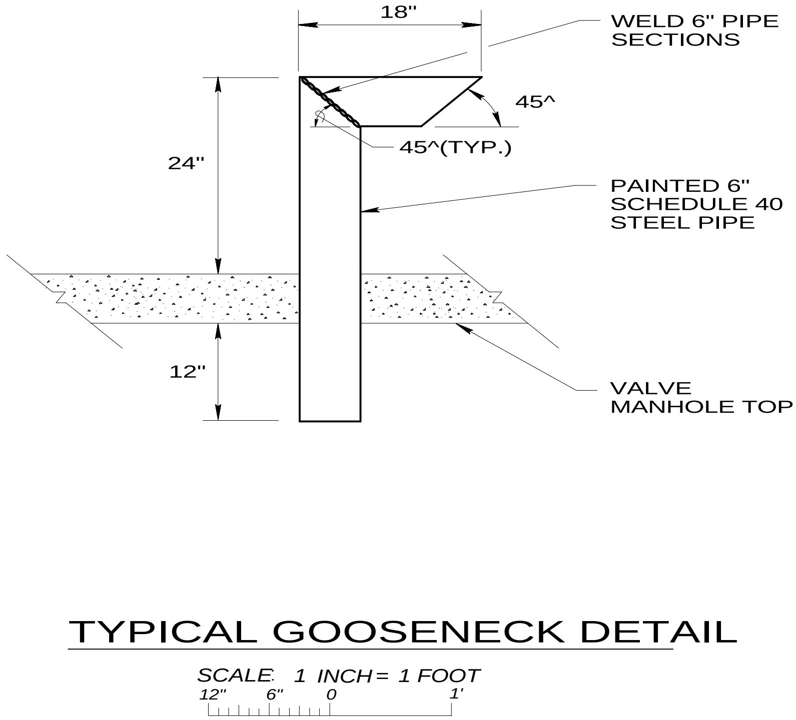


Figure 3-21. Gooseneck Detail.

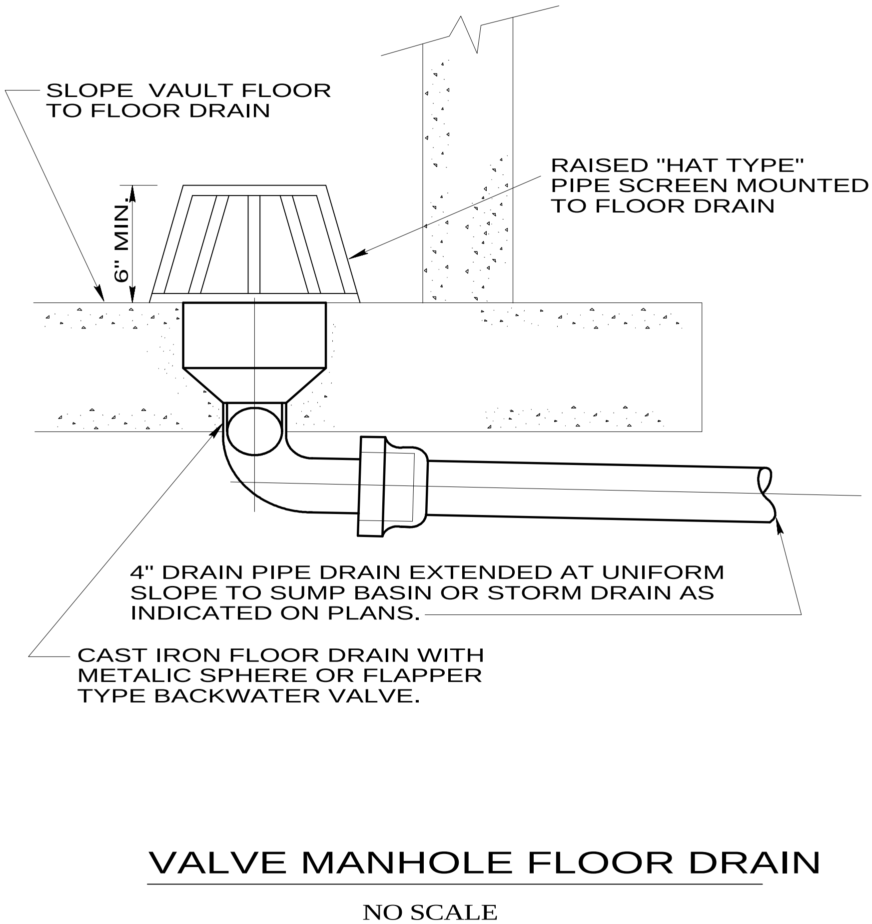
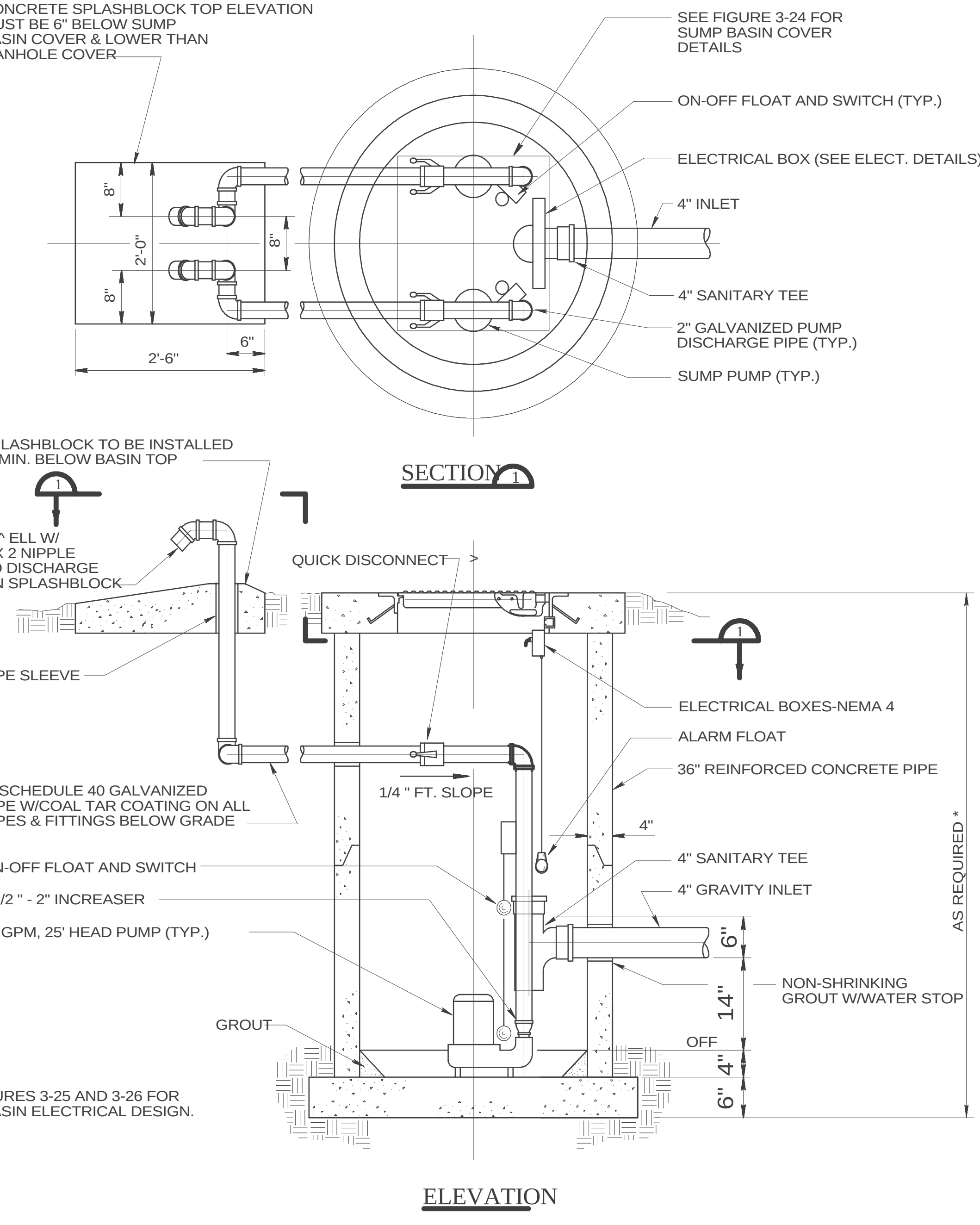


Figure 3-22. Valve Manhole Floor Drain Detail.



NOTES:
SEE FIGURES 3-25 AND 3-26 FOR SUMP BASIN ELECTRICAL DESIGN.

SUMP BASIN WITH DISCHARGE TO GRADE

SCALE: 1 INCH = 1 FOOT

NOTE TO DESIGNER:

DEPTH DEPENDANT ON MAINTAINING 1/8 " / FT. SLOPE FROM VAULT MANHOLE OUTLET TO THE SUMP BASIN. DEPTH WILL BE A MINIMUM OF 4' OR A MINIMUM OF 1' DEEPER THAN DESIGN FROST DEPTH, WHICHEVER IS GREATER.

Figure 3-23. Remote Sump Basin.

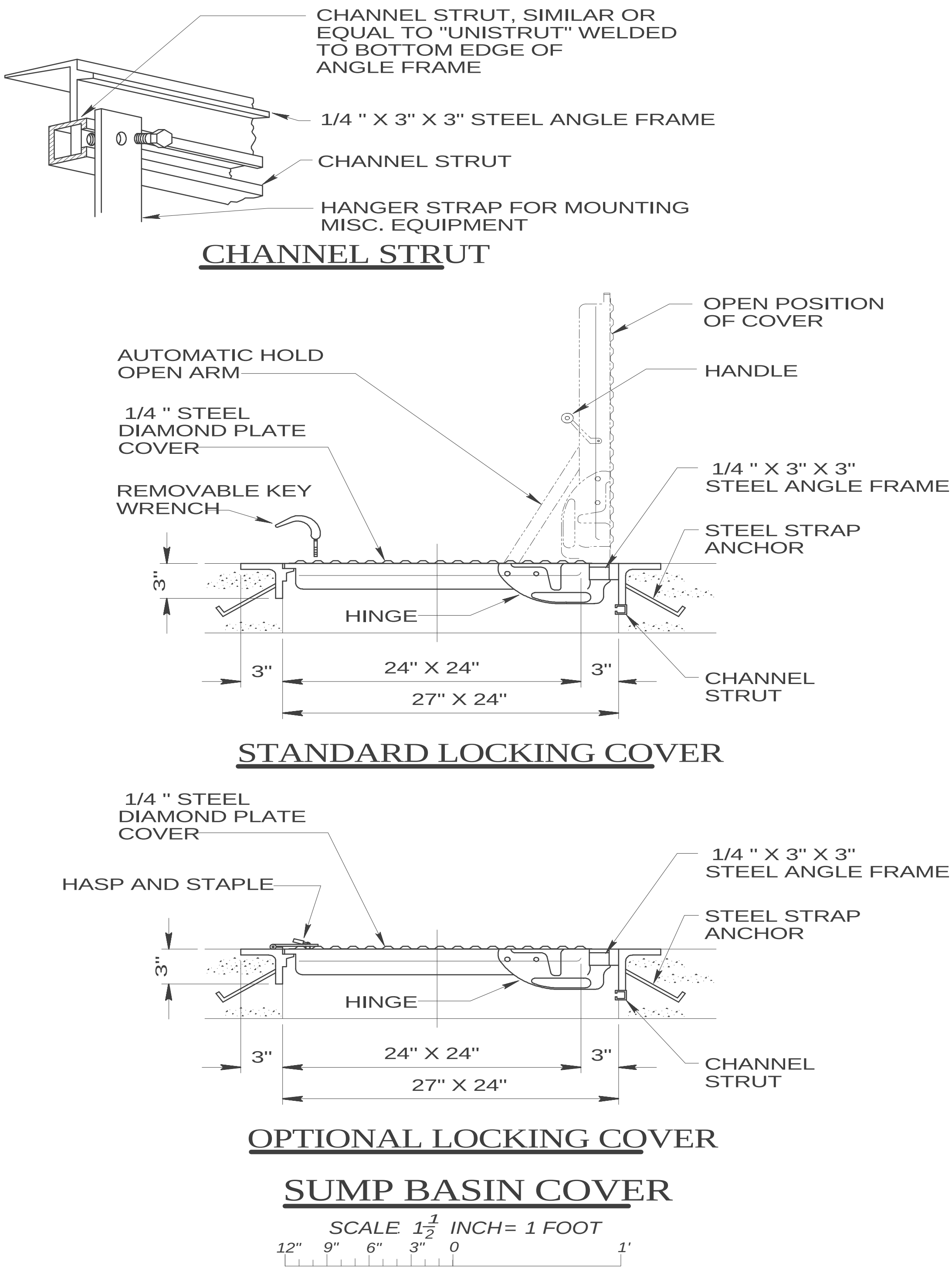
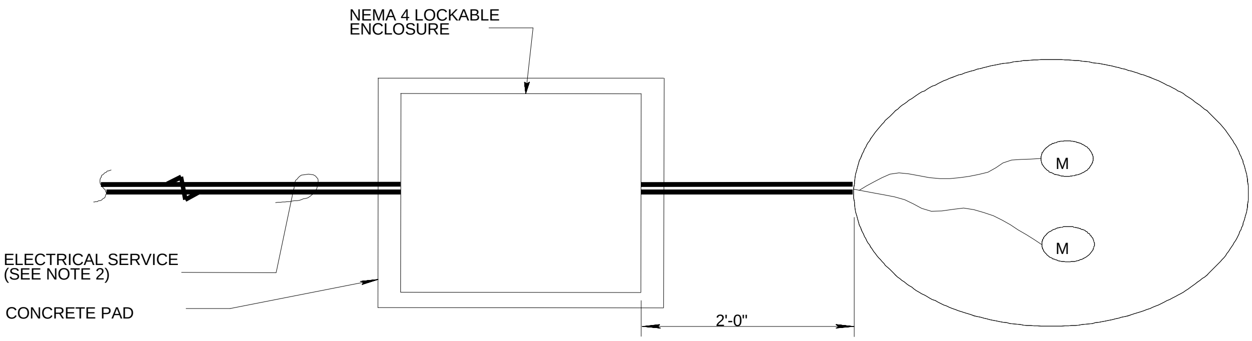
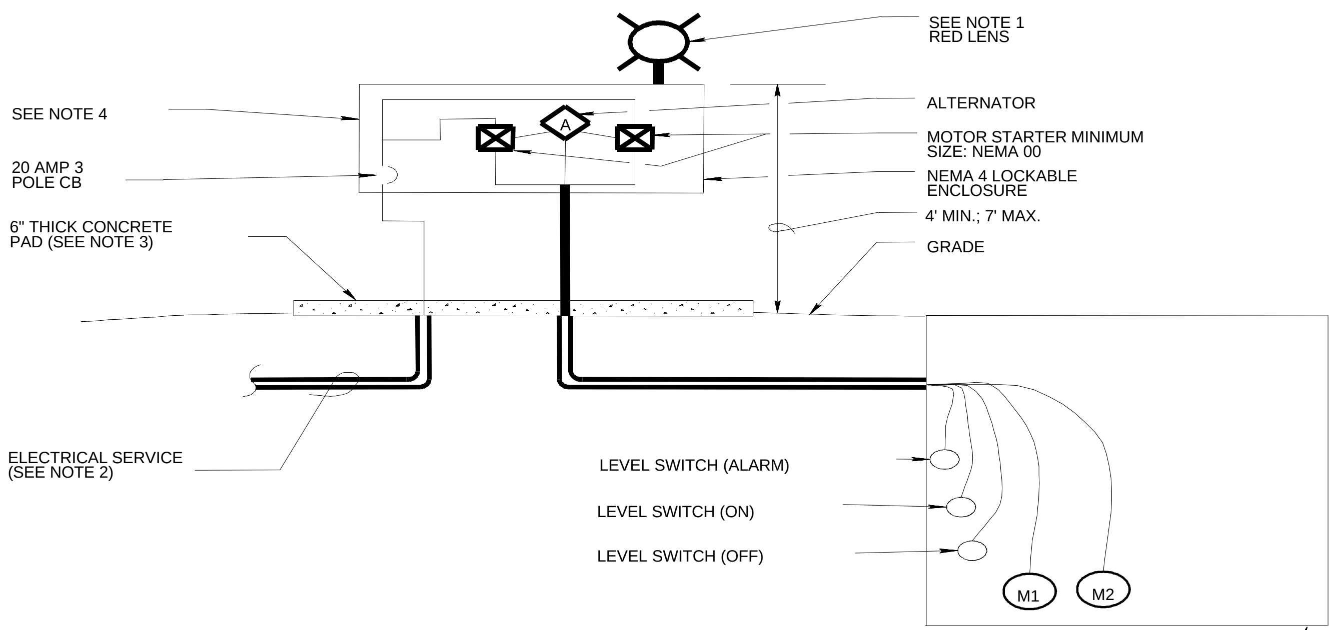


Figure 3-24. Sump Basin Cover Details.



PLAN
NO SCALE

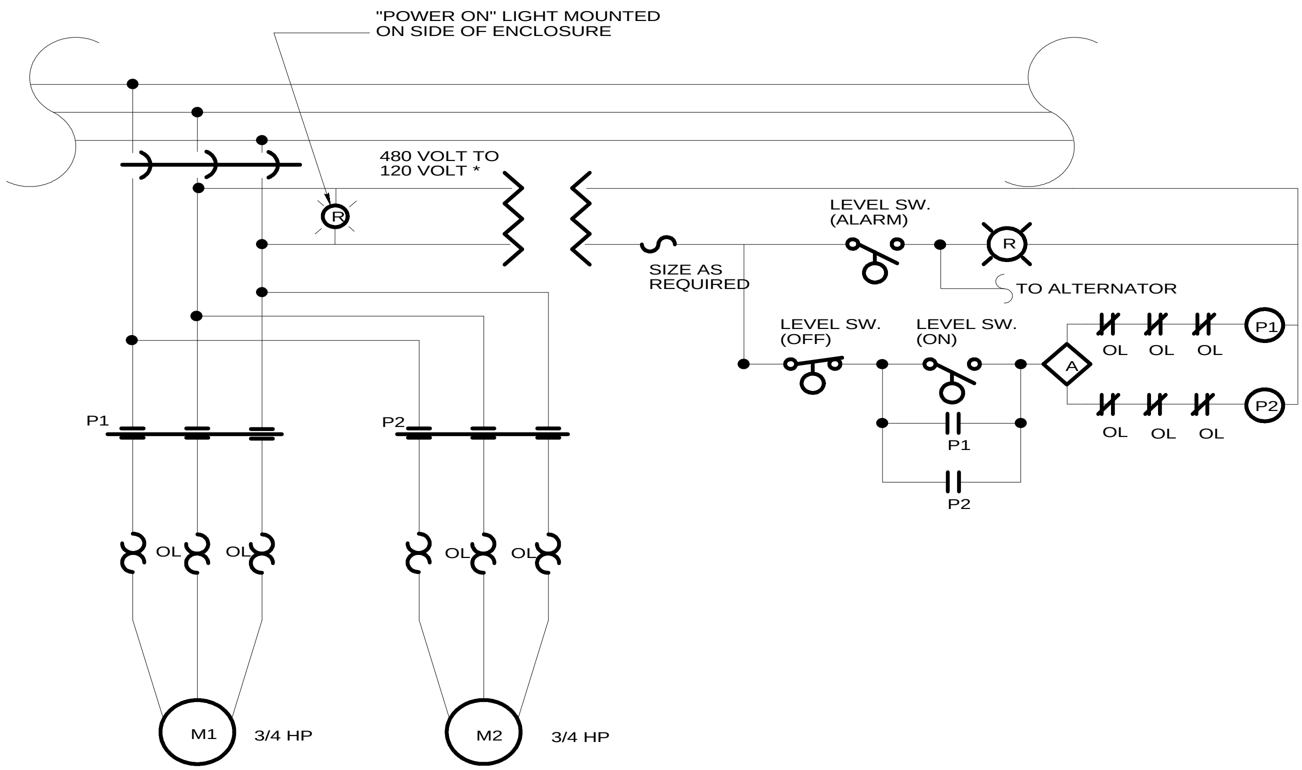


SCHEMATIC
NO SCALE

NOTES:

1. HIGH WATER LEVEL ALARM LIGHT. 120 VOLTS, 75 WATT SEALED BEAM LAMP, 60 FLASHES PER MINUTE. FEDERAL SIGNAL MODEL 27-S OR APPROVED EQUAL. THE LENS SHALL BE RED.
2. ABOVE GROUND CONDUIT FEEDING ENCLOSURE AND ALL PENETRATIONS OF CONCRETE PAD AND SUMP BASIN WALL WILL BE MADE OF RIGID STEEL.
3. CONCRETE PAD SHALL EXTEND BEYOND THE ENCLOSURE AT LEAST 6" ON ALL SIDES.
4. PROVIDE SIGN WITH 2" HIGH, 1/8 " STROKE, YELLOW LETTERS, STATING THE FOLLOWING; "THE CIRCUIT BREAKER MUST BE LEFT IN THE ON POSITION. THIS CIRCUIT PROVIDES POWER TO THE SUMP PUMPS ON THE UNDERGROUND HEAT DISTRIBUTION SYSTEM. FAILURE TO KEEP THIS CIRCUIT ON WILL CAUSE EXTENSIVE AND COSTLY DAMAGE TO THE UNDERGROUND HEAT (STEAM) DISTRIBUTION SYSTEM."

Figure 3-25. Sump Basin Electrical Details.



SEQUENCE OF OPERATION:

THE ALTERNATOR SHALL OPERATE A PUMP UPON WATER LEVEL REACHING LEVEL SWITCH ON AND DEENERGIZE IT WHEN THE WATER LEVEL FALLS BELOW LEVEL SWITCH OFF. IT SHALL ALTERNATE PUMPS ON EACH SUCCESSIVE CLOSING OF LEVEL SWITCH ON. IF THE WATER CONTINUES TO RISE PAST THE ALARM LEVEL, THE RED LIGHT SHALL BE ENERGIZED AND THE LAG (SECOND) PUMP SHALL BE ENERGIZED.

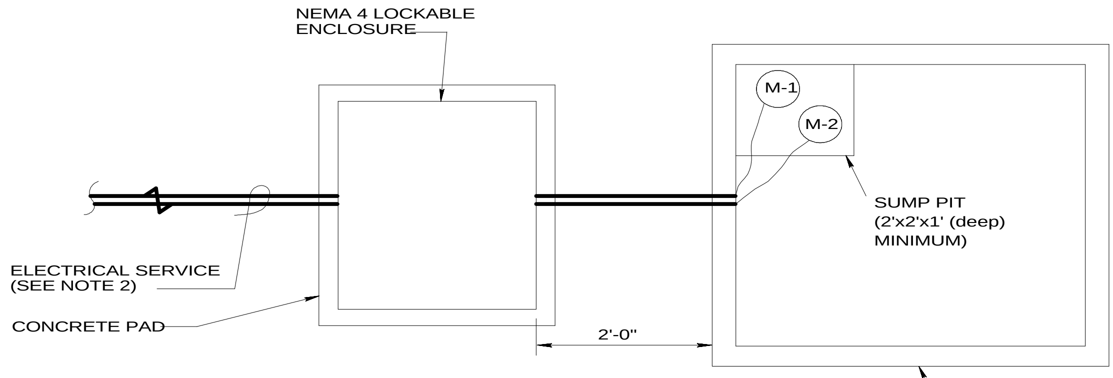
SUMP PUMP CONTROL-3 LINE DIAGRA

NO SCALE

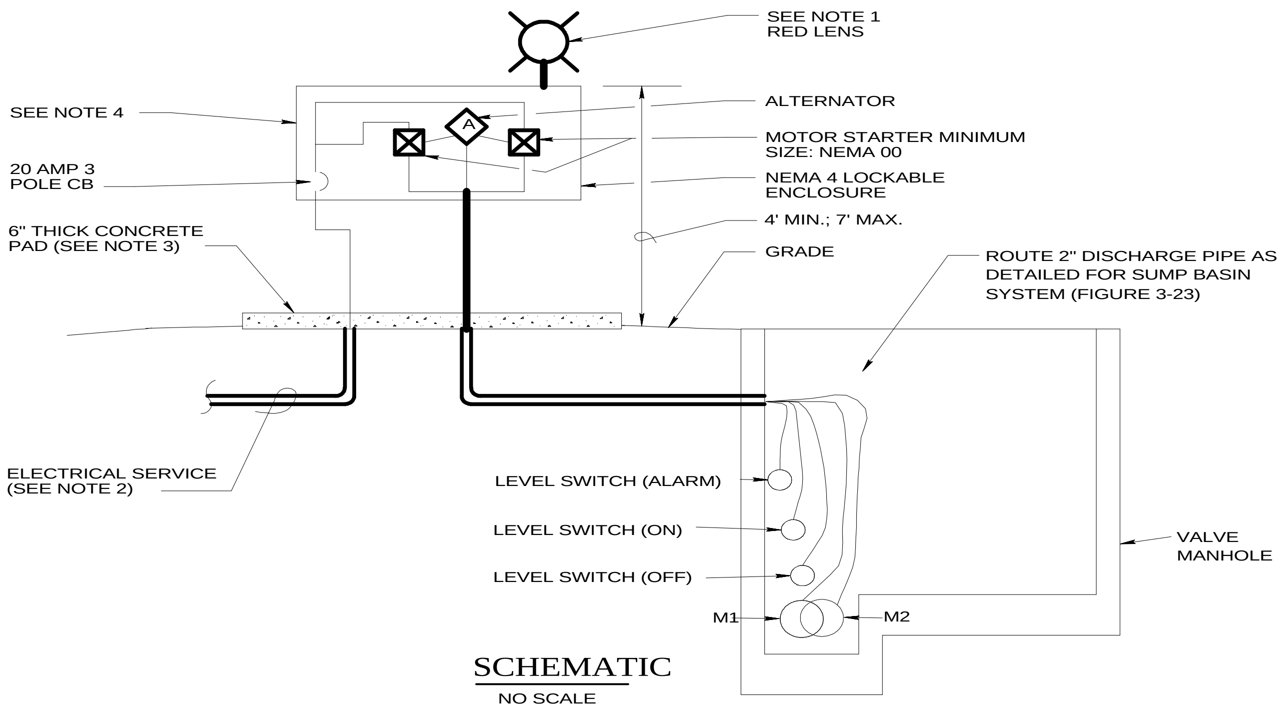
NOTE TO THE DESIGNER:

ACTUAL SYSTEM VOLTAGE AND HORSE POWER REQUIREMENTS MUST BE VERIFIED AND DETAILED FOR EACH DESIGN

Figure 3-26. Sump Pump Wiring Diagram.



PLAN
NO SCALE



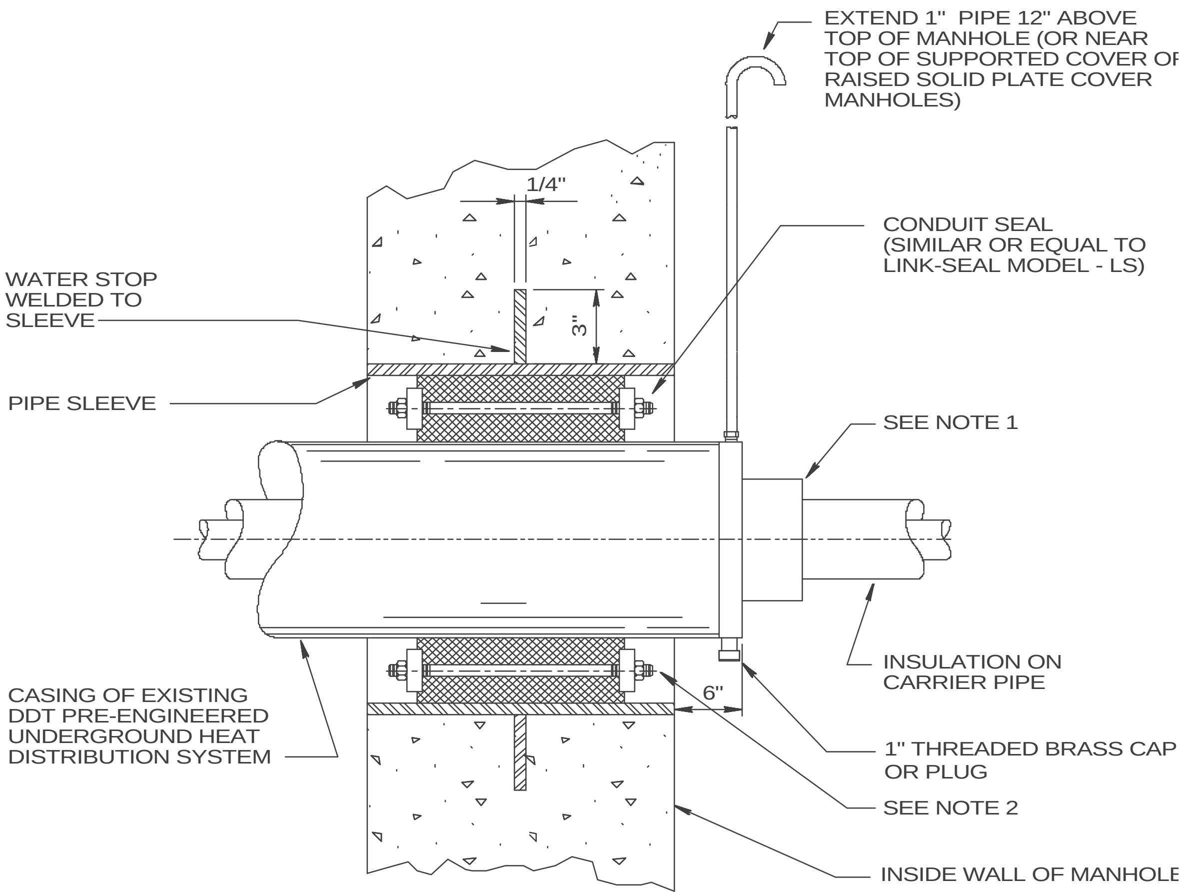
SCHEMATIC
NO SCALE

NOTES:

1. HIGH WATER LEVEL ALARM LIGHT. 120 VOLTS, 75 WATT SEALED BEAM LAMP, 60 FLASHES PER MINUTE. FEDERAL SIGNAL MODEL 27-S OR APPROVED EQUAL. THE LENS SHALL BE RED.
2. ABOVE GROUND CONDUIT FEEDING ENCLOSURE AND ALL PENETRATIONS OF CONCRETE PAD AND VALVE MANHOLE WALL WILL BE MADE OF RIGID STEEL.
3. CONCRETE PAD SHALL EXTEND BEYOND THE ENCLOSURE AT LEAST 6" ON ALL SIDES.
4. PROVIDE SIGN WITH 2" HIGH, 1/8 " STROKE, YELLOW LETTERS, STATING THE FOLLOWING; "THE CIRCUIT BREAKER MUST BE LEFT IN THE ON POSITION. THIS CIRCUIT PROVIDES POWER TO THE SUMP PUMPS ON THE UNDERGROUND HEAT DISTRIBUTION SYSTEM. FAILURE TO KEEP THIS CIRCUIT ON WILL CAUSE EXTENSIVE AND COSTLY DAMAGE TO THE UNDERGROUND HEAT (STEAM) DISTRIBUTION SYSTEM."

VALVE MANHOLE SUMP ELECTRICAL DETAILS

Figure 3-27. Valve Manhole Sump Pump Electrical Details.



NOTES:

1. END SEAL OR GLAND SEAL SHALL BE PROVIDED ON ALL DDT PRE-ENGINEERED BURY SYSTEMS INSIDE MANHOLE WALLS. CASING AIR SPACE SHALL BE PROVIDED WITH DRAIN PLUG AND VENT. VENT SHALL HAVE 1 " PIPE ROUTED AS INDICATED.

2. INSIDE DIAMETER (ID) OF SLEEVE SHALL BE DETERMINED AFTER CASING OUTSIDE DIAMETER (OD) HAS BEEN VERIFIED. GENERALLY, SLEEVE (ID) SHALL BE 5" MORE THAN CASING OD. VERIFY WITH SEAL MANUFACTURER.

CASING WALL PENETRATION

NO SCALE

Figure 3-28. Casing Wall Penetration Detail.

Table 3-1. Valve Manhole Clearances.

RECOMMENDED INTERNAL CLEARANCES					
MINIMUM DISTANCE (INCHES) FROM → TO ↓	O.D. OF PIPE INSULATION OR CONDUIT	END OF VALVE STEM OR BODY	ELEC. EQUIP.	LADDER	BOTTOM OF TRAP STATION OR DRAIN
WALL	18"	18"	-	6"	18"
FLOOR	24"	24"	36"	12"	12"
TOP OF MANHOLE	18"	12"	6"	6"	36"

NOTES:

1. IN ADDITION TO THE CLEARANCES FOR THE LADDER INDICATED PROVIDE 24" AROUND THE LADDER FOR MAINTENANCE ACCESS.

2. PROVIDE 24" AROUND SIDES OF MANHOLE DRAIN TO ALLOW FOR CLEANING OF DEBRIS.

VALVE MANHOLE CLEARANCES

Table 3-2. Reinforcing Steel Sizes.

VALVE MANHOLE REINFORCEMENT SCHEDULE							
MAXIMUM DIMENSION*		WALL REINFORCEMENT		SLAB REINFORCEMENT			
OUTSIDE L1XW1	INSIDE L2XW2	HORIZONTAL	VERTICAL	BOTTOM PRINCIPAL	TOP** PRINCIPAL	BOTTOM SECONDARY	TOP SECONDARY
9'4"X9'4"	8'0"X8'0"	#5@10"	#5@12"	#4@18"	#5@10"	#4@18"	#4@18"
15'4"X15'4"	14'0"X14'0"	#5@6"	#5@10"	#4@18"	#5@10"	#4@18"	#4@18"

NOTES TO THE DESIGNER:

* L1,L2,W1, AND W2 DIMENSIONS FROM FIGURE 3-5. MAXIMUM DEPTH (H1) FOR THIS TABLE IS 8'0"

** PRINCIPAL REINFORCEMENT WILL SPAN THE SHORTER DIMENSION

REINFORCED CONCRETE DESIGN IS BASED ON THE FOLLOWING:

1. LOADS : 200 psf SURCHARGE ADJACENT TO VAULT.
2. SOIL PROPERTIES = MOIST = 120 pcf WATER TABLE 2' BELOW SURFACE
   SATURATED = 125 pcf BEARING CAP. = 1500 psf. MIN.
   Ko = .80

VALVE MANHOLE REIN. STEEL SIZES

Table 3-3. Sump Pump Checklist.

SUMP PUMP CHECKLIST

ITEM	PUMPS' DESCRIPTION
1.	ELECTRICALLY DRIVEN.
2.	DUPLEX SYSTEM WITH ALTERNATOR.
3.	DEDICATED ELECTRICAL SERVICE.
4.	SUBMERGED OPERATION IN 200^F WATER.
5.	ENTIRE PUMPING SYSTEM CAPABLE OF 200,000 CYCLES OF OPERATION IN 200^F, 100% RELATIVE HUMIDITY ENVIR.
6.	PERMANANTLY LUBRICATED BEARINGS.
7.	BRONZE IMPELLER.
8.	MONEL SHAFT.
9.	CAPABLE OF PASSING 3/8 INCH SPHERES.
10.	SCREENED INLET.
11.	BRONZE HOUSING.

CHAPTER 4

HEAT DISTRIBUTION SYSTEMS IN CONCRETE TRENCHES

4-1. GENERAL. The concrete shallow trench (CST) is a system, which allows insulated carrier pipes to be routed underground but yet not have the piping in contact with the soil. The system also provides comparatively easy access for maintenance and repair by means of removable concrete tops. These exposed tops can be used as sidewalks since the system is installed at grade.

4-2. SYSTEM DESIGN. The designer is responsible for conducting a site investigation, designing the distribution system plan and profiles, and designing the valve manholes, as described in chapter 3 of this manual. In addition, the designer will use details and descriptions presented here to design a concrete shallow trench system at a particular site.

a. Trench Systems - General.

(1) Piping and fittings. All carrier piping and pipe fittings will be carbon steel and will be designed to satisfy the temperature and pressure requirements of the system. Materials will conform to the requirements in the guide specification.

(2) Pipe supports. Pipe supports will typically consist of three types: free, guided, and anchor. These supports are detailed in figure 4-1, figure 4-2, and figure 4-3. All of these pipe supports will be mounted on channel supports mounted to the trench walls as detailed in figure 4-4. Supports may be mounted by other means, such as on concrete pedestals, provided that paths for water flow are maintained. Table 4-1 provides guidance for the sizing of the channel supports. Note that the channels for anchor supports in the table are designed for more substantial loads than required for free and guided supports. The anchor support channel in this table is adequate for approximately 1,000 pounds force axially. The designer will determine axial force requirements at all anchor points and design the channels to accommodate these forces. **\1** Maximum distance between support channels shall be as listed in table 4-2. **/1/** These spacings are applicable to long, straight runs of piping only and must be reduced at elbows, vertical risers, valving, and equipment. The actual spacings, in these instances, will be determined by analyzing the pipe stresses with the pipe stress analysis, as described in chapter 3 of this manual. The designer should note that there are other types of supports (such as roller type) that may also be used. However, all supports must be capable of withstanding the thermal stresses and forces exerted on them.

(3) Clearances. Clearances in the trench will be adequate to provide room for expansion, air movement, and a sufficient amount of access for cleaning and maintenance. There must also be a minimum of 4 inches clearance under the support channels to ensure ground water drainage along the trench floor. Figure 4-5 provides a trench cross-section, which corresponds to the table 4-3 trench dimension schedule, which must be filled in by the designer.

(4) Insulation and jacketing. Insulation will be selected in accordance with insulation thickness tables in the guide specification. These insulation thicknesses were developed using a life cycle cost analysis. All insulations used have passed the Federal Agency Committee's boiling test and are listed in the guide specifications. All insulation in the trench will be covered with jacketing material in conformance to the guide specification.

b. Trench System - Structural. The concrete trench will be field constructed of reinforced concrete conforming to the current criteria. Trench walls and floors will be poured in place-they will not be precast. Trench tops will be poured in place or precast. Walls, floors, and tops will be constructed with 4,000 psi minimum compressive strength concrete. Reinforcing bars will conform to ASTM A 615, grade 60. Wall, floor, and top thicknesses shall be 6 inches, minimum. However, thicker sections may be required to accommodate site specific loadings or to prevent flotation. Concrete trench floors shall be sloped at a 1 inch in 20 feet slope toward all low points to ensure proper drainage. Doweled or keyed joints and water stops shall be provided at all construction joints and shall be detailed as shown in figure 4-6. Trench reinforcing details will be provided and will be similar to the section shown in figure 4-7. Note that actual concrete thicknesses and reinforcing bar sizes will be verified by the designer for each project. Trench corners will be constructed as detailed in figure 4-8. Trench tops will be no longer than eight feet to allow easy removal and placement.

c. Trench Top Removal Devices. The most common type of removal devices for the trench tops will be the sling type as detailed in figure 4-9. Four lifting devices are required to lift a trench top. One set of lifting devices will accommodate all trench tops for each contract. In some instances, sling type lifting devices will not be convenient to use (eg. when the trench top butts up against a parallel sidewalk or when the trench is routed through a parking area). In these instances, the designer shall require coil inserts to be cast into the trench cover in four locations that will accommodate threaded lifting eye bolts. When not being used, threaded plugs are inserted into the coil inserts. The lifting devices are also detailed in figure 4-9.

d. Road and Parking Lot Crossings. Road crossing requirements will be designed on a case by case basis and must take into account pavement materials, soils, and frost characteristics of the design site. A typical road crossing is shown in figure 4-10. Figure 4-11 details a concrete trench to curb and gutter system transition and figure 4-12 details a concrete trench to drain pan system transition. In all instances, the crown of the road crossing will be matched and the thickness of the trench top will be designed to accommodate worst case loadings. Parking lot crossings typically will have the trench top exposed at grade as shown in figure 4-13. Exposed tops allow for easier trench top removal over extended lengths of paved areas. If appearance of the crossing is critical, black pigments may be added to the concrete tops at the road crossing to match the surrounding pavement. In rare instances, the trench tops may be covered with asphalt surfacing, as detailed in figure 4-14.

e. Sidewalk Intersections. In the event the trench system intersects an existing sidewalk, the trench system will match the sidewalk as detailed in figure 4-15.

f. Expansion Compensation. Expansion loop and bend design is the responsibility of the designer, and is covered in chapter 3 of this manual. The expansion loop design is critical. Sufficient space needs to be provided in the expansion loop area to ensure that no pipe or insulation interference will occur due to pipe movement as shown in figure 4-16. This detail indicates location of supports and also shows how the piping system will be offset to allow for expansion movement in the trench. Table 4-4 is a typical loop schedule, which corresponds to figure 4-16. The locations of the supports in the expansion loops will be determined from the designer's piping stress analysis and then entered in Table 4-4. All piping stresses will be less than ASME B31.1 allowables for each application. The designer will require inspection ports be provided in the trench tops at each bend in the trench system routing for the purpose of observing pipe movement at the bends during system startup. The inspection port is similar to the access cover detailed in figure 4-18, except the nominal diameter of the lid will be 12 inches.

g. Sealants. The trench will be sealed to minimize the influx of ground water. A 1/4 inch thick neoprene pad will be used between trench tops and tops of trench walls. The pad will have a minimum width of 2 inches. All trench joints must be sealed with elastomeric sealants, which are available as a one or two component system. Asphaltic sealants have not performed as reliably for this application. The elastomeric sealant should be able to resist 50 percent total joint movement. The nonsagging type must be used for vertical joints. The self-leveling type must be used for trench top butt joints as shown in figure 4-17. Other horizontal joints may be sealed with either type of elastomeric sealant, but the sealant used in trench bottoms must finish flush with the floor.

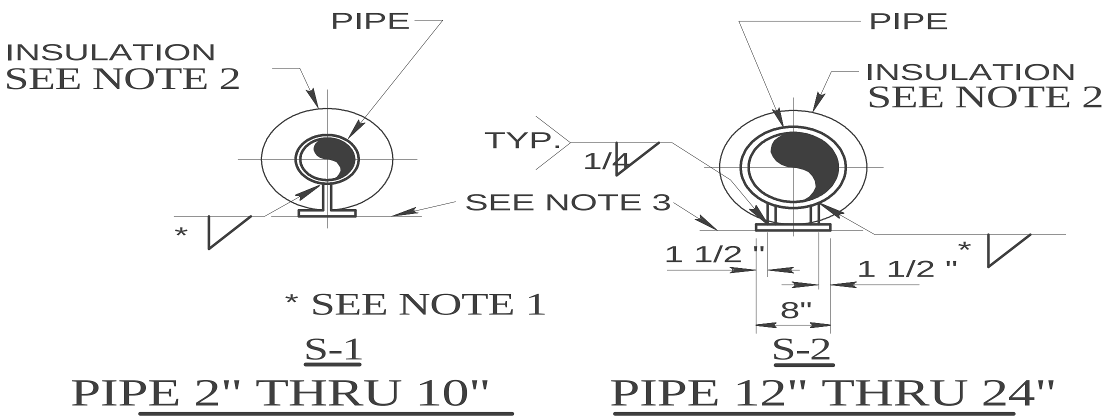
h. Vents and drains. Piping vents and drains will be located at all high and low points, respectively **\1** (see figure 4-19) **/1/**. Piping drains will be provided in valve manholes only where access can be achieved and where system drainage is provided. Piping vents may be located anywhere in the trench piping system with an access cover provided in the trench top, as detailed in figure 4-18 or with an aluminum access door shown in figure 3-19.

4-3. GENERAL CONSIDERATIONS. The designer will address these key areas to ensure a satisfactory shallow trench design.

a. The grading design will ensure ground water will not pond or sit over the trench. The trench will not be routed through existing flood plains, swales, or in areas where seasonal water accumulates. Another distribution system, preferably an Aboveground Heat Distribution System (chap 7), should be used in these areas. In areas where seasonal ground water will cause a trench flotation problem, the design will include a subdrainage system along the trench if thickening of system walls and floor slabs to offset the buoyancy effect is not practical.

b. The trench floors will slope a minimum of 1 inch in 20 feet toward valve manholes and the piping will parallel the trench floor. This will allow the trench to drain off all water that may enter. Drainage will then be provided from the valve manholes as described in chapter 3 of this manual.

c. Valve manholes should be spaced to minimize the depth of the trench system. Additional manholes may be less expensive than excessive trench depths to accommodate the slope while still keeping the trench tops at grade.



HEAT INSULATED PIPING (100^F - 750^F)			
SHOES FOR CARBON STEEL PIPE			
TYPE	MATERIAL		
	STEEL	ASTM	SIZE
S-1	CARBON	A-36	ST 6 X 15.9 X 16" LONG
S-2	CARBON	A-36	1 PLATE 8" X 16" X 1/4 " THK. (HORIZ.)
			2 PLATES 6" X 16" X 1/4 " THK. (VERT.)

NOTES:

1. WELD THICKNESS SHALL BE SAME AS PIPE SHOE OR PIPE WALL THICKNESS, WHICHEVER IS THINNEST.

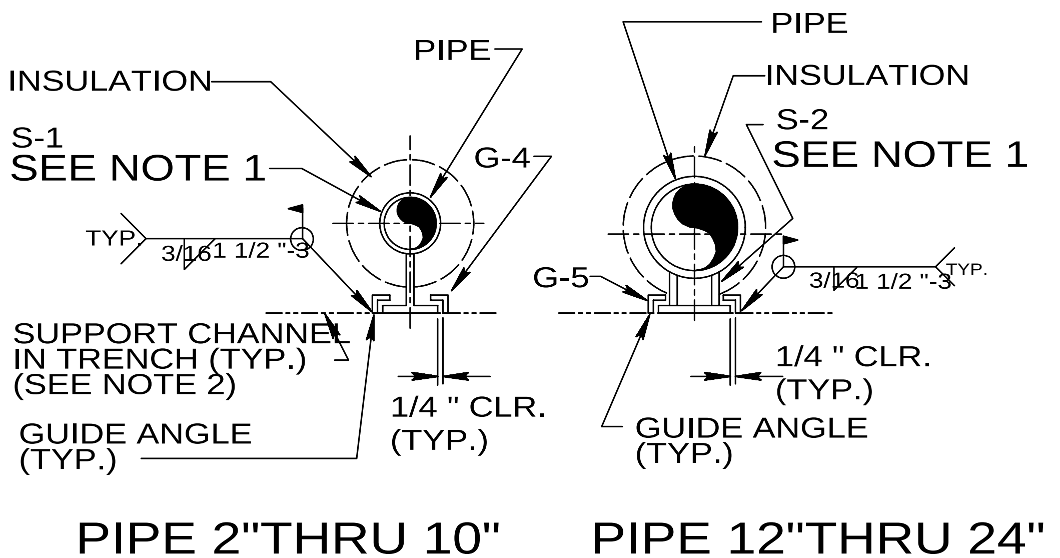
2. WHERE INSULATION IS GREATER THAN SHOE HEIGHT, CUT AWAY INSULATION PARTIALLY WHERE IT INTERFERES WITH PIPE SHOES AND SUPPORTS.

3. SEE TABLE 4-1 FOR CHANNEL SUPPORT SCHEDULE.

FREE PIPE SUPPORT FS

NO SCALE

Figure 4-1. Free Pipe Support Detail.



HEAT INSULATED PIPING			
GUIDES FOR PIPE SHOE			
TYPE	MATERIAL		
	STEEL	ASTM	SIZE
G-4	CARBON	A-36	1" X 1" X 3/16 " ANGLE 16" LONG
G-5	CARBON	A-36	1" X 1" X 3/16 " ANGLE 16" LONG

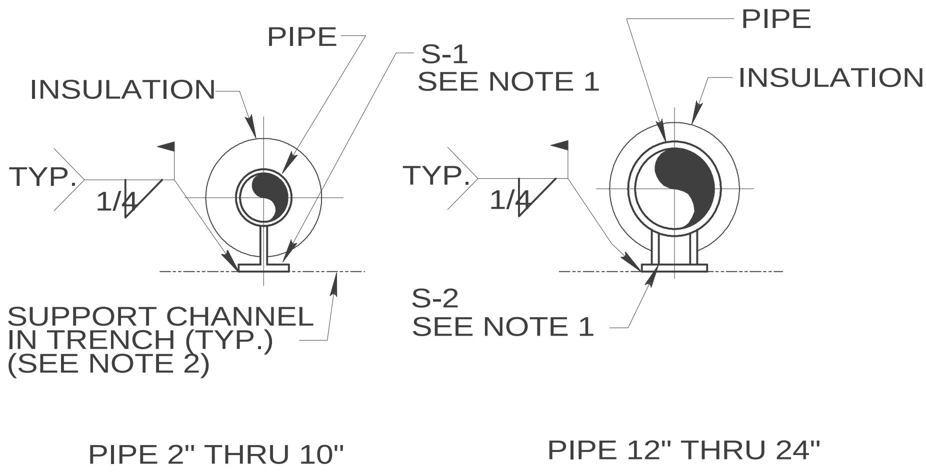
NOTE:

1. FOR PIPE SHOES S-1 AND S-2,
   SEE DETAILS FOR ,(Fig. 4-1)
2. SEE TABLE 4-1 FOR CHANNEL SUPPORT SCHEDULE.

GUIDED PIPE SUPPORT

NO SCALE

Fig. 4-2. Guided Pipe Support Detail.



NOTE:

1. FOR PIPE SHOES S-1 AND S-2
   SEE DETAILS ON FIGURE 4-1.

2. SEE TABLE 4-1 FOR CHANNEL SUPPORT SCHEDULE.

ANCHOR PIPE SUPPORT
NO SCALE
AS

Figure 4-3. Pipe Anchor Detail.

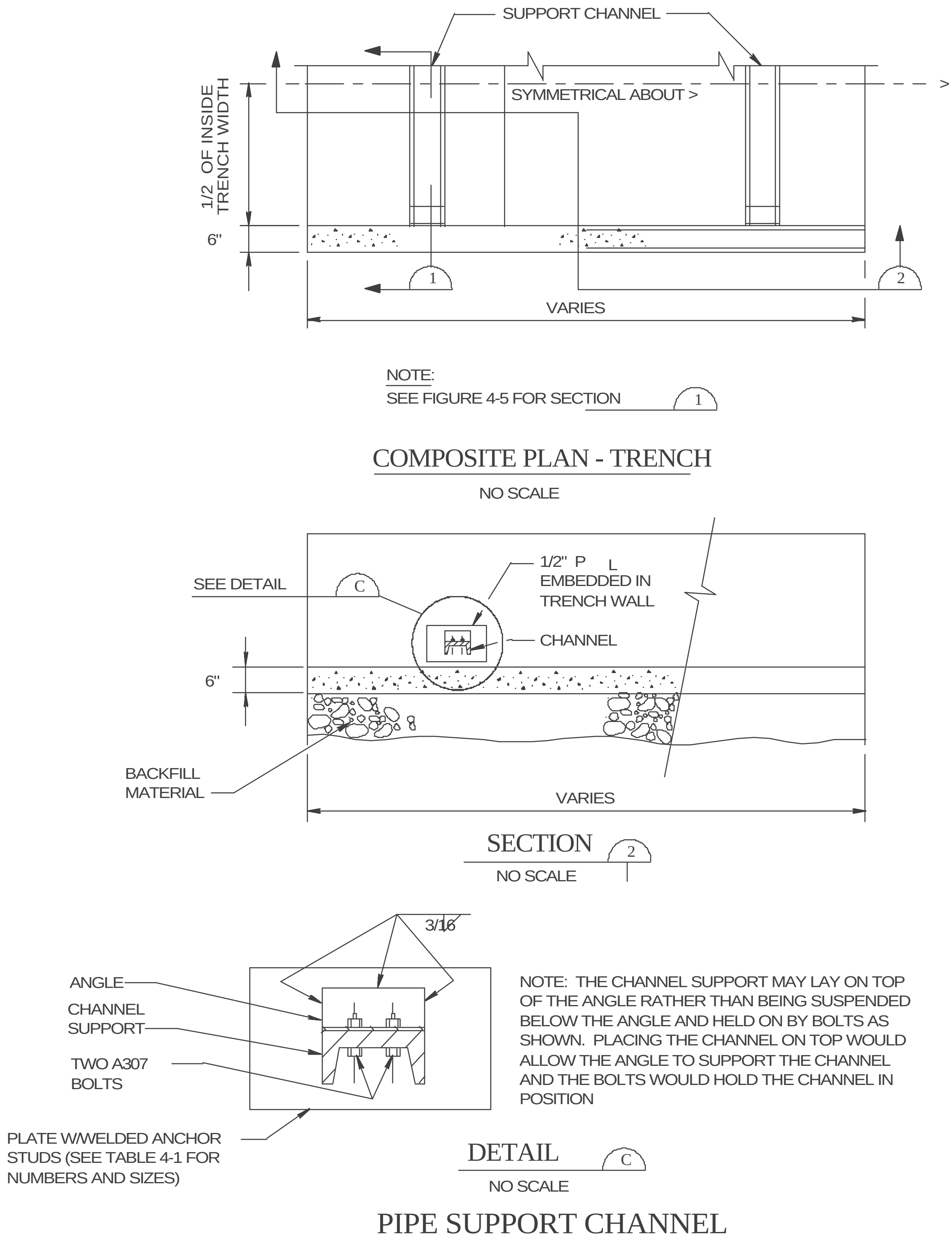
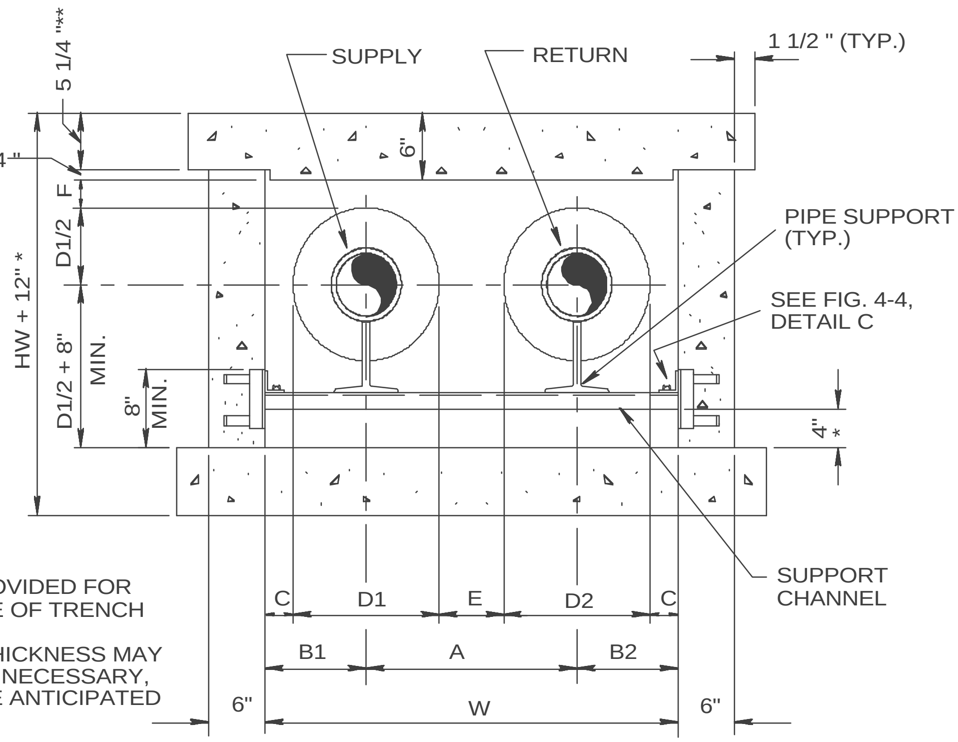


Figure 4-4. Pipe Support Channel.



* 4" CLEARANCE PROVIDED FOR PROPER DRAINAGE OF TRENCH SYSTEM.
** CONCRETE TOP THICKNESS MAY BE INCREASED, AS NECESSARY, TO ACCOMMODATE ANTICIPATED LLOADINGS.

NOTES:

1. DIMENSION "HW" SHALL BE INCREASED AS NECESSARY TO ACCOMADATE THE MINIMUM TRENCH BOTTOM SLOPE OF 1" PER 20 FEET.

2. SEE TABLE 4-3 FOR TRENCH DIMENSION SCHEDULE.

TYPICAL TRENCH & COVER DIMENSIONS

SECTION 1 FROM FIGURE 4-4

NO SCALE

Figure 4-5. Trench Dimension Section.

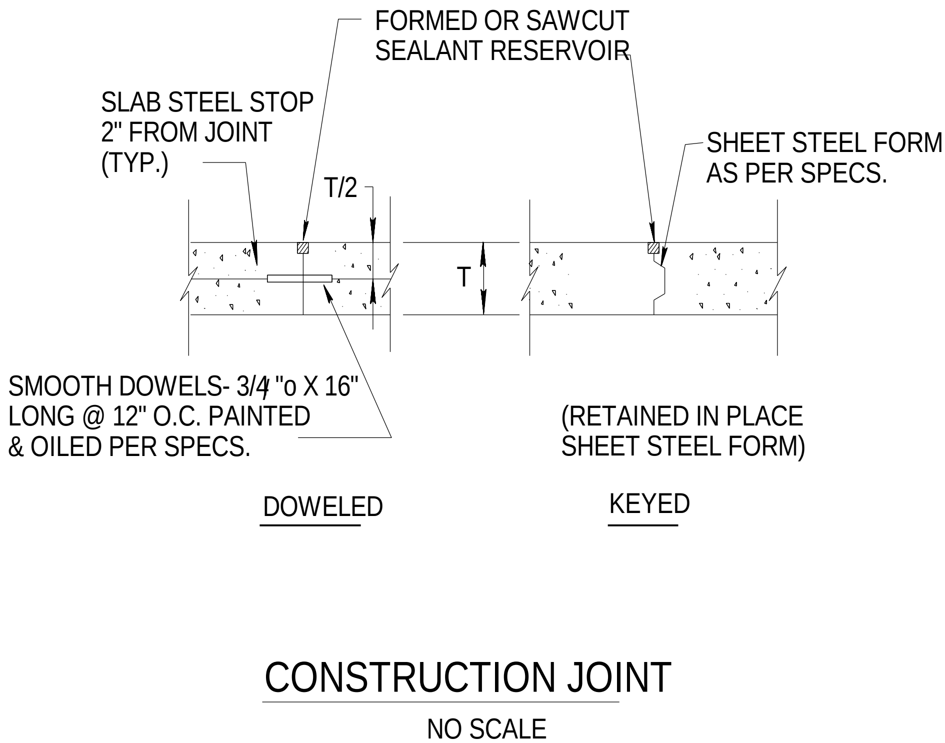
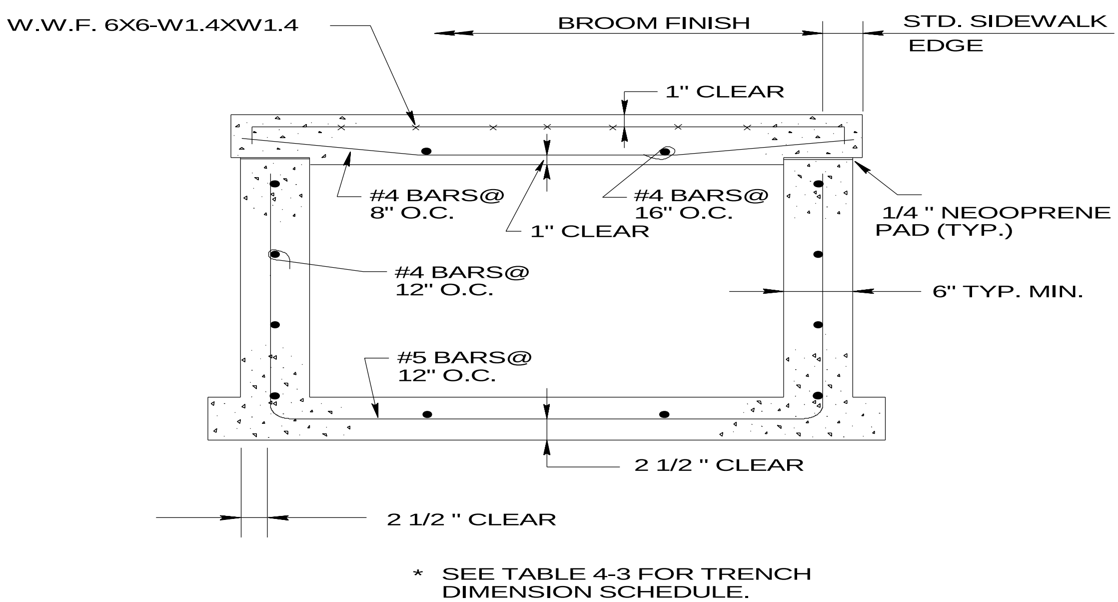


Figure. 4-6. Construction Joint Detail



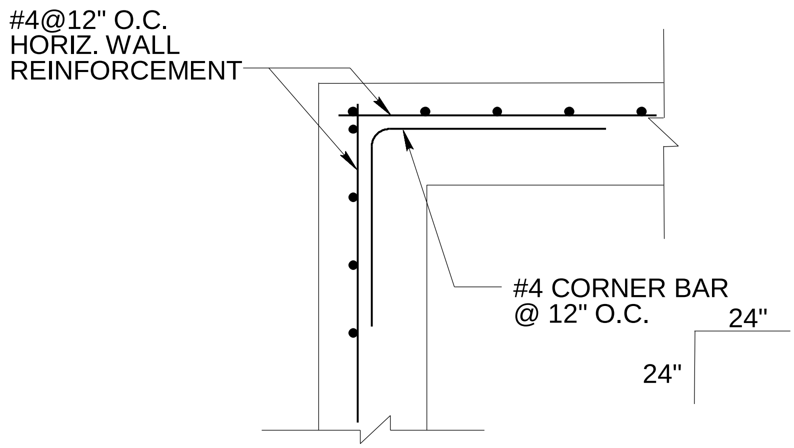
TRENCH & COVER REINFORCING

NO SCALE

NOTE TO THE DESIGNER:

TRENCH REINFORCEMENT AND CONCRETE THICKNESS SHALL DE DETERMINED BY A STRUCTURAL ENGINEER BASED ON SITE SPECIFIC LOADS AND SOIL PROPERTIES. REINFORCEMENT SHOWN IS THE MINIMUM REQUIRED.

Figure 4-7. Typical Trench Section.



TYPICAL TRENCH WALL
CORNER REINFORCING

NO SCALE

Figure 4-8. Trench Corner Detail.

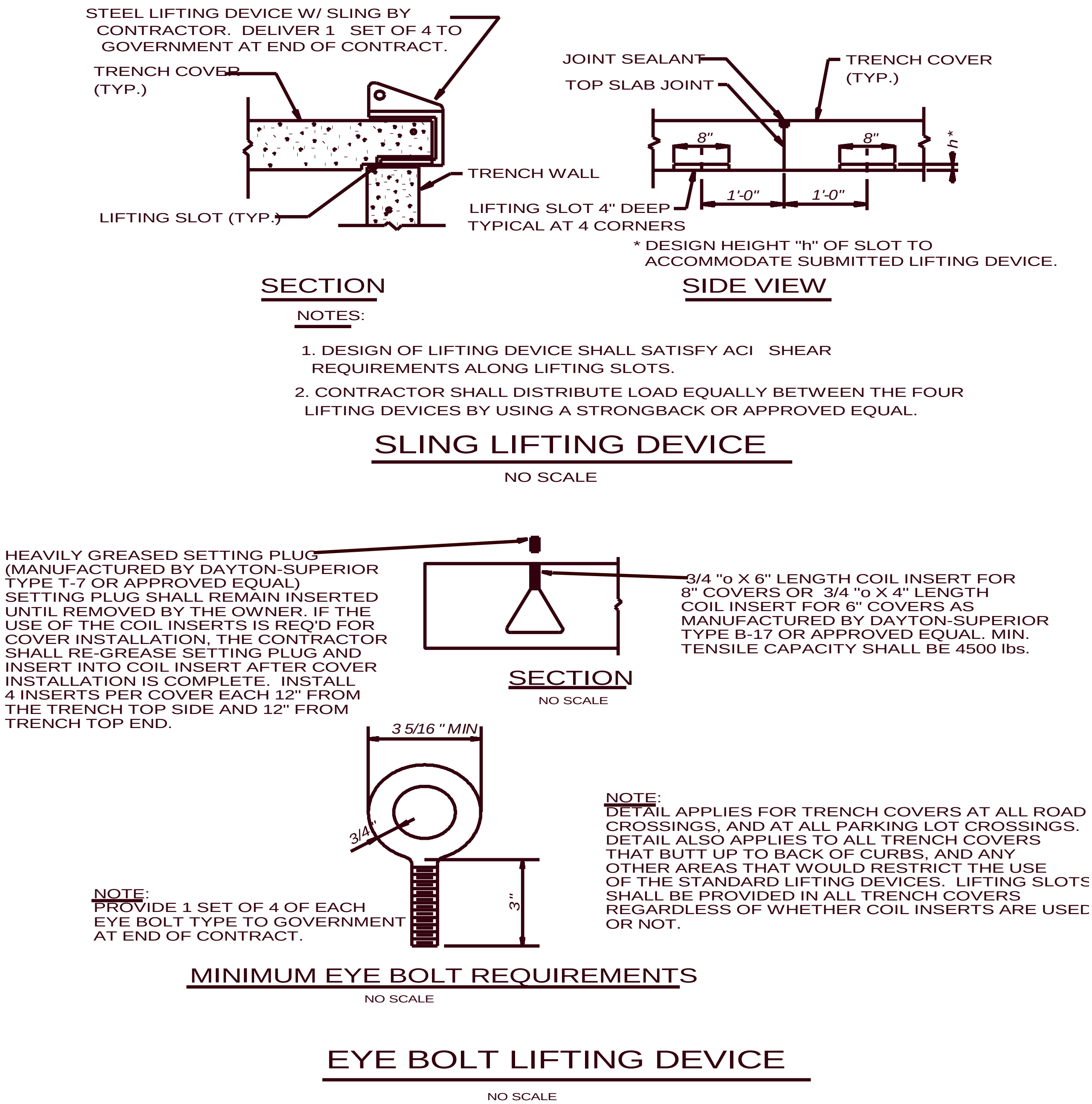


FIGURE 4-9. TYPICAL LIFTING DEVICES.

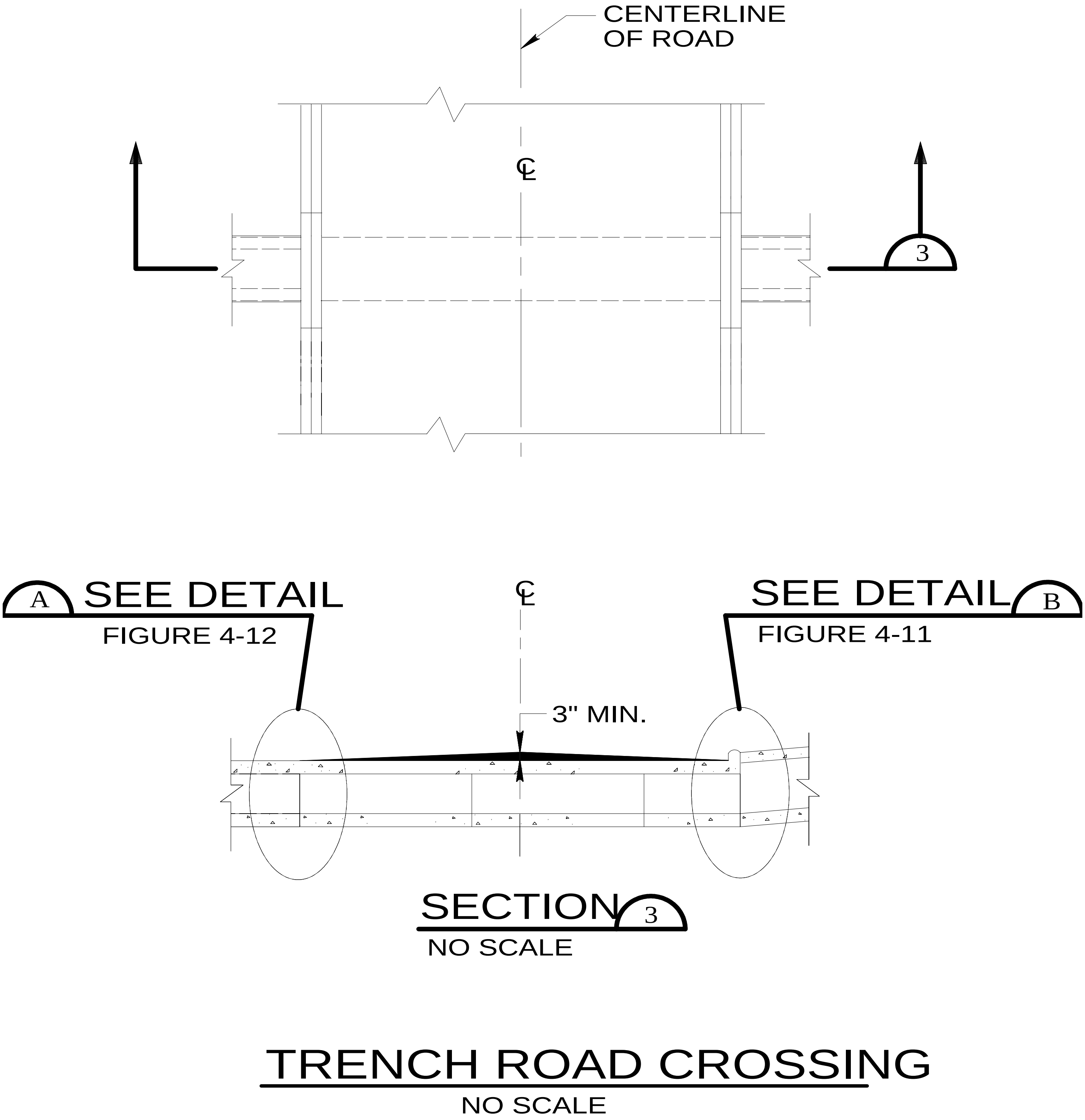
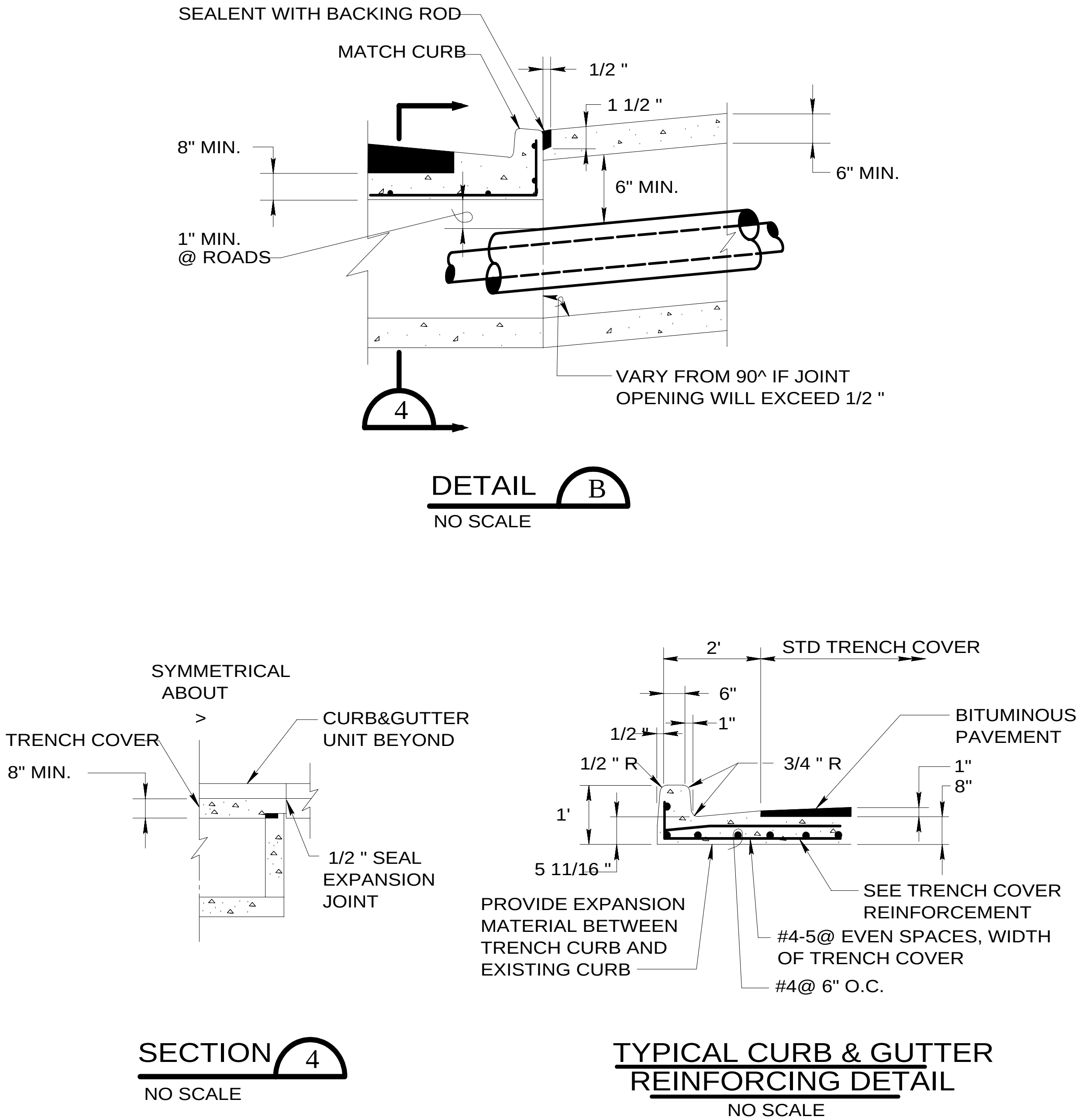


Fig. 4-10. Typical Trench Road Crossing.



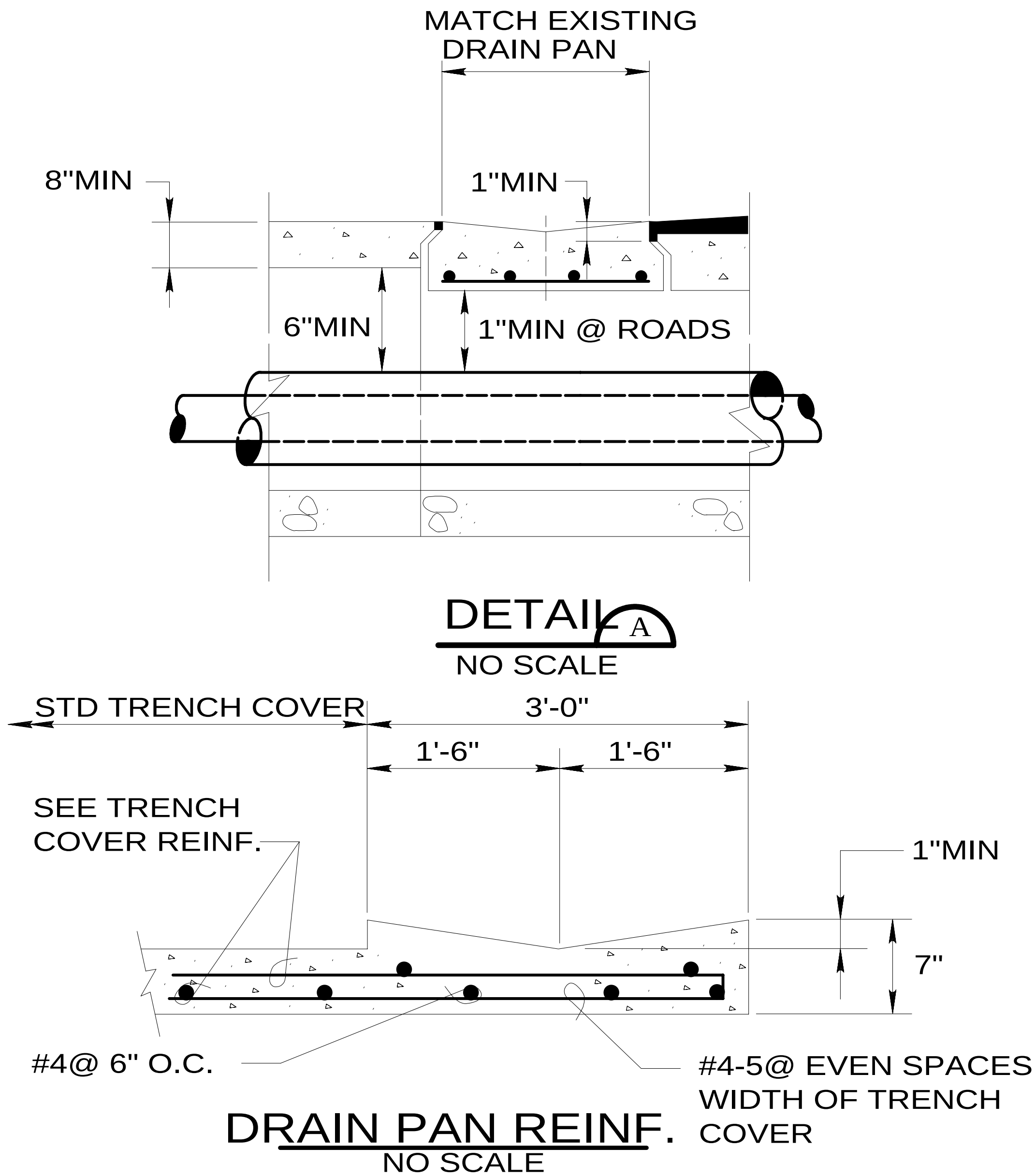
TRENCH CROSSING WITH CURB AND GUTTER

NO SCALE

NOTE TO THE DESIGNER:

TRENCH CONCRETE THICKNESSES AND REINFORCEMENT SHOWN MUST BE VERIFIED FOR EACH DESIGN BY THE DESIGNER.

Fig. 4-11. Trench Crossing with Curb and Gutter.



TRENCH CROSSING WITH DRAIN PAN

NOTE TO THE DESIGNER:

TRENCH CONCRETE THICKNESSES AND REINFORCEMENT SHOWN MUST BE VERIFIED FOR EACH DESIGN BY THE DESIGNER.

Fig. 4-12. Trench Crossing With Drain Pan.

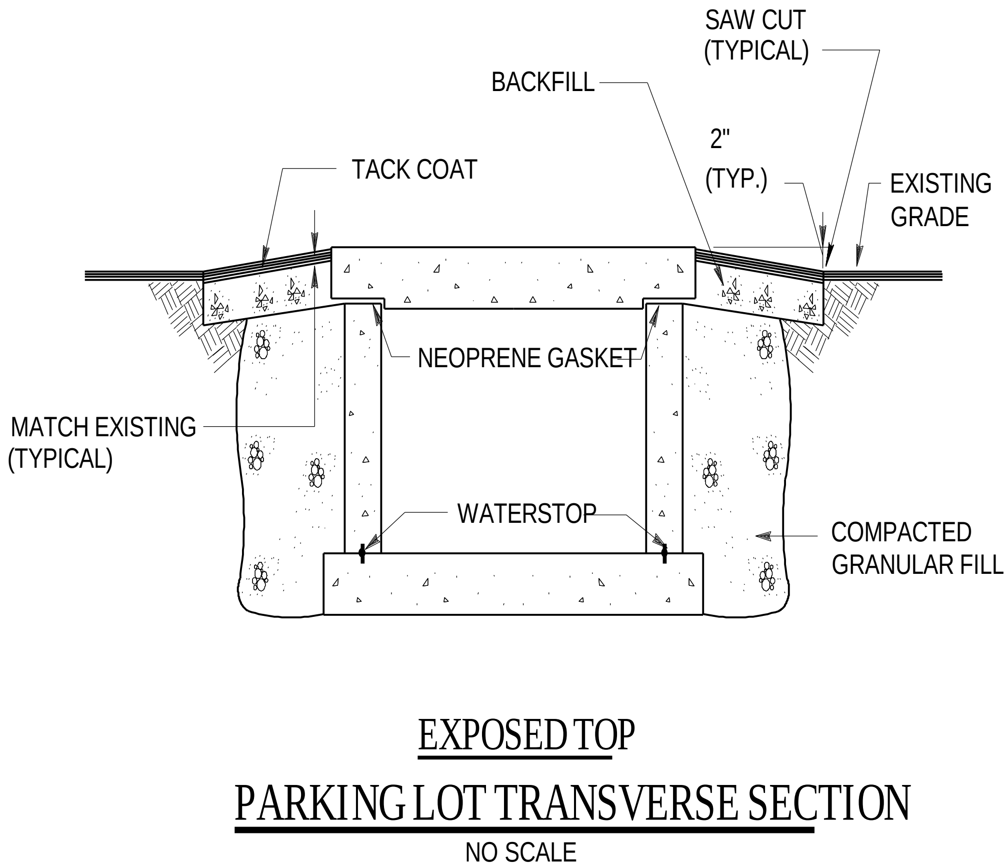


Figure 4-13. Parking Lot Crossing; Exposed Top

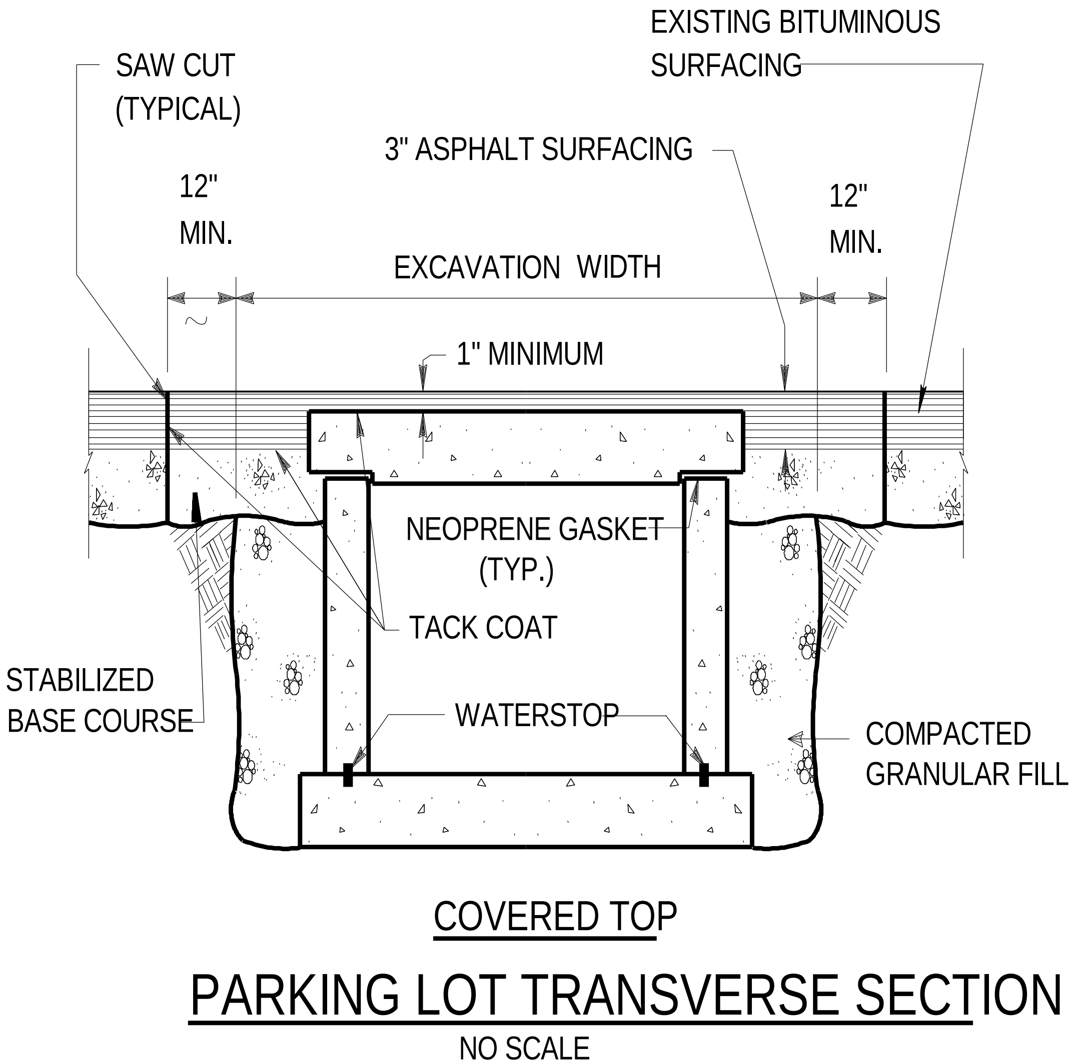
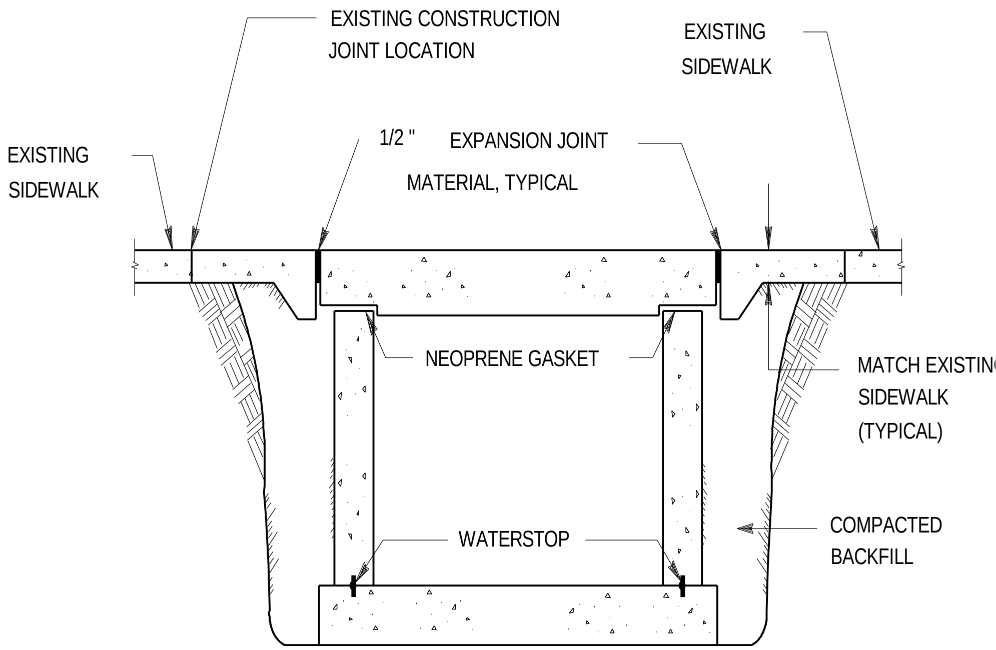


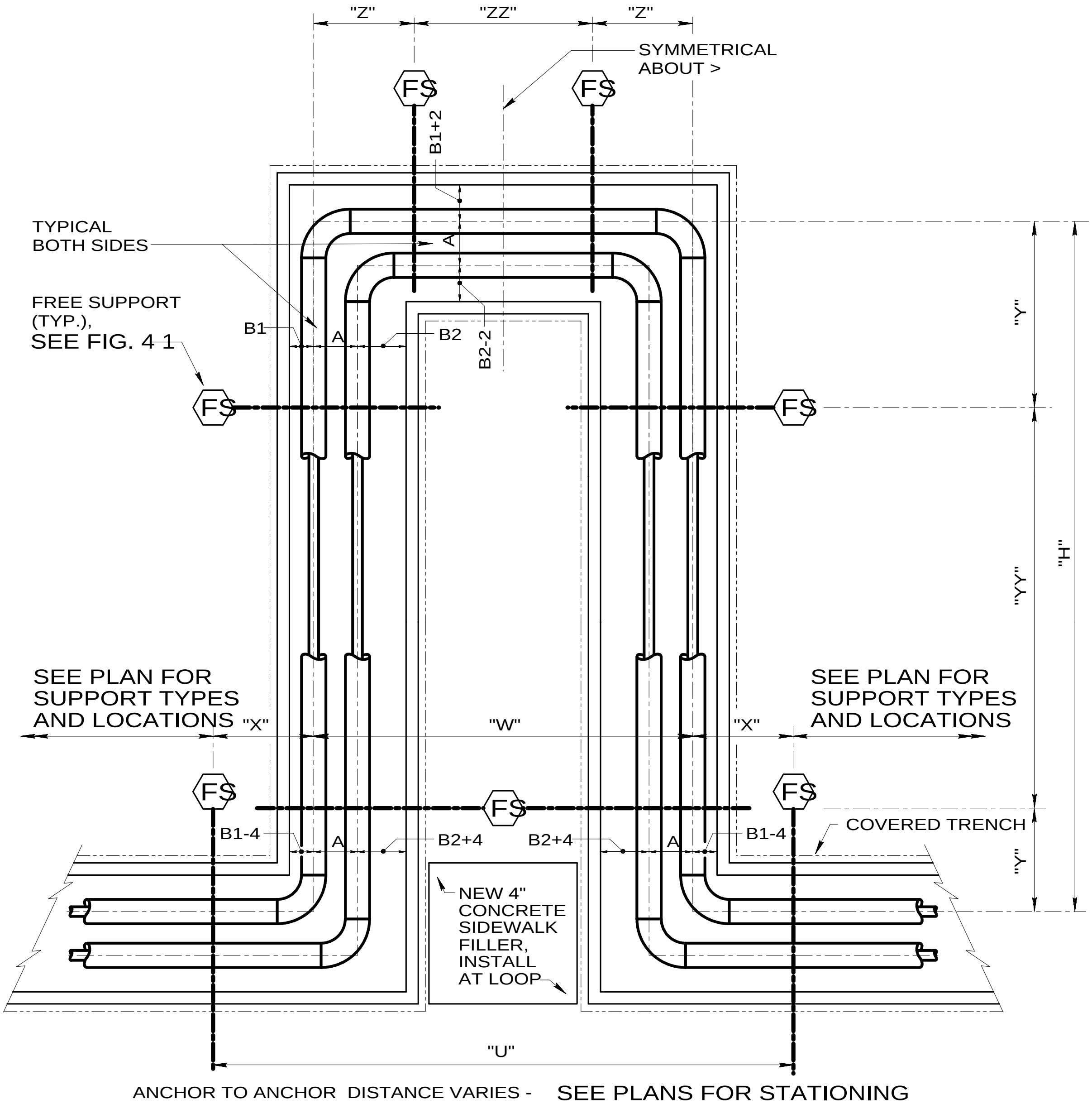
Figure 4-14. Parking Lot Crossing; Covered Top



SIDEWALK TRANSVERSE SECTION

NO SCALE

Figure 4-15. Sidewalk Transverse Section Detail.



NOTES:

1. DIMENSIONS A, B, AND B2 ARE FROM THE "TRENCH DIMENSION SCHEDULE", TABLE 4 3.
2. DIMENSIONS Z,ZZ,Y,YY,W,H,X, AND U ARE FROM THE "EXPANSION LOOP SCHEDULE", TABLE 4-4.

EXPANSION LOOP

NO SCALE

NOTE TO THE DESIGNER:

BETWEEN THE FIRST FS AT THE LOOP AND THE ANCHOR, ALTERNATE FS AND GS (FIGURES 4-2 AND 4-3) TO KEEP PIPING SYSTEM CENTERED IN TRENCH.

Fig. 4-16. Expansion Loop Detail.

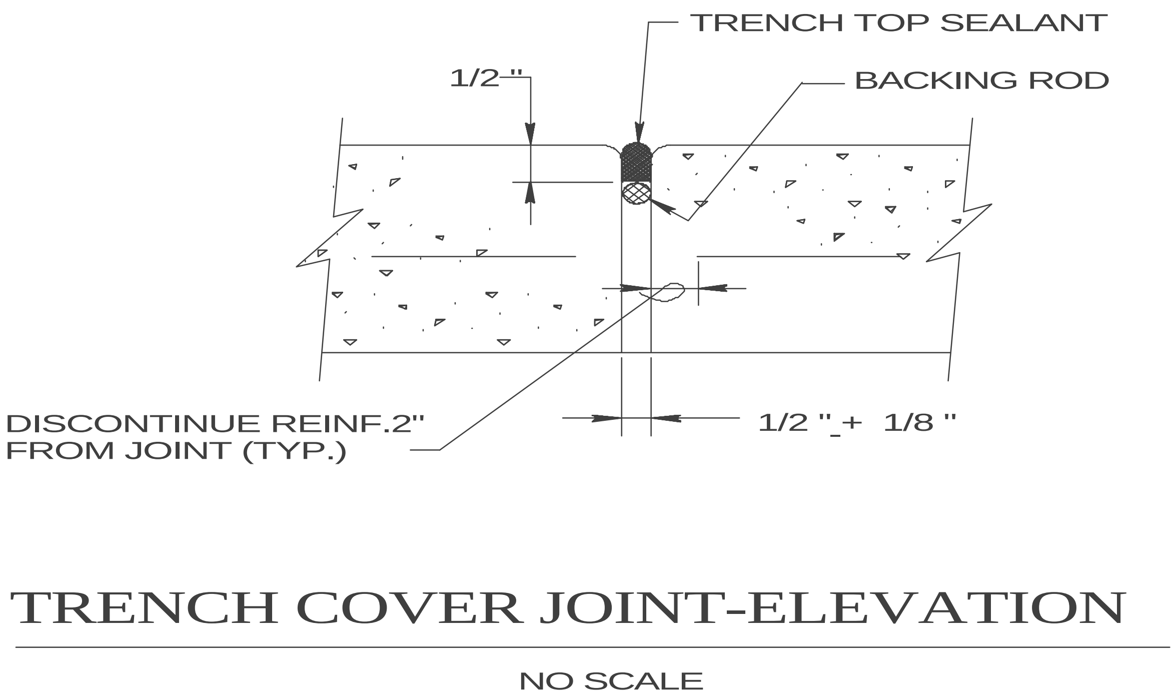
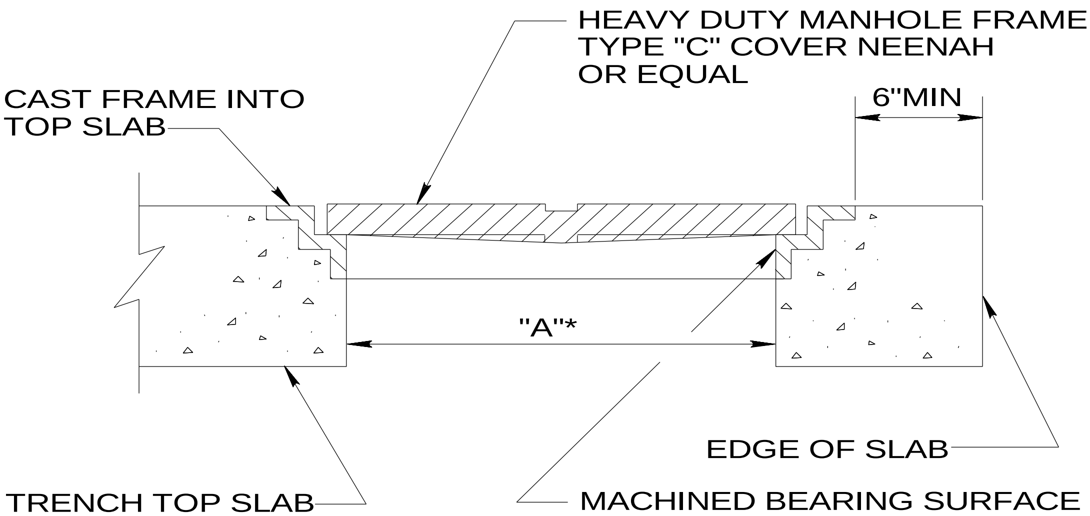


Figure 4-17. Trench Cover Joint Detail.



DIMENSION "A"

24 INCHES FOR VENT ACCESS
12 INCHES FOR INSPECTION PORT
* CENTER MANHOLE ON TRENCH TOP

ACCESS COVER

NO SCALE

Figure 4-18. Access Cover Detail.

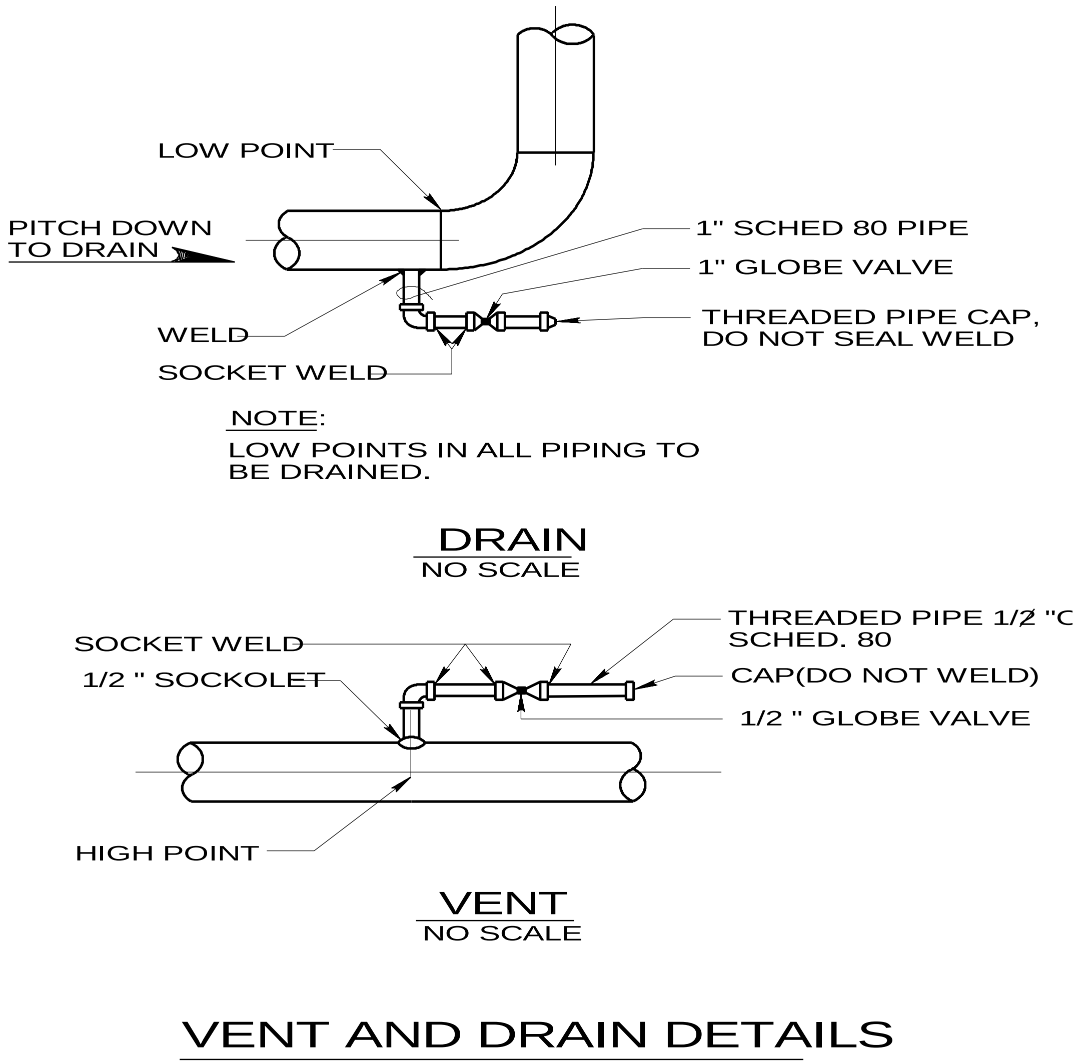


Figure 4-19. Vent and Drain Details.

Table 4-1. Channel Support Schedule *

LOCATION	PLATE	ANCHOR STUDS	ANGLE	CHANNEL	BOLTS
Free and Guided Supports	1/2" x 10" x 10"	4-1/2" x 4"	2" x 2" x 1/4" x 6" long	MC 6" x 15.3"	1/2"
Anchor Supports	3/4" x 10" x 10"	6-5/8" x 4"	2" x 2" x 1/4" x 6" long	MC 8" x 22.4"	3/4"

* Schedule for channel detailed in Figure 4-4.

NOTE TO THE DESIGNER:
Channels exceeding loadings indicated in manual shall be designed for vertical and axial loadings encountered.

Table 4-2. Support spacing schedule

\1\ MAXIMUM HORIZONTAL PIPE SUPPORT SPACING FOR STEEL /1/ DISTRIBUTION PIPING	
PIPE SIZE (INCHES)	SPACING (FEET)
1	7
1-1/4	7
1-1/2	9
2	10
2-1/2	11
3	12
2-1/2	13
4	14
5	16
6	17
8	19
10	22
12	23
14	25
16	27
18	28
20	30
24	32
30	33

NOTES TO THE DESIGNER: These spacings are maximum for horizontal, straight runs. More closely spaced supports must be provided for bends and risers and at equipment.

Table 4-3. Trench dimension schedule.

TRENCH DIMENSION SCHEDULE											
STANDARD TRENCH INTEM NO.	[PIPE SIZES (INCHES)	A	B_1	B_2	C*	D_1	D_2	E*	F MIN.	H_W MIN.	W
					6”		6”				
					6”		6”				
					6”		6”				
					6”		6”				

NOTES TO THE DESIGNER:

1. CLEARANCES BASED ON THE THICKEST INSULATION, IF LESS INSULATION (LOWER “k”) IS PROVIDED. DIMENSIONS C, D, E AND F WILL BE DIFFERENT THAN SCHEDULED. HOWEVER, OVERALL TRENCH DIMENSIONS SHSALL REMAIN THE SAME. C* & E* DIMENSIONS MUST BE MAINTAINED THROUGHOUT ALL STRAIGHT SECTIONS OF TRENCH TO ALLOW PROPER CLEARANCES FOR EXPANSION.

2. SCHEDULE DESIGNATIONS ARE ASSOCIATED WITH TRENCH DIMENSION SECTION, FIGURE 4-5.

Table 4-4. Expansion Loop Schedule*

Loop Name	Line Sizes	X	Y	YY	Z	ZZ	W	H	U	REMARKS

*See Expansion Loop Detail for Designations (Figure 4-16).

NOTE TO THE DESIGNER:
If only one support is required along parallel leg of loop, ZZ =0. If only one support is required along perpendicular legs of loop, YY = 0.

CHAPTER 5

PRE-ENGINEERED UNDERGROUND HEAT DISTRIBUTION SYSTEM

5-1. GENERAL. Unlike Heat Distribution Systems in Concrete Trenches, which are totally designed by the designer, Pre-engineered Underground Heat Distribution Systems are designed by the system manufacturer. These pre-engineered systems are factory fabricated in lengths, which are transported to the site for field assembly. Other types of systems and materials are continuously being evaluated and will be included in guide specifications and this manual when deemed acceptable. There are two types of these systems. The DDT type is allowed for severe, bad and moderate site conditions. In severe sites allow only drainable-dryable-testable type systems. In bad and moderate sites allow DDT and water spread limiting systems. These **\1** site **/1/** conditions (or classifications) are described in detail in the guide specifications. Although the manufacturer is responsible for the pre-engineered system design, the project designer also has design responsibilities which include establishing the site, soil, and groundwater conditions, pipe sizes, proposed routing (including construction limits) estimated length, elevations, profiles of the system along with existing and finished earth surfaces and obstructions **\1** within **/1/** 8m (25 feet) of the system centerline including adjacent or crossing utilities. The project designer also provides information on location and design of manholes and entrances to buildings and manholes.

5-2. MANUFACTURER'S RESPONSIBILITY.

a. Pre-engineered Underground Heat Distribution System design. The manufacturer is responsible for the Pre-engineered Underground Heat Distribution System. This responsibility includes any or all of the following: insulation types, guided and anchor supports, end seals, casing and piping joint closure, casing type and thickness, and carrier pipe depending on the type of Pre-engineered Underground Heat Distribution System provided. There are two types of Pre-Engineered Underground Heat Distribution Systems. The drainable-dryable-testable system is a factory fabricated system, which includes a water-tight outer protective casing of steel, an air space, and an insulated carrier steel pipe. Casing drains and vents are provided in end plates, which are installed in valve manholes. DDT systems can be used for any heating medium including HTHW, high and low pressure steam, and condensate return and in any site condition (severe, bad or moderate). The water spread limiting systems is also a factory fabricated system, which includes an outer protective casing and an insulated carrier pipe. The system is fabricated in sections, which are independent from each other. Ground water or condensate, which leaks from or into one section, cannot travel into the next section. Field-assembly of the sections requires no welding; the sections are pushed together and are sealed with a system of couplings and seals. WSL systems can be used only in bad and moderate site conditions. The designer must determine the site conditions before a system type is selected. The site conditions will be considered severe, bad or moderate based on the site investigation results. For DDT and WSL systems, steam and condensate lines must always be installed in separate casings, as shown for a DDT system in figure 5-1, due to the corrosion problems associated with condensate return systems. Water systems may use just one casing for both supply and return pipes as detailed for a DDT system in figure 5-2, although installing the pipes in separate casings is preferred by most users because it is less difficult to isolate leaks. The tops of the casings will typically be buried between 2 and 6 feet below grade. However, note that excessive burial depths increase the installation and repair costs and should be avoided where possible.

b. Expansion compensation. The manufacturer is responsible for the system expansion compensation. A detailed stress analysis will be submitted for review as part of the contract requirements. The manufacturer will normally make use of expansion loops and bends to absorb system expansion in DDT systems. For WSL systems, field joints may be used to accommodate expansion. Except in rare instances, expansion joints will not be permitted.

c. Pre-engineered system's representative. The manufacturer is required to ensure that a qualified direct employee of the system manufacturer is present to guarantee proper installation when the following types of work are performed:

(1) inspection, unloading and storage of materials.

(2) inspection of trench prior to laying of casing.

(3) inspection of concrete thrust blocks.

(4) hydrostatic test of all service lines.

(5) field joint closure work.

(6) air test of casing.

(7) coating patch work.

(8) holiday test of casing coating.

(9) initial backfill up to 10 inches above the top of the casing.

(10) radiographic weld examination.

(11) startup and operation tests.

5-3. PROJECT DESIGNER'S RESPONSIBILITY.

a. Site information. As with all buried distribution systems, the site investigation is the responsibility of the designer. As described in chapter 3 of this manual, the designer will obtain soil borings, be responsible for designing the grading in the area, investigate all utilities for possible conflicts, and design for utility relocation as necessary. The designer must then determine the site conditions (severe, bad, or moderate) before a system type (DDT or WSL) is selected. The designer will then provide plans and profiles of the Pre-engineered system routing. The designer will show approximate slope of the system (1 inch in 20 feet is required to ensure drainage). This slope must be maintained in the entire system including through each leg of each expansion loop to ensure proper system drainage.

b. Valve manholes. The designer will design all valve manholes for the system as described in chapter 3 of this manual. The manholes will be no further apart than 500 feet to minimize excavation if a leak in the system must be found. The manholes will also be provided at all high (vent) points and low (drain) points in the system. The valve manholes will include ground water drainage capabilities as explained in chapter 3. Casing vents and drains will be included for maintenance of the casing air space in DDT systems as shown in figure 5-3.

c. Insulation. The insulation types used on the Pre-engineered Underground system will only be those that are listed in the guide specification. The insulation thickness tables in the guide specification will be used in determining required insulation thickness. These insulation thicknesses were developed using life cycle cost analyses.

d. Cathodic protection. The designer will be responsible for the cathodic protection design for all systems with coated steel casings. The designer shall also require that dielectric flanges be provided to isolate the system's cathodic protection system from non protected systems. These dielectric flanges shall always be installed inside valve manholes.

e. Review. The designer will provide a detailed review of the manufacturer's shop drawings to ensure the system meets the requirements of the contract. As a minimum, the following items are required in this review process:

(1) carrier pipe size and thickness.

(2) insulation thickness, type and K-value.

(3) casing material and thickness.

(4) casing coating material and thickness.

(5) verification of constant system slope to all low points (proposed elevations at all casing joints on submitted shop drawing layouts).

(6) cathodic protection design.

(7) manufacturer's system stress analysis.

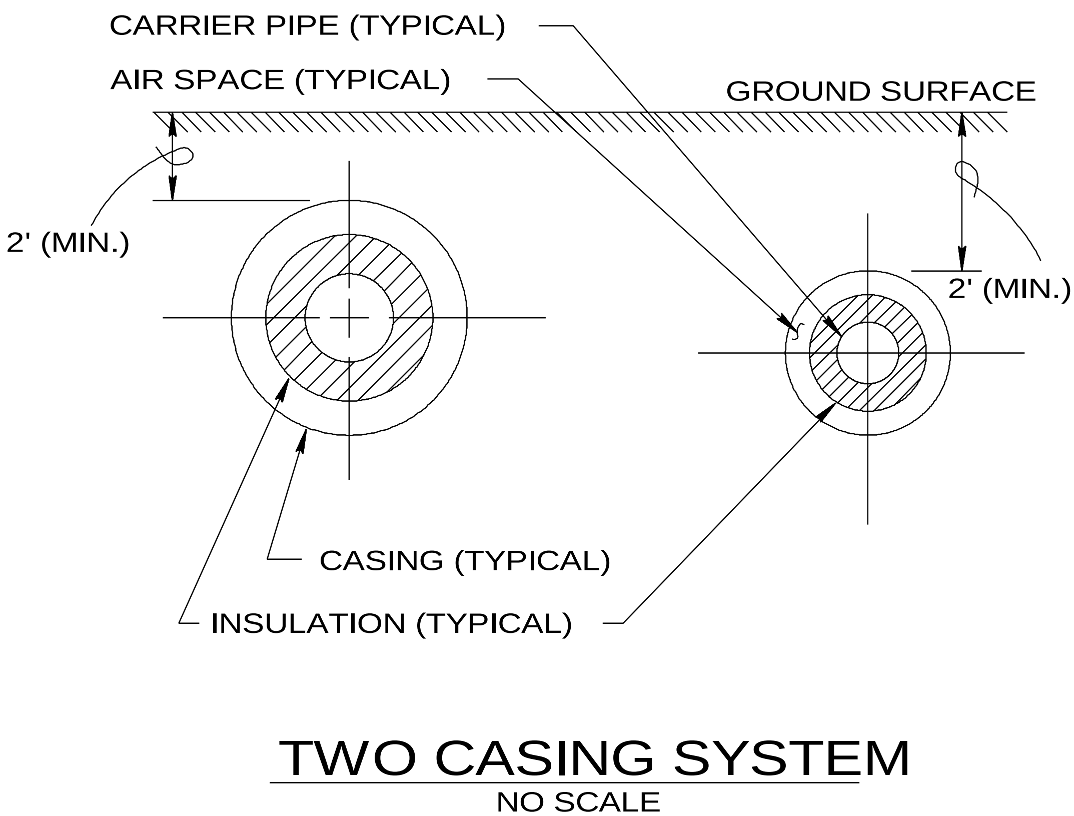
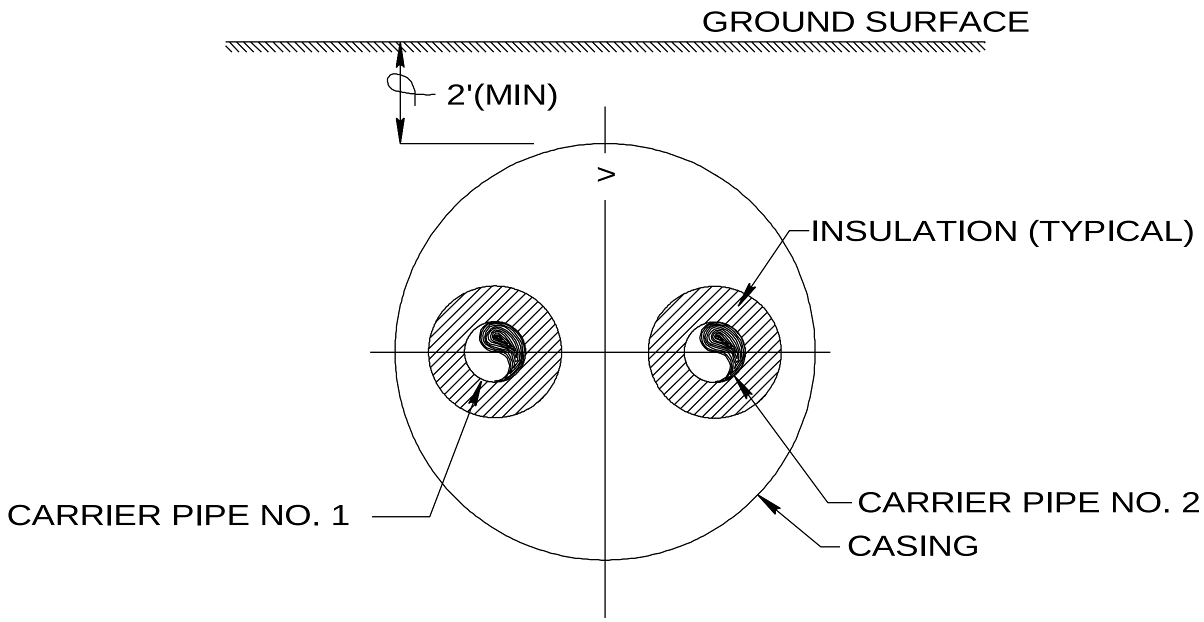


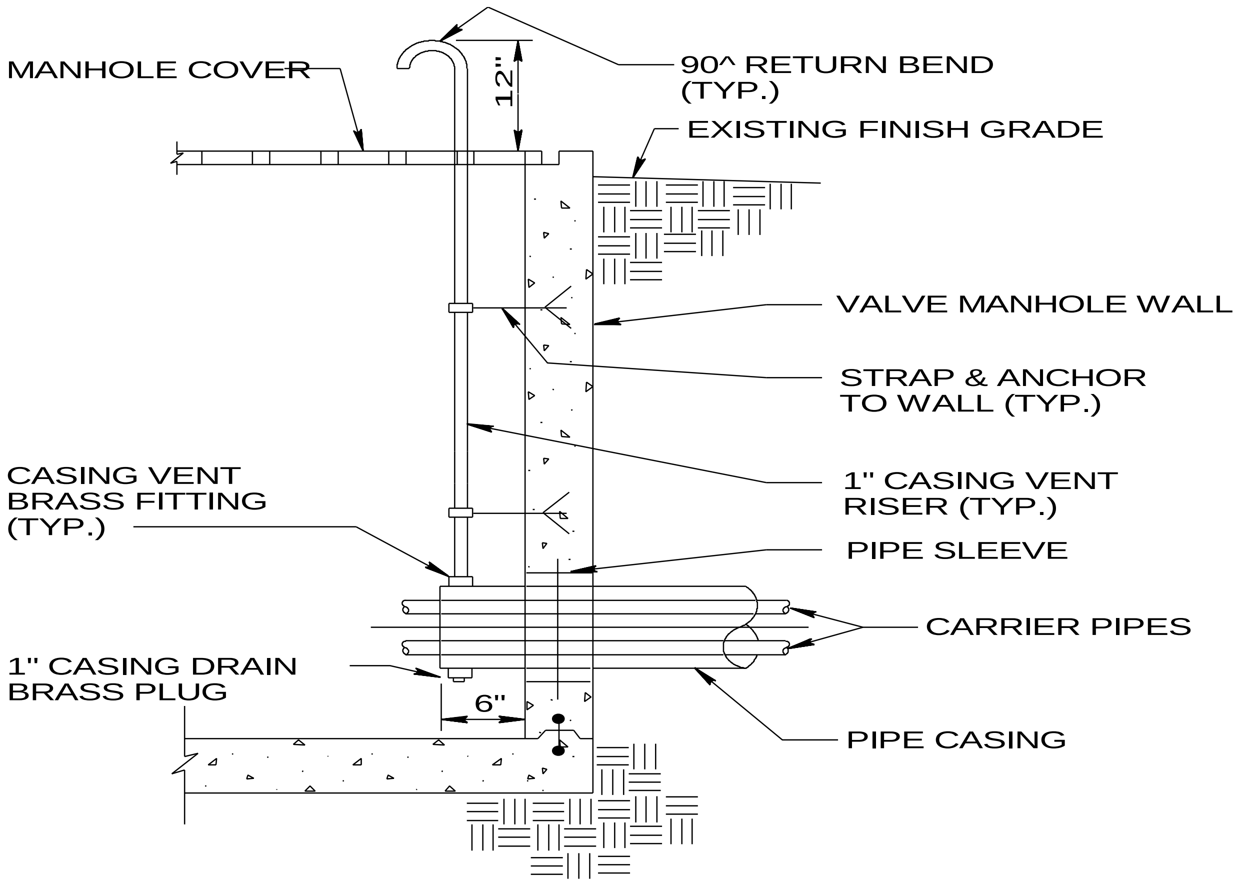
Figure 5-1. Two Casing System Detail.



NOTE: A STEAM LINE AND A CONDENSATE LINE ARE NOT TO BE INSTALLED IN THE SAME CASING.

SINGLE CASING SYSTEM (DDT)
NO SCALE

Figure 5-2. Single Casing System Detail.



CASING, VENT, AND DRAIN (DDT)

NO SCALE

Figure 5-3. Casing, Vent, And Drain Detail.

CHAPTER 6

PREFABRICATED UNDERGROUND HEATING/COOLING DISTRIBUTION SYSTEM

6-1. GENERAL. This system is similar to Pre-engineered Underground Heat Distribution System (chapter 5) because it is factory fabricated in lengths, which are transported to the site for field assembly. However, the system is not allowed for any high temperature water (greater than 200 deg. F) or steam/condensate systems. The project designer is also responsible for more of the overall design.

6-2. SYSTEM DESIGN.

a. Site information. As with all heat distribution systems, the site investigation is the responsibility of the designer. The designer will obtain soil borings, be responsible for designing all grading in the area, and investigate all utilities for possible conflicts with the system. The designer will provide detailed design plans and profiles of the distribution system routings. The design will ensure a minimum slope of 1 inch in 20 feet is maintained between valve manholes. The site information requirements are covered in detail in chapter 3 of this manual.

b. Valve manholes. The designer will design all valve manholes for the system as covered in chapter 3 of this manual. As with valve manholes for the Pre-engineered Underground Heat Distribution System, manhole spacing will not exceed 500 feet and all manholes will have drainage capabilities. Also, all valves, flanges, unions, and couplings shall be located within the manholes.

c. System Material Selections. Although this system is manufactured in sections in a factory, the designer will specify all materials.

(1) Piping. The piping materials allowed are steel, copper tubing, reinforced thermosetting resin plastic (RTRP), or polyvinyl chloride (PVC). RTRP piping can not be routed through valve manholes with heating systems that could damage the RTRP. PVC piping can not be routed in any valve manhole with any other heating system piping due to its comparatively low temperature tolerance.

(2) Casing. Allowed casing materials are PVC, polyethylene (PE), or RTRP. Because these casing materials are susceptible to damage from high temperatures, they must be installed a minimum of 15 feet from buried HTHW or steam systems to avoid plastic deformation and failures of the casing materials.

(3) Insulation. Insulation type for these systems is typically polyurethane foam. Open cell type insulations, such as fiberglass, mineral wool or calcium silicate, are unacceptable for use with chilled water systems due to the tendency of condensation forming in these insulations. Insulation thickness will be specified in the guide specification.

d. Expansion compensation. The designer will perform expansion compensation calculations as covered in chapter 3 of this manual. When required, based on these calculations, sizes and locations of all expansion loops and bends, and any other expansion-compensating device, will be clearly shown on the contract drawings. The designer shall provide expansion loop details.

CHAPTER 7

ABOVEGROUND HEAT DISTRIBUTION SYSTEMS

7-1. GENERAL. Aboveground distribution systems have the lowest first cost and lowest maintenance costs of any distribution system described in this manual and are completely designed by the project designer. This system is a good application for industrial areas and where water tables are high. Many installations, however, do not desire to have distribution piping above ground for aesthetic reasons.

7-2. SYSTEM DESIGN.

a. Site information. The designer will determine information on the site. The designer will design all grading for the area and investigate all utilities for conflicts. The designer will provide detailed plans and profiles of the above ground distribution system routing. Although this system is aboveground, profiles will indicate system drain and vent points and also potential interferences between the concrete support piers and any buried utilities.

b. Piping and fittings. All carrier piping and pipe fittings will be carbon steel and will be designed to satisfy the temperature and pressure requirements of the system. Materials will conform to the requirements of the guide specification.

c. Pipe supports. The two most common types of aboveground distribution systems are low profile and high profile.

(1) Low profile system. A typical low profile support is shown in figure 7-1. In this system, the distribution piping is mounted to concrete piers by means of pipe supports. Typically, the bottoms of the pipes are mounted no more than 4 feet above grade except at road crossings, which usually incorporate high profile supports. Typical anchor, free, and guided pipe supports mounted to the concrete piers are detailed in figure 7-2, figure 7-3, and figure 7-4. Spacing of supports in straight runs of piping will conform to the support spacing schedule in table 4-2. Provide extra supports, as necessary, at pipe bends and risers. Requirements for concrete piers and pipe supports are included in the guide specification.

(2) High profile systems. High profile systems are routed high enough to cross roads and avoid obstructions. Typically the piping will be installed 14 to 16 feet above grade. The system presented in this manual uses 6-inch concrete-filled pipes embedded in concrete footings as detailed in figure 7-5. The pipe guides are mounted on channels at the top of the support pipe as detailed in figure 7-6. The pipe anchors are also mounted to channels and then stabilized with guy cables as shown in figure 7-7. Structural design for the structural members on these high profile supports in figure 7-6 and 7-7 are for water filled, schedule 40 steel pipes up to 10-inch nominal size. Conditions outside these constraints must be designed on a case-by-case basis. The designer for each anchor application will also size the guy cables. Spacing of supports in straight runs of piping will conform to the support spacing schedule in table 4-2. Extra supports will be added, as necessary, at pipe bends and risers. Concrete footings and high profile supports will conform to the requirements of the guide specification.

c. Insulation and jacketing. All piping on aboveground systems shall be insulated and jacketed. Insulation thicknesses will be determined by insulation tables provided in the guide specification. These insulation thicknesses were developed using life cycle cost analyses. All insulation will be covered with a jacketing material in conformance with the guide specification.

e. Expansion Compensation. Expansion loops and bends will be designed as described in chapter 3 of this manual. Expansion loops will be located to minimize impacts to ground level interferences such as trees and sidewalks. For horizontal expansion loops, pipe supports will be spaced less than the maximums listed in table 4-2 because of the extra bends and associated movement in the loops. In low profile systems, vertical expansion loops may be used as road crossings. Details will be provided indicating support types and locations throughout the loops and bends.

f. Vents and Drains. Provide venting of all piping high points and draining of all low points to allow total drainage of the system. Vent and drain locations will be indicated on the profile drawings. Vents and drains are similar to those used for the concrete shallow trench system, figure 4-15.

g. Transition to Buried Systems. When a buried system transitions to an aboveground system a valve manhole will be provided at that point. A manhole top penetration will be provided to allow expansion of the distribution piping in the man-hole top yet keep rain and ground water out of the manhole. Figure 7-8 shows such a transition in a valve manhole with a concrete cover. The valve manhole used for this transition must be large enough to be accessible and will be designed in accordance with chapter 3 of this manual.

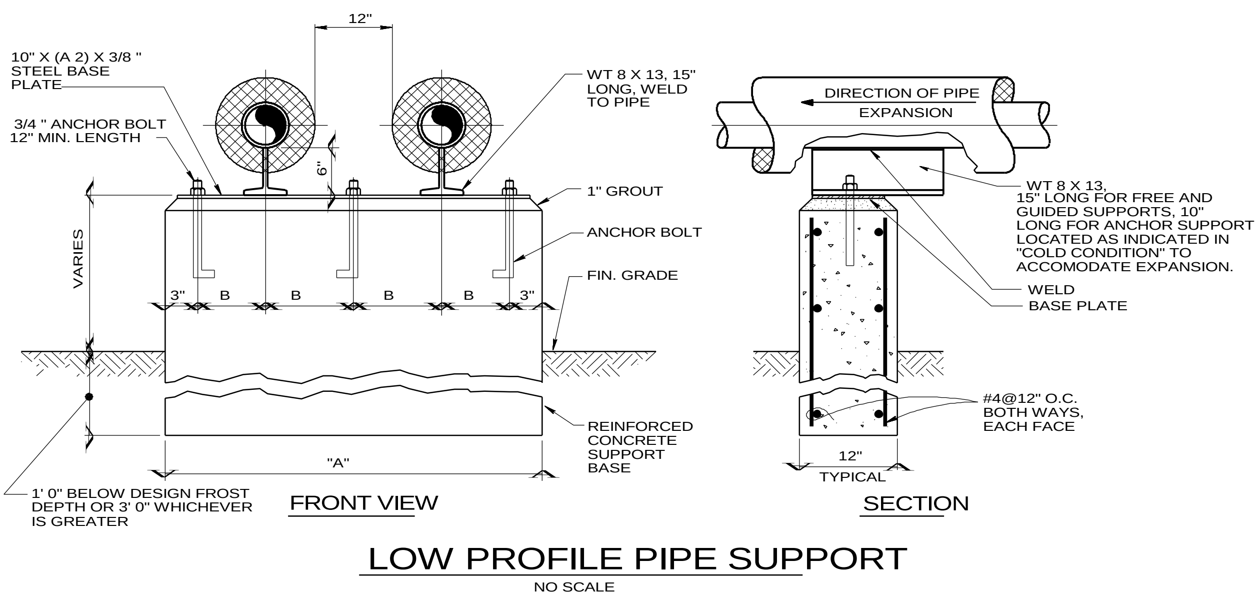


Figure 7-1. Typical Low Profile Support Detail.

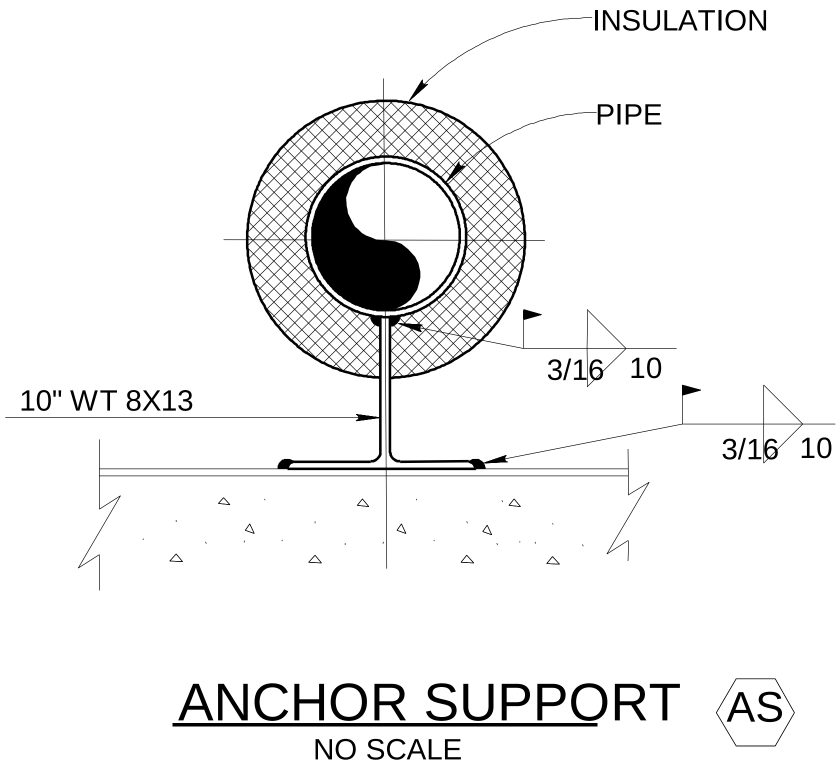


Figure 7-2. Typical Anchor Pipe Support.

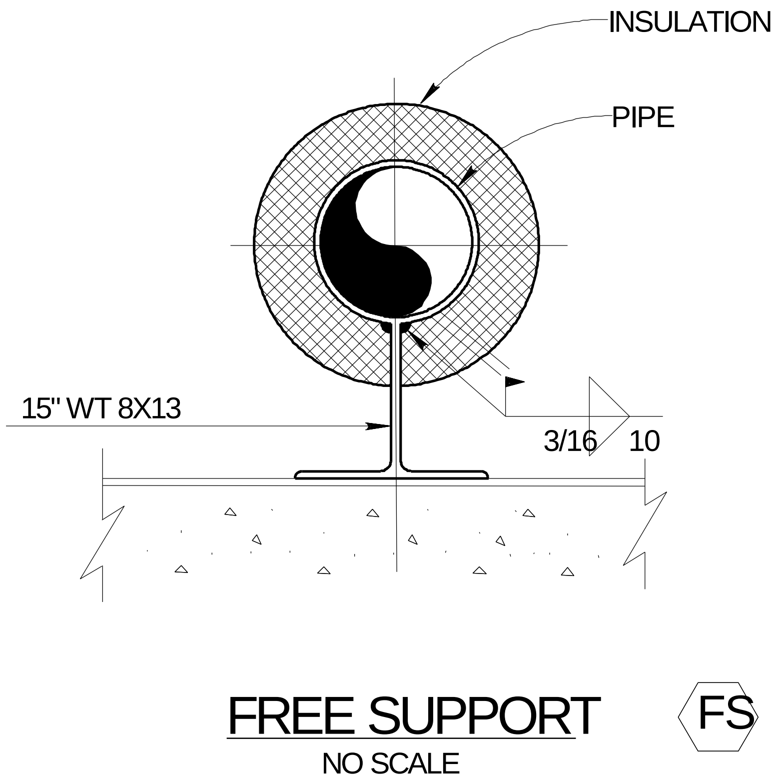


Figure 7-3. Typical Free Pipe Support.

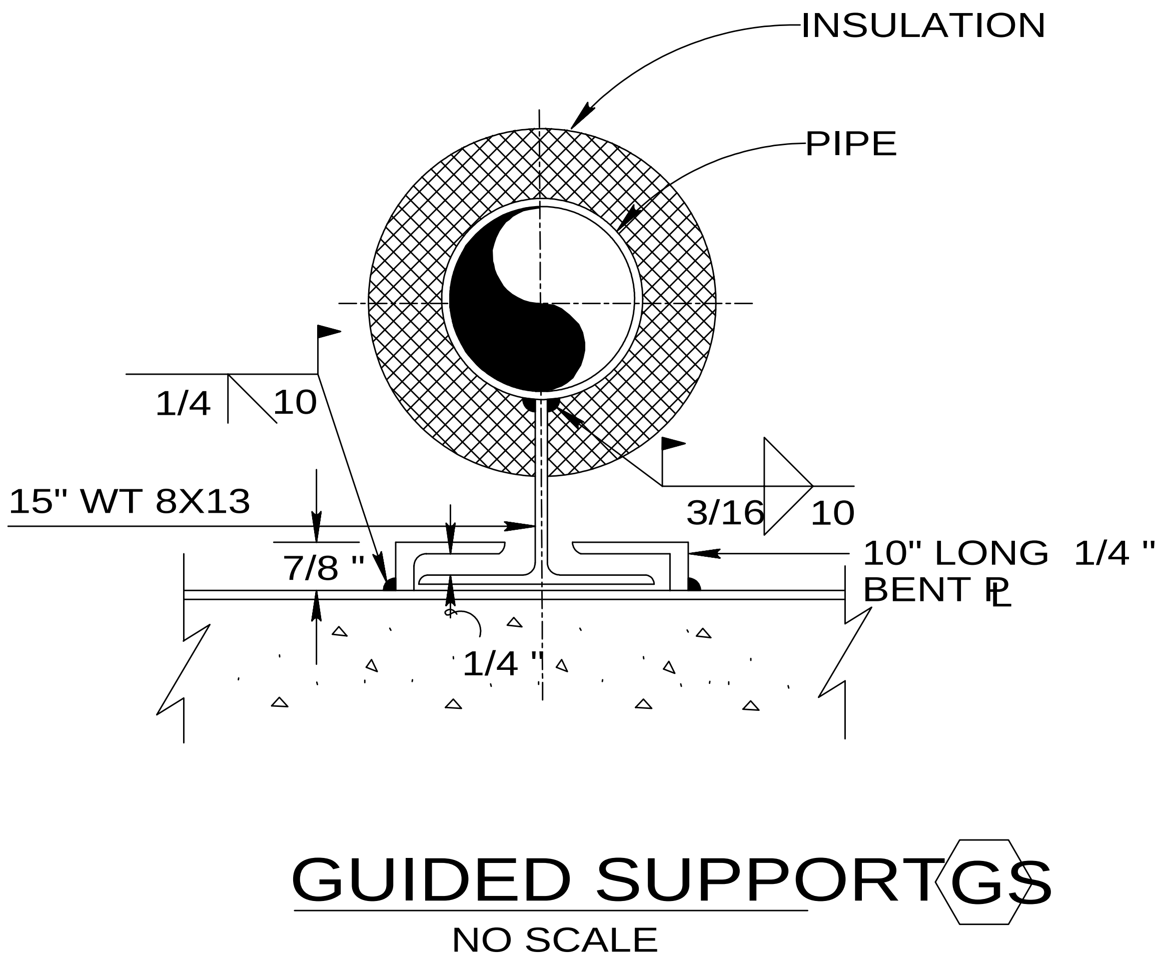
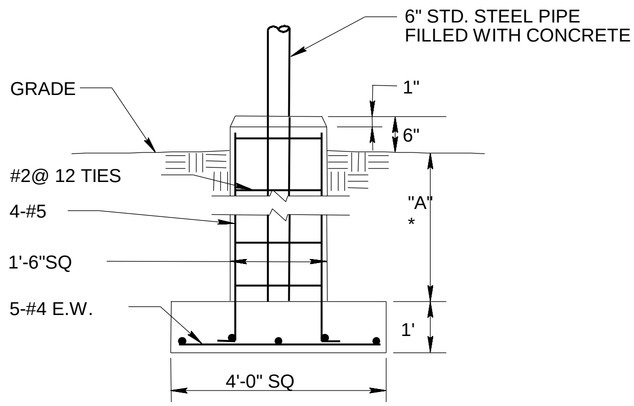


Fig. 7-4. Typical Guided Pipe Support.



HIGH PROFILE BASE
NO SCALE

NOTES TO THE DESIGNER:

* "A" IS THE DESIGN FROST DEPTH,
SEE TM 5-809-1 FOR FROST DEPTH

1. SITE SPECIFIC DESIGN REQ'D BASED ON
LOADS AND SOIL CONDITIONS.

Figure 7-5. Typical High Profile Base Detail.

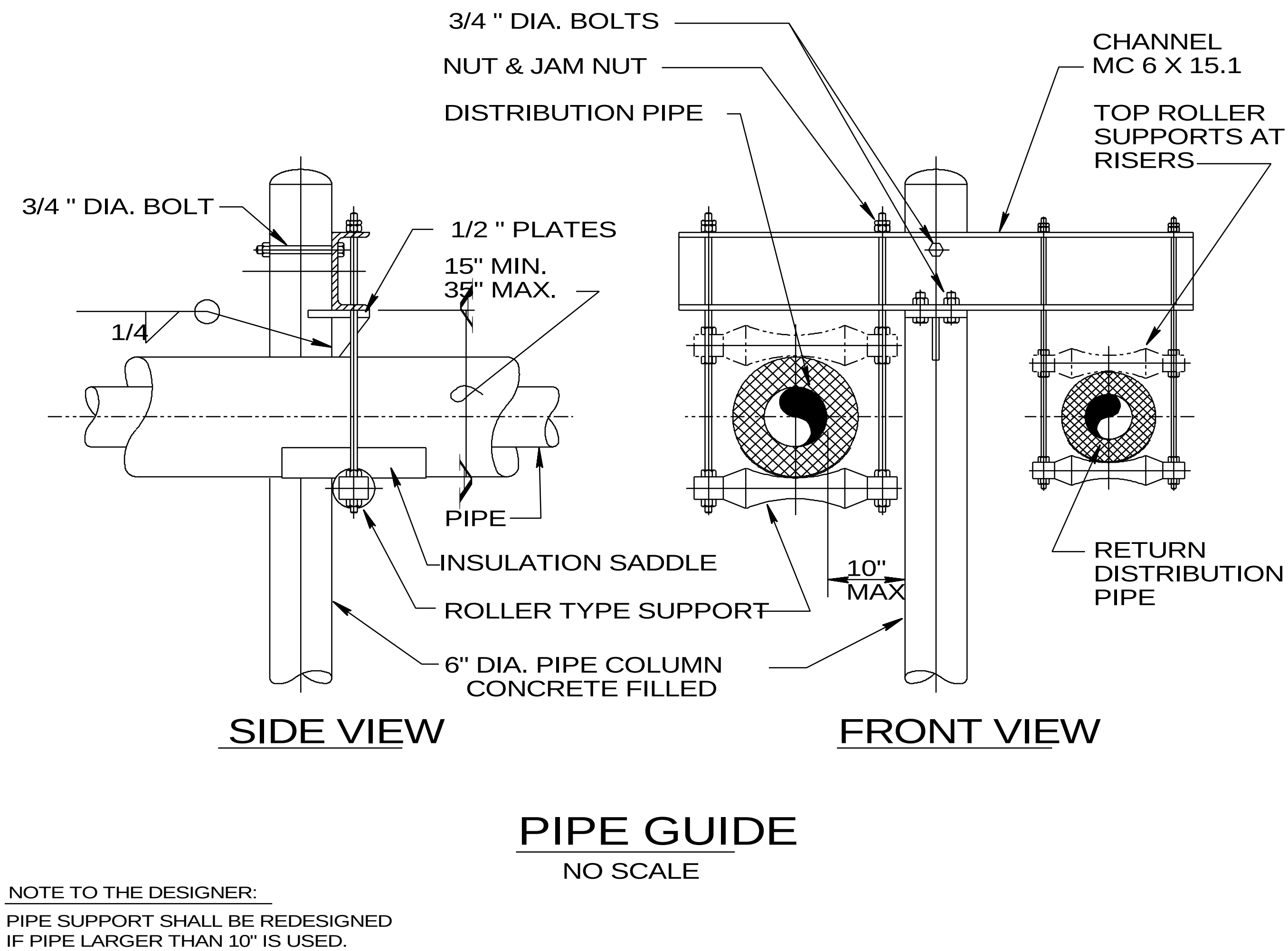
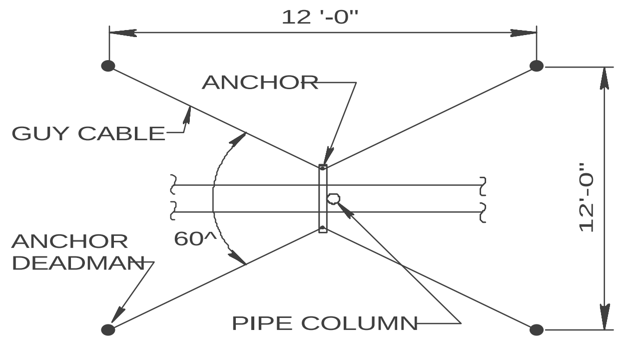
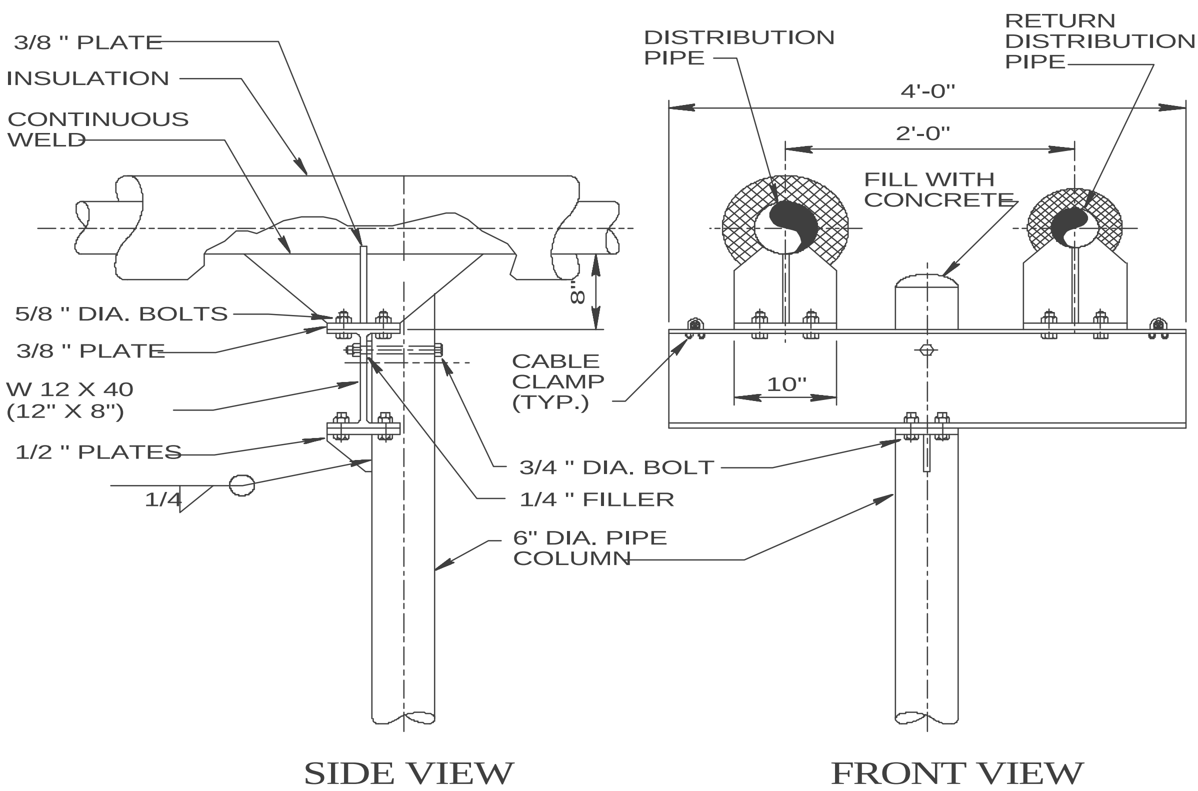


Figure 7-6. Typical Pipe Guide Detail.



PLAN - PIPE ANCHOR

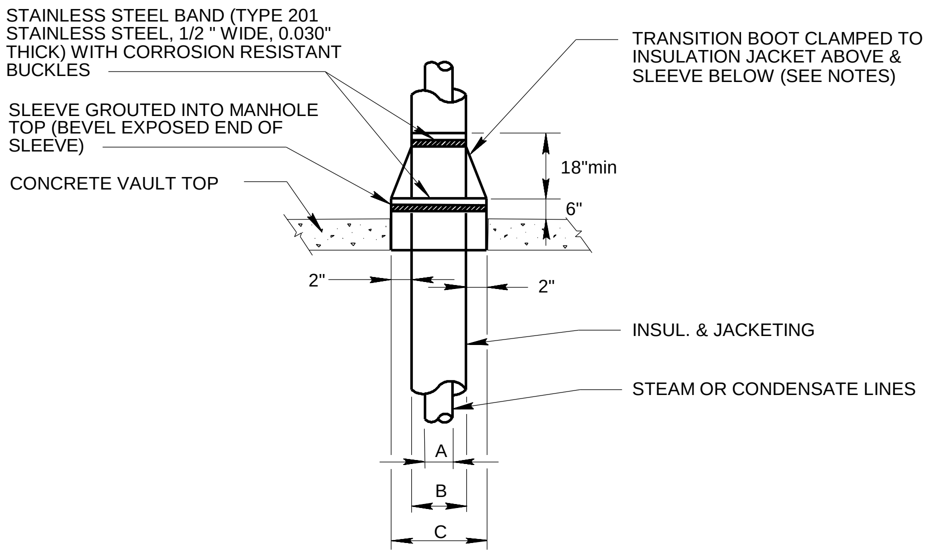
NO SCALE



HIGH PROFILE PIPE ANCHOR

NO SCALE

Figure 7-7. Typical Pipe Anchor Detail.



A=OUTSIDE PIPE DIA.
B=OUTSIDE INSUL.&JACKET DIA.*
C=MIN. SLEEVE INSIDE DIA.=B+4
* SEE SPEC. FOR INSULATION THICKNESS

NOTES:

1. TRANSITION BOOT (LINER) SHALL BE:
   - 25 MIL THICKNESS (MIN)
   - E.P.D.M. TYPE MEMBRANE
   - COMPATIBLE AT HIGH (220^ F) AND LOW (-40^ F) TEMPERATURES
   - RESISTANT TO ULTRAVIOLET LIGHT DEGRADATION

2. LINER SEAM SHALL PROVIDE 2" MINIMUM OF OVERLAP. USE SOLVENT CEMENT AS APPROVED BY LINER MANUFACTURER.

VALVE MANHOLE TOP PENETRATION
NO SCALE

Figure 7-8. Valve Manhole Top Penetration Detail.

CHAPTER 8

SPECIAL CONSIDERATIONS

8-1. GENERAL. Although it is impractical to cover all special considerations, which arise in heating and cooling distribution designs, this chapter presents typical design problems and solutions associated with steam, high temperature hot water, low temperature hot water and chilled water systems.

8-2. STEAM SYSTEMS.

a. Trap Selection. Steam traps are used to separate the condensate and non-condensable gases from the steam. Many types of traps are used on drip legs for steam distribution systems. Those trap types include float and thermostatic (F&T), inverted bucket, thermostatic and thermodynamic (disc). However, for buried heat distribution drip leg applications, inverted bucket or thermostatic (bimetallic type) should be the trap types selected. For drip leg applications where freezing is a consideration, thermodynamic type (installed vertically) or bimetallic thermostatic type should be selected.

b. Trap Sizing and Location. Trap sizing is important for obtaining an efficient steam distribution system. Condensation in the steam line is caused by heat loss from the steam line. Trap life will be shortened, function affected and excessive energy will be wasted if traps are oversized to handle the higher initial startup condensate flows. Therefore, the traps should be sized for the condensate load seen during the distribution system normal operation. Because the traps are not sized for startup loadings, the bypass must be opened at startup to allow condensate to pass until the steam line has reached normal operating temperatures (see figure 8-1). The designer will calculate heat loss and condensate flow for that particular design using the methods presented in appendix D for determining condensate loads during normal operation. It is critical that the designer calculate trap capacity using the Appendix D method for each trap station in the design to ensure proper steam system operation. In addition to trap capacity, steam trap type, differential pressures, and inlet pressure must always be provided on the contract documents. Do not locate steam drip legs, with associated traps, more than 500 feet apart.

c. Drip Leg Sizing. Drip legs, installed vertically down from the steam pipe, are used to collect condensate. Design all steam lines to slope at 1 inch in 20 feet minimum toward these drip legs. It is preferable to slope the steam lines in the direction of steam flow whenever possible. The steam trap line and bypass line are connected to the drip leg as indicated in figure 8-1. The drip leg will be the same nominal pipe size as the main line (up to a 12-inch line) and will provide a storage capacity equal to 50% of the startup condensate load (no safety factor, one-half of an hour duration) for line sizes 4 inches in diameter and larger and 25% of the startup condensate load (no safety factor, one-half of an hour duration) for line sizes less than 4 inches. In no case will the drip leg be less than 18 inches in length or larger than 12 inches in diameter for all steam line sizes. The designer will calculate startup loads for drip leg sizing using the methods presented in appendix D.

d. Trap Station Layout. All trap stations will be piped as indicated in figure 8-1, as a minimum. Valve and strainer sizes will match the line sizes on which they are installed. Pipe lines to and from the steam trap will be sized based on calculated trap capacity but will be no less than 3/4-inch nominal size (line size "A" on figure 8-1). If reducing fittings are needed at the trap inlet and outlet, eccentric reducers must be used. The bypass line will be sized to accommodate warm-up condensate loads. For steam systems with an operating pressure of 150 psig or less and pipe sizes 12 inches or less, provide a ¾-inch bypass line. If the condensate return main is a low pressure or gravity flow type, the trap discharge line will be routed through an accumulator, as indicated in figure 8-2. The accumulator will lower the trap discharge temperature and minimize flashing when the condensate is introduced into sloped condensate lines which are routed to receiver/pump sets located in valve manholes. The pumps push the condensate back to the central plant in a separate pressurized condensate line. See figure 8-3 for a duplex condensate pump set connection detail.

This type of condensate return system is referred to as a "three pipe" or a "pumped return" system. If the steam pressure is sufficiently high, it may be used to force the condensate through the condensate return system to the central plant as shown in figure 8-1. No accumulator is required for this type system, which is referred to as a "two pipe" system. Sizing of the lines for both of these systems is presented later in this chapter.

e. Condensate Cooling System. Fiberglass reinforced plastic (FRP) piping is usually allowed for most condensate return systems. Since internal corrosion is a frequent problem in steel condensate lines, FRP eliminates this problem. However, the FRP materials cannot withstand as high of pressures or temperatures as steel and often fail when exposed to these conditions. A common temperature in an FRP distribution piping system where damage will occur is 250 deg. F. Condensate temperatures may exceed 250 deg. F. at the outlet of steam drip leg traps on steam systems that have pressures greater than 15 psig. In order to use FRP condensate lines in this case, a condensate cooling system will be employed, as detailed in figure 8-4. In this system, the high temperature condensate is discharged into a cooling tank where it blends with the system condensate. The blended condensate is then routed to the condensate main. Note that the detail shows the FRP (or non-metallic) pipe transitioning to steel inside the valve manhole to avoid burying the transition point. Also, note that nonmetallic piping will not be allowed in a manhole with high temperature hot water or high pressure steam systems due to the potential for this pipe being exposed to damaging temperatures within the manhole if the manhole floods or the carrier pipe on the heating system leaks.

f. Non-metallic Pipe Anchors in Valve Manholes. If anchoring of a non-metallic piping system is required at the valve manhole wall to comply with the distribution system stress analysis, a typical method is as detailed in figure 8-5. If the system is to be anchored at both of the valve manhole wall penetrations, provide adequate piping bends in the manhole to accommodate the expansion between the two anchors. Steel straps and bolts will be sized to accommodate the axial force of that particular piping layout. These sizes will be entered on the detail. Also, valve manhole sizes must be large enough to accommodate the anchors and still allow for maintenance access.

g. Pipe Sizing. Pipe sizing is critical to proper operation of both the steam and the condensate return systems.

(1) Steam. There are several methods to size steam lines. One of the quickest and most popular methods is using pressure drop versus flow rate charts, which provide steam velocities based on the required flow and pressure drops. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Fundamentals Handbook, Chapter "Pipe Sizing", is a good source for these steam sizing tables. Recommended velocities for various system pressure ranges are:

0 - 10 psig, saturated - 1,000 to 4,000 fpm
10 - 50 psig, saturated - 4,000 to 8,000 fpm
50 - 150 psig, saturated - 8,000 to 12,000 fpm

In addition, ensure the total pressure drop in the system will not be excessive. Steam pressure must be high enough at the end users to meet all special process requirements.

(2) Condensate. As described previously in this chapter, there are basically two types of condensate return systems used on central heating systems: the two pipe system (which uses steam pressure to force condensate back to the plant) and the three pipe, or pumped return, system. When sizing lines for these condensate return systems, table 8-1 will be used for guidance.

h. Steam System Material Selection.

(1) Valves. For high-pressure steam systems (125 psig or greater), valves will be 300-pound class and

will have welded ends. Steam and condensate valves at lower pressures will be 150-pound class with welded ends. Valves on trap stations, including the bypass valve, will be 150-pound class with threaded ends. Shutoff valves will be gate type.

(2) Fittings. All fittings in the steam distribution system, except as discussed for valves, will be welded except at equipment, traps, strainers, and items which require frequent removal. These items will be threaded or flanged.

(3) Piping. Steam and condensate piping will usually be carbon steel conforming to ASTM A 53, Grade B, Type E or S. Steam piping will be schedule 40. Condensate lines will be schedule 80 as will all welded piping less than 1-1/2 inches. Condensate lines in a pre-engineered underground heat distribution system may be FRP as discussed in chapter 5.

i. Field Joints. Radiographic examination of all carrier pipe field joints is required.

8-3. HTHW SYSTEMS.

a. Pipe Sizing. Sizing lines for HTHW systems is similar to any water system, except at high temperatures water becomes less dense and less viscous, and, therefore, the mass flow rate of the system must be calculated considering the lower density (usually temperatures are around 400 deg. F for HTHW).

$$m = q \times 60 \text{ min/hr} \times 0.1335 \text{ ft}^3\text{/gal} \times ?$$

where

q = system flow in gal/min

m = mass flow rate in lbm/hr

? = density of water at maximum system temperature in lbM/ft^3

Pressure drop versus flow charts may be used to determine line size, such as the chart included in appendix B. This chart takes into account the characteristics of higher temperature water systems. Recommended velocities for various HTHW flows are as follows:

Up to 10,000 lbm/hr	-	1 to 2 feet/sec
10,000 to 30,000 lbm/hr	-	2 to 3 feet/sec
30,000 to 200,000 lbm/hr	-	3 to 5 feet/sec
200,000 lbm/hr on up	-	(use velocity to accommodate 0.50 psi/100 ft., maximum)

b. HTHW System Material Selection

(1) Valves. All valves on HTHW systems will be 300-pound class with welded ends. Shutoff (isolation) valves will be gate type. Valve packings must be capable of handling the pressures and temperatures associated with HTHW systems.

(2) Fittings. All fittings on HTHW systems will be welded. The only exceptions will be specialty equipment such as dielectric flanges used to isolate the piping system from a cathodically protected system.

(3) Piping. HTHW piping will be carbon steel conforming to ASTM A53, Grade B, Type E or S. All piping will be schedule 40 except for welded pipe less than 1-1/2 inches, which will be schedule 80.

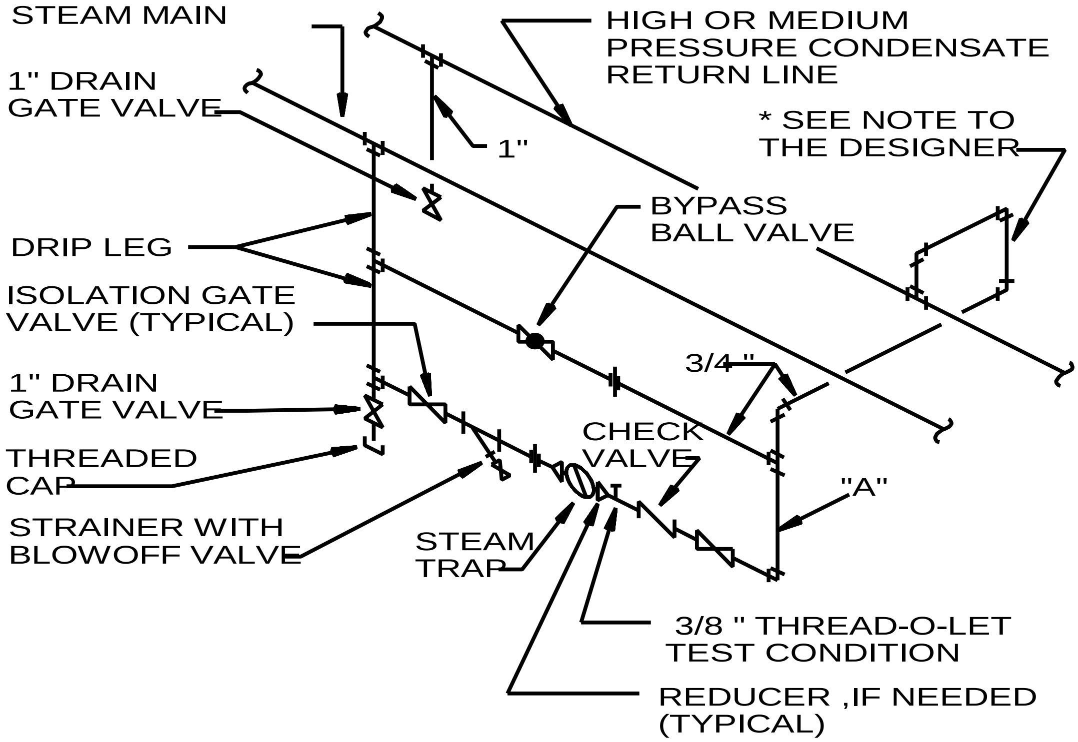
8-4. LTHW and CW systems.

a. Pipe Sizing. The most efficient method of determining pipe size for LTHW and CW systems is to use head loss vs. flow rate charts such as those found in ASHRAE Fundamentals, Chapter "Pipe Sizing". These tables are based on 60 deg. F water so for chilled water pipe sizing there is little error introduced using these charts. For LTHW systems, the use of the charts does introduce some error. However, the error is on the conservative side (the charts overstate the pressure drop of LTHW).

b. LTHW and CW Material Selection.

(1) Valves. Typically, valves on either LTHW or CW systems will be 150-pound class and will be located in the valve manholes. Ball valves provide a good means for line isolation. Although nonmetallic valves are sometimes allowed for these systems, metallic valves should be used for durability.

(2) Piping. The most common piping materials used for LTHW and CW systems are steel, copper tubing, reinforced thermosetting resin pipe (fiber- glass) and, for CW only, polyvinyl chloride and polyethylene. However, do not include nonmetallic piping in the same valve manholes with HTHW and steam systems. Chilled water lines using PVC piping must be installed in separate valve manholes since PVC can be thermally damaged at relatively low temperatures. Outside the valve manholes, a separation of 15 feet (minimum) must be maintained between pre-engineered underground HTHW and steam systems and PVC encased, prefabricated underground heating/cooling distribution systems to avoid thermal degradation of the PVC.



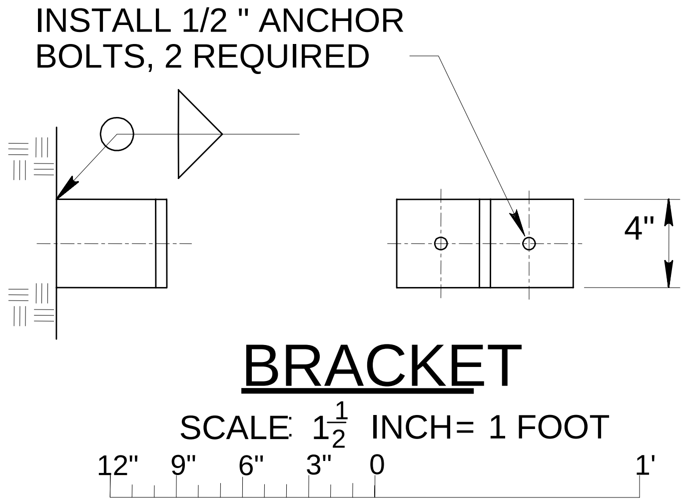
TRAP STATION LAYOUT ISOMETRIC

NO SCALE

NOTE TO THE DESIGNER:

* HIGH PRESSURE CONDENSATE DISCHARGE FROM THE TRAP WILL NOT BE DIRECTLY ROUTED TO A GRAVITY OR LOW PRESSURE CONDENSATE SYSTEM. IN THIS INSTANCE, A 3/4 " LINE WILL BE ROUTED TO AN ACCUMULATOR BEFORE BEING ROUTED TO A CONDENSATE PUMP (SEE FIGURE 8-2).

Figure 8-1. Trap Station Layout Schematic.



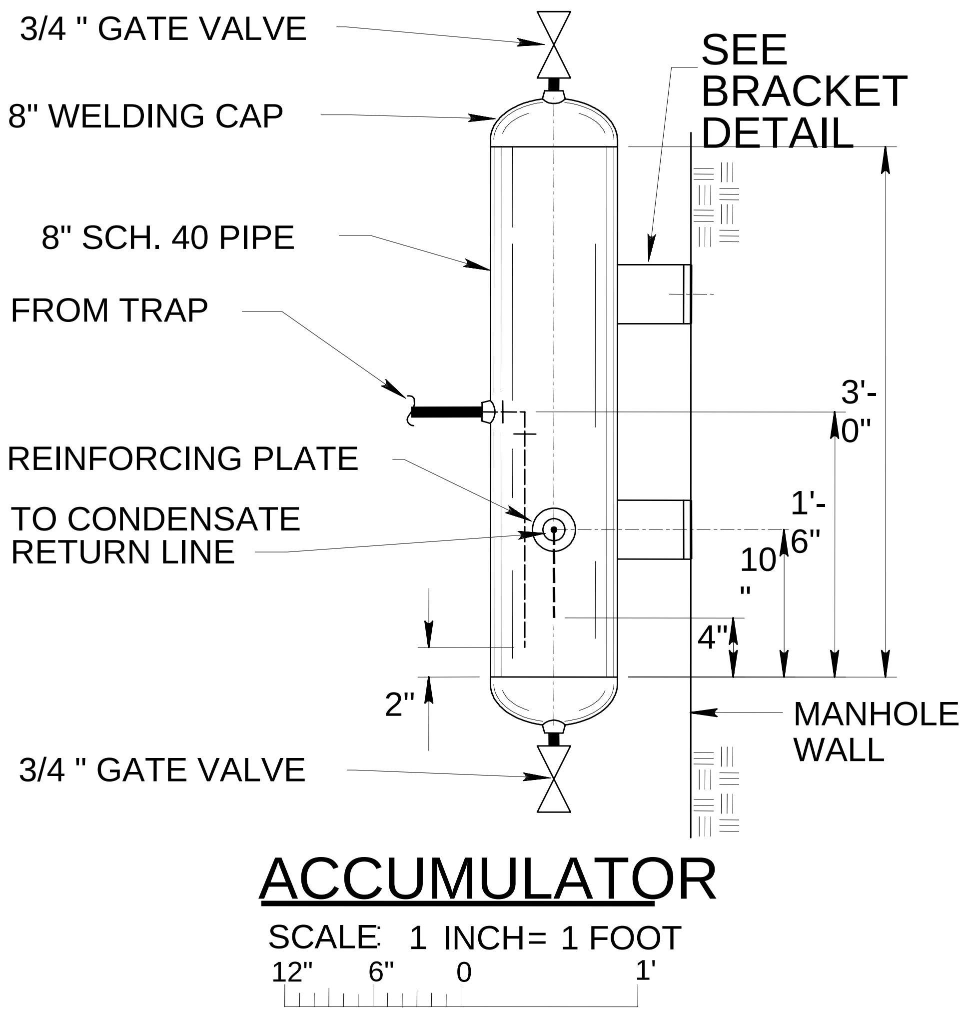
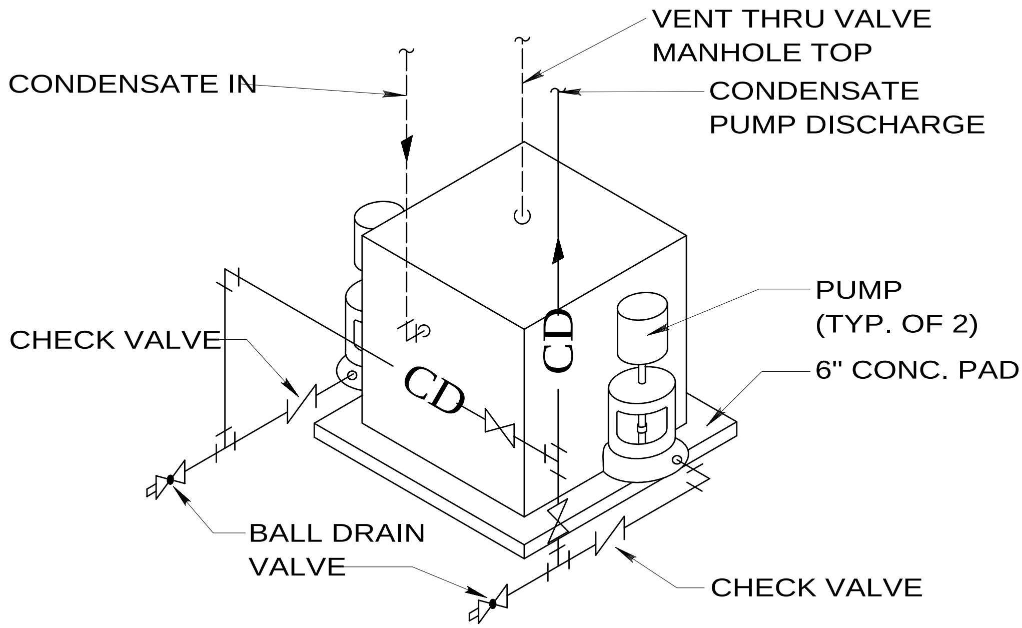


Fig. 8-2. Accumulator Detail.

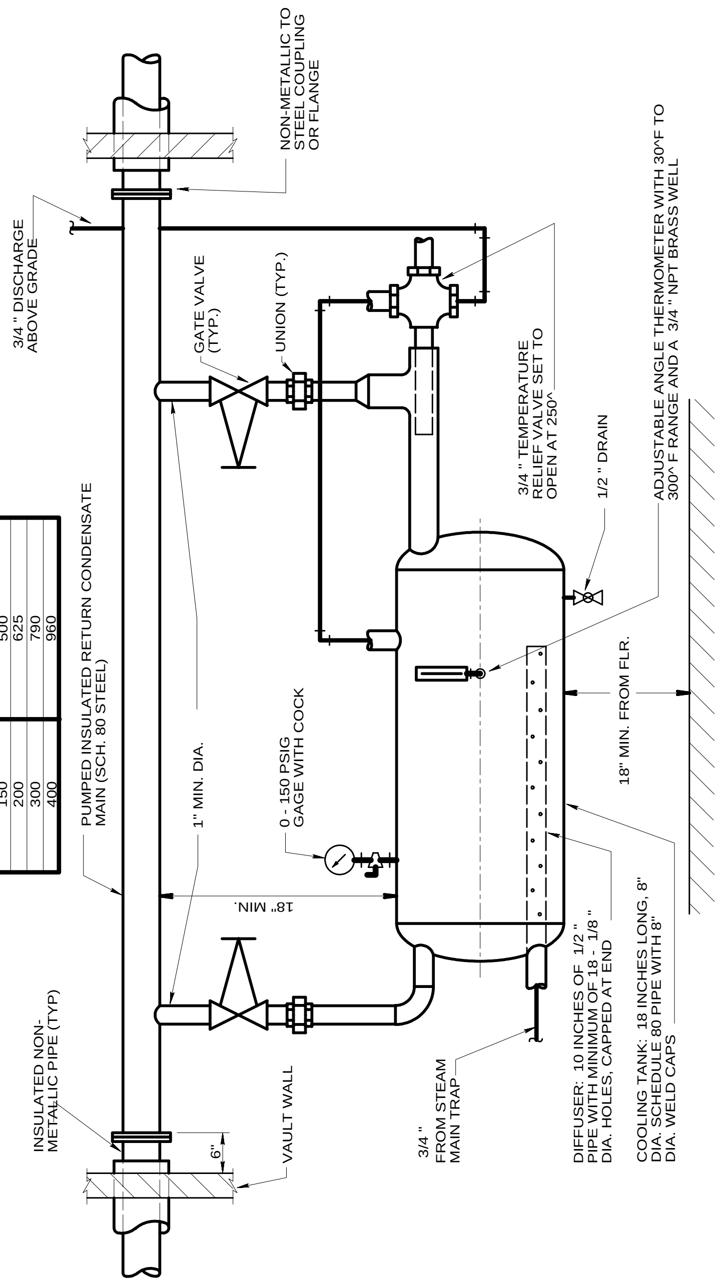


DUPLEX CONDENSATE PUMP
SET CONNECTION DETAIL

NO SCALE

Fig. 8-3. Duplex Condensate Pump Set Connection Detail.

STEAM TRAP CAPACITY LIMITATIONS	
SYSTEM PRESSURE (PSIG)	MAXIMUM TRAP CAPACITY (LBS./HR.)
50	250
100	380
150	500
200	625
300	790
400	960

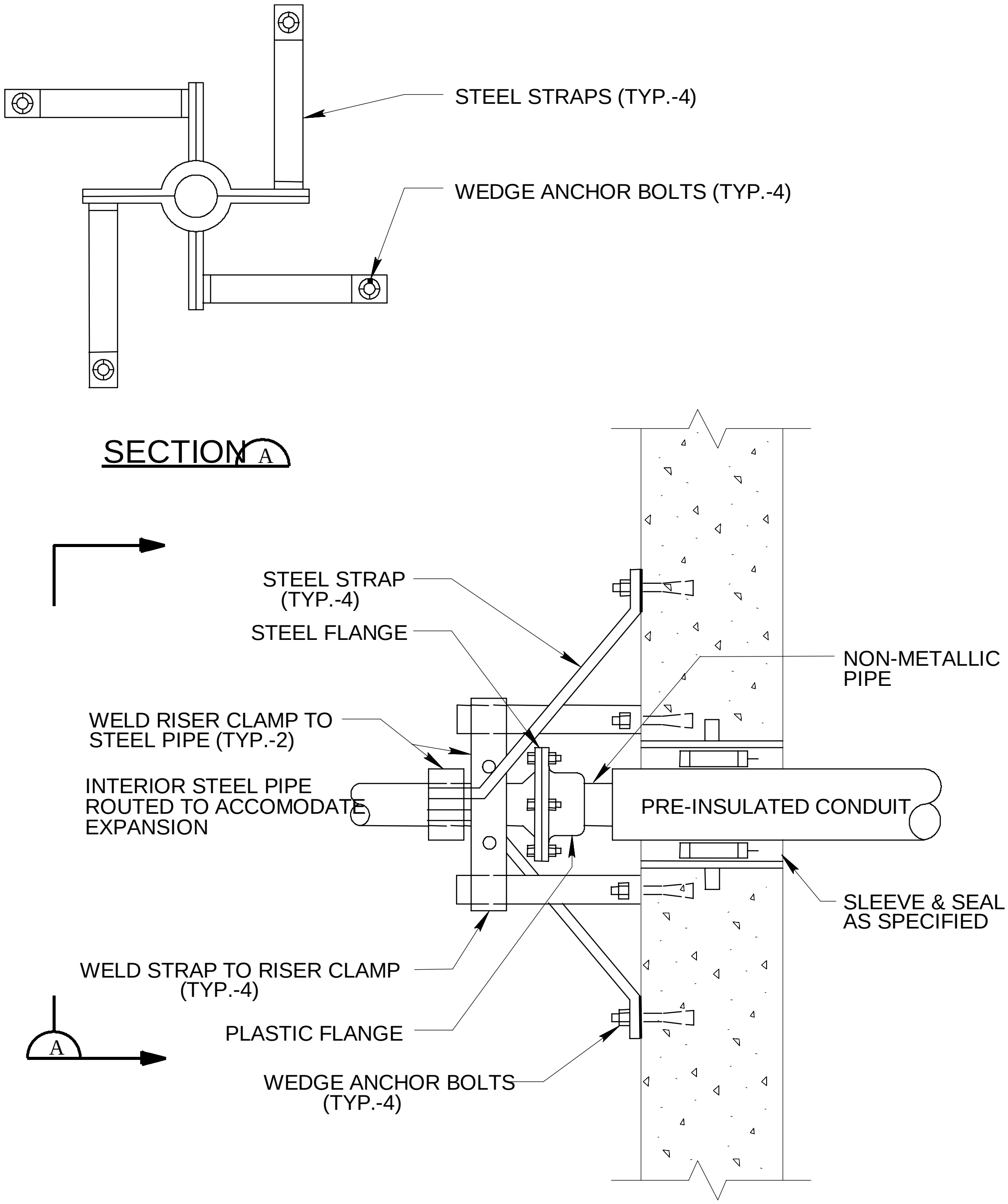


CONDENSATE COOLING SYSTEM

NO SCALE

Fig. 8-4

Condensate Cooling System for Non-metallic Pipe Detail.



WALL ANCHOR FOR NON-METALLIC PIPING SYSTEMS
NO SCALE

Fig. 8-5. Non-metallic Piping System Anchor Detail.

Table 8-1. Pipe sizing guidelines for condensate return systems.

TWO-PIPE SYSTEM SIZING GUIDELINES

- ?? DETERMINE CONDENSATE LINE PRESSURE (AS OBSERVED FROM ON-SITE PRESSURE GAGES).
- ?? DETERMINE CONDENSATE LOAD (lbm/hr) FROM CENTRAL PLANT LOGS AND OTHER INPUT.
- ?? ASSUME CONDENSATE AT TRAP DISCHARGE IS A COMBINATION OF CONDENSATE AND FLASH STEAM.
- ?? SIZE LINE TO ACCOMMODATE 5,000 ft/min STEAM AND CONDENSATE MIXTURE VELOCITY AND TO ENSURE MIXTURE PRESSURE IS HIGH ENOUGH TO OVERCOME LINE LOSSES.

THREE-PIPE SYSTEM SIZING GUIDELINES

GRAVITY LINE

- ?? SLOPE AT 1 inch/20 feet (MINIMUM) TOWARD RECEIVER.
- ?? TOTAL PRESSURE DROP LESS THAN 0.25 psi.
- ?? LINE SIZE WILL BE TWO (2) INCHES.

PUMPED LINE

- ?? SIZE PUMPS TO MOVE CONDENSATE TO THE CENTRAL PLANT AT THE REQUIRED HEAD AT 200 deg. F.

APPENDIX A

REFERENCES

Government Publications

Department of the Army

TM 5-802-1	Economic Studies for Military Construction Design-Applications
TM 5-809-1	Load Assumption for Buildings

Non-government Publications

American National Standards Institute (ANSI)
1430 Broadway, New York, NY 10018

H35.1	(1990) Alloy and Temper Design System for Aluminum

American Society for Testing and Materials (ASTM)
1916 Race Street, Philadelphia, PA 19103

A 36	(1991) Structural Steel
A 53	(1988a) Pipe, Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless
A 123	(1989a) Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A 615	(1990) Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329

ASHRAE Handbook	Fundamentals
ASHRAE Handbook	HVAC Systems and Applications

American Society of Mechanical Engineers (ASME), 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

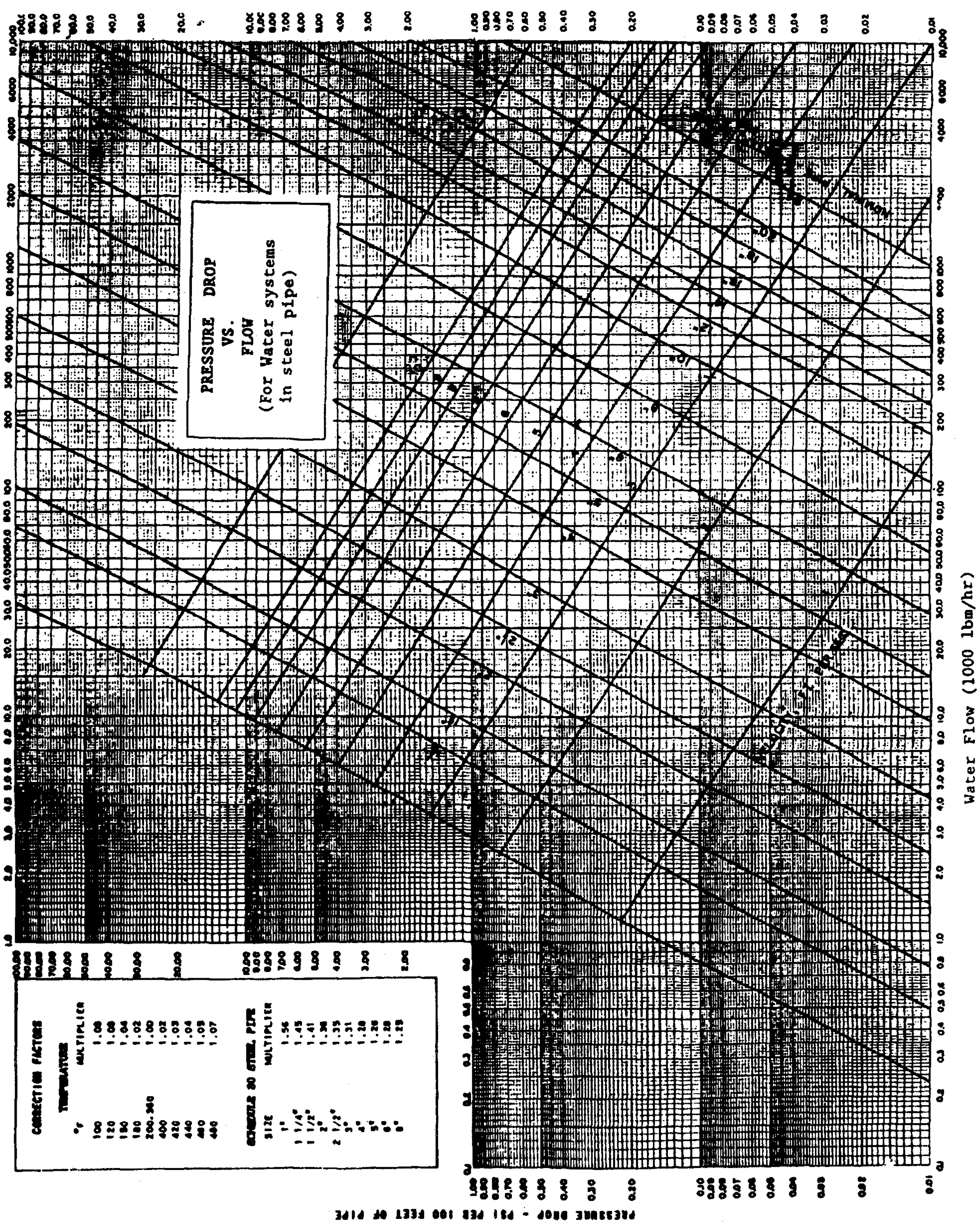
B31.1	(1989) Power Piping

Canadian Society of Civil Engineers, Montreal, Quebec, Canada

(1986) Cold Climate Utilities Manual

APPENDIX B

PRESSURE DROP VERSUS FLOW CHART



APPENDIX C

CONDENSATION LOAD CALCULATIONS (NORMAL)

Step #1 Determine the heat loss per foot of line.

$$Q = 2\pi\ (T_{st} - T_{out})/(\ln(r_o/r_i)/k_p + \ln(r_{io}/r_o)/k_{in} + 1/3r_{io})$$

Assumptions. This equation models an insulated pipe surrounded by air. The convective resistance between the insulation and the outside of the pipe is assumed to be negligible. Also, the convective heat transfer coefficient outside of the insulation is assumed to be 3 BTU/hr-ft^2 deg. F.

Step #2 Determine the flow of condensate from the heat loss calculated in step #1.

$$m = Q/(h_{st} - h_{con})$$

Step #3 Multiply the flow rate per foot, calculated in step #2, by the total number of feet of steam line that slopes toward the trap in question. The result is the minimum flow capacity of the trap.

where:

- Q = heat loss per foot of pipe; Btu/hr-ft
- T_{st} = temperature of steam; deg. F
- T_{out} = temperature of ambient conditions; deg. F
- r_o = outside pipe radius; feet
- r_i = inside pipe radius; feet
- r_{io} = outside insulation radius; feet
- k_p = thermal conductivity of pipe; Btu/hr-ft- deg. F; (26 Btu/hr-ft-deg. F for steel)
- k_{in} = thermal conductivity of insulation; Btu/hr-ft- deg. F * (see table below)
- m = mass flow rate of condensate; lbm/hr-ft
- h_{st} = enthalpy of saturated steam; Btu/lbm
- h_{con} = enthalpy of condensate; Btu/lbm

\1\ *K-value (Btu/hr-ft-deg. F /1/

Insulation Type	400 deg. F	300 deg. F	200 deg. F
Mineral Fiber	0.034	0.029	0.024
Calcium Silicate	0.042	0.038	0.035

APPENDIX D

CONDENSATION LOAD CALCULATIONS (STARTUP)

Step #1 Determine the heat loss per foot of line.

The startup load can be calculated by determining the amount of heat that is required to heat the steam pipe from an ambient temperature to the saturation temperature of the steam the pipe is to carry. This is done by using the following equation:

$$Q = (v_p * c_p * ?_p \ (t_{st} - T_{out}))/t; \text{ Btu/ft}$$

where:

$$v_p = ? \ (r_o^2 - r^2); \text{ in ft}^3\text{/ft}$$

Step #2 Determine the pounds of condensate per foot from the heat loss calculated in step #1.

$$m = Q/(h_{st} - h_{con}); \text{ lbm/ft}$$

Step #3 Multiply the condensate per foot, calculated in step #2, by the total number of feet of steam line that slopes toward the drip leg in question. Then convert the total pounds of condensate to gallons assuming 200 F condensate:

$$\text{Total Condensate Volume (gallons)} = \frac{(m*L)*7.49 \text{ gallons/ft}^3}{60.1 \text{ lbm/ft}^3}$$

where:

Q = heat loss per foot of pipe; Btu/hr-ft
T_{st} = temperature of steam; deg. F
T_{out} = temperature of ambient conditions; deg. F
r_o = outside pipe radius; feet
r_i = inside pipe radius; feet
m = mass flow rate of condensate; lbm/hr-ft
h_{st} = enthalpy of saturated steam; Btu/lbm
h_{con} = enthalpy of condensate; Btu/lbm
c_p = specific heat of pipe (steel); (0.10 to 0.11) Btu/lbm/degrees F
$?_p$ = density of pipe (steel); (489) lbm/ft_3

t = length of time for startup; hrs (typically 0.5 hrs.)

L = total length of pipe draining to drip; ft
v_p = volume of pipe material per foot; ft^3/ft

UFC 3-430-05
26 February 2021

UNIFIED FACILITIES CRITERIA (UFC)

NATURAL GAS AND LIQUEFIED PETROLEUM GAS (LPG) DISTRIBUTION PIPELINES

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NATURAL GAS AND LIQUEFIED PETROLEUM (LPG) DISTRIBUTION PIPELINES

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-430-09, dated January 2004.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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Deputy Assistant Secretary of Defense (Facilities Management)
Office of the Assistant Secretary of Defense (Sustainment))

UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-430-05, *Natural Gas and Liquefied Petroleum Gas (LPG) Distribution Pipelines*

Superseding: This change supersedes UFC 3-430-09 Exterior Mechanical Utility Distribution, dated 16 January 2004, with Change 1.

Description: This UFC provides guidance to the design and installation of new or modifications to existing distribution pipelines that convey natural gas, manufactured gas, or LPG in the vapor phase, that are installed on Government owned property. These requirements must be followed by the Government or its contractors when the Government is the responsible operator of the distribution pipeline. Where the Government is not the responsible operator, this UFC is intended to inform Government personnel of the requirements typically implemented by the responsible operator of the distribution pipeline.

Reasons for Document:

- This UFC has been completely rewritten in this change to comply with the Code of Federal Regulations, Title 49, Part 192 (49 CFR 192), Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards.

Impact:

- This change increases the initial and maintenance costs of gas distribution pipelines but ensures compliance with 49 CFR 192 in support of the requirements for reporting to the Pipeline and Hazardous Material Safety Administration (PHMSA). Proper application of these requirements also supports the transfer of responsible operation of compliant gas distribution pipelines from the Government to a Utility Privatization (UP) contractor or local gas provider.

Unification Issues

There are no unification issues with the guidance written herein.

TABLE OF CONTENTS

FIGURES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC is written to provide guidance for development of distribution pipelines carrying natural gas, manufactured gas or Liquefied Petroleum Gas (LPG) in its vapor phase, that are installed on Department of Defense (DoD) owned property, from the point of delivery by the gas supplier to the points of connection to the buildings' fuel gas piping. This UFC implements the regulations written in the Code of Federal Regulations (CFR), Title 49, Part 192 (49 CFR 192), Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards. This UFC applies where the DoD is the responsible operator of the distribution pipeline. Where a private utility provider is designated as the responsible operator, this UFC is to inform Government personnel of the requirements that apply to the distribution pipeline.

This document does not cover building fuel gas piping, which is the piping system that connects to the last downstream component of the distribution pipeline, either isolation valve, service regulator or meter, and supplies fuel gas to individual appliances. Refer to National Fire Protection Association (NFPA) 54, the International Code Council (ICC) fuel gas code and Unified Facilities Guide Specifications (UFGS) 23 11 25 Facility Gas Piping for guidance when installing building fuel gas piping.

This document does not cover systems used to convey LPG in its liquid phase. Refer to 49 CFR 195 and UFC 3-460-01 for liquid phase LPG pipelines and transfer systems. Refer to NFPA 58, the ICC fuel gas code and UFGS 23 11 25 Facility Gas Piping for guidance when installing a single LPG storage tank with LPG service to a single building.

1-2 APPLICABILITY.

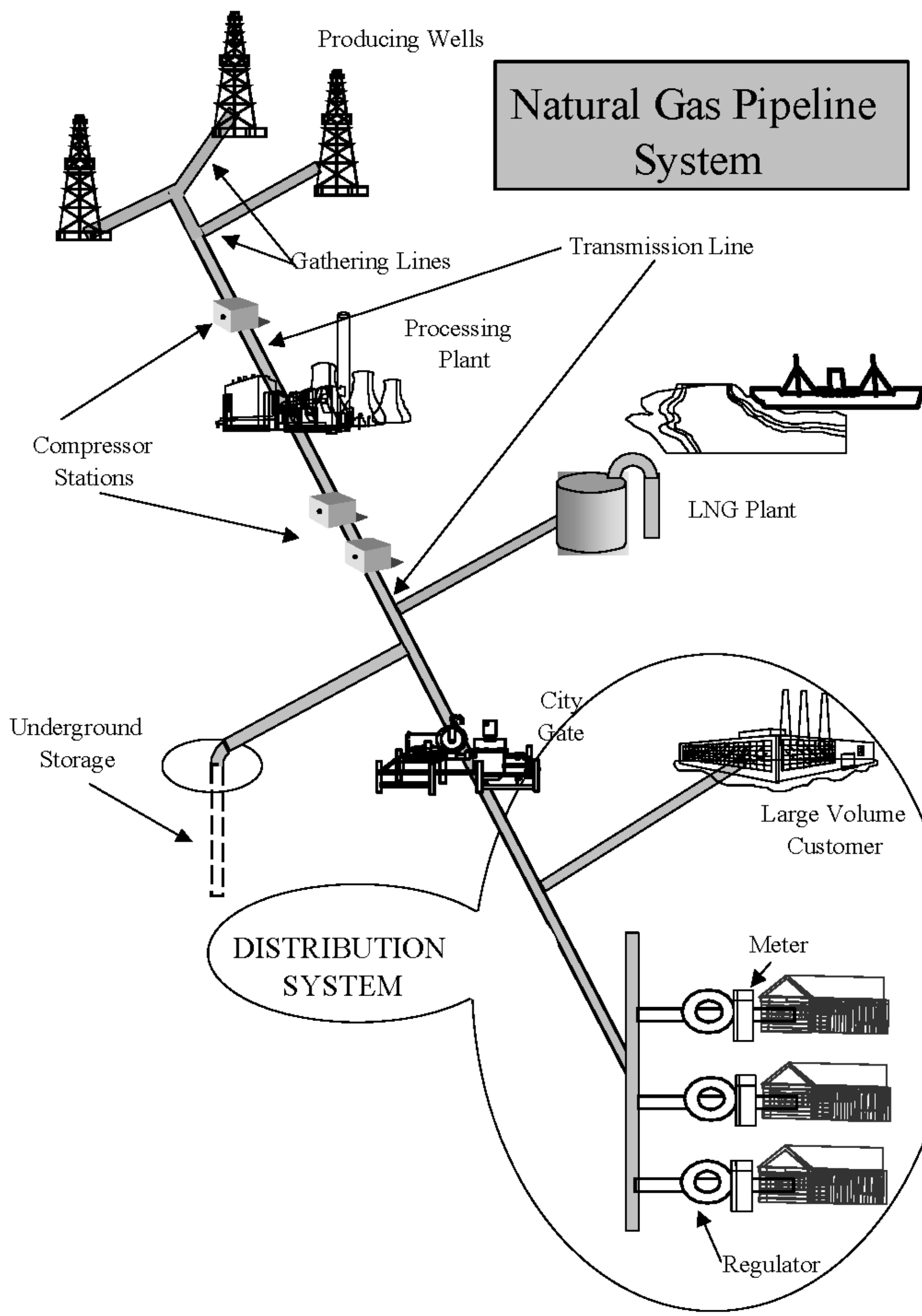
This UFC applies to all planning, design, design, construction, operations and maintenance for the gas distribution pipeline and all of the appurtenances where the DoD is designated as the responsible operator.

1-3 PIPELINE DISTRIBUTION.

1-3.1 Natural and Manufactured Gas.

Regulations written in 49 CFR 192 apply to every part of gas pipelines from the point of gas production to the point of connection of the service line components to a building's fuel gas piping system. An electronic version of 49 CFR 192 can be found at the Electronic CFR website: https://ecfr.io/Title-49/cfr192_main. Within 49 CFR 192, three distinct types of pipelines are described 1) Gathering Pipelines, 2) Transmission Pipelines and 3) Distribution Pipelines. See Figure 1-1 for a graphical representation of the 49 CFR 192 natural gas pipeline system. Gathering pipelines are not under the authority or scope of this UFC. Transmission pipelines typically owned and operated by gas suppliers and not covered by this UFC. Transmission lines installed on DoD installations are under an easement from the DoD to a responsible owner.

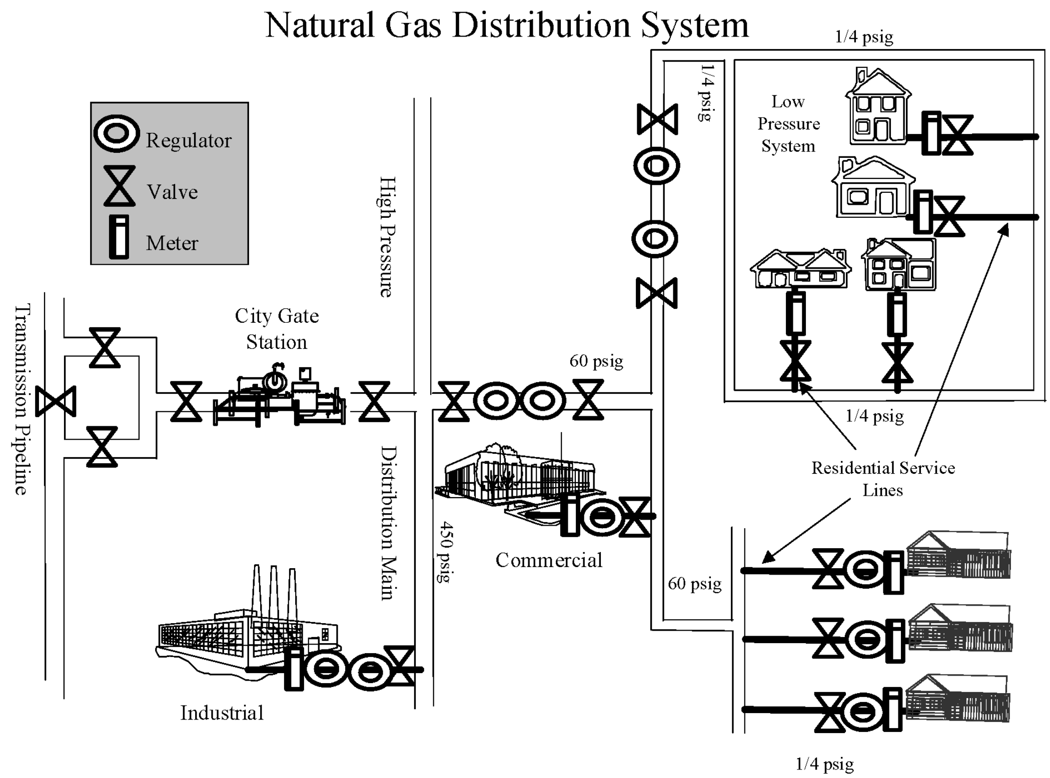
Figure 1-1 Example 49 CFR 192 Natural Gas Pipeline Network



Courtesy of the DOT Guidance Manual for Operators of Small Natural Gas Systems, January 2017

Gas pipelines for which the DoD is the responsible operator are typically classified as Distribution Pipelines and are characterized as a pipeline that receives gas from a gas utility purveyor who delivers, meters, and regulates the pressure of gas supplied to the distribution pipeline that is located on a DoD installation. See Figure 1-2 for a graphical representation of the natural gas distribution pipeline.

Figure 1-2 Example Typical Natural Gas Distribution System



Courtesy of the DOT Guidance Manual for Operators of Small Natural Gas Systems, January 2017

1-3.2 Liquefied Petroleum Gas (LPG).

49 CFR 192 also applies to LPG distribution pipelines that convey LPG in the vapor phase. Piping that conveys liquid LPG is not covered under 49 CFR 192, but is regulated by 49 CFR 195: Transportation of Hazardous Liquids by Pipeline. 49 CFR 195 §195.1 (b) (1) writes an exception to applicability for any hazardous liquid transported in a gaseous state. This exception implements, by default, 49 CFR 192 as the regulating document. 49 CFR 192 §192.11 refers to the vapor phase of LPG as 'petroleum gas' and requires that petroleum gas pipelines comply with 49 CFR 192 and NFPA 58, with NFPA 58 prevailing in the event of conflict. NFPA 58 applies to liquid LPG pipelines, liquid LPG storage containers, and pipelines that convey LPG in the vapor phase. This UFC provides guidance for the vapor phase distribution pipeline and the liquid storage container that serves that distribution pipeline. Please refer to UFC 3-460-01 for guidance on liquid phase LPG piping systems.

49 CFR 192 §192.1 (b) (5) allows two exceptions to applicability for any pipeline system that transports only petroleum gas.

"(5) The regulations of 49 CFR 192 do not apply to a pipeline system that transports petroleum gas or petroleum gas/air mixture to:

(i) Fewer than ten customers, if no portion of the system is located in a public place – or –

(ii) A single customer, if the system is located entirely on the customer's premises (no matter if a portion of the system is located in a public place)."

However, the requirements of NFPA 58 do apply. The exception allowed in paragraph (i) must not be applied on a DoD installation. On DoD installations, there is the likely possibility that a system will expand to include 10 or more customers. These exceptions do not change the materials or installation practices, as these are dictated by NFPA 58. What is exempted is the qualification of installation practices, installer qualifications, and reporting regulations of 49 CFR192. Therefore, the risk is that a system installed that does not comply with 49 CFR 192 regulations is very difficult, if not impossible, to expand into the scope of 49 CFR 192.

1-4 PIPELINE NOMENCLATURE.

Gas pipelines are described in 49 CFR 192 using the following nomenclature.

1-4.1 Gas.

Each time the term 'Gas' is used in this UFC, it is understood that the term applies to natural gas, manufactured gas, liquefied petroleum gas in its vapor phase, and any other flammable gas.

1-4.2 Gathering Lines.

Gathering lines transport gas from a gas production facility to the transmission pipeline or main. Gathering lines are not under the authority or control of DoD installations.

1-4.3 Transmission Lines.

Transmission lines are typically owned and operated by gas suppliers and are not operated by the DoD installation.

1-4.4 Distribution Lines.

Distribution lines transport gas from the transmission line or LPG storage container to each individual customer. Pipeline that operates at a hoop stress of 20% or more of the specified minimum yield stress (SMYS) must also meet the requirements of a transmission line.

1-4.4.1 Main.

A main is defined as a distribution line that serves more than one service line. Note that 49 CFR 192, Subpart G appears to apply only to transmission pipelines because it is entitled ‘General Construction Requirements for Transmission Lines and Mains’. Whenever 49 CFR 192 discusses a Main, the requirement applies to the distribution pipeline.

1-4.4.2 Service Line.

A service line is a distribution line that transports gas from a main to an individual customer’s meter, regulator, or isolation valve upstream of the customer’s piping. Note that this point of connection is the demarcation between the pipeline as governed by 49 CFR 192 and the fuel gas piping governed by NFPA 54.

1-4.4.3 High Pressure Distribution System.

A distribution system that operates with a gas pressure in the main that is higher than the pressure provided to the customer.

1-4.4.4 Low Pressure Distribution System.

A distribution system that operates with a gas pressure in the main that is substantially the same as the pressure provided to the customer.

Refer to 49 CFR 192 §195.3 for the official definition of each of these terms.

1-4.5 Master Meter Operators (MMO).

Small natural gas distribution systems are sometimes designated as Master Meter Systems (MMS). This designation is typically reserved for owners of apartment buildings, trailer parks, or other types of property managers. The 49 CFR 192 refers to MMO, the operator of an MMS, but does not provide clearly defined criteria for determining who is and who is not an MMO. The reporting regulations for an MMO are significantly less than the reporting regulations for the distribution pipeline operator; however, the requirement to obtain and retain complete knowledge of the system operated are nearly equal for each operator.

It is routine for natural gas systems installed on DoD installations to connect to transmission or distribution lines owned and operated by a natural gas purveyor through a metered and pressure regulated connection. Because of this method of connection and the limited reporting responsibility of an MMO, it is tempting for engineers, contractors, and operators to claim a natural gas distribution system to be a master meter system. No natural gas systems that are installed on a DoD installation shall be considered a master meter system without expressed written approval from the authorized administrator(s) of all applicable regulations.

1-4.6 Administering Agencies.

The Pipeline and Hazardous Material Safety Administration (PHMSA) is assigned as the administrator in 49 CFR 192 and is tasked with enforcing the regulations presented therein. Transmission line operators and distribution line operators are required by the regulations to report specific information to PHMSA. The reporting regulations are different and more detailed for the transmission line operator than for the distribution line operator. But, none the less, the distribution line operator is required to report to PHMSA. These reporting requirements create the need for the pipeline operator to obtain and retain complete knowledge of each pipeline segment and component installed in the system that the operator is responsible for. Details of the plans, procedures and reports that must be available for PHMSA review for distribution pipelines are defined in 49 CFR 192, Subparts L and P. A more comprehensive discussion of reporting requirements can be found in the January 2017 revision of "Guidance Manual for Operators of Small Natural Gas Systems", Chapter VIII, authored by the Department of Transportation (DOT). Paragraph 1-3.7 of this UFC briefly describes these reporting requirements to emphasize the importance of the detailed design and construction submittal process necessary to support the DoD installation in complying with the reporting regulations of 49 CFR 192.

State agencies may also enforce pipeline safety regulations that are more stringent than the regulations presented in 49 CFR 192. Local municipalities, gas purveyors, and the transmission line operator may also apply more stringent regulations. The distribution line operator must know the regulations that apply to the distribution pipeline that he operates and should transfer the requirements to design engineers and installing contractors who perform work on this system.

It is necessary that the Designer of Record (DoR) for any distribution pipeline projects such as construction, addition, rehabilitation, and repair on a DoD installation contact the person or department responsible for operating the pipeline to understand the requirements that apply.

1-4.7 Plans and Reports.

All operators of gas pipelines are required to maintain a number of plans for safe operation of the pipeline. Therefore, all information relative to work performed on gas distribution pipelines installed on DoD installations must be provided to the responsible operator through the design and construction process in order to support the ongoing planning and reporting efforts required from that responsible operator. The Department of Public Works (DPW)/Base Civil Engineer (BCE), a Utility Privatization (UP) contractor, or a gas supplier is typically the responsible operator of gas distribution pipelines located on DoD installations and should provide information on the distribution pipeline as it exists and must receive complete information on all work performed.

The plans required from a distribution pipeline operator are listed below to indicate the necessary thoroughness of the information that must be made available. Requirements for developing these plans and reporting the information contained in the plans are defined in 49 CFR 192.

- Operations and Maintenance (O&M) Plan: Subparts L and M, consist of 27 procedures covering all aspects of installing, operating and maintaining each pipe segment and component. These procedures include, but are not limited to, the following:
    - Making construction documents available to operating personnel.
    - Gathering data needed for reporting incidents.
    - Corrosion control.
    - Continued surveillance and damage prevention: §192.613 and 614.
    - Emergency Plan: §192.615.
    - Public Awareness Plan: §192.616.
    - Leak Survey: §192.723.
- Operator Qualification Plan: Subpart N.
- Distribution Integrity Management Plan: Subpart P, consists of 7 required elements.

The information necessary to develop these required plans mostly originates during design and construction of each segment of the pipeline. Therefore, the construction plans and specifications developed by the Designer of Record (DoR) must include appropriate system design and testing parameters as well as requirements for the installing contractor to submit all information necessary, including location, materials, equipment, installation procedures, procedure and personnel qualification, and testing results, for the DoD installation to develop and maintain the required plans and procedures.

1-5 ORGANIZATION OF 49 CFR 192.

49 CFR 192 is divided into Subparts, each describing a specific area of concern. The following sub-parts are not retroactive and apply to pipelines readied for service after 12 March 1971, or were replaced, relocated, or changed after 12 November 1970:

Subpart B – Materials
Subpart C – Pipe Design
Subpart D – Design of Pipeline Components
Subpart E – Welding of Steel in Pipelines
Subpart F – Joining of Materials other than by Welding
Sub part G – General Construction Requirements for Transmission Lines
Subpart H – Customer Meter, Services, Regulators, and Service Lines
Subpart J – Test Requirements
Subpart N – Qualification of Pipeline Personnel

The following subparts are retroactive and apply to all existing pipelines regardless of date of construction:

Subpart A – General
Subpart I – Requirements for Corrosion Control
Subpart K – Uprating
Subpart L – Operations
Subpart M – Maintenance
Subpart O – Gas Transmission Pipeline Integrity Management
Subpart P – Distribution Integrity Management

1-6 USE OF ASME B31.8.

Pipelines on DoD installations must comply with the requirements of 49 CFR 192. A comparable industrial standard is ASME B31.8, Gas Transmission and Distribution Piping Systems. Although ASME B31.8 may appear to be an acceptable piping code for compliant natural gas pipeline construction, it allows materials, components, and construction practices that do not comply with 49 CFR 192. §192.7 specifies that use of ASME B31.8 is approved only as referenced in §192.112(b) and §192.619(a).

As an industry standard, ASME B31.8 provides additional detail that is not found in the Code of Federal Regulations (CFR). Therefore, ASME 31.8 is a very good reference document and is recommended to help the reader better understand the material and construction practices available from the natural gas industry. But 49 CFR 192 is the defining requirements document and any decision made from information presented in ASME B31.8 must be confirmed to comply with the requirements of 49 CFR 192.

1-7 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

APPENDIX C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 DISTRIBUTION PIPELINE DESIGN

2-1 SYSTEM PLANNING.

2-1.1 System Layout.

Gas distribution pipelines will be planned carefully with due consideration for economy, safety, and uniformity of pressure. The lines will be well-looped within the main area and in all outlying areas whenever practicable and economically feasible to do so. It is not always practicable to loop a supply line to an outlying area and then back into the main system, but in such cases the objectionable effects of dead ends can often be relieved to some extent by looping such line around the area it serves and then back into itself.

2-1.2 Pipeline Location.

Gas distribution pipelines will never be installed under a building. They will not be laid in the same trench with other utilities to preclude the possibility of leaking gas following along or collecting in other conduits and creating an explosion hazard. For the same reason, gas lines will be above other utilities whenever they cross, if practicable. Underground gas pipelines must be installed with the minimum clearance from other underground structures as is specified in §192.325. Gas lines will not be laid under paved streets or in other locations subject to heavy traffic whenever practicably avoidable. Whenever it is necessary to locate gas lines in such locations, the lines will be protected in accordance with (IAW) 49 CFR 192. Sufficient clearance must be maintained between plastic mains and steam, hot water, power lines, and other sources of heat, to avoid temperatures in excess of the rated temperature and pressure combination of the pipe.

2-1.3 Location Classification.

49 CFR 192, §192.5 classifies the location of a gas pipeline based on its proximity to occupied buildings or frequently occupied outdoor locations. The location classification ranges from Class 1 to Class 4 and signifies the level of risk and consequence to human life in the event of pipeline failure. As population density increases, so the location class number increases. The location classification is used in defining several regulatory requirements for a given pipe segment.

The Designer of Record (DoR) of any project that modifies any segment of a gas distribution pipeline on a DoD installation must obtain existing location classifications, verify that the class meets §192.5, and identify the proper location class for all pipeline segments modified or connected to in the project. Design drawings must indicate the location classification for each pipe segment in the distribution pipeline. For projects on DoD installations, all new or modified distribution pipeline must be location Class 3 to minimize the impact that future building construction projects may have on existing pipelines. Where connection is made to a pipe segment designed for a location class other than Class 3, the drawings must identify the location of the change in class.

The pipeline operator is responsible for maintaining the proper location classification for each segment of pipe as additional buildings are constructed on the DoD installation. Therefore, the DoR must coordinate the intended location classification with appropriate DoD installation personnel.

2-2 ENGINEERING ANALYSIS, PLANS, AND SPECIFICATIONS.

The DoR must provide an engineering analysis, plans, and specifications that define the work to be performed and all of the information that the installing contractor is required to provide to the Government for a complete and functional installation that meets the regulatory requirements of 49 CFR 192 and provides the Government Operator with all information needed for proper reporting to the regulatory agency, for example PHMSA, State agency.

2-2.1 Engineering Analysis.

Engineering analysis will be presented in diagram form showing all connected loads, design flow rate, locations of valves, pressure regulators, and other pipeline devices, actual operating pressure before and after each regulator, and any other appurtenance required to control downstream pressure, relieve downstream pressure, or prevent excess flow. A complete set of supporting calculations will be prepared.

2-2.2 Plans.

The plans will include a layout drawing showing the entire distribution system and detail drawings clearly showing pipe sizes, the location of gas mains, service connections, details for abandoning gas piping, mechanical couplings, valves, service taps, regulators, and other appurtenances. ASME B31.8 requires that abandoned gas lines be physically disconnected from gas sources. Shutoff valves are not an acceptable means of disconnect.

2-2.3 Specifications.

2-2.3.1 Required Specifications.

The DoR must use UFGS 33 51 15 Natural-Gas / Liquefied Petroleum Gas Distribution Pipelines to specify gas distribution pipeline work from the gas source (gas purveyor's meter and regulator) and LPG storage tank where applicable, to the point of connection to building fuel gas piping. Be aware that UFGS 23 11 25 Facility Gas Piping specifies the requirements from the point of connection to the distribution system to the appliances.

2-2.3.2 Submittal Description (SD)-11 Close-Out Submittals Required.

Close-out submittals, SD-11, typically include items such as the as-built set of drawings and specifications, test results, and project acceptance documents. Close-out submittals for construction of distribution pipelines are required to include a complete display of all information obtained during the construction process in order to support the ongoing efforts of the DoD Installation to comply with the documentation and reporting tasks required by 49 CFR 192.

The following is a list of information that must be submitted at project close-out in order to support the DoD Installation in obtaining and retaining information pertinent to construction of distribution pipelines for which the DoD Installation is the operator:

- As-built Layout Drawings – Submit drawings that show the geographic information system (GIS) location each newly installed pipe segment, each connection to existing pipe, and each abandoned pipe segment. The drawing must include pipe size, material type, design gas flow capacity, and maximum allowable operating pressure as defined by the operator and specified by the DoR.
- Pipe Materials – Submit for each pipe segment the pipe material specification number (for example ASTM D2513), name of manufacturer, manufacturer's item or part number, length of segment purchased, lot number, date manufactured, and date installed. These material submittals must be keyed to the layout drawing.
- Mechanical Couplings – Submit for each mechanical coupling installed the name of manufacturer, manufacturer's part number, serial number, date manufactured, and date installed. Each mechanical coupling must be keyed to the layout drawing so as to identify the exact location of the particular serial number installed.
- Piping Joints – Layout drawings must identify the GIS location of each joint made in every segment of distribution pipeline. A pipe joint, as used here, is defined as any connection made to join a pipe to another pipe, a fitting, a piece of equipment, or any other appurtenance. The following information regarding each pipe joint must be correlated to the pipe joints shown on the layout drawing.
    - Manufacturer's written procedure for making the identified connection.
    - Name and identifying mark of the person making that connection.
    - Qualification certificate for the person who made the connection.
- Leakage and strength test results.

Geographic Information System (GIS) coordinates must be submitted for the pipeline including all joints in the pipeline, all taps and tee, and all mechanical fittings.

2-3 DISTRIBUTION PIPELINE DESIGN.

The design for any new or modified gas pipeline must comply with 49 CFR 192, Subpart C. For LPG (petroleum gas) pipelines, 49 CFR 192, §192.11 states that the requirements of NFPA 58 prevail in case of conflict.

Subpart C – Pipe Design, prescribes the minimum requirements for pipe design. Pipe must be designed with sufficient wall thickness to withstand the internal pressure of the gas without failure. The wall thickness must be increased or the pipe must be installed with adequate protection to withstand the anticipated external forces and loads without failure.

2-3.1 Load Diversity.

The design of a gas distribution pipeline installed on a DoD Installation will be based on the sum of rated gas load of all connected appliances to the distribution pipeline in the following proportions:

- Natural gas, more than 15 buildings: More than 80 percent of the full connected appliance load.
- Natural gas, 15 buildings or fewer: 100 percent of the full connected appliance load.
- LPG, vapor phase: 100 percent of the full connected appliance load regardless of the system size.

2-3.2 Design Pressure for Steel Pipe.

2-3.2.1 Design Pressure.

The DoR must determine the design pressure of each pipe segment in accordance with 49 CFR 192, Subpart C.

Steel pipe design pressure is calculated using the equation presented in §192.105. This equation uses the basic hoop stress equation with reduction factors for increased temperature, type of longitudinal joint, and location classification. Each of the variables used in the equation are defined in §192.107 through 115.

2-3.2.2 Yield Strength.

The yield strength of pipe is defined in the pipe specifications that are listed in 49 CFR 192, Appendix B, and is the Specified Minimum Yield Strength (SMYS) stated in the Appendix B specification list for the pipe material used. Because pipe specifications not listed in Appendix B are not allowed on Government DoD installations, alternative means of determining yield strength are not allowed for new construction. These alternative means may, however, be required for evaluating the design pressure existing pipe.

Class 3 location is the minimum class allowed for all distribution pipelines on a DoD Installation.

2-3.3 Design Pressure for Plastic Pipe.

The DoR must determine the design pressure of each pipe segment in accordance with 49 CFR 192, Subpart C.

Plastic pipe design pressure is calculated using the equation presented in §192.121. This equation is a modified version of the basic hoop stress equation that uses terms common in the plastic piping industry. The yield strength is the Hydrostatic Design Basis (HDB) at or above the operating temperature of the pipe. The HDB is typically found in the pipe specification that defines the particular type of plastic pipe.

2-3.3.1 Standard Dimension Ratio (SDR).

The maximum allowed Standard Dimension Ratio (SDR) for plastic pipe installed on a DoD installation is SDR-11. The SDR is the diameter of the pipe divided by the wall thickness. SDR-11 represents the minimum wall thickness allowed on DoD installations.

A design factor of 0.32 reduces the design pressure of polyethylene (thermoplastic) and reinforced epoxy resin (thermosetting) pipe. A design factor of 0.40 reduces the design pressure of polyamide-11 (PA-11) pipe.

2-3.3.2 Maximum Design Pressure.

Maximum design pressure for plastic pipe is limited by §192.121. 49 CFR 192 limits the design pressure of plastic pipe to 100 pounds per square inch gauge (psig) with exceptions in specific piping materials to allow higher pressures. These exceptions must be thoroughly investigated and documented prior to providing plastic pipe in systems with greater than 100 psig.

Note that ASTM F2945 for PA-11 states that heat fusion joining of PA-11 pipe and fittings is not allowed to pipes and fittings made from any other thermoplastic materials. Therefore, care should be taken when specifying a different type of plastic than has been previously installed because of the complexity in connecting different plastic materials.

2-3.4 Maximum Allowable Operating Pressure (MAOP).

The MAOP of the distribution pipeline is controlled by the responsible operator of that distribution system, in accordance with 49 CFR 192. The DoR must obtain the MAOP for the existing distribution system from this responsible operator prior to designing work on the distribution pipeline. The MAOP must be included in the design calculations and on the design drawings for each pipe segment connected to or installed in the project.

Maximum Allowable Operating Pressure (MAOP) for steel and plastic pipelines is determined from the requirements stated in §192.619 thru 623, which prescribe the MAOP for distribution mains and service lines respectively. MAOP, as determined under §192.619 thru 623, is generally associated with the lowest of the design pressure or a fraction of the test pressure that the pipe segment was initially tested to after installation. The test pressure for Class 3 locations is 1.5 times the MAOP. Every pipe segment must be tested IAW 49 CFR 192, Subpart J in order to substantiate the MAOP determined under §192.619. It is recommended that new pipe be tested at the highest pressure that is safely practical to set the MAOP of that pipe segment has high as safely possible to prevent having to uprate in the future.

MAOP for distribution mains is limited to 60 psig unless every service line connecting to the distribution main contains devices installed for the purpose of protection against over-pressurization IAW §192.197(c). These devices must limit the inlet pressure to the service regulator by pressure regulation, flow relief, or isolation. ASME B31.8, para. 845 may be used as reference, as this reference provides additional information on these overpressure devices, and all devices listed are included in 49 CFR 192.

2-3.5 Increasing the MAOP by Uprating.

Pipelines may have their pressure increased above a previously determined MAOP by following the requirements of 49 CFR 192, Subpart K and logically determining a new MAOP IAW §192.619. All pipe segments to be uprated must be tested to the requirements of a new pipe of the same material installed in the same location.

The process required by 49 CFR 192, Subpart K is quite detailed, requiring much research and field work before the pipeline pressure increase is allowed. Therefore, it is recommended to initially test all pipelines to the highest test pressure that is safely practical in order to prevent the need for uprating in the future.

2-3.6 Alternative MAOP.

Although 49 CFR 192.619 allows for determining alternative MAOP, this method is difficult to implement due to the vast amount of information necessary to apply the method. An acceptable alternative is to utilize §192.620 which provides the requirements for determining and using an alternative MAOP. §192.620(b) (2) requires that the pipeline segment that uses an alternative MAOP be constructed to meet the additional design requirements of § 192.112. This section stipulates that only pipe manufactured to API SPEC 5L may use the alternative MAOP. The requirements further mandate several documented quality control manufacturing processes, which are typically not available for existing systems and not cost effective for new systems.

2-3.7 Test Requirements.

Every pipe segment must be tested IAW 49 CFR 192, Subpart J in order to substantiate the MAOP determined under §192.619. Tests are required to prove that the pipeline does not leak and in specified cases must be strength tested for a specified duration. For safety reasons, hydrostatic testing is preferred; however, 49 CFR 192 allows air, inert gas, and even the natural gas source to be used under specific constraints. 49 CFR 192 does not allow the use of LPG in the vapor phase, a.k.a. petroleum gas, to be used as a test media.

LPG pipelines operating under 49 CFR 192 must comply with the testing requirements of 49 CFR 192, rather than testing described in NFPA 58.

2-3.7.1 Test Pressure for Steel Pipelines.

The test pressure that applies to most distribution pipelines installed on DoD installation are defined in the 2018 revision of 49 CFR 192 as follows:

- §192.507 for steel pipelines operating at 100 psig or higher and less than 30% SMYS: Leak test between 100 psig and the pressure that creates stress of 20% SMYS. Strength test at leak test pressure for duration of 1 hour.
- §192.509 for steel distribution mains operating below 100 psig: A minimum leak test pressure of 90 psig for operating pressures of 1 psig or greater. A minimum leak test pressure of 10 psig for operating pressures less than 1 psig.
- §192.511 for steel service lines with operating stress less than 20% SMYS: A minimum leak test pressure of 50 psig for operating pressures from 1 to 40 psig. A minimum leak test pressure of 90 psig for operating pressures greater than 40 psig.
- §192.513 for plastic distribution mains and service lines: Leak test pressure at least 150% of the maximum operating pressure. Not less than 50 psig. Refer to §192.513 for further restrictions during testing. Pneumatic leak testing must be performed IAW ASTM F2786. Hydrostatic testing must be performed IAW ASTM F2164

For steel pipelines that operate at or above 100 psig, with a hoop stress less than 30% of the SMYS, the rules presented in §192.507 must be applied using an appropriate test pressure and inspection that discovers all leaks in the segment being tested. In the rare case that a steel distribution pipeline operates with a hoop stress above 30% of the SMYS, the reader should follow §192.505 for hydrostatic strength testing and leak testing requirements.

Please refer to these 49 CFR 192 sections for updates to the required test pressures and more detail of the required tests.

2-3.7.2 Test Pressure for Polyethylene Pipelines.

2-3.7.2.1 Leak Testing.

49 CFR 192 §513 requires that leak test on plastic distribution mains and service lines be performed at a pressure at least 150% of the maximum operating pressure, but not less than 50 psig. Refer to §192.513 for further restrictions during testing.

Leak testing of polyethylene and other plastic pipelines must be specified and performed with an understanding of the effects that pressure has on the plastic material. Pneumatic leak testing of polyethylene pipelines must be performed IAW ASTM F2786. Hydrostatic testing of polyethylene pipelines must be performed IAW ASTM F2164. Both of these documents prescribe procedures that limit the maximum test pressure to 1.5 times the design pressure of the weakest component. This limitation is in contrast 49 CFR 192 §513, which states that the maximum test pressure must not exceed 3 times the design pressure calculated in §192.121. This is because the two documents define ‘design pressure’ differently.

2-3.7.2.2 Hydrostatic Design.

49 CFR 192 §121 uses the Hydrostatic Design Basis (HDB) of the particular material at the testing temperature and a design factor of 0.32 to reduce the pipeline design pressure.

ASTM F2786 uses the Hydrostatic Design Stress (HDS) of the particular material to calculate the pressure rating of the pipeline and a temperature reduction factor to reduce the pipeline maximum test pressure. ASTM F2164 uses the terms ‘design pressure’ and ‘pressure rating’ synonymously.

2-3.7.2.3 Pressure Testing.

It is recommended that the maximum test pressure be determined using the methods presented in ASTM F2786 for pneumatic testing or ASTM F2164 for hydrostatic testing. Although the ASTM and CFR methods produce the same maximum test pressure when the pipe temperature is at 73° F, as the pipe temperature increases, 3 times the design pressure as specified in 49 CFR 192 §513 exceeds the maximum test pressure calculated from the ASTM methods.

Because pipe strength reduces with increasing pipe temperature, it necessary to monitor the pipe temperature during testing. Pipe temperature increases during pneumatic testing due to the heat of compression in the compressible test media, sunlight exposure, and ambient temperature. Contact the manufacturer of pipe, fitting, and components for guidance during pneumatic testing. The cooler temperature and higher heat capacitance of a hydrostatic test media helps to reduce the temperature of the test section.

In both pneumatic testing per ASTM F2786 and hydrostatic testing per ASTM F2164, the length of time that the pipeline is pressurized above its MAOP is limited to 8 hours. Therefore, from the start of pressurizing the pipeline, through the test phase, and ending at depressurization of the pipeline, the total time duration must not exceed 8 hours. If retesting is necessary, the pipeline must be allowed to relax at a pressure less than the operating pressure for a duration of 8 hours before restarting the test.

CHAPTER 3 MATERIALS AND COMPONENTS

3-1 LPG STORAGE CONTAINERS.

Containers used for storage of LPG in the liquid phase must comply with NFPA 58 requirements. Where piping systems are to be designed for filling LPG storage tanks, please refer to UFC 3-460-01 for guidance in design of these specialized, LPG liquid piping systems.

LPG storage containers must be designed, fabricated, tested, and marked in accordance with the regulations of the department of transportation (DOT), ASME Section VIII "Rules for the Construction of Unfired Pressure Vessels, or API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases. Storage containers having 4,000-gallon water storage capacity or less must include all appurtenances as required by NFPA 58, paragraph 5.9 to include, but not limited to, the following:

- Vapor shutoff valve
- Liquid shutoff valve
- Pressure relief valve
- Fixed maximum liquid level gauge
- Filler valve
- Overfilling protection device
- Actuated liquid withdrawal excess-flow valve for 25-gallon water capacity or more
- Float gauge for 125-gallon water capacity or more

Please refer to NFPA 58, paragraph 5.9.4.2 for connection and appurtenance requirements that apply to LPG storage containers having storage capacity greater than 4,000 gallons of water capacity. Container appurtenances must have a minimum service pressure rating of 250 psig.

3-2 PIPE MATERIAL SELECTION.

Pipe materials used in LPG distribution pipelines installed on a DoD installation must comply with the material specifications listed in NFPA 58, with the exceptions of DoD installations below.

Pipe materials used in natural gas and manufactured gas distribution pipelines installed on a DoD installation must comply with the material specifications listed in 49 CFR 192, Subpart B and Appendix B, with the following exceptions:

3-2.1 Exceptions of DoD Installations.

The following are exceptions to the materials listed in Appendix B of 49 CFR 192:

- It is recommended that steel pipe not be installed below grade due to corrosion. Where a fuel gas compressor is installed on the user's fuel gas supply piping, governed by NFPA 54, a steel service line may be necessary to withstand the forces caused by pressure pulsation and vibration. See API RP 686, ASME B31.8, and 49 CFR 192 for guidance. Steel pipe installed below grade must be coated and cathodically protected from corrosion.
- Polyethylene (PE) piping, ASTM D2513, must be installed below grade, SDR-11 or thicker wall.
- Polyamide-11 (PA-11), SDR-11 or thicker wall, can be installed below grade only to connect to existing PA-11 piping because heat fusion of PA-11 to any other plastic is not qualified. Recommend using ASTM F2945 for specifying PA-11 piping because this material was moved from the PE piping ASTM after 1999.
- Plastic pipe that passes through vaults or is otherwise uncovered by soil, the plastic pipe must be encased in ASTM A53/A53M minimum schedule 40 steel pipe that is properly protected from corrosion and vented. Materials and installation must comply with 49 CFR 192.
- Although ASTM D2517, Standard Specification for Reinforced Epoxy Resin Gas Pipe and Fittings, for example thermosetting plastic, is included in the Appendix B list. Thermosetting plastic material should not be specified unless the existing distribution pipeline is also constructed of this material.
- For LPG, NFPA 58 does not allow ASTM D2517, thermosetting plastic pipe to be used.

3-2.2 Restricted Materials.

Cast iron and ductile iron are restricted materials within 49 CFR 192. Cast and ductile iron should not be used in natural or manufactured gas distribution pipelines on DoD installations. Where existing cast iron or ductile iron pipe is installed, the DoR must make every effort to know all details of its installation and any rehabilitation that has been performed. The construction documents created by the DoR that connect to the existing cast iron or ductile iron pipe must require the installing contractor to perform all inspections and tests and make all necessary enhancements or take all necessary precautions required by 49 CFR 192. The following information is identified from the 2018 revision of 49 CFR 192, but is not inclusive of all restrictions. NFPA 58 does not allow cast iron pipe or pressure containing components constructed from cast iron to be used in LPG pipelines. NFPA 58 does not allow ductile iron pipe to be used in LPG pipelines, but does allow metallic fittings and pressure containing components to be constructed from ductile iron that meets ASTM A395/A395M.

The following apply to existing cast iron or ductile iron natural or manufactured gas pipelines as stated:

- §192.621 limits the operating pressure of cast iron pipe segment with unreinforced bell and spigot connections to 25 psig.
- §192.753 (a) requires all bell and spigot connections in pipe segments operating at pressures higher than 25 psig to be sealed with mechanical leak clamps or equivalent. For pipe segments operating at 25 psig or below, the connection must be sealed IAW §192.753. (b) if the connection is exposed for any reason.
- Existing cast iron connections that are sealed with a gasket and retained by a follower ring are qualified under §192.275 but are restricted in MAOP.
- Cast iron flanges must be cast integrally into the pipe, fitting, or valve and must conform to ASME B16.1.
- Neither cast iron nor ductile iron pipe that is less than 6" nominal pipe size (NPS) may be used as a service line, per §192.373.
- Requirements of §192.557 must be met before the operating pressure of a cast iron or ductile iron pipe segment is increased above its previously established MAOP.
- Ductile iron components are typically allowed to operate at 80% of their rated pressure at temperature.

In addition, §192.489 requires the replacement of cast and ductile iron piping that shows general graphitization might cause the pipe to fracture or leak. Only localized graphitization may be repaired. Several other paragraphs throughout 49 CFR 192 place requirements on construction practices that may be required when modifying a distribution pipeline that is constructed from cast iron or ductile iron. The reader is cautioned to pay particular attention to all design elements when modifying an existing pipeline constructed of these materials.

3-3 DESIGN OF PIPELINE COMPONENTS.

Components installed in distribution pipelines must comply with the requirements of 49 CFR 192, Subpart D, which prescribes the qualification of all valves, fittings, pressure regulators, and other devices installed in a natural gas pipeline.

3-3.1 Fittings.

Fittings used on steel pipe must be butt welded or flanged and be rated for the operating pressure and temperature of the distribution pipeline. Butt weld fittings should be factory made wrought steel per ASME B16.9 with butt weld ends per ASME B16.25. Flanges should comply with ASME B16.5 and MSS SP-44.

3-3.1.1 Threaded Fittings.

Threaded fittings complying with ASME B1.20.1 may be used above ground only, due to the corrosion potential when installed underground. Threaded fittings must have at least the minimum metal thickness required for the operating pressure and temperature of the system.

Threaded fittings may be used on LPG pipelines to connect piping to equipment or appurtenances that are provided from the manufacturer with threaded connections. The proper type of threaded fitting must be specified to make connection to the manufacturer's equipment or appurtenance. Butt weld fittings are preferred to connect lengths of pipe in all sizes. Threaded fittings should not be used to connect lengths of pipe, but where this type of connection is necessary in the construction, specify schedule 80 pipe and back weld at the threaded connection.

3-3.1.2 Socket Weld Fittings.

Socket weld fittings must not be used in natural gas, manufactured gas, or LPG distribution pipelines installed on DoD installations for the reasons listed hereinafter. Socket weld fittings are connected by a fillet weld, which is not a full penetration weld and cannot be confirmed by nondestructive testing to meet pull-out requirements. The socket weld fitting also contains a void between the pipe and fitting that can be a site for contaminant, corrosion, natural gas, and petroleum distillate to reside, undetected.

3-3.1.3 Branch Connections.

Branch connections must be designed for both pressure and temperature requirements and mechanical strength. Tee fittings should be used for branch connections where practical. Welded branch connection must be designed and constructed to ensure that the strength of the pipeline system is not reduced, taking into account the stresses in the remaining pipe wall due to the opening in the pipe or header, the shear stresses produced by the pressure acting on the area of the branch opening, and any external loadings due to thermal movement, weight, and vibration.

3-3.1.4 Mechanical Fittings.

Mechanical fittings used to make a hot taps must be qualified to withstand the maximum anticipated operating pressure and temperature of the pipeline.

3-3.1.5 Mechanical Compression Joints.

Mechanical compression joints are allowed to connect plastic pipe only in locations where other fitting types are not feasible. When compression joints are utilized, they must be installed in accordance with the requirements of 49 CFR § 192.281(e). Proof of satisfying the design requirements must be provided by a knowledgeable third party such as a representative of the compression joints manufacturer. The manufacturer of the mechanical compression fitting must certify that the fitting is intended for the specific gas service, that the gasket is compatible with the type of plastic specified, and that a rigid tubular internal stiffener, not split tubular, is incorporated in the design. The manufacturer must provide the part number, serial number and year made for each mechanical fitting used on a DoD installation and the contractor must submit this information along with the GIS Location and date of installation for the Government's permanent record.

3-3.2 Valves.

Steel valves installed in natural and manufactured gas distribution pipelines must comply with API SPEC 6D. Although ASME B16.34 is the basis for all valves specified in API SPEC 6D, §192.145 mandates that all steel valves in a natural gas pipelines comply with the requirements of API SPEC 6D, which adds substantial additional features and testing over and above the requirements of ASME B16.34. Metallic valves installed in metallic distribution pipelines conveying LPG must comply with UL 125. Valves installed in polyethylene distribution pipelines that convey natural gas, manufactured gas, or LPG must comply with ASTM D2513 and ASME B16.40. Valves installed in polyamide distribution pipelines that convey natural gas, manufactured gas, or LPG must comply with ASTM F2945 and ASME B16.40.

3-3.2.1 Restricted Valve Materials.

Cast iron, malleable iron, and ductile iron are restricted materials for use in natural or manufactured gas pipelines within 49 CFR 192 and should not be used in valve shell construction on Government DoD installations. Although these materials have been used in the past, and may qualify under certain conditions, these materials should not be used in new natural gas pipelines installed on Government DoD installations. These materials are not qualified for use at compressor stations.

3-3.2.2 Valve Locations.

Valves must be installed in the distribution pipeline in the locations required by 49 CFR §192.181 and as described below:

- Each high-pressure distribution system must have valves spaced so as to reduce the time to shut down a section of main in an emergency. The valve spacing is determined by the operating pressure, the size of the mains, and the local physical conditions.
- An isolation valve must be installed on the inlet piping to each regulator station that controls the flow or pressure of gas in a distribution system. This isolation valve must be installed at a safe distance from the regulator station sufficient to permit the operation of the valve during an emergency that prevents access to the station.
- Service line operating or emergency shut-off valve must be installed upstream of regulator/meter, must be readily accessible, outside of the building, and in a covered valve box if installed below grade.

Valve locations must be compliant with all requirements of the current edition of 49 CFR §192.181.

3-3.3 Control of Gas Pressure and Over Pressure Protection.

Where a gas source that is at higher pressure than the MAOP of a distribution pipeline, and is connected to that distribution pipeline, a pressure regulator is required and a pressure relieving device or pressure limiting device that meets the requirements of

§192.199 and §192.201 is required to protect the distribution pipeline from over pressurization that could result from failure of the upstream pressure control or of failure of some other type.

3-3.3.1 Natural and Manufactured Gas Pressure Regulators and Relief/Limiting Devices.

The pressure of gas delivered from a high-pressure distribution system must be controlled IAW 49 CFR §192.197. This section differentiates pressure regulation and protection requirements for pipelines operating at pressures 60 psig or less from those required for pipelines operated at pressures greater than 60 psig. It is recommended that distribution pipelines installed on DoD installations must apply the “greater than 60 psig” pressure regulation and protection requirements to allow flexibility in future uprating of MAOP.

Four different types of pressure regulators are used in the design of a natural gas or manufactured gas systems, which are as follows:

- Appliance regulator: allowed in the fuel gas piping defined by NFPA 54, but not qualified to operate in a 49 CFR 192 distribution pipeline.
- Line regulator: allowed in the fuel gas piping defined by NFPA 54, but not qualified to operate in a 49 CFR 192 distribution pipeline.
- Main regulators: supplied by a qualified manufacturer of regulators intended for use in a distribution system.
- Service regulator: qualified by AGA ANSI B109.4 to be installed at the end of service line, with an isolation valve.

Each service regulator installed on a service line intended to regulate the pressure of fuel gas supplied to a consumer must comply with §192.197(c)(3). This paragraph requires that a pressure relief device be installed to protect the piping system connected to the low-pressure side of the regulator. This pressure relief device may be built into the service regulator or may be a separate relief valve installed downstream of the service regulator. The relief device must be capable of relieving downstream pressure, at the rated regulator flow, to prevent over pressurization of the consumer’s fuel gas piping. Even though §192.197(a) allows regulators with specified characteristics, but having no pressure relief, to be installed on distribution systems that operate at 60 psig or less, this practice is not recommended for DoD installations because future pressure increases would require major infrastructure rehabilitation.

3-3.3.2 Natural and Manufactured Gas Pressure Relief and Limiting Devices.

Where the distribution pipeline pressure exceeds 60 psig, a pressure relieving or pressure limiting device is required by §192.197(c) to ensure that the MAOP of the downstream pipeline or service line and appurtenances is never exceeded. The devices required are listed below:

- Pressure relief valve, spring loaded or weight loaded.

- Pilot loaded, back-pressure regulator that acts as a relief device to maintain the inlet pressure of the primary regulator to a specified set point. A pilot senses the pressure downstream from the back-pressure regulator (inlet to the primary regulator) and vents to atmosphere to ensure the inlet pressure to the primary regulator never exceeds the specified set point. This vent must discharge in a safe manner to a non-hazardous location.
- An automatic shut off device installed in series with the primary regulator with manual reset.
- A second regulator installed upstream of the primary or service regulator, set to limit the inlet pressure of the downstream regulator to 60 psig or less, and a device set to relieve the pressure between the two regulators in the event that the upstream regulator fails.
- A monitoring regulator installed upstream of a primary or service regulator. In this arrangement, a sensing line is connected downstream of the primary or service regulator to allow the monitoring regulator to sense the pressure downstream of the primary or service regulator. If the downstream regulator fails, then the monitoring regulator takes over the pressure control. The set point of the monitoring regulator is slightly higher than the set point of the working regulator, but never higher than the MAOP of the downstream pipeline. During normal operation, the monitoring regulator is fully open.
- A service regulator with internal pressure relief or separate relief valve installed downstream of the service regulator, as long as the inlet pressure does not exceed 125 psig.

These devices are more clearly described by trade name in ASME B31.8, para 845, which may be used as a reference.

The pressure relieving or limiting device must be designed IAW §192.199. The capacity of the pressure relieving and limiting device must be IAW §192.201. In all cases where natural gas is vented from a pressure relieving or limiting device to the atmosphere, the vent must be constructed to prevent blockage by rain, snow, ice, insects, or vermin and must discharge safely to the environment without undue hazard.

3-3.3.3 LPG Pressure Regulators and Relief Devices.

The pressure of LPG in the vapor phase must be reduced and regulated when leaving the LPG liquid container in accordance with NFPA 58, paragraph 5.10. This pressure regulator must be one of the two stage regulator combinations specified in NFPA 58, paragraph 5.10, and must contain the required pressure relief device or overpressure shutoff device. The regulators used in an LPG distribution pipeline must comply with UL 144. Do not use line pressure regulators per ANSI Z21.80, or appliance regulators per ANSI Z21.18 in an LPG distribution pipeline. Line and appliance regulators belong in the fuel gas piping system as specified in NFPA 54 with specific reference to NFPA 58.

A summary of regulator combinations qualified to be installed in an LPG distribution pipeline are as follows:

- Automatic changeover regulator incorporating an integral two stage regulator, with integral pressure relief to limit second stage outlet pressure to 2 psig when seat disc is removed, and inlet pressure is 15 psig or overpressure shutoff with manual reset on the outlet of the second stage regulator. This regulator is for use on multiple cylinder installation.
- Integral two-stage regulator with means to determine the outlet pressure of the high-pressure regulator, and with integral pressure relief to limit second stage outlet pressure to 2 psig when seat disc is removed, and inlet pressure is 15 psig or overpressure shutoff with manual reset.
- High pressure regulator installed on the LPG container with integral relief valve, and a first stage regulator, with integral pressure relief, installed downstream of the high-pressure regulator to serve multiple second stage regulators. Second stage regulators must have integral pressure relief to limit second stage outlet pressure to 2 psig when seat disc is removed, and inlet pressure is 15 psig or overpressure shutoff with manual reset on the outlet of the second stage regulator.
- First stage regulator, 10 psig maximum outlet pressure, with integral pressure relief, and a second stage regulator with integral pressure relief to limit second stage outlet pressure to 2 psig when seat disc is removed, and inlet pressure is 15 psig or overpressure shutoff with manual reset.
- 2 psig regulator system including a first stage regulator, 10 psig maximum outlet pressure, with integral pressure relief, and a 2 psig regulator, 2.5 psig maximum outlet pressure with integral pressure relief to limit 2 psig regulator outlet pressure to 5 psig when seat disc is remove and inlet pressure is 15 psig or overpressure shutoff with manual reset.
- Or an integral 2 psig service regulator meeting the design intent of the 2 psig regulator system but manufactured into one assembly.

Automatic changeover, integral two stage, high pressure, first stage, and integral 2 psig regulators must be installed in compliance with NFPA 58, paragraph 6.10.1, either on the LPG storage tank vapor service valve or connected to the vapor discharge valve using a flexible metallic connector that is qualified for LPG service. The regulators must be installed so that weather elements do not affect their operation. The relief vent discharge must be located in compliance with NFPA 58 such that the termination point presents little hazard, is a minimum of 3 horizontal feet from any building opening and 5 feet from sources of ignition, mechanical air intake, or direct vented gas appliance.

3-3.4 Customer Meters, Regulators and Service Lines.

Customer meters, service regulators and service lines must comply with the requirements of 49 CFR 192, Subpart H. This subpart addresses the allowed locations for installation, the requirement for protection against damage, and the elimination of stress on the piping system.

DoD installations require, in most cases, adherence to an Advanced Metering Program. Each branch of military service has written its own specific requirements that guide the design of advanced metering systems and their electronic reporting system. Cybersecurity and on-board memory are necessary elements of each program. Please refer to the requirements of the specific DoD installation for guidance on specifying the required metering systems and connectivity.

3-3.4.1 Meters.

§192.359 requires that all new meters be tested by the manufacturer at a shell pressure of not less than 10 psig. Meters may not be operated at a pressure higher than 67% of the manufacturer's shell test pressure. A rebuilt or repaired tinned steel meter may not be operated at more than 50% of the pressure used to test the meter after rebuilding or repairing. Gas meters that comply with AGA ANSI B109 are qualified for natural gas, manufactured gas and LPG in the vapor phase, but the manufacturer must know which gas will be metered. LPG in the vapor phase may or may not require metering when it is supplied from a distribution pipeline to multiple customers on a DoD installation. Please coordinate with the contracting officer of the project to determine the Government's desire for metering of LPG.

3-3.4.2 Regulators.

The service regulator that reduces the natural or manufactured gas pressure to the meter and the customer's fuel gas piping system are described in paragraph 3-2.3 of this UFC. Refer to NFPA 54 for specific usage of line pressure regulators that reduce 2 psig gas supply to appliance regulator inlet pressure and appliance regulators.

The term 'service regulator' does not apply to LPG distribution pipelines. Required regulators are described in paragraph 3-2.3 of this UFC. Refer to NFPA 58 and NFPA 54 for specific usage of line pressure regulators that reduce 2 psig LPG vapor supply to appliance regulator inlet pressure and appliance regulators.

3-3.4.3 Service Lines.

Each steel service line to be operated at less than 100 psig must be constructed of pipe designed for a minimum of 100 psig. Additional requirements are defined in §192.361 through §192.379. Exception to §192.375 is that a plastic service line may not be exposed above grade level on a DoD installation. An anode less riser must be used to bring a plastic service line from below grade to a steel pipe serving the isolation valve, service regulator, and meter.

3-3.5 Excess Flow Valve (EFV).

An EFV must be installed on all new or replaced single and branched service lines that serve single-family residences where the service line operates at 10 psig or greater. EFVs are also required to be installed on multifamily residences, and small commercial entities consuming gas volumes not exceeding 1,000 standard cubic feet per hour (SCFH). The EFV must comply with the requirements of §192.381 and close upon detection of flow in excess of the anticipated maximum flow through the service line.

Sizing an EFV requires knowing the maximum gas demand of all the appliances connected to the service line. The potential for adding future gas burning equipment should also be considered.

3-3.6 Vaults.

Vaults must be structurally sound, designed to minimize entrance of water, and must not be drained to any other underground structure. Vaults serving as access to natural gas distribution pipelines must comply with §192.183 through §192.189. Where plastic pipe passes through a vault must be encased in ASTM A53/A53M minimum schedule 40 steel pipe that is properly protected from corrosion and vented.

CHAPTER 4 CONSTRUCTION OF DISTRIBUTION PIPELINES

4-1 QUALIFICATION OF PROCESSES.

Methods used to install natural gas distribution pipelines must be proven to provide a durable, gas-tight system. All pipe joints made in the system must be made in accordance with qualified written procedures and by personnel qualified by training and testing that have been proven by test or experience to produce strong, gas-tight joints.

The DoD installation must include these qualified written procedures and personnel qualifications in its operations and maintenance manual. It is therefore required that the installing contractor provide a qualified written procedure and personnel qualifications for each joint made in the distribution pipeline.

4-2 WELDING OF STEEL PIPE.

Welding of steel pipelines must comply with the requirements of 49 CFR 192, Subpart E.

4-2.1 Welding Procedures for Steel Pipe.

The installing contractor must submit for Government approval, a written procedure for welding steel pipe and fittings installed in the distribution pipeline. Welding procedures must be qualified under API STD 1104, Section 5, Section 12, or Appendix A or under the ASME/BPVC SEC IX as written in §192.225. The contractor must make sure that welding is performed in accordance with these established written welding procedures that have been qualified and tested to produce quality welds.

4-2.2 Welder Qualifications.

Welders must be qualified IAW API STD 1104, Section 6, Section 12, or Appendix A or under the ASME/BPVC SEC IX as written in §192.227. The contractor must submit to the Government, proof of each welder's current certification of qualification. Welders qualifications must further comply with the limitations specified in §192.229, which include qualification intervals and methods of qualification.

Welders of pipe segments and components intended to serve natural gas compressors must be qualified under the destructive test requirements of the applicable API STD 1104 sections.

4-2.3 Inspection and Testing of Welds.

All welds must be inspected by a person that is qualified by training and experience to ensure welding is performed by certified welders, using a qualified written procedure, and has produced acceptable welds under API STD 1104, Section 9 or Appendix A, which will not be used to accept cracks. In accordance with §192.243, and minimum location class 3 for DoD installations, 100% of welds on pipelines and components operating at a hoop stress of 20% or more of the SMYS must be nondestructively tested.

4-3 HEAT FUSION JOINING OF PLASTIC PIPE.

4-3.1 Written Joining Procedures.

The installing contractor must submit for Government approval, a qualified, written procedure for joining plastic materials obtained from the manufacturer of the plastic pipe and fittings installed in the system. The procedure must have been proven to make strong, gas-tight joints by passing the tests specified in §192.283. Vendors who cannot provide this qualified jointing procedure must be disqualified from supplying materials for the work. The contractor must make sure that each joint is made in accordance with these Government approved procedures. Any contract that purchases plastic pipe for use in the natural gas distribution system must disallow the purchase of plastic pipe from any manufacturer or supplier that does not certify qualified joining procedures for the pipe. It is the DoD installation's responsibility to verify that the contractor follows these written joining procedures for each type of pipe and fitting used.

4-3.2 Joint Maker Qualifications.

The contract documentation must require the contractor to train, test, and qualify each person performing work on the natural gas distribution system located on a DoD installation in accordance with 49 CFR 192, Subpart F. No person may make a plastic pipe joint unless that person has been qualified under the pipe manufacturer's written joining procedure by making a specimen joint that passes inspection and test. The specimen joint used to qualify the joiner must be visually examined during and after joining and found to have the same appearance as a joint or photograph of a joint that is acceptable under the procedure. In the case of heat fusion, the specimen must be cut into at least three longitudinal straps, each of which is:

- Visually examined and found not to contain voids or discontinuities on the cut surfaces of the joint area;
- Deformed by bending, torque, or impact, and if failure occurs, it must not initiate in the joint area.

Each person joining plastic in a distribution pipeline must be re-qualified under the applicable procedure §192.285(c), or after any production joint is found unacceptable by testing under §192.513. A person that is qualified by appropriate training or experience to evaluate the acceptability of the joint must inspect each joint installed in a gas piping system. This inspection may be performed by the person installing the joint if so qualified.

4-4 PIPELINE INSTALLATION AND REPAIR.

All pipelines must be installed IAW 49 CFR 192. Joining of new pipe to existing pipe must be in a manner approved in 49 CFR 192.

Where a distribution pipeline passes under a roadway or a railroad, the pipeline must be encased in steel pipe that protected from corrosion. If the casement is not vented it must be sufficiently strong to contain the operating pressure of the gas without exceeding the stress levels presented in §192.323. Vented casements must be protected from the weather. Distribution pipeline must be installed with sufficient underground clearance from other buried items to allow for proper maintenance and to protect against damage caused by those buried items.

Distribution mains must have minimum cover of 24” or be otherwise protected from external loads and excavation damage. In accordance with §192.361, the part of the service line installed in a public right-of-way must have minimum cover of 18”. This service line is allowed to have a minimum cover of 12” once it has passed onto private property. For DoD installations, it is recommended that the 12” cover apply only to single family dwellings but could be safely expanded to duplexes and quad-plexes. A minimum 18” cover is required for service lines serving any other type of building on a DoD Installation.

4-4.1 Plastic Pipe Installation.

Plastic pipe installed in a distribution pipeline must be installed below grade and must be continuously supported in suitable compacted soil to prevent movement after installation. Ensure that the installation has sufficient slack to prevent pullout due to thermal contraction. Inspect pipe and fittings for damage prior to backfilling. If the pipe has a scratch or cut that exceeds 10% of the wall thickness, it must be replaced.

Plastic pipelines must be installed with sufficient clearance from any item that may increase the temperature of the plastic pipe segment, to prevent degradation of the pipe strength. These items may include, but are not limited to, hot water piping, steam piping, condensate piping, and electrical equipment. Where proximity cannot be avoided, the DoR must design adequate protection to prevent pipe temperature increase. Where temperature increase of the plastic pipe cannot be avoided, the DoR must reduce the design pressure of the plastic pipe by using a Hydrostatic Design Basis value for a temperature that is higher than the actual anticipated temperature.

4-4.2 Steel Pipe Installation.

Aboveground steel pipe must be securely supported and protected from vehicular collisions. Steel pipe must be painted for corrosion protection.

Where steel pipe is required for below grade installations the pipe must be coated with an approved anti corrosion coating and must be cathodically protect IAW 49 CFR 192, Subpart I. The pipe must be continuously supported by properly compacted material.

Where connections are made to existing underground steel pipe, the contractor must inspect the existing pipe for corrosion and take remedial action IAW 49 CFR 192 Subpart I if corrosion is found.

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CHAPTER 5 CONTROL OF CORROSION

5-1 METALLIC PIPELINES.

Metallic pipelines installed underground must be protected from corrosion IAW 49 CFR 192, Subpart I, which includes both an approved anti corrosion coating per §192.461 and a cathodic protection system in compliance with the requirements of §192.463.

5-2 DISTRIBUTION PIPELINE INTEGRITY MANAGEMENT PLAN.

The distribution pipeline operator is required to maintain a Distribution Pipeline Integrity Management Plan that details, among other items, all aspects of metallic pipeline installed underground, methods used to protect against corrosion, and inspections to determine the efficacy of the corrosion control program. A complete listing of information required to be maintained can be found in Chapter IX "Guidance Manual for Operators of Small Natural Gas Systems", current edition, DOT Pipeline and Hazardous Materials Safety Administration.

The DoR for any project installing or connecting to existing underground metallic pipe must support the distribution pipeline operator's efforts to control corrosion through proper design and requiring the installing contractor to do the following:

- Perform corrosion inspection and report on inspections of any underground metallic natural gas pipe that is uncovered during construction.
- Provide mill coating on steel pipelines installed below grade.
- Properly install and backfill coated pipe without damage to the coating.
- Properly field coat all connection and components.
- Thoroughly inspect and test the coatings for holidays.
- Properly install and test new cathodic protection systems.
- Properly install test stations for new cathodic protection systems.
- Electrically isolate protected pipelines from other, unprotected below grade metal and all above grade pipeline connections.
- Hire a corrosion control expert to help solve known corrosion problems.
- Obtain the operator's acceptance of the installation before backfill.

Where corrosion is found, remedial methods described in §192.487 and §192.489 should be employed.

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CHAPTER 6 NATURAL GAS COMPRESSORS

6-1 COMPRESSOR STATIONS PER 49 CFR 192.

Compressor Stations are not defined but are only described within 49 CFR 192. 49 CFR 192 and ASME B31.8 provide the following specific requirements for piping that connects to compressor stations:

- Steel pipe from the gas distribution main to the compressor, 49 CFR 192 §192.229 and ASME B31.8, 843.4.
- Cast iron components must not be used in compressor station piping systems, 49 CFR 192 §192.145 (e) and ASME B31.8, 831.1.
- Welders must be qualified based on destructive test requirements of API 1104. 49 CFR 192 §192.229 and ASME B31.8, 823.2.2.
- Butt welds must be 100% tested by non-destructive methods such as radiography, 49 CFR 192 §192.243, ASME B31.8, 826.3.

6-2 FUEL GAS BOOSTER COMPRESSORS.

It is rare that a compressor station as described by 49 CFR 192 is installed in the pipeline that is operated by a DoD installation. It is quite common, however, that a fuel gas booster compressor be installed on a distribution service line in order to boost pressure and gas flow to a local, point-of-use piece of equipment such as a gas turbine. Although the 49 CFR 192 and ASME B31.8 code requirements would not seem to apply to the connection of a point-of-use fuel gas booster compressor, the engineering precautions necessary to ensure safe operation do apply. The booster compressor has the potential to transmit vibration and pressure pulsation to the service line, which can cause the service line to fail. It is recommended that the service line be welded steel pipe, constructed and inspected in accordance with 49 CFR 192. Where alternative methods are used, the Designer of Record must ensure the installation and pipe connections comply with the requirements of the compressor manufacturer, state and local codes. Analysis must also be performed and submitted to the government showing that the vibration and pulsation load and cycle will not cause the pipe to fail. It is recommended that fuel gas piping that connects to the discharge of a booster compressor be welded steel, but this piping is beyond the scope of this UFC as it is downstream from the demarcation between 49 CFR 192 and NFPA 54. There are codes that apply to specific fuel gas using equipment that also place requirements on the fuel gas supply piping. NFPA 37 is an example of code that places requirements on the fuel gas piping system from the discharge of the booster compressor to a gas turbine.

Requirements for construction of natural gas compressors are defined in the following American Petroleum Institute (API) documents:

- API STD 617 Axial and Centrifugal Compressors and Expander Compressors

- API STD 618 Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services
- API STD 619 Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries

Recommended practices for installing these compressors can be found in API RP 686 – Recommended Practices for Machinery Installation and Installation Design. This reference requires a vibration analysis, pulsation analysis and a mechanical piping analysis to ensure that pressure limits of the piping system are not exceeded. It further places requirements on pipe arrangement and components, supports and anchors, places restrictions on branch connections, and identifies the need for pulsation and vibration dampeners.

APPENDIX A BEST PRACTICES

Appendix A identifies background information and practices for accomplishing certain design and engineering services. The Designer of Record (DoR) is expected to review and interpret this guidance and apply the information according to the needs of the project. If a Best Practices document has guidelines or requirements that differ from the UFGS or Unified Facilities Criteria, the UFGS and the UFC must prevail. If a Best Practices document has guidelines or requirements that are not discussed in the Unified Facilities Guide specification (UFGS) or UFC, the DoR must submit a list of the guidelines or requirements being used for the project with sufficient documentation to the Government Project Manager for review and approval prior to completing design.

A-1 WHOLE BUILDING DESIGN GUIDE.

The Whole Building Design Guide provides additional information and discussion on practice and facility design, including a holistic approach to integrated design of facilities.

The WBDG provides access to all Construction Criteria Base (CCB) criteria, standards and codes for the DoD Military Departments, National Aeronautics and Space Administration (NASA), and others. These include, Unified Facilities Criteria (UFC), Unified Facilities Guide Specifications (UFGS), Performance Technical Specifications (PTS), design manuals, and specifications. For approved Government employees, it also provides access to non-government standards.

A-2 GUIDANCE.

A-2.1 DOT Manual for Operators of Small Natural Gas Systems.

In absence of installation specific directive instructions and guidance, follow gas pipeline safety regulations defined in the DOT manual as it applies to natural gas systems and operators of natural gas master meter systems. The pipeline safety regulations require operators of natural gas systems to: deliver gas safely and reliably to customers; provide training and written instruction for employees; establish written procedures to minimize the hazards resulting from natural gas pipeline emergencies; and, keep records of inspection and testing.

A-2.2 State Compliance.

Designers and operators should check with the pipeline safety agency in their state to determine:

- Whether a state agency has safety jurisdiction;
- Whether the state agency has pipeline safety requirements that exceed the federal regulations
- The inspection and enforcement procedures of the state agency.

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APPENDIX B GLOSSARY

B-1 ACRONYMS

AFCEC	Air Force Civil Engineer Center
AGA	American Gas Association
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BCE	Base Civil Engineer
BIA	Bilateral Infrastructure Agreement
CCB	Construction Criteria Base
CCR	Criteria Change Request
CFR	Code of Federal Regulations
DoD	Department of Defense
DoR	Designer of Record
DOT	Department of Transportation
DPW	Department of Public Works
EFV	Excess Flow Valve
GIS	Geographic Information System
HDB	Hydrostatic Design Basis
HDS	Hydrostatic Design Stress
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
IAW	in accordance with
ICC	International Code Council
LPG	Liquefied Petroleum Gas

MAOP	Maximum Allowable Operating Pressure
MMO	Master Meter Operators
MMS	Master Meter Systems
NAVFAC	Naval Facilities Engineering Command
NFPA	National Fire Protection Association
NPS	Nominal Pipe Size
O&M	Operations and Maintenance
PA-11	Polyamide-11
PE	Polyethylene
PHMSA	Pipeline and Hazardous Material Safety Administration
psig	pounds per square inch gauge
PTS	Performance Technical Specifications
SCFH	Standard Cubic Feet per Hour
SD	Submittal Description
SDR	Standard Dimension Ratio
SMYS	Specified Minimum Yield Strength
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UP	Utility Privatization
U.S.	United States

APPENDIX C REFERENCES

AMERICAN GAS ASSOCIATION (AGA)

www.aga.org

AGA ANSI B109.4, *Self-Operated Diaphragm-Type Natural Gas Service Regulators for Nominal Pipe Size 1¼ inches (32 mm) and Smaller with Outlet Pressures of 2 psig (13.8 kPa) and Less*

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

www.ansi.org

ANSI Z21.18, *Gas Appliance Pressure Regulators*

ANSI Z21.80, *Line Pressure Regulators*

AMERICAN PETROLEUM INSTITUTE (API)

www.api.org

API RP 686, *Recommended Practice for Machinery Installation and Installation Design*

API SPEC 5L, *Line Pipe*

API SPEC 6D, *Specification for Pipeline and Piping Valves*

API STD 617, *Axial and Centrifugal Compressors and Expander-Compressors*

API STD 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*

API STD 619, *Rotary-Type Positive Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries*

API STD 1104, *Welding of Pipelines and Related Facilities*

API-ASME Code, *Unfired Pressure Vessels for Petroleum Liquids and Gases*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

www.asme.org

ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*

ASME B16.1, *Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

ASME B16.9, *Factory Made Wrought Steel Butt Welding Fittings*

ASME B16.25, *Butt Welding Ends*

ASME B16.34, *Valves – Flanged, Threaded, Welding End*

ASME B16.40, *Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems*

ASME B31.8, *Gas Transmission and Distribution Piping Systems*

ASME Section VIII, *Rules for the Construction of Unfired Pressure Vessels*

ASME/BPVC SEC IX, *ASME Boiler and Pressure Vessel Code, Section IX*

ASTM INTERNATIONAL (ASTM)

www.astm.org

ASTM A53/A53M, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*

ASTM A395/A395M, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM D2513, *Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings*

ASTM D2517, *Standard Specification for Reinforced Epoxy Resin Gas Pressure Pipe, Tube, and Fittings*

ASTM F2945, *Standard Specification for Polyamide 11 Gas Pressure Pipe, Tubing, and Fittings*

ASTM F2164, *Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure*

ASTM F2786, *Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing)*

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

http://msshq.org

MSS SP-44, *Steel Pipeline Flanges*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

www.nfpa.org

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*

NFPA 54, *National Fuel Gas Code*

NFPA 58, *Liquefied Petroleum Gas Code*

PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION (PHMSA)

www.phmsa.dot.gov

Guidance Manual for Operators of Small Natural Gas Systems

UNDERWRITERS LABORATORIES (UL)

www.ul.com

UL 125, *UL Standard for Safety Flow Control Valves for Anhydrous Ammonia and LP-Gas*

UL 144, *UL Standard for Safety LP-Gas Regulators*

UNIFIED FACILITIES CRITERIA (UFC)

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 3-460-01, *Design: Petroleum Fuel Facilities*

UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs

UFGS 23 11 25, *Facility Gas Piping*

UFGS 33 51 15, *Natural-Gas / Liquefied Petroleum Gas Distribution Pipelines*

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

www.archives.gov

49 CFR 192, *Transportation of Natural and Other Gas by Pipeline: Minimum Safety Standards*

UFC 3-430-09
16 January 2004
with Change 1, 25 March 2009

UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR MECHANICAL UTILITY DISTRIBUTION

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-430-09
16 January 2004
with Change 1, 25 March 2009

UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR MECHANICAL UTILITY DISTRIBUTION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEERING SUPPORT AGENCY

Record of Changes (changes indicated by **1**\ ... /**1**/)

Change No.	Date	Location
1	25 Mar 2009	Removed "N" designation to unify document.

This document replaces UFC 3-430-09N and UFC 3-430-05FA.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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CHAPTER 1

INTRODUCTION

1-1 **PURPOSE AND SCOPE**. This UFC is comprised of two sections. Chapter 1 introduces this UFC and provides a listing of references to other Tri-Service documents closely related to the subject. Appendix A contains the full text copy of the previously released Military Handbook (MIL-HDBK) on this subject. This UFC serves as criteria until such time as the full text UFC is developed from the MIL-HDBK and other sources.

This UFC provides general criteria for the design of steam, high-pressure water, chilled water, natural gas, and compressed air.

Note that this document does not constitute a detailed technical design, maintenance or operations manual, and is issued as a general guide to the considerations associated with design of economical, efficient and environmentally acceptable heating plants.

1-2 **APPLICABILITY**. This UFC applies to all Navy service elements and Navy contractors; all other DoD agencies may use this document unless explicitly directed otherwise.

1-2.1 **GENERAL BUILDING REQUIREMENTS**. All DoD facilities must comply with UFC 1-200-01, *Design: General Building Requirements*. If any conflict occurs between this UFC and UFC 1-200-01, the requirements of UFC 1-200-01 take precedence.

1-2.2 **SAFETY**. All DoD facilities must comply with DODINST 6055.1 and applicable Occupational Safety and Health Administration (OSHA) safety and health standards.

NOTE: All **NAVY** projects, must comply with OPNAVINST 5100.23 (series), *Navy Occupational Safety and Health Program Manual*. The most recent publication in this series can be accessed at the NAVFAC Safety web site: www.navfac.navy.mil/safety/pub.htm. If any conflict occurs between this UFC and OPNAVINST 5100.23, the requirements of OPNAVINST 5100.23 take precedence.

1-2.3 **FIRE PROTECTION**. All DoD facilities must comply with UFC 3-600-01, *Design: Fire Protection Engineering for Facilities*. If any conflict occurs between this UFC and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.

1-2.4 **ANTITERRORISM/FORCE PROTECTION**. All DoD facilities must comply with UFC 4-010-01, *Design: DoD Minimum Antiterrorism Standards for Buildings*. If any conflict occurs between this UFC and UFC 4-010-01, the requirements of UFC 4-010-01 take precedence.

APPENDIX A

MIL-HDBK 1003/8A
EXTERIOR DISTRIBUTION OF STEAM, HIGH PRESSURE WATER, CHILLED WATER, NATURAL GAS, AND COMPRESSED AIR

INCH-POUND

MIL-HDBK-1003/8A
15 AUGUST 1990
SUPERSEDING
MIL-HDBK-1003/8
30 SEPTEMBER 1987

MILITARY HANDBOOK

EXTERIOR DISTRIBUTION OF STEAM,

HIGH TEMPERATURE WATER, CHILLED WATER,

NATURAL GAS, AND COMPRESSED AIR

NO DELIVERABLE DATA REQUIRED BY THIS DOCUMENT AREA FACR

ABSTRACT

Presented here is basic yet comprehensive design guidance and technical data for exterior distribution piping systems. Services supported by these systems include: steam supply, high-temperature water, chilled water, cooling or condensing water, natural gas, and compressed air to various buildings and other facilities. This handbook also contains data covering return systems for condensate, water, and other spent services. Additional design data includes information on loads and fluid conditions, fluid characteristics, and distribution site locations. Factors governing tests for field permeability, soil resistivity, soil stability, and water conditions, information on distribution pipe sizing, valves and supports, distribution methods, and piping specifications and codes are provided. Material included also covers ownership, operations, and maintenance cost variables associated with permanent or temporary sites.

FOREWORD

This military handbook has been developed from an extensive evaluation of shore establishment facilities, surveys of new materials' availability and construction methods, selections from the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other government agencies and the private sector. MIL-HDBK-1003/8A uses and references design data standards established and validated by national professional societies, associations, and technical institutes. Deviations from these criteria, in planning, engineering, design and construction of naval shore facilities, cannot be made without prior approval of NAVFACENGCOM HQ Code 04.

Design methods and practices cannot remain static any more than the functions they serve or the technologies used. Accordingly, recommendations for improvement are encouraged and should be furnished on the DD Form 1426 provided inside the back cover to Commander, Western Division, Naval Facilities Engineering Command, Code 406, Building 203, San Bruno, CA 94066, telephone (415) 244-3331.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

NOTICE OF CHANGE

MILITARY HANDBOOK

EXTERIOR DISTRIBUTION OF STEAM, HIGH TEMPERATURE WATER CHILLED WATER, NATURAL GAS, AND COMPRESSED AIR

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41	15 November 1991	41	15 August 1990
42	15 November 1991	42	15 August 1990

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MECHANICAL ENGINEERING CRITERIA MANUALS

Criteria Manual	Title	Preparing Activity
DM-3.01	Plumbing Systems	WESTDIV
MIL-HDBK-1003/2	Incinerators	WESTDIV
DM-3.03	Heating, Ventilating, Air Conditioning, and Dehumidifying Systems	WESTDIV
DM-3.4	Refrigeration Systems for Cold Storage	WESTDIV
DM-3.5	Compressed Air and Vacuum Systems	WESTDIV
MIL-HDBK-1003/6	Central Heating Plants	NEESA
MIL-HDBK-1003/7	Steam Power Plants - Fossil Fueled	NEESA
MIL-HDBK-1003/8A	Exterior Distribution of Steam, High Temperature Water, Chilled Water, Natural Gas, and Compressed Air	WESTDIV
DM-3.09	Elevators, Escalators, Dumbwaiters, Access Lifts, and Pneumatic Tube Systems	WESTDIV
DM-3.10	Noise and Vibration Control for Mechanical Equipment (Tri-Service TM-5-805-4, AFM 88-37)	ARMY
MIL-HDBK-1003/11	Diesel Electric Generating Plants	WESTDIV
MIL-HDBK-1003/12	Boiler Controls	NEESA
MIL-HDBK-1003/13	Solar Heating of Buildings and Domestic Hot Water	NCEL
DM-3.14	Power Plant Acoustics (Tri-Service TM-5-805-9, AFM 88-20)	ARMY
MIL-HDBK-1003/17	Industrial Ventilation Systems	NEESA
MIL-HDBK-1003/19	Design Procedures for Passive Solar Buildings	NCEL

MILITARY HANDBOOK

EXTERIOR DISTRIBUTION OF STEAM, HIGH TEMPERATURE HOT WATER, CHILLED WATER, NATURAL GAS, AND COMPRESSED AIR

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iii	30 December 1991	iii	15 August 1991
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vii	30 December 1991	vii	15 August 1990
viii	30 December 1991	viii	15 August 1990
1	30 December 1991	1	Reprinted w/o Change
2	30 December 1991	2	15 August 1990
3	30 December 1991	3	15 August 1990
4	30 December 1991	4	Reprinted w/o Change
9	30 December 1991	9	15 August 1990
10	30 December 1991	10	15 August 1990
13	30 December 1991	13	15 August 1990
14	30 December 1991	14	Reprinted w/o Change
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42a	30 December 1991		New Page
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64	30 December 1991	64	30 August 1991
81	30 December 1991	81	Reprinted w/o Change
82	30 December 1991	82	15 August 1990
83	30 December 1991	82	15 August 1990
84	30 December 1991	82	15 August 1990
85	30 December 1991	82	15 August 1990

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EXTERIOR DISTRIBUTION OF STEAM, HIGH TEMPERATURE WATER,
CHILLED WATER, NATURAL GAS, AND COMPRESSED AIR

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Section 1: INTRODUCTION

1.1 Scope. Data and criteria in this military handbook apply to design of exterior distribution piping systems for supplying certain central generating plant services to various buildings and facilities and for returning such spent services to the plants.

1.2 Cancellation. This handbook, MIL-HDBK-1003/8A, cancels and supersedes MIL-HDBK-1003/8 of September 1987.

1.3 Related Criteria. All documents referenced in this handbook are listed in the reference section.

Section 2: PLANNING FACTORS

2.1 Types of Exterior Distribution Systems. Types of exterior distribution systems are as follows:

2.1.1 Steam and Condensate. These systems supply heat in the form of steam from central steam generating plants. Several buildings, building groups, or ship berthing facilities may be supplied with steam for domestic hot water and/or for space heating. Heating equipment using steam includes unit heaters, radiators, convectors, heating coils, and other devices. Process equipment using steam includes hot water heaters, laundry machinery, cleaning/plating tanks, kitchen equipment, and other devices. Condensate is returned to the central plant whenever possible.

2.1.2 Hot Water. System circulates hot water which supplies heat from a central heating plant to several buildings for space heating, domestic hot water, and process work, and returns the water to the central plant. High Temperature Water (HTW) systems operate at 260 degrees Fahrenheit (F) (127 degrees Celsius (C)) and higher; Medium Temperature Water (MTW) systems operate between 200 degrees F (93 degrees C) to 259 degrees F (126 degrees C); and Low Temperature Water (LTW) systems operate below 200 degrees F (93 degrees C). Material shall be selected to the same specifications as for High Temperature Water systems, except that Military Specification (Mil. Spec.) MIL-P-28584A, Pipe and Pipe Fittings, Glass Fiber Reinforced Plastic for Condensate Return Lines, plastic piping may be used for LTW distribution systems which have maximum of 125 psig at 250 degrees F (refer to para. 2.2.6).

2.1.3 Compressed Air. System supplies compressed air from a compressor plant to docks, air start systems, shops, hangars, and other structures.

2.1.4 Chilled Water. System circulates chilled water from a central refrigeration plant to several buildings for space cooling and returns the water to the central plant (refer to para. 2.2.7).

2.1.5 Cooling or Condensing Water. System distributes cooling water from a central source (such as a bay, stream, or cooling tower) to several facilities for condensing steam or refrigerants, for cooling water jackets, or stuffing boxes. The water is then returned to the source (cooling tower) or sent to waste in once-through systems.

2.1.6 Natural Gas. System distributes natural gas or propane for gas burning operations.

2.2 Naval Facilities Guide Specifications (NFGS) Related to Distribution Systems. The following NFGSs are for use in the design of the exterior distribution systems discussed in this handbook.

2.2.1 NFGS-02685, Exterior Buried Natural Gas Distribution Systems. NFGS-02685 covers these requirements for maximum system working pressures of 60 psig at 100 degrees F for exterior distribution systems for natural gas. Project drawings shall indicate the design for the entire piping system.

2.2.2 NFGS-02693, Exterior Shallow Trench Heat Distribution System. NFGS-02693 covers the requirements for exterior shallow trench heat distribution systems, including concrete trench, manholes, piping, pipe anchors, pipe supports, interface with each manhole and watershed to aboveground piping. The specification covers system components for working pressure of 150 psig (1034 kiloPascal (kPa)) steam at 366 degrees F (185 degrees C) and 125 psig (862 kPa) condensate at 250 degrees F (121 degrees C) or hot water at 450 degrees F (232 degrees C). Show the design for the entire piping systems and shallow concrete trench systems on the project drawings.

2.2.3 NFGS-02694, Exterior Underground Heat Distribution Systems. NFGS-02694 (formerly NFGS-15705) covers the requirements for Contractor designing and providing exterior buried factory-prefabricated preinsulated or pre-engineered preinsulated steam and condensate piping systems and hot water piping systems for Class A, B, C, and D ground water conditions including concrete pipe anchors exterior of manholes, interface with each manhole, and the watershed to aboveground piping. The specification covers system components for working pressure of 150 psig (1034 kPa) steam at 366 degrees F (185 degrees C) and 125 psig (862 kPa) condensate at 250 degrees F (121 degrees C) or hot water at 450 degrees F (232 degrees C). Show the design for the aboveground piping, the manholes, the piping within manholes, and the piping not in approved conduit systems on the drawings. The Contractor designs and provides buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping system for which a Federal Agency Approved Brochure has been issued including concrete pipe anchors exterior of manholes, interface with each manhole and building, and the watershed to aboveground piping.

2.2.4 NFGS-02695, Exterior Aboveground Steam Distribution System. NFGS-02695 covers the requirements for exterior aboveground steam and condensate (hot water) piping systems: exposed to the weather exterior of buildings and supported on pedestals or poles; on piers, under piers, and in trenches on piers; and in tunnels, in manholes, and related work. The work also includes providing buried factory-prefabricated preinsulated steam and condensate piping under roads. The specification covers system components for working pressure of 150 psig (1034 kPa) steam at 366 degrees F (185 degrees C) and 125 psig (862 kPa) condensate at 250 degrees F (121 degrees C). Show the design for the aboveground piping, and the piping under roads on project drawings. The design includes manholes, the piping within manholes, (buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping under roads for which a Federal Agency Approved Brochure has been issued), concrete pipe anchors, interface with each manhole, and the watershed to aboveground piping.

2.2.5 NFGS-02696, Exterior Piping Insulation. NFGS-02696 covers field-applied exterior piping insulation, insulation requirements for exterior steam piping, exterior condensate piping including aboveground piping, piping on piers, piping under piers, piping in trenches on piers, piping in tunnels, and piping in manholes.

2.2.6 NFGS-02697, Exterior Buried Pumped Condensate Return System. NFGS-02697 covers the requirements for exterior buried factory-prefabricated preinsulated pumped condensate (hot water) return piping systems suitable for installation in Class A, B, C, and D ground water conditions, including piping in manholes, plastic piping systems for which a Federal Agency Approved Brochure has been issued, and related work. Use the plastic carrier piping only for sizes 2, 3, 4, 5, 6, 8, and 10 inches. Thus, the connecting system piping should be of equal size or increased to the next size of the plastic carrier piping. NFGS-02697 also covers Contractor's responsibilities which include the following:

a) design,

b) provide exterior buried factory-prefabricated preinsulated pumped condensate (hot water), and

c) provide plastic piping systems for Class A or Class B ground water conditions including concrete pipe anchors exterior of manholes, interface with each manhole, and the watershed to aboveground piping.

Show the design for the aboveground piping, the manholes, the piping within manholes, and the piping not in approved prefabricated conduit or pre-engineered systems on project drawings. The Contractor designs and provides direct buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping system for which a Federal Agency Approved Brochure has been issued, including concrete piping anchors exterior of manholes, interface with each manhole, and the watershed to aboveground piping.

2.2.7 NFGS-02698, Exterior Buried Preinsulated Water Piping. NFGS-02698 covers the requirements for exterior buried factory-prefabricated preinsulated domestic water piping, including hot domestic water piping, recirculating hot domestic water piping, chilled water piping, chill-hot (dual-temperature) water piping, and hot water piping. Show the design for the entire piping systems on project drawings.

2.2.8 Exterior Compressed Air Piping System. Use NFGS-02682, Exterior Fuel Distribution System, for the requirements of furnishing and installing exterior compressed air piping.

2.3 Loads and Distribution System Locations. For approximate conditions, refer to Table 1.

Table 1
Distribution Loads and Fluid Conditions

FLUID	USE	CAPACITY	FLUID PRESSURE, PSIG VACUUM, IN HG TEMPERATURE, DEGREES F	DEMAND FACTORS 1/	COMMENTS
Steam	Auxiliary power	Determined by heat balance	Boiler steam	1.0	Feedwater and fuel-oil heating
	Heating and snow melting	See criteria in DM-3.03	2 to 10 psig	1.0 2/ for heating radiation, 0.8 2/ for ventilation	- - -
	Waterfront demands	See criteria in MIL-HDBK-1025/2	150 psig maximum	1.0 single berths 0.8 multiple berths	High purity steam for nuclear ships
	Process	Laundry	100 psig	0.65	7 hr/day, 5 days/week, normally
		Kitchen	10 to 40 psig	1.0	2-8 hr/day, 7 days/week, normally
		Bakery	10 psig	1.0	8 hr/day, 5 days/week, normally
		Dry cleaning	70 psig	0.65	- - -
		Hospital	40 to 60 psig	0.65	- - -
		Laundry HW	5 to 45 psig	0.65	7 hr/day, 5 days/week, normally
		Domestic HW: DM-3.01	5 to 45 psig	0.65	- - -
	Refrigeration	Tons x steam rate/ton	Boiler steam pressure 26-28 in. Hg. vacuum	1.0	Turbine-driven centrifugal compressor
		Tons x steam rate/ton	12 in Hg	1.0	Absorption machine
Condensate return	Distribution loss				
	Boiler feed	Losses: Condensate blow-down or blow-off: Determined by amount and analysis of makeup	20 to 60 psig	1.0 for continuous operation of condensate pumps	Check economics of returning condensate
		Process depends on usage. Distribution 10 percent		1.5 to 3 for intermittent operation of condensate pumps	

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Table 1 (continued)
Distribution Loads and Fluid Conditions

FLUID	USE	CAPACITY	FLUID PRESSURE, PSIG VACUUM, IN HG TEMPERATURE, DEGREES F	DEMAND FACTORS 1/	COMMENTS
Hot Water (supply and return)	Heating and snow melting	Same criteria as for steam	10 to 100 psig	- - -	- - -
	Process	- - -	Same as for steam	Same as for steam	
Chilled water supply and return	Refrigeration	gpm = 12,000 Btu/ton x tons / 500 x (t_s - t_r) 3/	Supply: 42 degrees F to 45 degrees F Return: 52 degrees F to 60 degrees F Pressure depends on friction and static heads	1.0 2/	- - -
Condenser water	Refrigeration	3 gpm/ton	Supply 85 degrees F. Return 105 degrees F	1.0	- - -
	Power system	gpm = steam x 950 lbs/hr Btu/lb / 500 x (t_s - t_r) 3/	Pressure depends on friction and static heads	1.0	
Fuel Gas	Process fuel gas burners	- - -	- - -	- - -	
Compressed air	Low pressure medium pressure high pressure	- - -	- - -	- - -	

1/ Demand factors are to be applied to total connected loads.
2/ Values shown are approximate. Actual Demand Factor is a site-specific determination and is based on actual load diversification.
3/ t_s = Water supply temperature; t_r = water return temperature.

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2.3.1 Requirements for Individual Facilities. The actual loads and conditions are determined from the design of each building and facility. Refer to P-272, Definitive Designs for Naval Shore Facilities, as guidance for preliminary estimates of requirements. The facility layout, design, and geographic factors will further define requirements.

2.3.2 System Load Demand Factors. For demand factors, refer to Table 1.

2.3.3 Aboveground and Underground Systems. When selecting a system, factors to consider are: permanent versus temporary use, high-water table, corrosiveness of soil for underground systems, cost and degree of hazard. Refer to para. 3.3.6.6.

2.3.4 Distribution Routes. Select the most direct routes, avoiding all obvious obstacles where possible.

2.3.4.1 Aboveground Piping Routes. Aboveground systems are generally lower in life-cycle costs but are less convenient in areas of heavy traffic. Consider blockage of access to areas for future development along with vulnerability to damage and acts of vandalism or sabotage.

Consider aboveground heat distribution systems for use in lieu of underground systems because of generally longer life and lower maintenance and use wherever operations and local conditions permit.

2.3.4.2 Buried Piping Routes. Select routing to allow for proper drainage of the system. Manholes and provision for piping expansion must be considered in space allocation. Consider minimum separation of parallel piping runs where temperatures in the runs vary widely. Consider cover and drainage provisions for manholes.

2.3.5 Economic Studies. Refer to NAVFAC P-442, Economic Analysis Handbook, for procedures in life-cycle cost analyses. Economic studies for all piping system types must include life-cycle (owning, operating, and maintenance) costs. For prefabricated/pre-engineered underground steam or hot water systems, perform the economic analysis, developing costs from heat loss data provided in Part 1 of Appendix A or from heat losses calculated from procedures provided in NFGS-02694. For concrete shallow trench systems of greater than 500-foot (152.5 m) length, use the additional procedures outlined in para. 2.3.6 and modify NFGS-02696 accordingly. Consider first an aboveground system, which, in most cases, will be economically advantageous to the Government. Also consider whether or not the facility is permanent or temporary. Provide a separate economic analysis for the selection of an insulation system among those allowed in NFGS-02696.

2.3.5.1 Annual Owning, Operating, and Maintenance Costs. Consider the following:

a) Base selection of the distribution system and route on the results of life-cycle economic analyses of alternatives. Consider esthetics within the limits of the Station Master Plan.

b) Operation and maintenance costs depend on the type of system design and past experience with various systems.

2.3.5.2 Steam Versus High Temperature Water Distribution. For criteria on steam versus high temperature water distribution, refer to DM-3.6, Central Heating Plants. Some advantages and disadvantages of each system type are summarized on Table 2.

2.3.5.3 High-Pressure (above 50 psig) (344.5 kPa) Steam Versus Low-Pressure (0 to 15 psig) (0 to 103.4 kPa) Steam Distribution. Compare costs of higher pressure pipe, valve, and fitting standards against lower pressure standards plus costs of pressure reducing stations in selecting the most economical system. Low pressure steam may not require full-time boiler operator attendance. If operationally adequate, consider medium-pressure steam systems, 15 to 50 psig (103.4 to 344.5 kPa). End-use temperature requirements of terminal equipment must be met by the system selected.

2.3.6 Insulation for Shallow Trench Systems Which Exceed 500 Feet. If the estimated distribution line length exceeds 500 feet (152.5 m), determine the required insulation thickness as follows and edit NFGS-02693 as required.

2.3.6.1 Heat Loss Formula. For concrete shallow trench systems, perform the economic analysis with heat losses calculated using the following equation:

Equation: $Q = 6.28(T_f - T)/\ln(r_p/r)/K_p + \ln(r_i/r_p)/K_i + 0.5/r_i$

where:

- r = inside radius of pipe, feet (one half of id)
- r_p = outside radius of pipe, feet (one half of od)p
- r_i = radius of insulation, feet (one half of od)
- T_f = temperature of fluid, degrees Ff
- T = temperature of ambient, degrees F (use 75)
- K_p = steel pipe thermal conductivity, Btu-in/(hr)(sq-ft) (degrees F)
- K_i = Insulation thermal conductivity, Btu-in/(hr)(sq-ft)i (degrees F)
- Q = pipe heat loss, Btu/hr (ft of pipe)

Table 2
Advantages and Disadvantages of Steam and
Hot Water Distribution Systems

STEAM SYSTEM ADVANTAGES

1. Smaller return pipe sizes are required.
2. Pumping costs for maintaining circulation are lower. Motor size is a fraction of that required for water, as is operating time in some cases.
3. Maintenance costs are lower. The small difference of pressure under which the system components operate reduces wear and maintenance expense to a minimum.
4. When the condensate is repeatedly recycled through the boiler and system, makeup water requirements and corrosion are negligible, and equipment life is lengthened.

STEAM SYSTEM DISADVANTAGES

1. Larger supply piping sizes are required.
2. Larger expansion loops, joints and swing connections are required.
3. Convectors and radiators must be installed in a pitched position.
4. Additional specialty items such as traps, lifts and in some cases pressure-reducing valves are required.
5. Condensate systems fail frequently, causing significant losses of heat.

Reference:
ASHRAE Handbook –
HVAC Systems and Applications

HOT WATER SYSTEM DISADVANTAGES

1. Fast, uniform response to instantaneous load changes using minimum pipe sizes.
2. Piping may be installed level or at any pitch.
3. Smaller supply pipe sizes are used.
4. Forced circulation provides, in the total water mass, the desirable inertia effect which helps to diversify system load requirements contributing to uniform input at fuel burners.
5. Requires fewer specialty items.
6. Permits practical air elimination to minimize corrosion and maintenance.
7. Resetting of system supply water temperature to meet changing loads permits more efficient energy usage.

HOT WATER SYSTEM DISADVANTAGES

1. Larger motor sizes are required for circulating pumps.
2. Larger return pipe sizes are required.
3. Expansion tanks and air vents are required.
4. More maintenance is required due to increased equipment wear caused by longer operating times.
5. More intricate controls may be required, to compensate for areas with frequent load variations, in order to keep system in balance.

Reference:
ASHRAE Handbook – Fundamentals

2.3.6.2 Heat Loss and Cost Relationship. To optimize the costs the designer must calculate the total owning and operating cost of different sections of the system, assuming use of one particular type of system configuration with various thicknesses of insulation. Only one type of system configuration needs to be considered because the optimum heat loss rate in a particular set of circumstances is not significantly different for different types of system configurations. As illustrated in Figure 1, the total owning and operating cost of a system is represented by a "U" shaped curve when cost is plotted against heat loss which is a function of insulation thickness. The curve is the sum of three other curves: the owning cost curve, which increases as heat loss increases; the maintenance cost curve, which is constant within limits regardless of heat loss; and the operating cost curve, which is directly proportional to the heat loss. The lowest point of the total cost curve is the minimum total owning and operating cost for the system, and the heat loss for the point is the optimum heat loss for the system. When total cost curves are generated for various types of system configurations for a particular site, the point of optimum heat loss is approximately the same for all the system configurations even though the total cost of owning and operating the different systems is different, as illustrated in Figure 2. Therefore, it is not necessary to calculate the insulation requirements for all types of system configurations.

2.4 Federal Agency Approved System Suppliers. The following list contains all approved system suppliers issued Federal Agency Letters of Acceptability required in NFGS-02694, Exterior Underground Heat Distribution System.

2.4.1 Class A, B, C, and D Ground Water Conditions.

a) Intergy Systems, Brecksville, OH
b) Perma Pipe, Niles, IL
c) Rovanco Pipe, Joliet, IL
d) E. B. Kaiser Company, Glenview, IL
e) Pittcon Preinsulated Pipes, Inc., Syracuse, NY
f) U. S. Polycon Corporation, Panama City, FL
g) Nova Group, Inc., Napa, CA
h) Thermacor Process, Inc., Fort Worth, TX
i) Sigma Piping Company, Inc., Incline Village, NV

2.4.2 Class B, C, and D Ground Water Conditions.

a) Thermal Pipe Systems, Media, PA

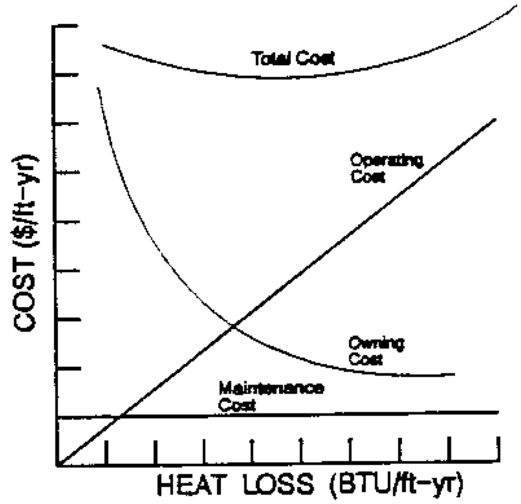


Figure 1
Relation Between Heat Loss and System Costs

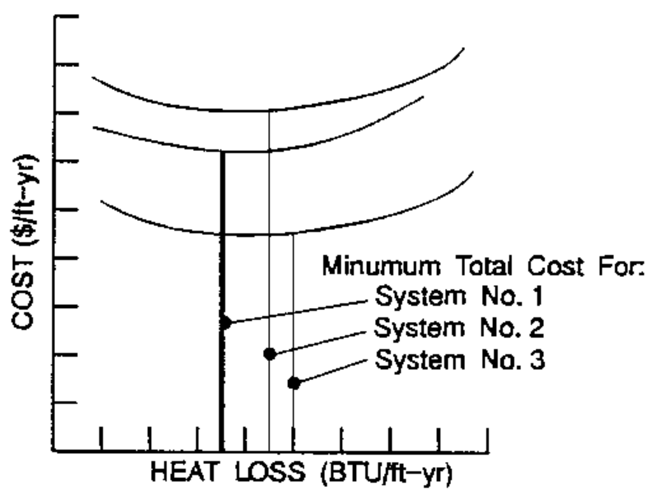


Figure 2
Total Cost of Owning and Operating Three Hypothetical Systems

Step 1. After the general layout of the system has been made and the site and application conditions have been determined, size the system carrier piping assuming a 2 percent heat loss from the supply line at maximum flow.

Step 2. Select one particular type of system configuration which is relatively low in first cost and is approved for use with the site and application conditions identified, to use as a model in making the economic analysis.

Step 3. Determine separately, for each section of the system, the installed cost per foot of the system configuration with each of the applicable combinations of insulation thicknesses shown in Table 3. A section can be considered as any portion of the system in which the conditions that affect heat loss are similar--e.g., pipe size, tunnel shape, cover type. The cost of all components, other than valve vaults called for in the selected system should be included in the cost estimate. If only one pipe is to be installed (i.e., either a supply or return, but not both), use only the appropriate column from the table for that type of pipe.

Step 4. Determine the annual owning cost per foot of each section of the system with each of the different thicknesses of insulation called for in Table 3, using the following equation:

$$\text{Owning Cost (\$/ft-yr)} = \frac{\text{Installed Cost (\$/ft)}}{\text{*Series Present Worth Factor}}$$

*The series present worth factor is the reciprocal of the capital recovery factor.

The series present worth factor can be obtained from any set of interest tables, given the annual interest rate (or rate or return) and the number of years over which the cost is to be amortized (i.e., the economic life of the item). Use an economic life of 25 years and a discount rate as published in National Bureau of Standards (NBS) Handbook 135, entitled Life Cycle Cost Manual for the Federal Energy Management Program.

Step 5. Calculate the heat loss per linear foot separately for each pipe in each section of the selected model system, assuming the various thicknesses of insulation called for in Table 3, using applicable calculation procedures in para. 2.3.6.1.

Table 3
Insulation Thickness (in inches) to be Assessed in Calculations

Thermal Conductivity of Insulation (Btu/hr, square feet, degrees F/in.)	WITH HIGH TEMPERATURE WATER (above 250 degrees F) On the Supply Pipe	WITH HIGH TEMPERATURE WATER (above 250 degrees F) On the Return Pipe	WITH LOW TEMPERATURE WATER (250 degrees F and lower) On the Supply Pipe	WITH LOW TEMPERATURE WATER (250 degrees F and lower) On the Return Pipe	WITH STEAM (any pressure) On the Supply Pipe	WITH STEAM (any pressure) On the Condensate Pipe
Up to 0.2	1/2	1/2	1/2	0	1/2	0
	1	3/4	1/2	1/2	1/2	1/2
	1	1	1	1/2	1	0
	1-1/2	1	1	3/4	1	3/4
	1-1/2	1-1/2	1-1/2	3/4	1-1.2	0
	-	-	1-1/2	1	1-1/2	1
From 0.2 to 0.4	3/4	3/4	3/4	0	3/4	0
	1-1/2	1	3/4	3/4	3/4	3/4
	1-1/2	1-1/2	1-1/2	3/4	1-1/2	0
	2-1/2	2	1-1/2	1	1-1/2	3/4
	2-1/2	2-1/2	2	1	2-1/2	0
	-	-	2	1-1/2	2-1/2	1-1/2
From 0.4 to 0.6	2	2	2	0	2	0
	3	2	2	2	2	2
	3	3	3	2	3	0
	4	3	3	3	3	2
	4	4	4	2	4	0
	-	-	4	4	4	2
Above 0.6	3	3	3	0	3	0
	4	3	3	3	3	3
	4	4	4	3	4	0
	5	3	4	4	4	3
	5	5	5	3	5	0
	-	-	5	4	5	3

Section 3: GENERAL DESIGN FACTORS

3.1 Design Responsibilities for Underground Pre-engineered Heat Distribution Systems. The project designer is responsible for accomplishing the following prior to project bidding:

a) Define site conditions for underground water classification (A, B, C, or D), soil corrosiveness, soil pH if less than 5.0, and potential soil load bearing problems.

b) Determine the general layout and essential characteristics of the system such as system media, maximum operating temperature and pressure, location and design of manholes, and branch runouts. The interface detail of the system at manhole walls shall be provided by the system supplier.

c) Design special elements of the system as required.

d) Calculate the maximum heat loss per lineal foot of the conduit in accordance with the procedures outlined in NFGS-02694.

3.1.1 Design by Project Designer. The project designer shall design on project drawings the exterior steam and condensate piping systems aboveground, the manholes, piping within manholes, and piping not in approved conduit systems. The project designer shall establish the system design parameters of the entire underground piping system, such as site classification, general layout, essential characteristics of the system, and specially designed elements of the system. The project designer is responsible for sizing the pipe, establishing the piping elevations, identifying the piping right-of-way, obstructions and utilities (plan and profile) within 25 feet (7.62 m) of the center line of the right-of-way, and every area within 25 feet of the center line that must be avoided; for example, paved areas and buildings. The project designer is also responsible for the location and sizing of manholes, the design of concrete manholes and the piping and equipment layout of manholes including valves, fittings, traps, expansion joints (when required), and manhole drains.

3.1.2 Design by System Supplier. The construction Contractor shall design and provide buried factory-prefabricated preinsulated piping in a conduit or pre-engineered insulated piping system for which a Federal Agency Approved Brochure has been issued. It is intended that the supplier of a Federal Agency approved system provide the details of design for his system in accordance with his Federal Agency Approved Brochure. The preapproved brochure and the design will address expansion loops, bends, offsets, concrete pipe anchors outside of manholes, interface with each manhole, and the watershed to aboveground piping. When prefabricated steel manholes are indicated, the system supplier is responsible for the structural design of the manhole and the manufacture of the complete manhole, including installation of valves, fittings, and other equipment as specified herein and indicated on the project drawings. The Contractor is responsible for the design, fabrication, and installation of the underground piping system within the system design parameters established by the project designer.

3.2 Distribution Site Location. Fluid distribution site locations should be according to the following:

3.2.1 Location Factors. For location factors for each system, refer to Table 4.

3.2.2 Subsurface Explorations. When a concrete trench or a buried steam or hot water system is specified, make a thorough investigation of ground and water conditions shall be made. Employ a soils engineer familiar with ground water conditions at the site to establish the classification. In the absence of existing definitive information on soil types and ground water conditions, make a detailed site classification survey. Upon completion of the survey, classify each exploration point as A, B, C, or D on the basis of the criteria presented in Tables 5 and 6. The worst ground water condition encountered between adjacent manholes determines the class of the system to be installed between adjacent manholes. Conduct this survey within the guidelines specified in paras. 3.2.2.1 through 3.2.2.12. When concrete shallow trench systems are specified, use the criteria of NFGS-02693 for prefabricated piping systems covered in this handbook.

3.2.2.1 Timing of Survey. Conduct the survey after the general layout of the system has been determined.

3.2.2.2 Time of Year. Make the survey at a time of year when the highest water table is expected to exist, if possible. If this is not possible, correct water table measurements on the basis of professional judgment, to indicate conditions likely to exist at the time of year when the water table is at its highest point. Follow exploration methods indicated in the NAVFAC criteria manual DM-7.01, Soil Mechanics.

3.2.2.3 Exploration Considerations. As a minimum, collect information on ground water conditions, soil types, terrain, and precipitation rates and irrigation practices in the area of the system. Information on terrain and precipitation rates and irrigation practices may be obtained from available records at the installation.

3.2.2.4 Test Explorations. Make test explorations (borings or test pits) at least every 100 feet (30.5 m) along the line of a proposed system. If changes in stratification are noted, decrease the boring spacings so an accurate horizontal soil profile may be obtained.

MIL-HDBK-1003/8A

Table 4
Location Factors for Each Distribution System

ITEM	DETERMINE THE FOLLOWING
Load Centers	Maximum demand load of system. (See criteria in Table 1 and ascertain requirements of all facilities.)
	Distance from generating plant.
	Basements or crawl spaces under buildings available for piping.
	Location of entry of system to load center structure.
	Location or need of meters for billing purposes.
	Future expansion.
Route	Existing piers, tunnels or trenches available for system.
	Aboveground obstructions, such as rivers, lakes, roads, railroads, structures, etc.
	Belowground obstructions, such as tunnels, trenches, piping, rock, storage tanks, etc.
	Location of expansion loops, joints and manholes.
	Master Plan. (Refer to DM-1.01)
Site	For above and underground systems: Ground contours along route.
	For underground systems:
	Borings every 100 feet along route (refer to para 3.1.2) - longer for larger projects.
	Absorption test (refer to para 3.1.2.5)
	Resistivity test (refer to para 3.1.2.7)
	Stability of soil (refer ro para 3.1.2.8)
	Water table survey made at time of highest levels if possible, or modify by judgement based on local data.
	Maximum, normal, and minimum groundwater levels.
	Frost level.
	Location of distribution line drainage and venting.
Coordination	Installation of other related distribution systems and manholes.
	Interference with electric distribution lines and manholes.
	Interference with water supply and fire extinguishing systems.
	Interference with sanitary and storm sewers and manholes.
	Interface with communications systems.
	Interference with ground drainage lines, catch basins, and manholes.
	Interference with fuel distribution piping systems.
	Interface with other gas supplies such as argon, nitrogen and carbon dioxide used in industrial process work.
	Excavation and backfill.
	Landscaping.
Cooperation	Local rules and regulations (permits, tests approvals, etc.).
Hazards	Refer to DM-1.01 for criteria.
Unit costs	Excavation of soil and rock and of landfill.
	Piping material.
	Piping insulation or covering.
	Pipe conduit.
	Construction of manholes.
	Construction of expansion loops and field joints.
Local labor	Availability and costs.
Local material	Availability and costs.

Table 5
Soil Classification

Major division	Subdivision	Fines	Field identification procedures (Excluding particles larger than 3 inches and basing frictions on estimated weights)	Dry strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group symbols	Typical names	Permeability when compacted
COURSE GRAINED SOILS More than half of material is larger than No. 200 sieve size (The No. 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse friction is larger than No. 4 sieve size. (For visual classifications, the 1/4" size may be used as equivalent to the No. 4 sieve size.)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.				GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Pervious
			Predominantly one size or a range of sizes with some intermediate sizes missing.				GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	Very Pervious
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).				GM	Silty gravels, poorly graded gravel-sand-salt mixtures.	SemiPervious to Impervious
			Plastic fines (for identification procedures see CL below).				GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.	Impervious
	SANDS More than half of coarse friction is smaller than No. 4 sieve size	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.				SW	Wel graded sands, gravelly sands; little or no fines	Pervious
			Predominantly one size or a range of sizes with some intermediate sizes missing.				SP	Poorly graded sands, gravelly sands; little or no fines.	Pervious
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)				SM	Silty sands, poorly graded sand-salt mixtures	Semi-pervious to Impervious
			Plastic fines (for identification procedures see CL below).				SC	Clayey sands, poorly graded sand-clay mixtures	Impervious
FINE GRAINED SOILS More than half of material is smaller than No. 200 sieve size	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE								
	SILTS AND CLAYS Liquid Limit less than 50			None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock, flour, silty or clayey fine sands with slight plasticity.	Semipervious to Impervious
				Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Impervious
				Slight to medium	Slow	Slight	OL	Organic silts and organic silts-clays of low plasticity.	Semipervious to Impervious
	SILTS AND CLAYS Liquid limit greater than 50			Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Semipervious to Impervious
				High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays	Impervious
				Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity.	Impervious
HIGHLY ORGANIC SOILS			Readily identified by color, odor, spongy feel and frequently by fibrous texture.				Pr	Peat and other highly organic soils	

Table 6
Site Classification Criteria

Site Class	General Conditions Required for such Classification	Conditions Found During Site Classification Survey that are Indicative of the Class			
		Relative to Water Table Level	Relative to Surface Water Accumulation		
			Soil Types	Terrain	Precipitation Rates or Irrigation Practices in Area
A–Severe	Water table frequently above bottom of the system	Groundwater within 1 ft of bottom of system	Any	Any	Any
	Water table occasionally above bottom of the system and surface water accumulates and remains for long periods of soil surrounding the system	Groundwater within 1 ft of bottom of system	GC, SC, CL, CH, OH	Any	Any
B--Bad	Water table occasionally above bottom of the system and surface water accumulates and remains either for short periods in soil surrounding the system	Groundwater within 5 ft of bottom of system	GW, GP, SW SP GM, SM, ML, OL, MH	Any	Any
	Water table never above the bottom of the system, but surface water accumulates and remains for long periods in soil surrounding the system	No groundwater encountered	GC, SC, CL CH, OH	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
C--Moderate	Water table never above the bottom of the system, but surface water accumulates and remains for short periods in soil surrounding the system	No ground water encountered	GM, SM, ML, OL, MH	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
			GC, SC, CL, CH, OH	Any except low areas	Equivalent to less than 3 in. in any one month and to less than 20 in. in one year
D--Mild	Water table never above the bottom of the system and surface water does not accumulate and remain in soil surrounding the system	No groundwater encountered	GW, GP, SW, SP	Any	Any
			GM, SM, ML, OL, MH	Any except low areas	Equivalent to less than 3 in. in any one month and to less than 20 in. in one year

3.2.2.5 Depth of Exploration. Extend all explorations 5 ft (1.53 m) below the expected elevation of the concrete trench invert or the depth of the pre-engineered system to determine ground water conditions.

3.2.2.6 Special Ground Considerations. Give particular attention to the following conditions:

a) The possibility that the ground below a backfilled piping system may not be able to absorb runoff that has seeped into it.

b) Areas where ponding may occur, either along a sloping surface or in low flat areas.

c) The permeability of the ground below the system (see below).

3.2.2.7 Permeability Tests. Perform field permeability tests as follows:

a) Space field permeability tests (percolation) along the line of a trench at intervals of approximately 100 feet (30.5 m). When available information indicates uniform subsurface conditions, longer intervals may be allowed for larger projects.

b) Dig holes approximately 1 foot2 (0.093 m2) to a depth of 2 feet (620 mm) below the approximate bottom of a trench.

c) Fill each hole with water to the bottom elevation of the planned trench.

d) After the water has completely seeped away, immediately refill each hole with water to the same depth.

e) If it requires 20 minutes or less for the water to drop 2 inches (51 mm), consider the soil dry; otherwise, consider it as saturated at times.

3.2.2.8 Test Results. Use test results as follows:

a) If the soil is saturated, no further tests are required. Class A underground conduit systems for wet soils must be used.

b) If the soil is dry, as defined above, deepen permeability test holes an additional 3 feet (920 mm) to determine if the water table is within 5 feet (1.53 m) of the trench bottom.

3.2.2.9 Soil Resistivity. Considerations for soil resistivity are as follows:

a) Take soil resistivity readings along the conduit line (in accordance with Table 4).

b) A cathodic protection system is required to protect metallic piping systems and manholes. This applies to all sites where soil resistivity is less than 30,000 ohms per cubic centimeter (ohm-cm), where stray direct currents can be detected underground or where underground corrosion, due to local soil conditions, has been found to be severe.

3.2.2.10 Soil Corrosiveness Classification. Have an experienced corrosion engineer make the classification based on a field survey of the site carried out in accordance with recognized guidelines for conducting such surveys. Classify the soil at the site as corrosive or noncorrosive on the basis of the following criteria:

a) Corrosive: The soil resistivity is less than 30,000 ohms-centimeter (ohm-cm) or stray direct currents can be detected underground.

b) Noncorrosive: The soil resistivity is 30,000 ohm-cm or greater and no stray direct currents can be detected underground.

3.2.2.11 Soil Stability. During the above survey, observe and note the soil stability. Use NAVFAC DM-7.01 for criteria. Note areas of unstable soil on the site plans depicting the distribution route.

3.2.2.12 Soil Load-Bearing Capacity. As a part of the project designer's survey, have an experienced soils engineer investigate the load-bearing qualities of the soil in which the system will be installed. Identify the location and nature of potential soils problems. Depending on the nature of the problem, the designer may choose to reroute the line, use a combination of concrete shallow trench, direct buried, or aboveground low-profile systems, or elect to over-excavate and replace with nonexpensive fill.

3.2.3 Site Classification. Base selection of the conduit system type on the underground water conditions at the project site as defined in Tables 4, 5, and 6 for Class A, B, C, or D application corresponding to underground water conditions ranging from severe to mild, respectively.

3.2.3.1 Class A, Severe. The water table is expected to be frequently above the bottom of the system or the water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system.

3.2.3.2 Class B, Bad. The water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for short periods (or not at all) in the soil surrounding the system or the water table is expected never to be above the bottom of the system but surface water is expected to accumulate and remain for long periods in the soil surrounding the system.

3.2.3.3 Class C, Moderate. The water table is expected to never be above the bottom of the system, but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.

3.2.3.4 Class D, Mild. The water table is expected never to be above the bottom of the system and surface water is not expected to accumulate or remain in the soil surrounding the system.

3.2.4 Analyzing Site Classification for Application of Pre-Engineered Underground System. The Federal Agency Committee on Underground Heat Distribution Systems has reviewed and approved systems by suppliers. Each system is defined in the brochure approved by the Committee. No system may be installed without prior approval as given in the brochure. The letter of certification contained in the conduit system brochure stipulates the approved site classification. A system approved for higher classification is acceptable for use in lower classifications. For example, Class A is acceptable for Classes B, C, and D, etc.

3.2.5 Analyzing Site Classification for Application of Shallow Concrete Trench System

3.2.5.1 Soils

a) Fine grained soils (impervious). The highest ground water level evident during the wettest period of the year should be a minimum of 1 foot (305 mm) below the lowest point of water entry into the concrete shallow trench system. The lowest point of entry is defined as the joint between the concrete trench wall and concrete trench bottom. The concrete trench bottom will be continuous with no openings. The above condition will ensure that constructability of the concrete shallow trench is practical and that potential infiltration of water into the shallow trench will be negligible. Open drainage ways, swales, or swampy/boggy areas will preclude use of a concrete shallow trench system because of ground water level guidance in Table 5. The concrete shallow trench system must be rerouted or regraded to bring the concrete trench out of the unsuitable conditions. Have the geotechnical engineer who performed the detailed site classification survey provide regrading instructions. The designer will ensure that the fill will remain stable and will not be subject to future wash-outs. If the specific site conditions are such that these alternatives are not viable, consider aboveground low profile or a direct buried system of the prefabricated or preengineered type in accordance with NFGS-02694 for these areas.

b) Coarse grained soils (semipervious/pervious). The ground water level during the wettest period of the year should be at least 1 foot (305 mm) below the lowest point of water entry into the concrete shallow trench system.

(1) Water table located 1 to 2 feet (305 to 610 mm) below lowest point of water entry. The criteria of para. 3.2.5.1 a) applies.

(2) Water table located 2 or more feet below lowest point of water entry: Concrete shallow trench systems with noncontinuous bottom (tunnel constructed of noncontinuous concrete bottom with openings provided in bottom at intervals of 4 feet (1220 mm) or more to permit drainage into the semipervious/pervious soils) may be used. Special considerations are required when the concrete shallow trench would traverse open drainage ways or swales where the water table would be less than 2 feet (610 mm) below the concrete trench bottom. The designer may elect to reroute the system, place fill to bring the system out of the unsuitable conditions, or provide a continuous bottom trench floor for this area of the site.

c) Swelling Soils (material with high swell potential): If the specific site conditions are such that these alternatives are not viable, consider aboveground low profile or a direct buried system of the prefabricated or preengineered type in accordance with NFGS-02694 for those areas. Design the concrete shallow trench system in materials having high swell potential in accordance with para. 3.2.5.1 a). Soils having a liquid limit (LL) greater than 50 and a plasticity index (PI) greater than 25 require testing (consolidation swell) to determine the swell characteristics. When the results of the swell test indicate high swell potential, special considerations such as over excavation (width and depth) and replacement with nonexpansive fill, under-trench drainage system or other methods of minimizing differential heave will be provided. The design of special features such as described above will be in accordance with instructions provided by the geotechnical engineer who performed the detailed site classification survey. Design of joint spacing and joint details to accommodate movements will also be provided when required.

3.2.5.2 Settlement of Trenches. Generally, settlement of concrete trenches will not be a problem since the unit load of the shallow trench system will be similar to the existing unit overburden load. Backfill adjacent to the concrete trench must be thoroughly compacted to prevent settlement which would create ponding. Positive slopes away from the concrete trench are desirable. Special care of backfill and compaction is required where the system crosses existing streets to preclude settlement and cracking of the roadway adjacent to the trench from repeated traffic loads.

3.2.5.3 Under-Trench Drainage Systems. Use concrete trench subdrain systems as required. When subsurface conditions are of differing soil types, (fine grained and coarse grained) and those differing soil conditions will cause blocked drainage either horizontally or vertically adjacent to the concrete trench, provide subdrains to ensure drainage to prevent ponding or entrapment of water adjacent to the shallow trench system. Base the design of the subdrain system on the instructions provided by the geotechnical engineer who performed the detailed site classification survey and classified each exploration point. Soils of low permeability and high moisture content (lean and fat clays (CL-CH)) shall not require under-drains when the shallow trench system is designed to accommodate all anticipated inflow with systems or equipment such as direct connections to storm sewers or the use of dual sump pumps. Connect drainage system sump pump discharge pipes to storm sewer system where feasible. If not feasible, provide discharge to splash blocks on grade. When discharging to grade install the pump discharge line without a check valve to allow complete drainage of the discharge pipe to prevent freezing. Do not use under-trench drainage to alter ground water level to meet requirements of Table 5.

3.2.6 Reinforced Thermosetting Resin Plastic (RTRP) Pipe. RTRP pipe is normally supplied under Mil Spec. MIL-P-28584, when used for condensate systems. This pipe is suitable for service pressures up to 150 psig (1034 kPa) and temperatures up to 200 degrees F (93 degrees C). Above 200 degrees F (93 degrees C) the pressure rating drops off rapidly. At 250 degrees F (121 degrees C) the pressure rating is 125 psig (861.3 kPa) and drops to 45 psig (310.1 kPa) at 270 degrees F (132 degrees C). These ratings are for hot water. Live steam cannot be tolerated, although RTRP pipe may be used for vented gravity condensate piping as well as for pumped condensate piping. RTRP pipe is acceptable at Class B sites (refer to para. 3.2.3). It is recommended for Class A sites, as permitted in para. 2.1.2, due to its low cost and long service life. Procure and install RTRP condensate piping in accordance with NFGS-02697. Take special care in the design of steam drip connections to protect the RTRP piping from live steam from failed traps. Insulate condensate piping only when a life-cycle cost analysis indicates a payback in energy savings, or where needed for personnel protection (manholes, for example).

3.3 Service and Loads. Determine from Section 2 the services, such as steam, high temperature water, hot water, chilled water, compressed air, fuel gas and others, required for each load center or building, the load demands for each service, and the capacity of a source or central plant for each service. (Refer to Section 2 for fluid conditions inside service lines, for sizing pipes for these conditions, and for the required capacities.)

3.3.1 Alternate Routes. Refer to Master Plan and consider system routing and size to accommodate future construction.

3.3.2 Pressure Drop. From the total allowable pressure drop and ultimate length of a line, determine the pressure drop per 100 feet (30.5 m). Note the maximum flow between each load center and size the different pipeline sections accordingly.

3.3.3 Obstacles. From a field survey, note all obstacles for each route.

3.3.4 Future Loads. Refer to Master Plan and consider system routing to accommodate future construction.

3.3.5 Distribution Circuits. Select a circuit which is economical, easy to operate, balance and control, and is suitable for a particular project terrain. Note that types easiest to balance and control are those where pressure and temperature differences are fairly constant between equipment supply and return branches.

3.3.6 Route Types. Run distribution piping through buildings, aboveground, or underground and below piers.

3.3.6.1 Through Buildings. Select the route considered technically and economically best justified; make full use of building piers, underpiling spaces, basements, crawl spaces, and attics, including connecting corridors between buildings, existing tunnels and concrete trenches. However, high-pressure fuel gas, steam, and HTW piping inside buildings should be routed to comply with federal and local fire and life safety codes. Gas piping shall comply with ANSI B31.8, Gas Transmission and Distribution Piping Systems, and NFPA 54, National Fuel Gas Code. Steam, condensate and compressed air lines shall comply with ANSI B31.1, Power Piping.

3.3.6.2 Exterior Steam Distribution. Use NFGS-02695 for all steam distribution piping exposed to the weather, on building exteriors, aboveground piping supports, piers (pedestals), poles, and for all steam piping on piers and under piers, in tunnels and in manholes. Use NFGS-02693 for piping in trenches. Use NFGS-02694 for buried steam piping .

3.3.6.3 Aboveground Overhead Piping. Locate piping as low as 1 foot (305 mm) or as high as 22 feet (6.7 m) above the ground surface. A 16-foot (4.9 m) clearance is required for automobile and truck traffic, and a 22-foot (6.7 m) clearance for railroad cars.

3.3.6.4 Buried Piping. For buried piping routes, the following criteria apply (refer to NFGS-02694):

a) Compressed Air and Gas Piping. Compressed air and gas piping generally require no insulation, but they should be shop coated, wrapped, tested, and handled in accordance with provisions of NFGS-02685, Exterior Buried Natural Gas Distribution Systems, NFGS-02682, Exterior Fuel Distribution System), and NFGS-09809, Protection of Buried Steel Piping and Steel Bulkhead Tie Rods. Provide for testing of coverings by electrical flow detectors (spark test).

b) Minimum Cover. Protect all buried piping and conduits by laying them under a minimum cover of 24 inches (610 mm). However, protect buried piping under railroads, roads, streets, or highways or due to changes in ground contours against possible external damage due to the superimposed car or truck traffic. Lay pipes below the frost line. Casings may be needed where there is no frost.

c) Other Hazards. When piping must be laid where it will be subjected to hazards such as earthquakes, washouts, floods, unstable soils, landslides, dredging of water bottoms and other categorically similar conditions, protect it by increasing pipe wall thickness, constructing intermediate supports or anchors, erosion prevention, covering pipes with concrete, adding seismic restraints for above-grade piping or other reasonable protection.

d) Manholes. Select manhole locations in accordance with the following. Details of piping and design of manholes are the responsibility of the project designer. Design manholes to provide adequate space for maintenance, proper venting and quick egress. Manholes are required where vertical offsets in steam piping are required to conform to grading requirements. Manholes accommodate the required steam main drip traps and any block valves needed. Manholes are usually provided at all major branch line connections and at drip traps on compressed air lines.

e) Tunnels. Construct tunnels for underground routes with a walkway minimum height of 76 inches (1.93 m) and clear width of 36 inches (920 mm), with piping stacked vertically on one side and enlarged zones for crossovers and takeoffs. Label all pipes and conduit. Provide enough room to reach all flange bolts, to operate tools, and to operate or to replace any component. Run a drainage trench along one wall to a point of disposal such as a storm sewer or a sump pit, with an automatic drainage pump driven by an electric motor or steam jet. Install all electrical systems in rigid metal conduit. Identify and separate by voltage class. Tunnels shall be well lighted and ventilated. Use moisture resistant electrical fixtures. Tunnels may be built of reinforced concrete, brick, or other suitable structural materials, and shall be membrane waterproofed.

3.3.6.5 Condensate Return Cost. Refer to para. 4.1.2 and 4.2.2.3.

3.3.6.6 Choice of Route. Except in congested and vulnerable areas, choose aboveground routes for heat distribution systems. Otherwise, adapt site conditions to comparative advantages of going above or underground as stated below:

Aboveground	Underground
Lower first cost	Less heat loss on hot lines Less vulnerable target
Less maintenance	Less obstruction to aboveground traffic
Easy detection of failure	Less unsightly
Higher continuous operating efficiency	Freeze protected when buried
Longer life	Less heat gain in chilled and condenser water piping

3.3.6.7 Piping Layouts. The project designer is responsible for determining location of expansion bends, loops and joints, anchors, takeoffs, isolation valves, and drip points. The project designer is also responsible for locating all manholes, takeoffs, isolation valves, and drip points. The system designer determines the initial location of anchors, expansion bends, loops and joints; the system supplier determines final location and design of these features to fit actual field conditions. Plan and position piping layouts as follows:

a) Determine what lines between the same points should be parallel to each other (such as supply and return) or be separated (such as steam from chilled water). The minimum clearance between pipe conduits in the same trench shall be 6 inches (150 mm).

b) Determine locations of expansion bends or loops, anchors, takeoffs, and drip points. In non-pre-engineered/prefabricated heat distribution systems, the project designer is responsible for determining location of expansion bends, loops and joints; anchors; takeoffs; isolation valves; and drip points. In pre-engineered/prefabricated heat distribution systems, the project designer is responsible for locating all manholes, takeoffs, isolation valves and drip points. Initial location of anchors, expansion bends, loops and joints shall be by the system designer. The system designer determines the initial location of anchors, expansion bends, loops and joints; the system supplier determines final location and design of these features to fit actual field conditions.

c) Lay out piping on a scaled contour map of the site and on a profile drawing along the route, locating all obstructions and interferences, such as streams, roads, railroads, buried tunnels, concrete trenches, drainage piping, sewers, water piping, electrical conduits, and other service piping, within 25 (7.6 m) feet of the center line of the right-of-way and identify areas within 25 feet of the center line that must be avoided. If sufficient right-of-way to accommodate pipe expansion cannot be identified and expansion joints are required, they must be specified and located with installation details noted on the drawings.

d) Provide a log of soil conditions along the piping right-of-way which gives, as a minimum, soil type, soil resistivity and pH, bearing strength and unstable conditions, and indicate corrective work required.

e) Provide details at building entries on the project drawings to show pipe elevation, floor elevation, building wall construction, and existing equipment.

3.3.6.8 Underground. Use only approved and certified conduit systems for steam, condensate and HTW, and procure and install in accordance with the requirements of NFGS-02694, NFGS-02697, and NFGS-02698, respectively. The Federal Agency Committee for Underground Heat Distribution Systems approves and certifies the various types of conduit systems, i.e., drainable and dryable (pressure testable), sectionalized, prefabricated (non-pressure testable), and poured-in-place granular insulation type conduit systems. Concrete shallow trench systems may be used only if the soil characteristics set forth in NFGS-02693 are met. In this case, design and specify the system in accordance with NFGS-02693.

3.4 Insulation. Evaluate insulation for all piping systems with the potential for significant thermal losses. These include steam, condensate, HTW, MTW, LTW, and CHW piping. Use NFGS-15250, Insulation of Mechanical Systems, for CHW, LTW and special applications requiring insulation of fuel gas and compressed air piping systems. Use NFGS-02696 for above-grade steam, HTW, MTW, LTW, and condensate return piping systems. (Alternately, NFGS-15250 may be used for these above-grade piping systems.) Use aluminum jackets and organic felt as specified in NFGS-15250 and NFGS-02696. Use NFGS-02694 for underground heat distribution piping insulation. Insulation materials shall not contain asbestos.

3.5 Miscellaneous Criteria. Anchor or guy exterior distribution systems to withstand the wind velocity specified for design of structures, refer to MIL-HDBK-1002/2, Loads.

Section 4: SPECIFIC PIPING DESIGN FACTORS

4.1 Fluid Characteristic

4.1.1 Steam. Refer to Keenan and Keyes, Thermodynamic Properties of Steam.

4.1.2 Condensate. For the economics of returning condensate, use the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 1985 Handbook - Fundamentals and ASHRAE 1987 Handbook - HVAC Systems and Applications.

4.1.3 High Temperature Water (HTW), Medium Temperature Water (MTW), and Low Temperature Hot Water (LTW). Use ASHRAE 1985 Handbook - Fundamentals and ASHRAE 1987 Handbook - HVAC Systems and Applications.

4.1.4 Compressed Air. For data on compressed air, refer to DM-3.5, Compressed Air and Vacuum Systems.

4.1.5 Natural Gas. Refer to NFPA 54.

4.2 Distribution System Piping

4.2.1 Equivalent Lengths of Piping. To the straight lengths of pipe along a pipeline route, add equivalent lengths for valves and fittings as indicated in Table 7.

4.2.2 Sizing of Distribution Piping. Size distribution piping as follows:

4.2.2.1 Minimum Pipe Size. Use minimum of 2-inch (51 mm) pipe which requires extra strong piping for direct buried piping with threaded end connections sized for piping in shallow trench system with all joints welded. Smaller pipe sizes and threaded joints are allowable in valve manholes.

4.2.2.2 Steam Piping. The project designer shall specify the design temperatures and pressures. The approved systems are suitable for temperatures to 450 degrees F (232 degrees C). If higher temperature systems are required, review manufacturers' approved brochures to determine the exceptions to the brochures to be made in the project specification relative to pipe material, pipe expansion, and valve classification. Design considerations are as follows:

Table 7
Representative Equivalent Length in Pipe/Diameter Ratio (L/D) for Various Valves and Fittings 1/

ITEM	DESCRIPTION OF PRODUCT		EQUIVALENT LENGTH IN PIPE LENGTH/DIAMETER
Valves:			
Conventional globe	With no obstruction in flat, bevel or plug type seat.	Fully open	340
	With wing or pin guided disc.	Fully open	450
Y-pattern globe	With stem 60 degrees from run of pipe line.	Fully open	175
	With stem 45 degrees from run of pipe line.	Fully open	145
Conventional angle	With no obstruction in flat, bevel or plug type seat.	Fully open	145
	With wing or pin guided disc.	Fully open	200
Conventional wedge, disc, plug or gate.		Fully open	13
		Three-quarters open	35
		One-half open	160
		One-quarter open	900
Pulp stock gate		Fully open	17
		Three-quarters open	50
		One-half open	260
		One-quarter open	1,200
Conduit pipe line gate		Fully open	3 2/
Butterfly 6-inch and larger		Fully open	20
Conventional swing check		0.5 3/ - Fully open	135
Clearway swing check		0.5 3/ - Fully open	50
Globe lift check or stop-check		2.0 3/ - Fully open	Same as conventional globe
Angle lift check or stop-check		2.0 3/ - Fully open	Same as conventional angle
Foot valves	With strainer and poppet lift-type disc.	0.3 3/ - Fully open	420
	With strainer and leather-hinged disc.	0.4 3/ - Fully open	75
in-line-ball check	2.5 vertical and 0.25 horizontal	3 - fully open	150
Straight-through cocks	Rectangular plug port area equal to 100% of pipe area.	Fully open	18
Three-way cocks	Rectangular plug port area equal to 80% of pipe area (fully open).	Flow straight through	44
		Flow through branch	140
Fittings:			
90 degrees standard elbow			30
45 degrees standard elbow			16
90 degrees long radius elbow			20
90 degrees street elbow			50
45 degrees street elbow			26
Square corner elbow			57
Standard tee	With flow through run.		20
	With flow through branch.		60
Close pattern return bend			50

1/ Legitimate for all flow conditions except in laminar flow range where Reynolds number is less than 1000.
2/ Exact equivalent length is equal to the length between flange faces of welding ends.
3/ Minimum calculated pressure drop in psi across vavle to provide sufficient flow to lift disc fully.
Note: For additional data refer to DM-3.05.

a) Steam Flow Charts. For pressures of 30 psig (206.7 kPa), 50 psig (344.5 kPa), 100 psig (689.4 kPa), and 150 psig (1033.5 kPa), see Figures 3 through 6. These charts show weight-rate pressure drop and velocities of saturated steam in Schedule 40 steel pipe. By selecting all pipe sizes on an optimum pressure drop, the total pressure drop of a pipeline may be estimated from an equivalent length, irrespective of pipe size. The charts are based on the rational flow formula (Darcy) shown below. For higher pressures, refer to Piping Handbook, by Crocker and King.

b) Rational Flow Charts. The simplified rational flow formula (Darcy) is used for compressible fluids for all pressures:

EQUATION: $$P_{100} = W^{2}(0.000336f)\ v/d^{5} = C_{1} \times C_{2} \times v \quad (2)$$

Where:

P_{100} = pressure drop per 100 feet of equivalent length of pipe (psi)

C_{1} = $W^{2}10^{-9}$ (for values, see Figure 7)

C_{2} = $336000f/d^{5}$ (for values, refer to Table 8)

W = rate of flow, pounds per hour (pph) (0.454 Kg/h)
f = friction factor
d = inside diameter of pipe (in)
v = specific volume of fluid (ft^{3} per lb) at average pressure

c) Velocities. (Refer to Table 9.)

EQUATION: $$V = \frac{3.06W}{d^{2}} \quad (3)$$

Where:

V = velocity of flow (fpm)
R = density (pcf)

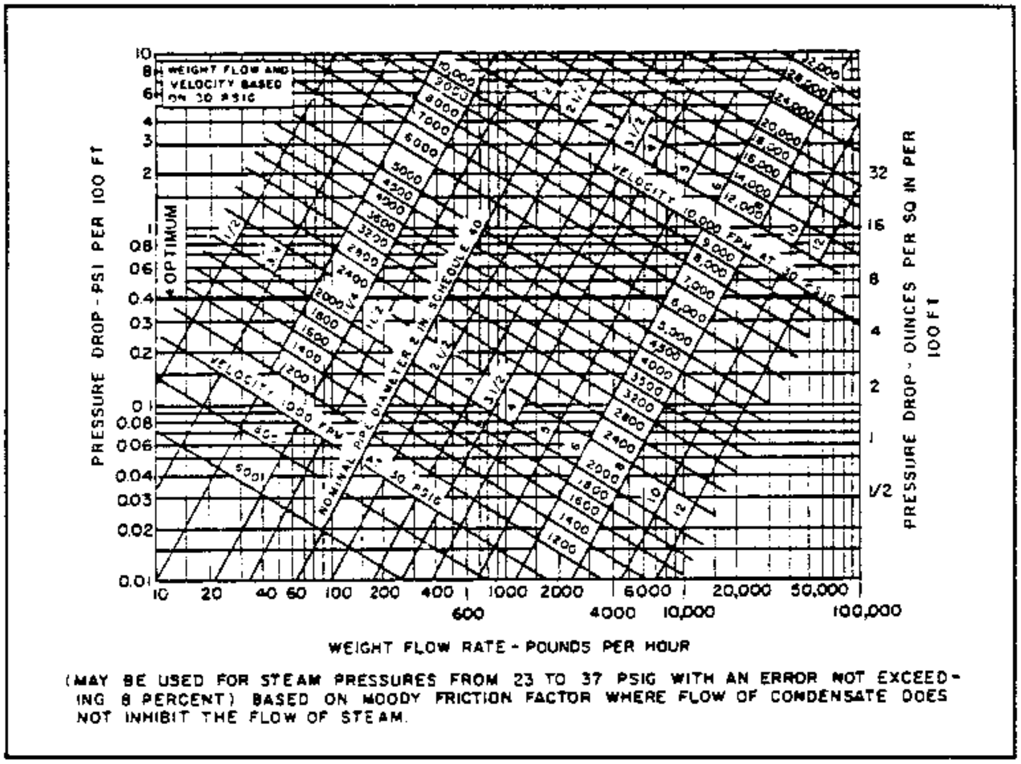


Figure 3
Chart for Weight-Flow Rate and Velocity of Steam (30 psig) (206.7 kPa)

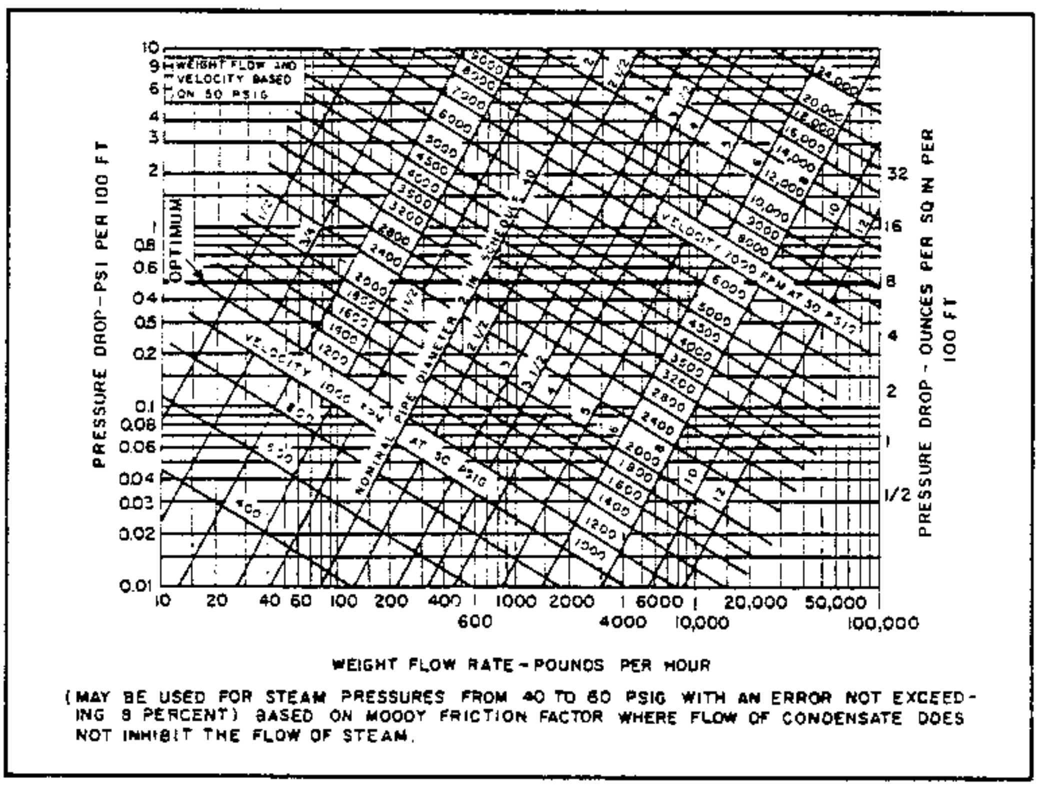


Figure 4
Chart for Weight-Flow Rate and Velocity of Steam (50 psig) (344.5 kPa)

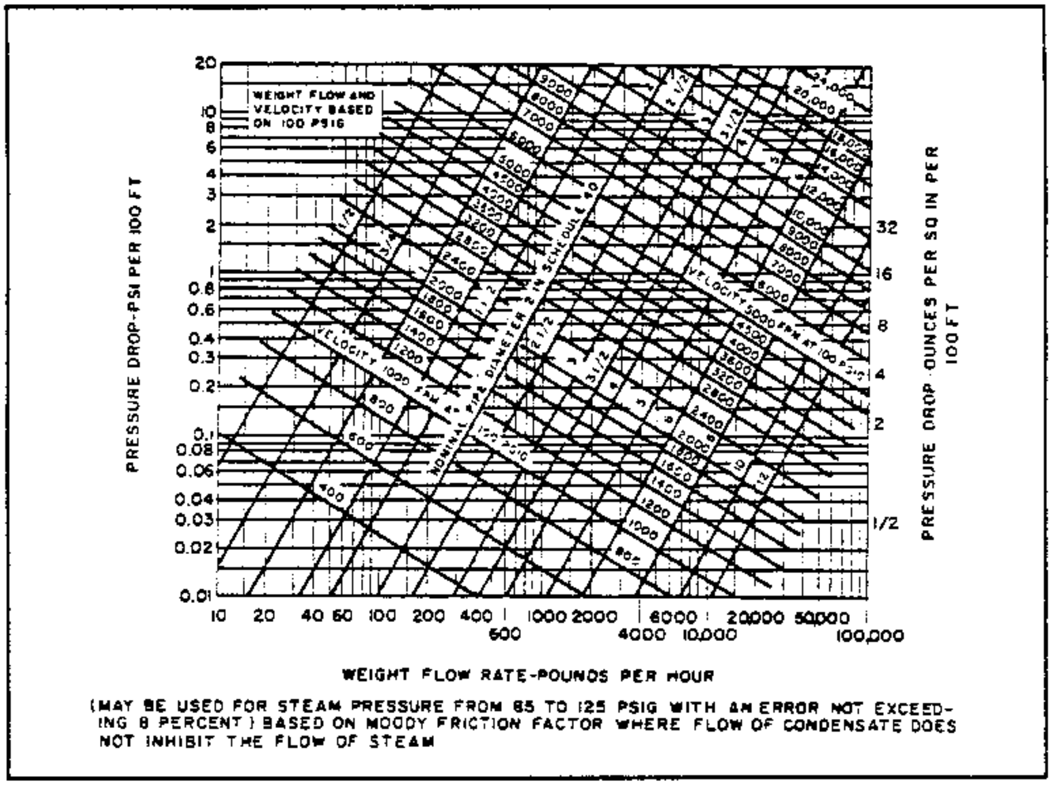


Figure 5
Chart for Weight-Flow Rate and Velocity of Steam (100 psig) (689.4 kPa)

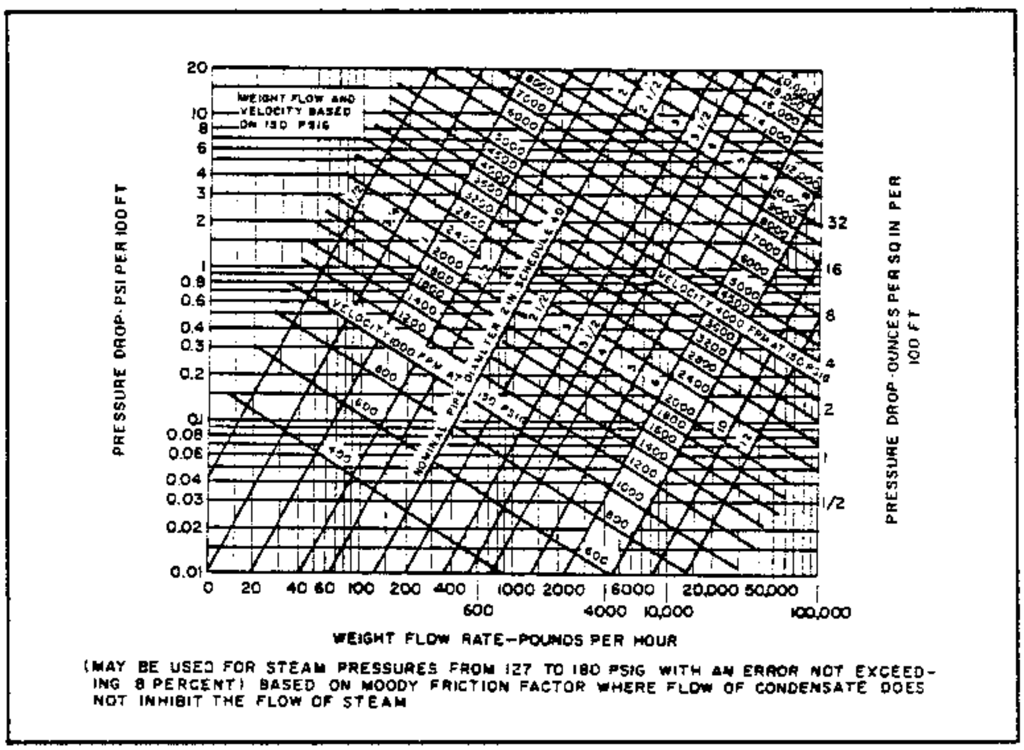


Figure 6
Chart for Weight-Flow Rate and Velocity of Steam (150 psig) (1033.5 kPa)

MIL-HDBK-1003/8A

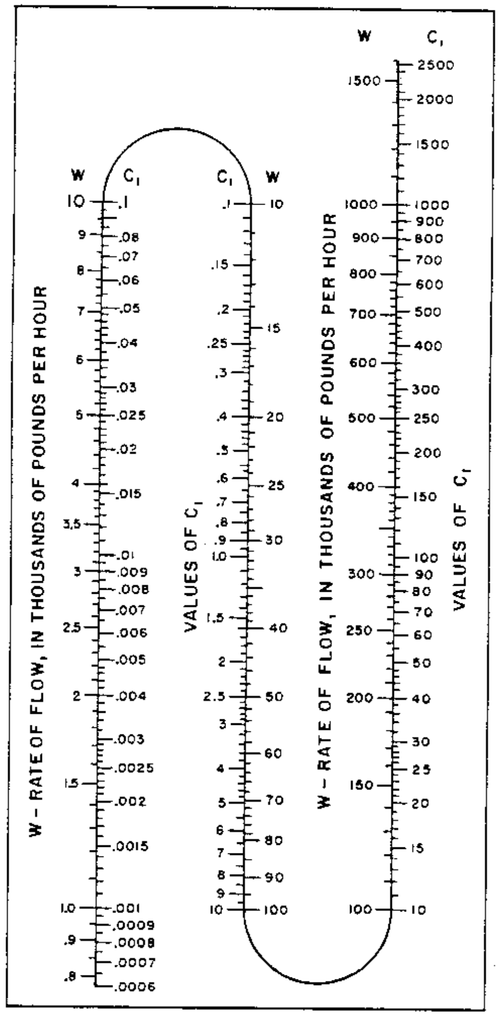


Figure 7
Values of C_1, Flow Factor in Equation 1

MIL-HDBK-1003/8A

Table 8 (Continued)
Values of C_2, Flow Factor in Equation (1)

NOMINAL PIPE SIZE	SCHEDULE		VALUE OF C_2	NOMINAL PIPE SIZE	SCHEDULE		VALUE OF C_2
12	20		0.015 7	20	10		0.001 41
	30		0.016 8		20	S	0.001 50
		S	0.017 5		30	X	0.001 61
	40		0.018 0		40		0.001 69
		X	0.019 5		60		0.001 91
	60		0.020 6		80		0.023 1
	100		0.026 7		120		0.031 0
	140		0.035 0		160		0.042 3
14	10		0.009 49	24	10		0.000 534
	20		0.009 96		20	S	0.000 565
	30	S	0.010 46			X	0.000 597
	40		0.010 99		30		0.000 614
		X	0.011 55		40		0.000 651
	60		0.012 44		60		0.000 741
	80		0.014 16		80		0.000 835
	100		0.016 57		100		0.000 972
	120		0.018 98		120		0.001 119
	140		0.021 8		140		0.001 274
	160		0.025 2		160		0.001 478
16	10		0.004 63				
	20		0.004 21				
	30	S	0.005 04				
	40	X	0.005 49				
	60		0.006 12				
	80		0.007 00				
	100		0.008 04				
	120		0.009 26				
	140		0.010 99				
	160		0.012 44				
18	10		0.002 47				
	20		0.002 56				
		S	0.002 66				
	30		0.002 76				
		X	0.002 87				
	40		0.002 98				
	60		0.003 35				
	80		0.003 76				
	100		0.004 35				
	120		0.005 04				
	140		0.005 73				
	160		0.006 69				

NOTE: The letters s, x, and xx in the columns of Schedule No. indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

Table 9
Reasonable Velocities for Flow of Steam in Pipes

CONDITION OF STEAM	PRESSURE (psig)	SERVICE	REASONABLE VELOCITY [1] (fpm)
Saturated	Vacuum	Turbine exhaust	Up to 18,000
	0 to 25	Heating	4,000 to 6,000
	25 and up	Steam distribution	6,000 to 10,000
	125 and up	Underground steam distribution	Up to 20,000
Superheated	200 and up	Boiler and turbine leads	7,000 to 20,000

[1] Velocities should be below those which would produce excessive noise or erosion.

d) Steam Distribution Pressures. Steam pressure is governed by the highest pressure needed by the equipment served at the most remote location as well as by an economic analysis of the feasible systems, including pressure considerations. The advantages of a low-pressure system (under 15 psig) (103.4 kPa) are low distribution loss, lower losses and less trouble from leakage, traps, and venting, simplified pressure reduction at buildings, standard steel fittings, and low maintenance. The advantages of high-pressure distribution, over 50 psig (344.5 kPa), are smaller pipe sizes, availability of steam for purposes other than for heating, and more flexibility in velocities and pressure drops.

e) Selection of Valve Types. Install double-ported, pilot-operated valves for large capacities, especially for inlet pressures above 125 psig (861.3 kPa). Double-ported valves will not shut off completely on no-load demand; therefore, single-seated valves must be used for such services. Do not install reducing valves on the basis of pipe sizes, because oversized valves do not give satisfactory service. Select valves to operate generally fully open, with ratings and reduction ratios as recommended by the manufacturer. Install a strainer and condensate drain ahead of the pressure-reducing valve. Because the volume of steam increases rapidly as the pressure is reduced, a reducing valve with increased outlet or expanding nozzle is required when the reduction ratio is more than 15 to 1. Provide cutout valves to isolate the pressure reducing valve to permit maintenance. Where the resulting superheated steam temperature is objectionable to the process on the low pressure side or the temperature-use limit of the equipment has been exceeded, a desuperheater must be used to lower the steam temperature to that for saturation. Provide a manual bypass for emergency operation when the pressure reducing valve is out of service. Provide a pressure gauge on the low pressure side. Where steam requirements are relatively large, above approximately 3,000 pounds/hour (1364 kg/hr), and subject to seasonal variation, install two reducing valves in parallel, sized to pass 70 percent and 30 percent of maximum flow. During mild spring and fall weather, set the large valve at a slightly reduced pressure so that it will remain closed as long as the smaller valve can supply the demand. During the remainder of the heating season reverse the valve settings to keep the smaller one closed except when the larger one is unable to supply the demand.

f) Safety Valves. Provide one or more relief or safety valves on the low pressure side of each reducing valve in case the piping and/or equipment on the low pressure side do not meet the requirements of the full initial pressure. The combined discharge capacity of the relief valves shall be such that the pressure rating of the lower pressure piping and equipment will not be exceeded. For special conditions refer to ASME B31.1 and ASHRAE Handbooks - Systems and Applications.

g) Takeoffs from Mains. Takeoffs from mains to buildings must be at the top of mains and located at fixed points of the mains, at or near anchor points. When a branch is short, valves at each takeoff are unnecessary. Takeoffs shall have valves when the branch is of considerable length or where several buildings are served. A 45 takeoff is preferred; 90 takeoffs are acceptable. Branch line slope of 1/2 inch (12.6 mm) should be used for lines less than 10 feet (3.05 m) in length and should be 1/2 inch per 10 feet (3.05 m) on branch lines longer than 10 feet.

4.2.2.3 Condensate Returns. Condensate returns are preferred if owning and operating costs of such a system are less than that of using and treating raw water for makeup. Factors favoring condensate return are: high area concentration of steam usage; restriction on condensate disposal; high raw water treatment costs; water treatment space unavailable; high cost of raw water; and high cost of fuel for feedwater heating. Design considerations are as follows:

a) Return Piping. Size condensate trap piping to conform with 30 to 150 psig (206.7 to 1033.5 kPa) steam piping in accordance with Tables 10 and 11 and interpolate these for other pressures.

b) Discharge Piping. Size discharge piping from condensate and heating pumps in accordance with pump capacities, which may be between one to three times the capacity of the steam system branch which they serve, depending on whether continuously or intermittently operated.

Table 10
Return Pipe Capacities for 30 psig (206.7 kPa) Steam Systems (a)
(Capacity Expressed in lbs/hr)

	DROP IN PRESSURE (psi PER 100 ft IN LENGTH)				
PIPE SIZE (in.)	1/8	1/4	1/2	3/4	1
3/4	115	170	245	308	365
1	230	340	490	615	730
1-1/4	485	710	1,025	1,290	1,530
1-1/2	790	1,160	1,670	2,100	2,500
2	1,580	2,360	3,400	4,300	5,050
2-1/2	2,650	3,900	5,600	7,100	8,400
3	4,850	7,100	10,300	12,900	15,300
3-1/2	7,200	10,600	15,300	19,200	22,800
4	10,200	15,000	21,600	27,000	32,300
5	19,000	27,800	40,300	55,500	60,000
6	31,000	45,500	65,500	83,000	98,000

(a) Based on 0-4 psig maximum return pressure.

Table 11
Return Pipe Capacities for 150 psig (1033.5 kPa) Steam Systems (a)
(Capacity Expressed in lbs/hr)

	DROP IN PRESSURE (psi PER 100 ft IN LENGTH)					
PIPE SIZE (in.)	1/8	1/4	1/2	3/4	1	2
3/4	156	232	360	465	560	890
1	313	462	690	910	1,120	1,780
1-1/4	650	960	1,500	1,950	2,330	3,700
1-1/2	1,070	1,580	2,460	3,160	3,800	6,100
2	2,160	3,300	4,950	6,400	7,700	12,300
2-1/2	3,600	5,350	8,200	10,700	12,800	20,400
3	6,500	9,600	15,000	19,500	23,300	37,200
3-1/2	9,600	14,400	22,300	28,700	34,500	55,000
4	13,700	20,500	31,600	40,500	49,200	78,500
5	25,600	38,100	58,500	76,000	91,500	146,000
6	42,000	62,500	96,000	125,000	150,000	238,000

(a) Based on 1-20 psig maximum return pressure.

c) Common Pump Discharge Mains. Size common pump discharge mains to serve the sum of their capacities. Use the Hydraulic Institute (HI) Pipe Friction Manual for steel pump discharge pipe sizing of new clean steel pipe, 6 feet per second (fps) (1.83 m/s) maximum velocity, and a correction factor of 1.85 to provide for increased pressure drops when the pipe becomes dirty and rough with age. Friction plus static heads shall not exceed the pump characteristics of standard pump and receiver units.

4.2.2.4 High Temperature Water (HTW) Piping. High temperature water piping is as follows:

a) Sizing Piping. Use pipe friction charts in ASHRAE 1985 Handbook Fundamentals. These charts are based on the rational flow formula using clean pipe. A reasonable average velocity is approximately 5 fps (1.53 m/s). The minimum allowable velocity is 2 fps (0.61 m/s).

b) Venting and Draining. For methods of venting high points of distribution lines, refer to DM-3.03, Heating, Ventilating, Air Conditioning and Dehumidifying Systems. Piping must have drainage means at low points.

4.2.2.5 Chilled Water Piping. Use the standards of the Hydraulic Institute Pipe Friction Manual for sizing new clean pipe, unless water is renewed annually, in which case a correction factor of 1.41 for pressure drop is also to be used. For recommended velocities, refer to DM-3.03.

4.2.2.6 Condenser Water Piping. Use the standards of the Hydraulic Institute Pipe Friction Manual for pipe sizing, multiplying the pressure drop by a factor of 1.85 to correct for the increase of pipe roughness with age. For recommended velocities, refer to DM-3.03. No correction faction is required for RTRP pipe.

4.2.2.7 Natural Gas Piping. Apply criteria in DM-3.01, Plumbing Systems, for sizing pipe inside buildings. Use Figure 8 for low volume flow rates and Figure 9 for high volume flow rates in sizing distribution piping. Using these figures will simplify design of piping by indicating required diameter, maximum rate of flow, permissible pressure drop, initial pressure, or final pressure when the rest of these values are known. These charts are based on the Weymouth formula for rate of flow in cubic feet of gas per hour. (The chart is based upon the following conditions: gas at 60 degrees F (15.5 degrees C) and specific gravity of 0.60, with air = 1.0.). Exterior distribution piping usually stops 5 feet (1.53 m) outside of buildings.

4.2.2.8 Compressed Air. For criteria on distribution piping, refer to DM-3.5, Compressed Air and Vacuum Systems.

4.2.3 Piping Specifications and Codes. Piping specifications and codes are as follows:

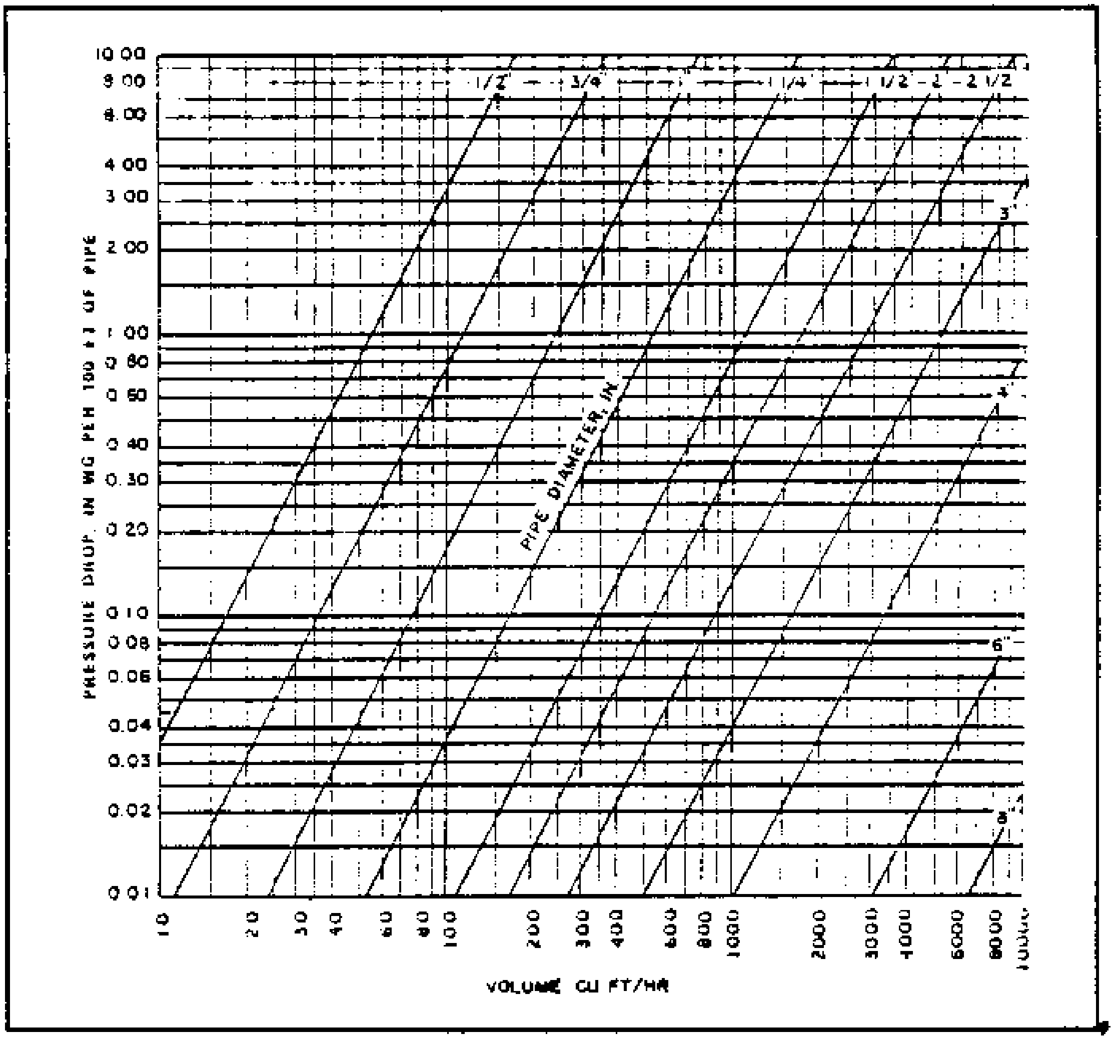


Figure 8
Low Volume Flow Rate Natural Gas Chart (10 to 10,000 ft^3/hr)
(.283 to 283 m^3/hr)

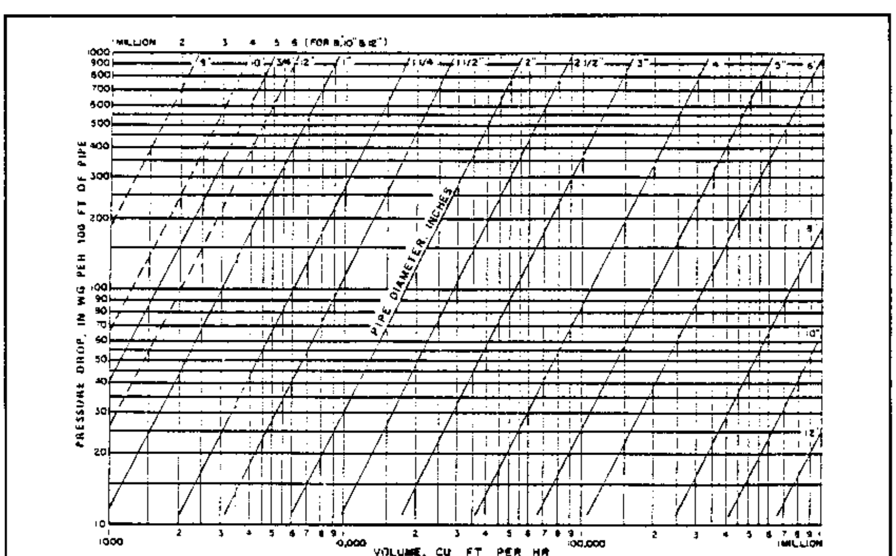


Figure 9
High Volume Flow Rate Natural Gas Chart (1,000 to 1 million ft^3 hr)
(28.3 to 28,300 m^3/hr)

4.2.3.1 Steam Supply and Condensate Return. Piping shall conform to ASME B31.1, except for underground prefabricated or pre-engineered type systems, in which case the entire system shall conform to NFGS-02694.

a) If a separate pump condensate return system is used, it shall conform to NFGS-02697.

b) For condensate provided as a part of an underground prefabricated, pre-engineered system, include Mil. Spec MIL-P-28584 plastic condensate piping in the specification as a Contractor's option for sites classified B, C, or D. Plastic piping is optional but encouraged for sites classified A. The Contracting Officer shall give specific approval for plastic condensate piping in Class A systems. Take particular care that the failure of high pressure steam drip traps shall not discharge high temperatures and pressures into the plastic condensate piping.

4.2.3.2 High Temperature Water, Medium Temperature Water, and Low Temperature Hot Water. Piping specifications and codes are as follows, except for underground prefabricated or pre-engineered types, in which case the entire system shall conform to NFGS-02694.

a) Piping. HTW metallic piping (450 degrees F maximum) (232 degrees C) and medium temperature water metallic piping shall conform to ASME B31.1.

b) Joints. Welded joints are preferred. Threaded joints are not permitted. Hold flanged joints to a minimum and use ferrous alloy gaskets in such joints. Avoid the use of copper and brass pipe.

c) Valves. All valves shall have cast steel bodies with stainless steel trim (no bronze trim). All valves shall be capable of being repacked under operational pressures. Use gate valves only as shutoff or isolation valves.

4.2.3.3 Natural Gas and Compressed Air. Piping shall conform to ASME B31.1 and B31.8 including guidance for abandoning existing gas lines. Note that ASME B31.8 requires that abandoned gas lines be physically disconnected from gas sources and purged prior to sealing. Shutoff valves are not an acceptable means of disconnect. Cathodic protection systems on lines to be abandoned should be evaluated for modifications required to ensure continuity of the systems after abandoned lines are disconnected or removed. Provide excess-flow (earthquake) shutoff valves in gas supply piping outside of each building served in earthquake zones 3 and 4. In addition, provide flexible connections. Gas piping and appurtenances from point of connection with existing system to a point approximately 5 feet (1.53 m) from the building shall conform to NFGS-02685.

4.2.3.4 Chilled and Condenser Water. Use Schedule 40 steel pipe in 10-inch (254 mm) size and smaller, and use 1/2-inch (12.5 mm) wall thickness steel pipe for 12-inch (305 mm) size and larger. RTRP pipe and PVC pipe are also acceptable. RTRP pipe and PVC pipe are available in 2 through 12-inch (51 through 305-mm) pipe sizes.

4.2.4 Thermal Expansion of Steel and Copper Pipe. Pipe expands with temperature increases (such as between installation and operating temperatures) as indicated in Table 12. Make provisions for the control of expansion in any piping system where thermal expansion is a factor. Wherever possible, provide for expansion of pipes by changes in direction of pipe runs.

4.2.4.1 Branch Lines. Where practicable, design branch line piping to provide for expansion inside buildings. Expansion control of branch lines should be designed so as to have no effect on mains.

4.2.4.2 Expansion Bends. Bends are to be factory fabricated except for RTRP pipe.

a) Loop Sections. Loops may be furnished in sections to facilitate delivery and handling.

b) Anchors. A reasonable distance between anchors for expansion loops is 200 feet (61 mm) for 125 psig (861.3 kPa) steam system. Expansion is usually kept at about 6 inches (150 mm) between anchors.

c) Cold Springing. Cold springing may be used in installations but no design stress relief is allowed for it. For credit permitted in thrust and moments, refer to ANSI B31.1.

4.2.4.3 Expansion Joints. Install expansion joints only where space restrictions prevent the use of other means. When necessary to use, expansion joints shall be in an accessible location and shall be one of the following types:

a) Mechanical Slip Joint. An externally guided joint designed for repacking under operating pressures. Hold maximum traverse of piping in expansion joints under 8 inches (203 mm).

b) Bellows Type Joint. Use these joints on steel pipe for thermal expansion with stainless steel bellows, guided and installed according to manufacturer’s instructions. Make bellows or corrugations for absorbing vibrations or mechanical movements at ambient temperatures of copper or other materials suitable for the job conditions. A maximum travel of 4 inches (102 mm) is allowed for this type. RTRP expansion joints may be polytetrafluoroethylene bellows type.

c) Flexible Ball Joints. Install these joints according to manufacturer’s instructions.

4.2.4.4 Flexibility Analysis. Refer to ASME B31.1 for expansion and flexibility criteria and allowable stresses and reactions.

Table 12
Pipe Expansion in Inches Per 100 Feet (30.5 m) of Length
for Temperature Shown

CHANGE IN TEMPERATURE (Degrees F)	MATERIAL STEEL	COPPER	CHANGE IN TEMPERATURE (Degrees F)	MATERIAL STEEL	COPPER
0	0	0	390	3.156	4.532
10	0.075	0.111	400	3.245	4.653
20	0.149	0.222	410	3.334	4.777
30	0.224	0.333	420	3.423	4.899
40	0.299	0.444	430	3.513	5.023
50	0.374	0.556	440	3.603	5.145
60	0.449	0.668	450	3.695	5.269
70	0.525	0.780	460	3.785	5.394
80	0.601	0.893	470	3.874	5.519
90	0.678	1.006	480	3.962	5.643
100	0.755	1.119	490	4.055	5.767
110	0.831	1.233	500	4.151	5.892
120	0.909	1.346	520	4.342	6.144
130	0.987	1.460	540	4.525	6.396
140	1.066	1.575	560	4.715	6.650
150	1.145	1.690	580	4.903	6.905
160	1.224	1.805	600	5.096	7.160
170	1.304	1.919	620	5.291	7.417
180	1.384	2.035	640	5.486	7.677
190	1.464	2.152	660	5.583	7.938
200	1.545	2.268	680	5.882	8.197
210	1.626	2.384	700	6.083	8.460
220	1.708	2.501	720	6.284	8.722
230	1.791	2.618	740	6.488	8.988
240	1.872	2.736	760	6.692	9.252
250	1.955	2.854	780	6.899	9.519
260	2.038	2.971	800	7.102	9.783
270	2.132	3.089	820	7.318	10.056
280	2.207	3.208	840	7.529	10.327
290	2.291	3.327	860	7.741	10.598
300	2.376	3.446	880	7.956	10.872
310	2.460	3.565	900	8.172	11.144
320	2.547	3.685	920	8.389	11.420
330	2.632	3.805	940	8.608	11.696
340	2.718	3.926	960	8.830	11.973
350	2.805	4.050	980	9.052	12.253
360	2.892	4.167	1,000	9.275	12.532
370	2.980	4.289	1,000	10.042	13.950
380	3.069	4.411	1,200	11.598	15.397

4.2.4.5 Stress Analysis. For methods of analyzing stresses in piping systems, use piping handbooks and publications of pipe and pipe fitting manufactures. These manufacturers also supply calculation forms and charts. Keep calculated pipe stresses under those allowed by ANSI B31.1.

4.2.5 Insulation of Piping Systems. Use NFGS-02694 for insulation design for underground heat distribution piping. Use NFGS-02696 for above grade steam, condensate, HTW, MTW, and LTW. Use applicable sections of NFGS-15250 for other systems.

4.2.5.1 Insulation Thickness. Insulation thicknesses indicated in NFGS-02696 and in NFGS-15250 are suitable for most geographic locations. However, in locations where extreme annual temperatures occur, the project designer should evaluate different thicknesses of insulation. Make final selection based on an economic analysis in accordance with para. 2.3.5.

4.2.5.2 Jackets. Design insulation jackets in waterfront or other locations subject to flooding to drain; they shall not be watertight.

4.2.6 Drainage Provisions. Drainage provisions must conform to requirements listed below.

4.2.6.1 Pitch. The surrounding terrain and piping application both affect the pitch of piping as indicated below.

a) Horizontal Piping. Pitch horizontal steam piping down at a minimum of 2-1/2 inches (64 mm) per 100 feet (30.5 m) of length in the direction of steam flow.

b) Underground Piping. Pitch horizontal piping down towards drain points (unless otherwise noted) a minimum of 2-1/2 inches (64 mm) in 100 feet (30.5 m). Where the ground surface slopes in the opposite direction to steam piping, step up underground piping in vertical risers at drip points in manholes, and pitch them down to the next drip point. Use this method also for all very long horizontal runs, above- or belowground, to keep piping within a reasonable range of elevations with reference to the ground surface.

c) Counter-Flow Conditions. Where counter-flow of condensate within the steam pipe may occur in a portion of a pipeline because the stepped construction cannot be built, or because of steam flow reversal in a loop system, pitch that portion up in the direction of steam flow a minimum of 6 inches (152 mm) per 100 feet (30.5 m) and increase pipe diameter by one standard pipe size.

d) Compressed Air and Natural Gas Lines. Pitch compressed air and gas piping as for steam piping.

e) Pumped Water Pipe. Pitch pumped water pipes (condensate, HTW, MTW, LTW, CHW, or condenser water) up or down in direction of flow at a minimum slope of 2-1/2 inches (64 mm) per 100-foot (30.5 m) length. Place drain valves at all low points and vents at high points.

4.2.6.2 Drips and Vents. Provide drips and vents as follows:

a) Drip Legs. Provide drip legs to collect condensate from steam piping and compressed air piping for removal by automatic moisture traps, or by manual drain valves for compressed air piping when practicable. Locate drip legs at low points, at the bottom of all risers, and at intervals of approximately 200 to 300 feet (61 to 91.5 m) for horizontally pitched pipe where a trap is accessible, and not over 500 feet (152.5 m) for buried underground pipe systems. On gas piping, drip legs are not usually required where dry gas is provided. Where there is moisture in the gas, provide drip legs and sediment traps in accordance with NFPA 54. Automatic traps are not utilized.

b) Water Piping. Vent piping, especially high-temperature water piping, at distribution piping high points.

c) Fuel Gas Piping. Provide capped dirt traps in vertical risers upstream of gas-burning devices.

4.2.6.3 Condensate Systems. Condensate systems are as follows:

a) Furnish a complete system of drip traps and piping to drain all steam piping of condensate from drip legs. Ensure drip piping to traps is the same weight and material as the drained piping.

b) Preferably, run a condensate line from a trap separately to a gravity condensate return main or to a nearby flash tank. (Refer to ASHRAE Handbooks - Systems and Applications for flash tank details and specific trap applications. Additionally, refer to Naval Civil Engineering Laboratory (NCEL) UG-0005, Steam Trap Users Guide.) However, a trap may be discharged through a check valve into the pumped condensate line if pressure in the trap discharge line exceeds the back pressure in the pumped condensate line during standby time of an intermittently operated pump. If the pumped condensate line is RTRP pipe, install a condensate cooling device, similar to that shown in Figure 10, to limit temperature of the condensate entering the line to less than 250 degrees F (121 degrees C).

c) Select traps using a safety load factor no greater than 2. The condensate load should be indicated on design drawings and may be determined for aboveground lines by using Table 13. The condensate load for underground distribution lines is determined from maximum heat loss as indicated by the design. With the tight safety load factor for sizing traps, an alternate method of expelling gasses during warmup is required. To this end, all strainers should have blowdown valves which will also be used for controlled warmup.

Table 13
Condensate Loads from Aboveground Heat Distribution Piping
(Pounds Per Hour Per 100 Linear Feet)

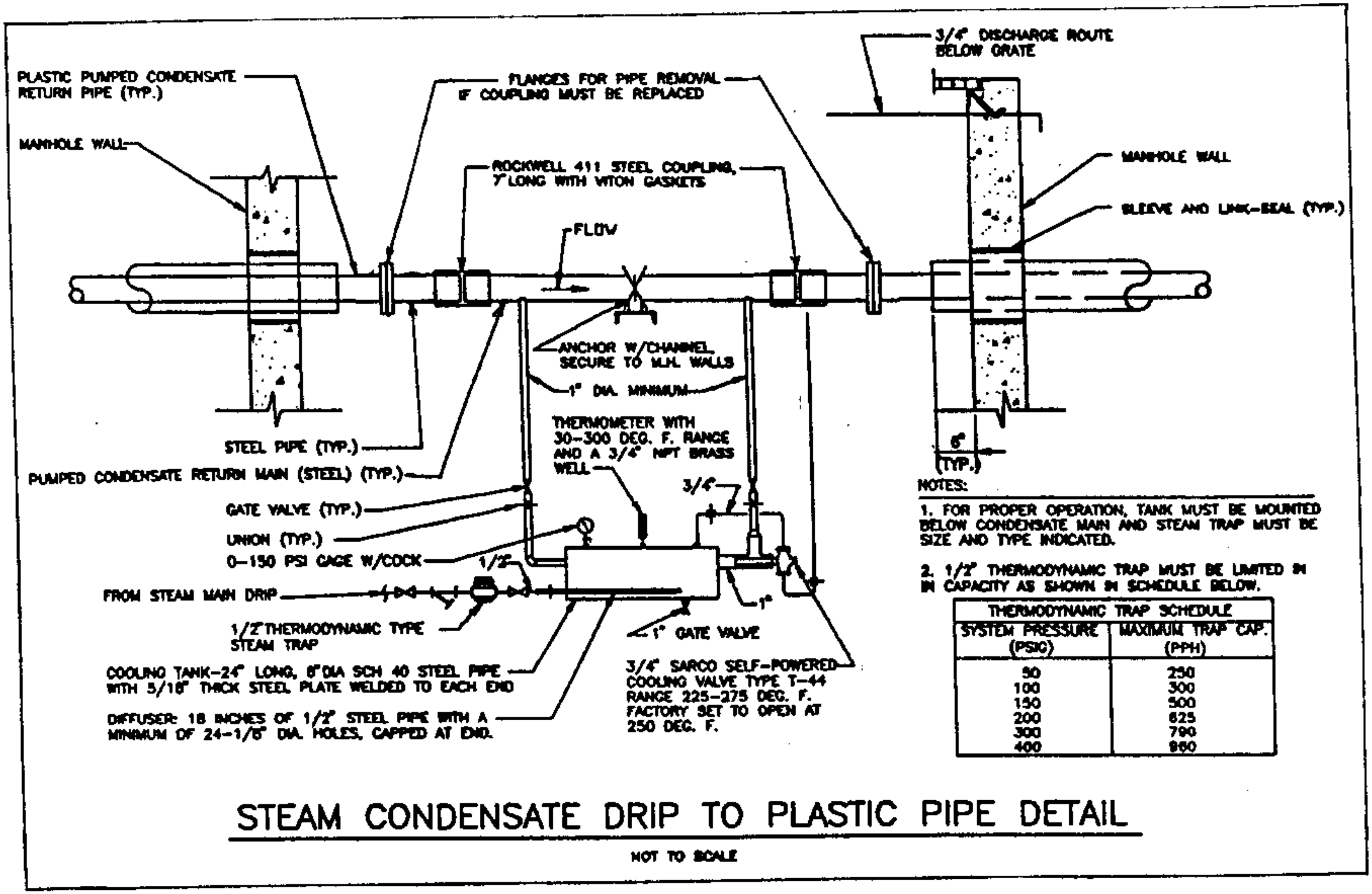
STEAM PRESSURE (psig)	STEAM PIPE SIZE (INCHES, DIAMETER)					
	2	4	6	8	10	12
10	6	12	16	20	24	30
30	10	18	25	32	40	46
60	13	22	32	41	51	58
125	17	30	44	55	68	80
300	25	46	64	83	203	122
600	37	68	95	124	154	182

d) Pitch discharge piping down a minimum of 3 inches (76 mm) per 100 feet (30.5 m) to the collection tank. This applies where a condensate pump set or reliance upon a gravity return is used. An exception to this "rule-of-thumb" exists when there is sufficient pressure in a steam line to overcome its friction and static head, whether the line is level, or pitched up. Trap discharge line shall not be RTRP pipe nor shall the trap discharge connect to an RTRP pipe by direction connection. Install pipe through a condensate cooling device as depicted in Figure 10. This system provides a cooling tank and diffuser, plus a temperature relief valve to limit the temperature of condensate returned to a pumped RTRP condensate line to less than 250 degrees F (121 degrees C).

e) If it is not justifiable to return drips to a condensate system, they may be drained as waste to a sewer. If the temperature exceeds sewer limitations, condensate must be cooled in a sump or by other means. Disposal of condensate from steam systems along the waterfront or under piers warrants special consideration to be determined on a case-by-case basis.

4.2.7 Pipe Anchors. Ensure anchors comply with the following criteria:

4.2.7.1 Location. Locate anchors for non-pre-engineered/prefabricated systems at takeoffs from mains and other necessary points to contain pipeline expansion. If possible, locate anchors in buildings, piers, tunnels, and manholes with suitable access.



NOTES:

1. FOR PROPER OPERATION, TANK MUST BE MOUNTED BELOW CONDENSATE MAIN AND STEAM TRAP MUST BE SIZE AND TYPE INDICATED.

2. 1/2" THERMODYNAMIC TRAP MUST BE LIMITED IN IN CAPACITY AS SHOWN IN SCHEDULE BELOW.

THERMODYNAMIC TRAP SCHEDULE

SYSTEM PRESSURE (PSIG)	MAXIMUM TRAP CAP. (PPH)
50	250
100	300
150	500
200	625
300	790
400	960

STEAM CONDENSATE DRIP TO PLASTIC PIPE DETAIL

NOT TO SCALE

Figure 10
Protective Arrangement for RTRP Pipe

4.2.7.2 Specification. Design and locate anchors in accordance with ASME B31.1.

4.2.7.3 Strength. Design anchors to withstand expansion reactions. With expansion joints, consider the additional end reactions due to internal fluid pressure, and add end reactions due to spring rate of the joint.

4.2.7.4 Guying. Anchors for elevated aboveground systems shall consist of wire rope guys running from embedded concrete deadmen to pipe saddles welded to the pipe and secured to the vertical support(s). Guy in both directions. Guys may be located on the diagonal to serve also as sway bracing.

4.2.7.5 Embedding. In underground concrete tunnels, the ends of structural steel shapes anchoring a pipe may be embedded in the tunnel walls or floors.

4.2.8 Supports. Insure pipe supports conform to ASME B31.1.

4.2.8.1 Low Elevations. For aboveground systems at low elevations (defined as lower than 5 feet (1.53 m) above grade or the working surface), use and space concrete pedestals, steel frames, or treated wood frames as required depending on pipe sizes.

4.2.8.2 High Elevations. At higher elevations above ground, support pipelines on wood, steel pipe, H-section steel, reinforced concrete, prestressed concrete poles with crossarms, or steel frameworks fitted with rollers and insulation saddles. (See Figure 11.) Details of design will vary depending on site conditions.

4.2.8.3 Long Spans. When long spans are necessary, cable-suspension or catenary systems may be used.

4.2.8.4 Underground Conduits. Use approved types of manufacturers' standard designs supports for underground conduits.

4.2.8.5 In Trench. Suspend pipes either from the walls or the tops of the walls. Do not support piping from either the floor of the trench or from the removable top. The pipe hanger design must provide for adequate system expansion and contraction.

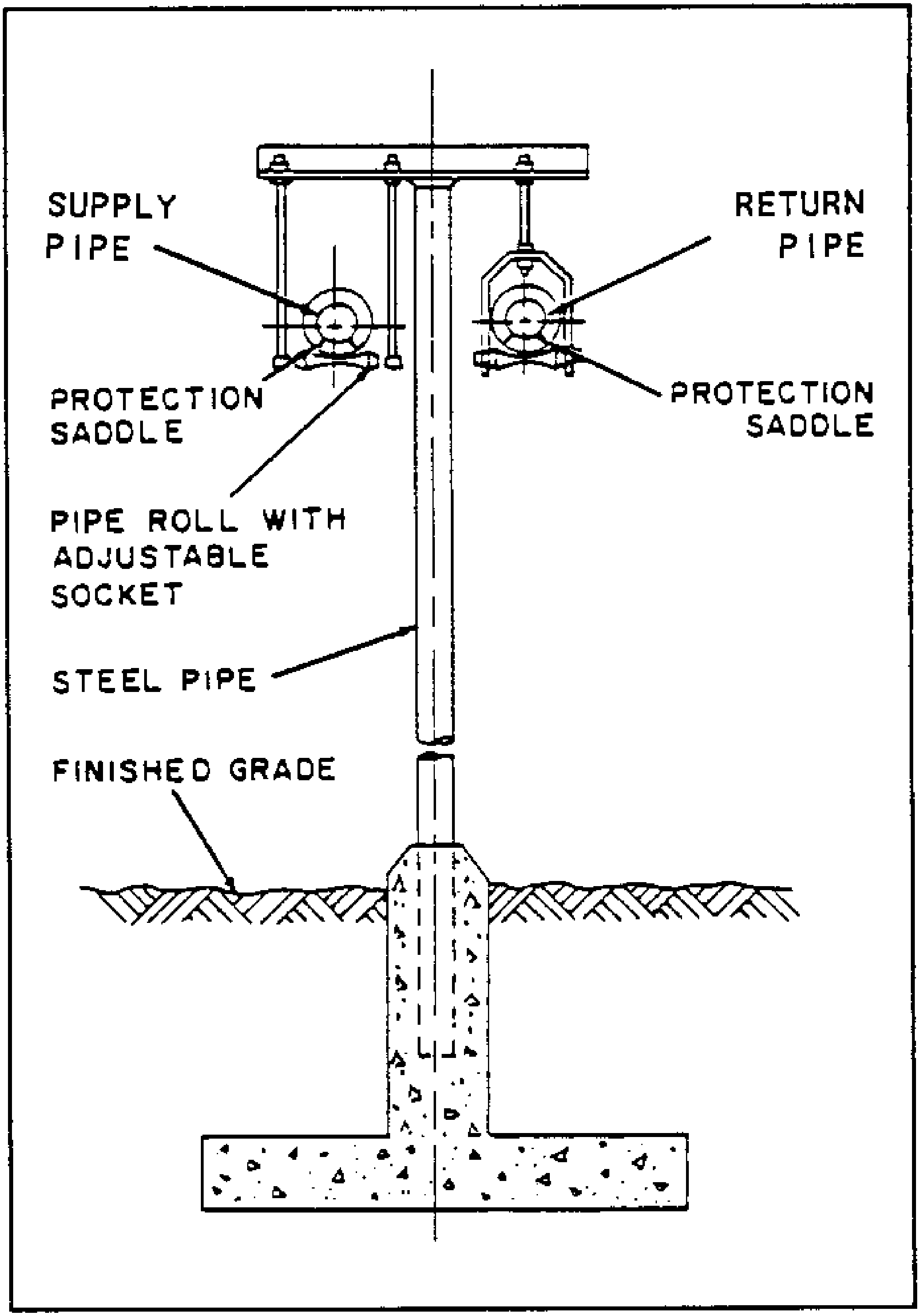


Figure 11
Typical Aboveground Pipe Supports

4.2.9 Finish and Protection. All noninsulated ferrous parts of the piping, piping support system, or equipment will be hot-dipped galvanized or primed with red oxide primer and painted with epoxy paint.

4.3 Concrete Trench Design. The concrete shallow trench will consist of poured concrete sides and floor, with removable tops. Portions of the floor may be omitted at locations outlined previously under course grained soils with water table 2 feet (610 mm) or more below lowest point of water entry.

4.3.1 Depth of Trench. Ensure the depth of the concrete trench is sufficient to provide adequate protection to the piping system and, slope the floor of the trench to provide adequate internal drainage, but in all cases not less than 6 inches (150 mm) from the bottom surface of the suspended pipe insulation to the floor of the trench. Ensure there is a minimum of 3 inches (75 mm) between the surface of the pipe insulation and the adjoining trench walls and a minimum of 4 inches (100 mm) between surfaces of adjacent pipe insulation.

4.3.2 Drainage of Trench. Base the design on sound engineering practices which provide for drainage under all anticipated conditions. Consider the annual rainfall, water table, and other topographic conditions in the basis for the design. For those instances where natural drainage cannot be provided (storm water drainage system at least 2 feet (610 mm) below trench bottom at all times), provide a dual sump pump capability with failure annunciator.

4.3.3 Tops. The tops of the concrete trenches will be removable by use of a portable lifting device such as a forklift or backhoe, and can also be used for sidewalks, if practical. Earth must not cover the tops. Covers will be close tolerance fit with a maximum gap tolerance build up of 0.12 inch from all causes.

4.3.4 Details. Design the Concrete Shallow Trench Heat Distribution System and show on the contract drawings. Use Figures 12 through 23 as appropriate.

Provide the following information on the contract drawings for the concrete Shallow Trench System, as applicable: dimension on all runs of pipe; elevations of the pipe along the systems path; sizes of the pipe; location of all valves; location and details of all expansion loops, Z- and L-bends; location of pipe anchors; how changes in pipe direction are made; thickness of the insulation on the pipe; concrete trench details; final elevations of concrete trench; profile of trench showing all existing utilities; manhole dimensions; manhole cover details; how manhole is drained and vented where required; sump pump piping details; sump pump capacity; condensate pump capacity and details; include specific requirements for modification to existing; steam drip trap locations and capacity; steam pressure reducing valve capacity and details; and other pertinent information and details required to clearly show the intent of the Shallow Trench Heat Distribution System. Also indicate any obstructions in the path of the distribution system that the Contractor may have to work around.

4.3.5 Valve Manholes. Extend valve manholes at least 9 to 12 inches (175 to 305 mm) above finished grade to prevent seasonal runoff from entering except where trench will be a pedestrian walk, in which case the vault cover will be flush with the trench covers.

4.3.6 Inspection Ports. Where required, provide inspection ports at appropriate locations to enable the user to observe drains or expansion at loops or locations requiring frequent (monthly) observation.

4.3.7 Crossings. At all road and railroad type crossings, provide required slab thickness for railroad crossings and H-20 loading for street crossings. Review railroad track removal/replacement with respective authority and coordinate all activities. Road and rail crossing where maintenance of traffic is critical may be accomplished by jacking using an acceptable conduit/tunnel.

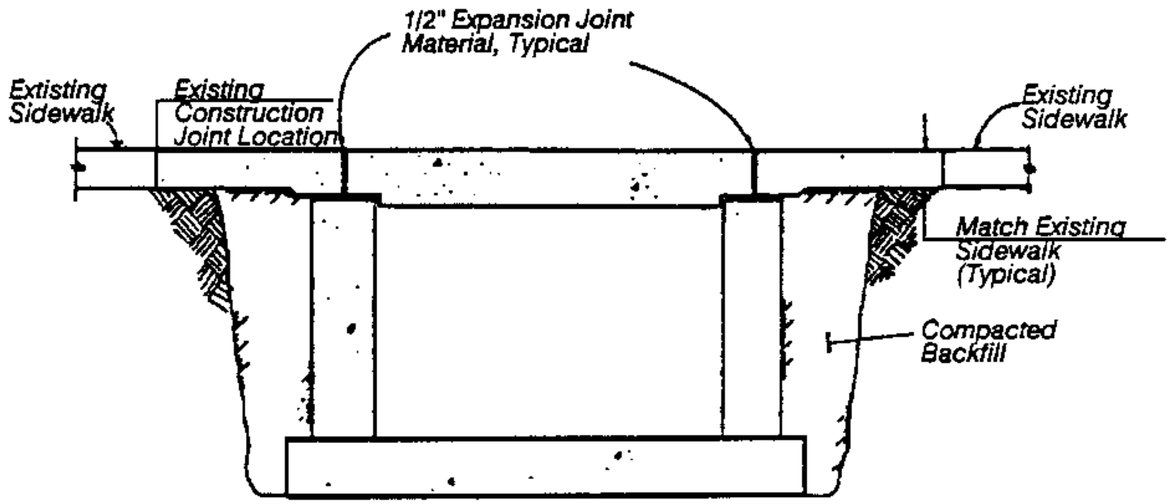
4.3.8 Precast Concrete Shallow Trench Options. In addition to or in combination with a poured-in-place concrete shallow trench system, a precast or prefabricated shallow trench system consisting of precast concrete covers, concrete trench, or supports may be specified. If the designer selects this option, he must include special details and specification requirements of the precast system and the transition between the poured-in-place and precast system.

4.4 Manholes

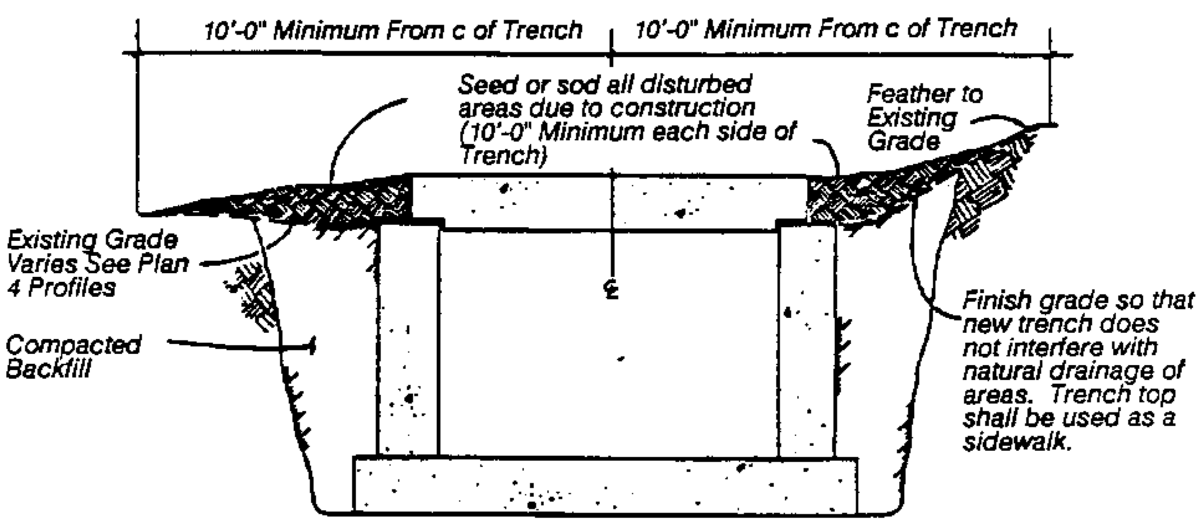
4.4.1 Drainage. Provide sump pumps in manholes. Units should discharge by buried piping to nearest storm sewer if possible. Where not economical to discharge to storm sewer, pumps are to discharge above grade to splashblocks. Plan discharge locations carefully so water will not be placed over tunnel tops, sidewalks, etc. Use sump pumps capable of passing 3/8-inch (12 mm) solid (sphere) minimum. Adjust float switches so the pumps start sequentially, reducing electrical line surge. Coordinate power requirements with electrical designer and provide tell-tale light above ground to indicate that power is available to sump pumps.

4.4.2 Waterproofing. If portions of manholes are installed below the water table, waterproof that portion below the water table.

4.4.3 Pipe Entry. Pipe entry, for buried pre-engineered systems piping, shall be in accordance with Figure 24.



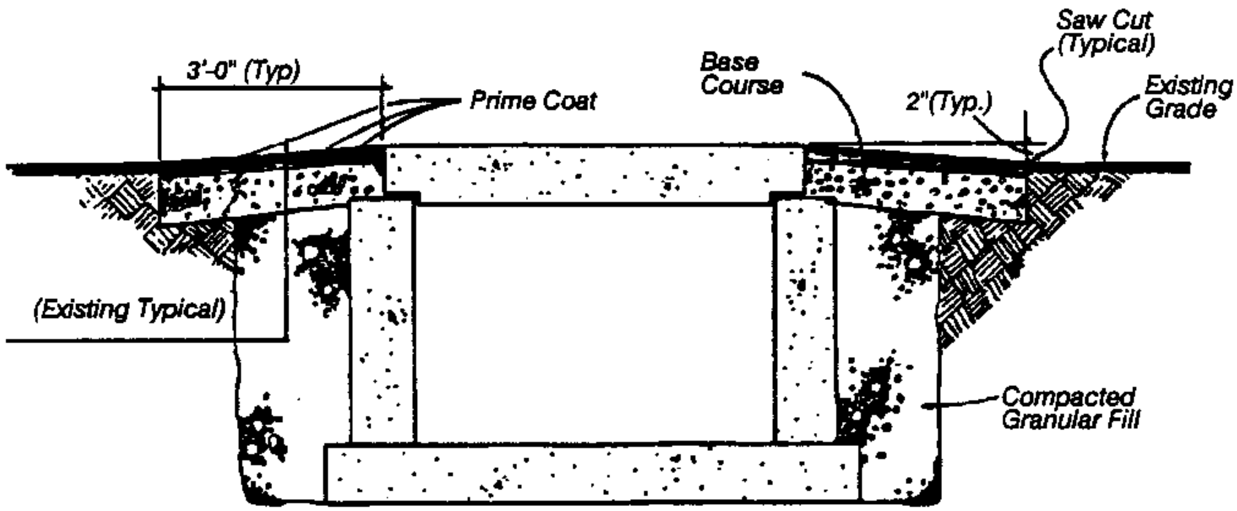
Sidewalk Transverse Cut Detail



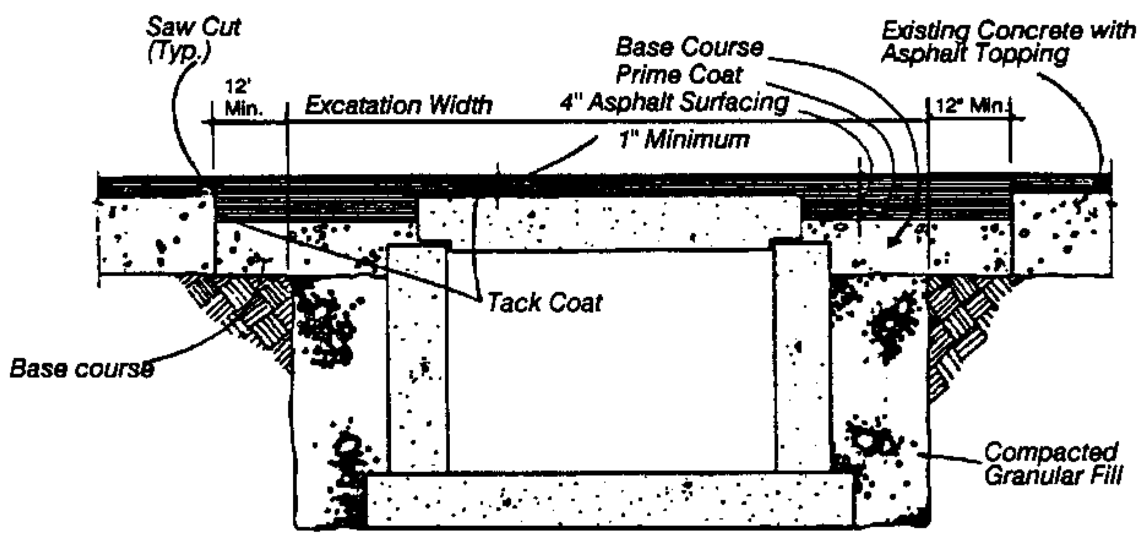
Note:
Trench floors must be sloped to provide continuous drainage to sump pumps in manholes. All pockets found in trench floor shall be provided with a floor drain to the nearest manhole sump or the floor shall be sloped to provide gravity drainage.

TYPICAL TRENCH GRADING DETAIL

Figure 12
Concrete Shallow Trench Heat Distribution System
Detail 1

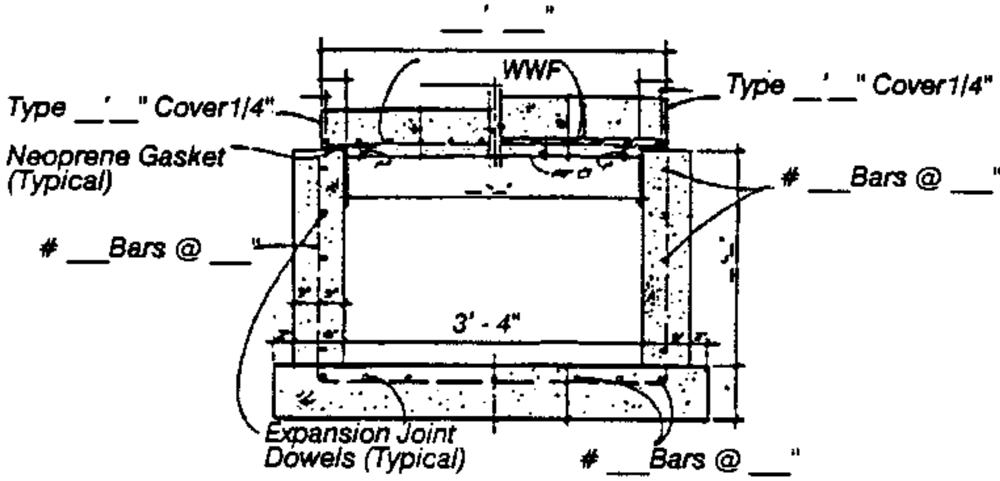


Parking Lot Pavement Cut Detail

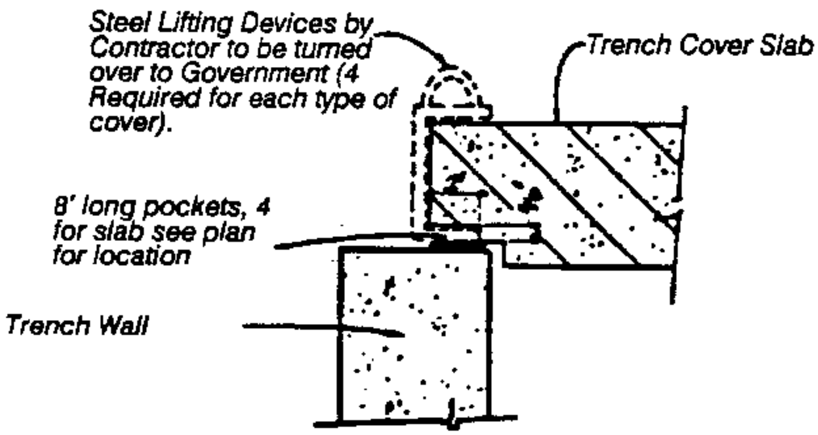


Street Pavement Cut Detail

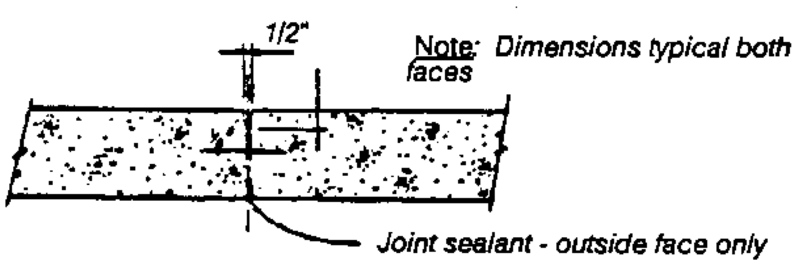
Figure 13
Concrete Shallow Trench Heat Distribution System
Detail 2



TYPICAL TRENCH

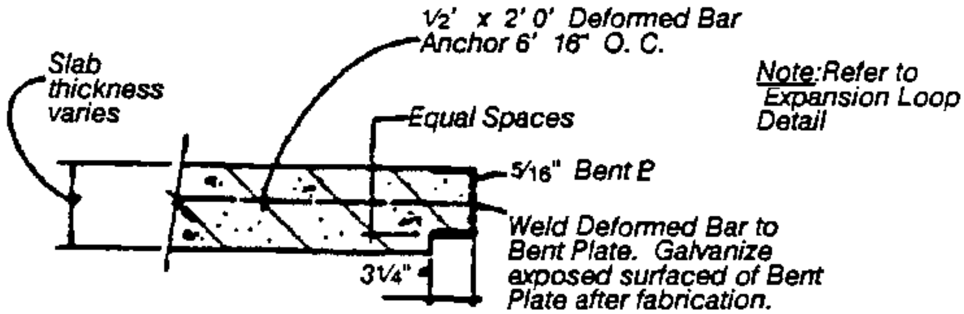


SLAB REMOVAL PROVISION

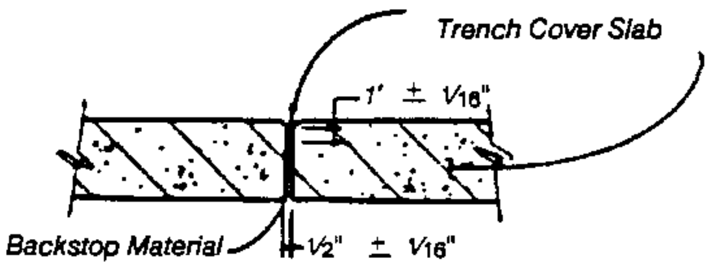


TYPICAL TRENCH WALL CONTROL JOINT
MAXIMUM SPACING 20'0"

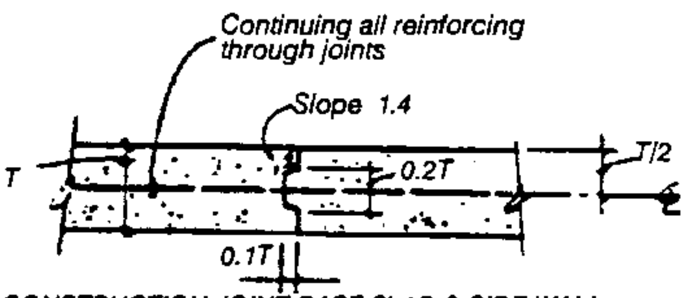
Figure 14
Concrete Shallow Trench Heat Distribution System
Detail 3



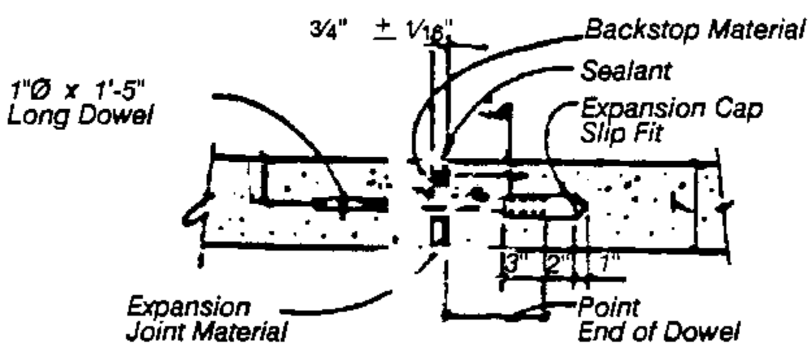
COVER SLAB EDGE REINFORCEMENT AT INTERSECTION



TYPICAL COVER SLAB JOINT

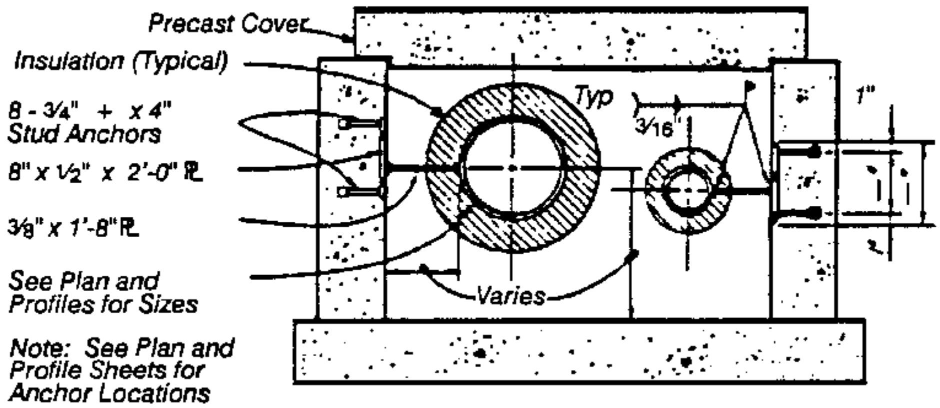


KEYED CONSTRUCTION JOINT BASE SLAB & SIDE WALL

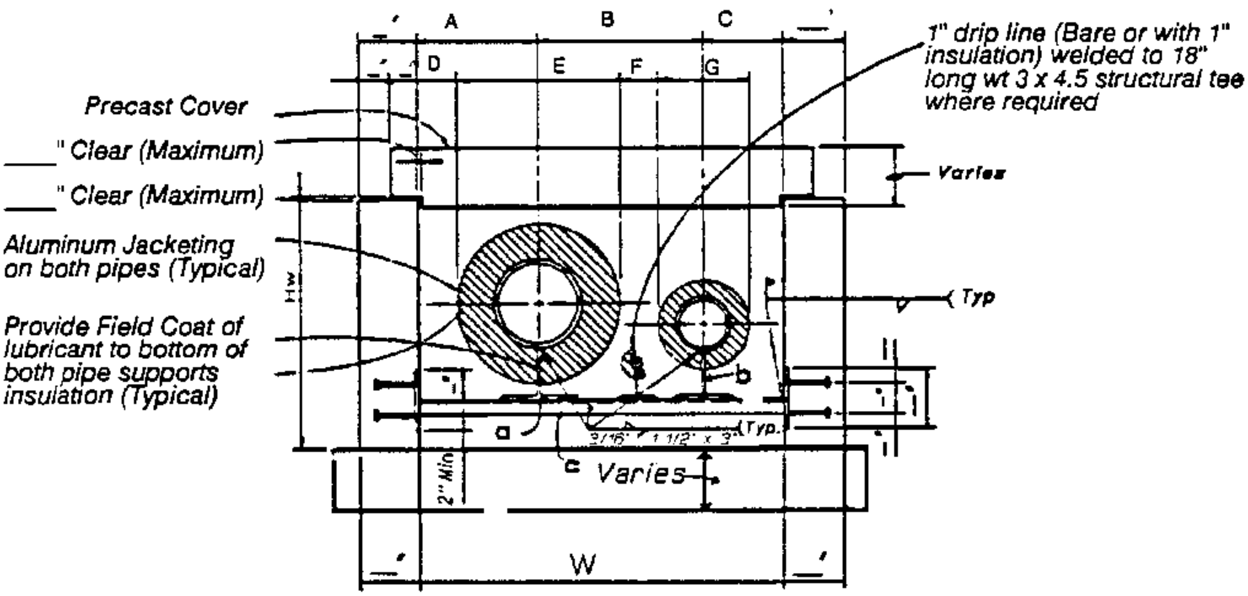


TYPICAL EXPANSION JOINT

Figure 15
Concrete Shallow Trench Heat Distribution System
Detail 4



TRENCH PIPE ANCHOR DETAIL



SHALLOW TRENCH PIPE
AND SUPPORT DETAIL

Figure 16
Concrete Shallow Trench Heat Distribution System
Detail 5

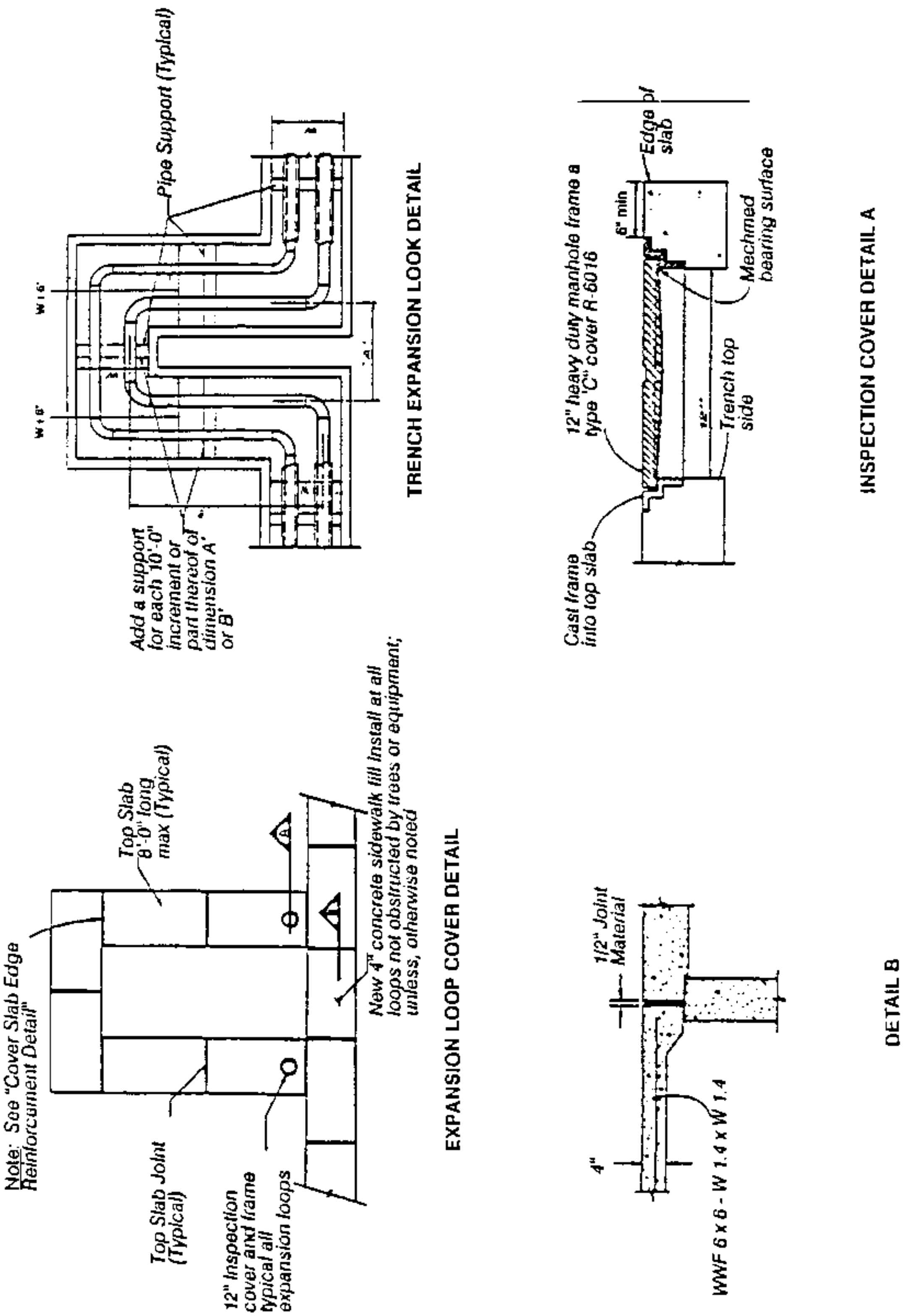


Figure 17
Concrete Shallow Trench Heat Distribution System
Detail 6

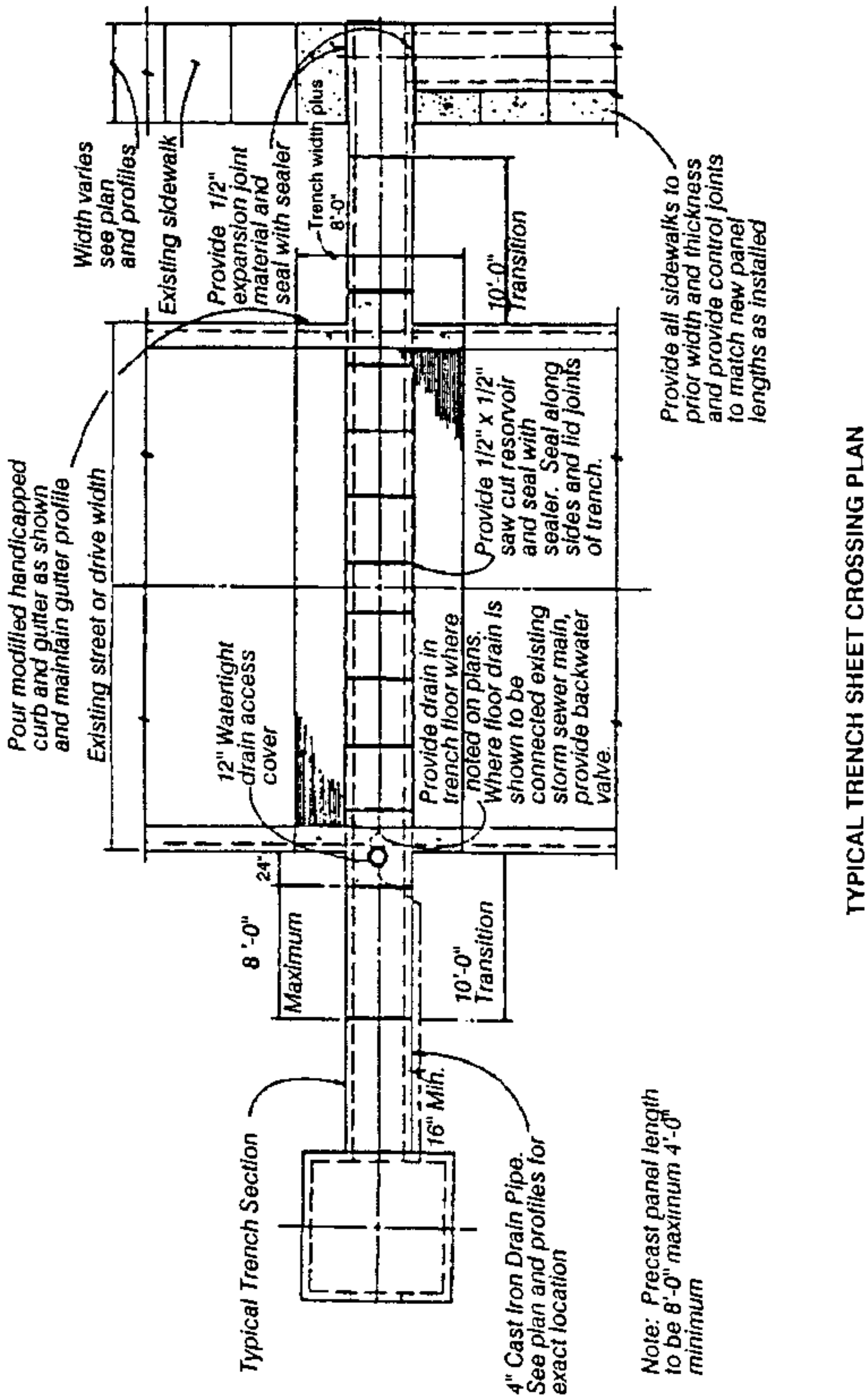


Figure 18
Concrete Shallow Trench Heat Distribution System
Detail 7

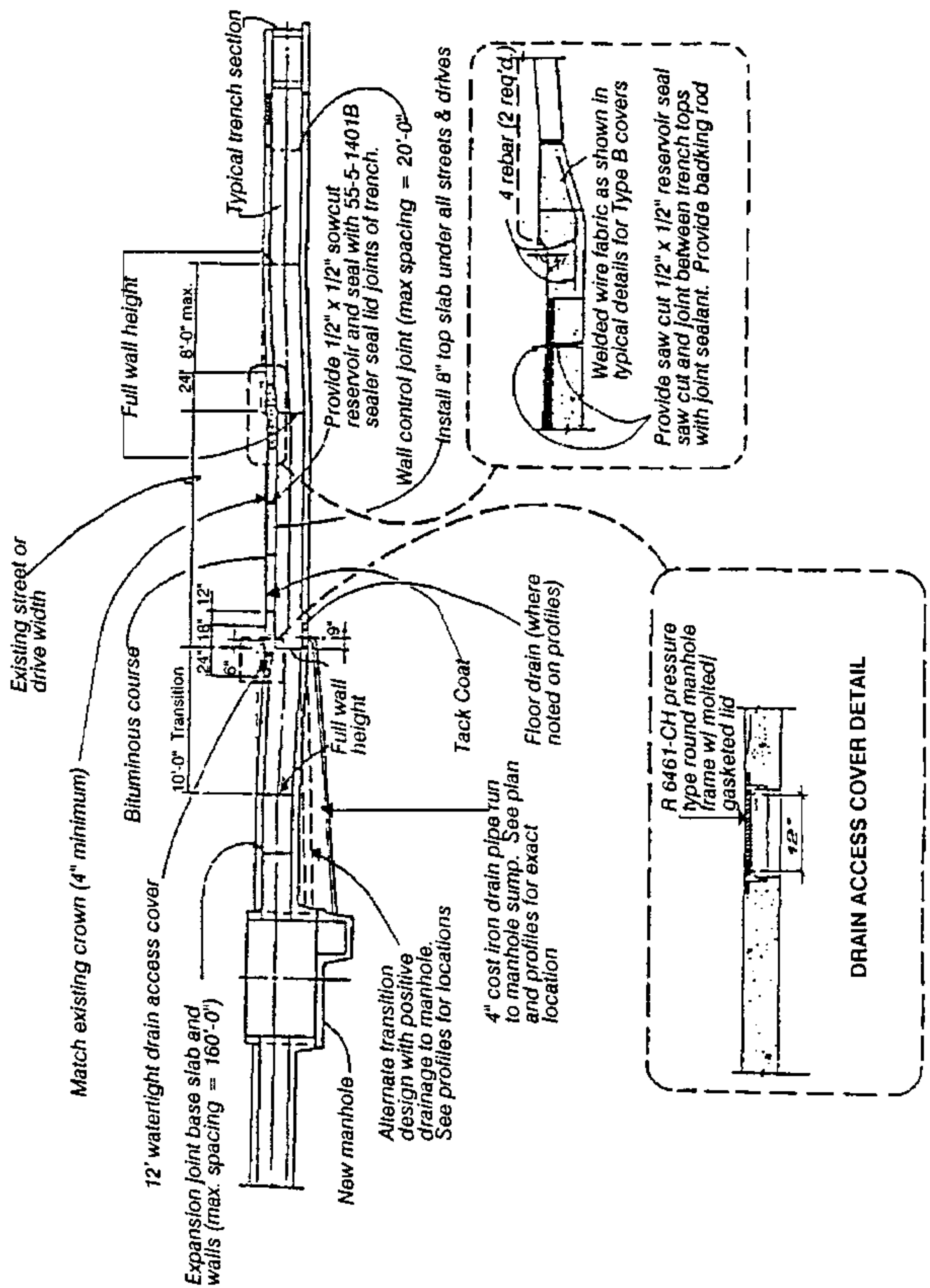
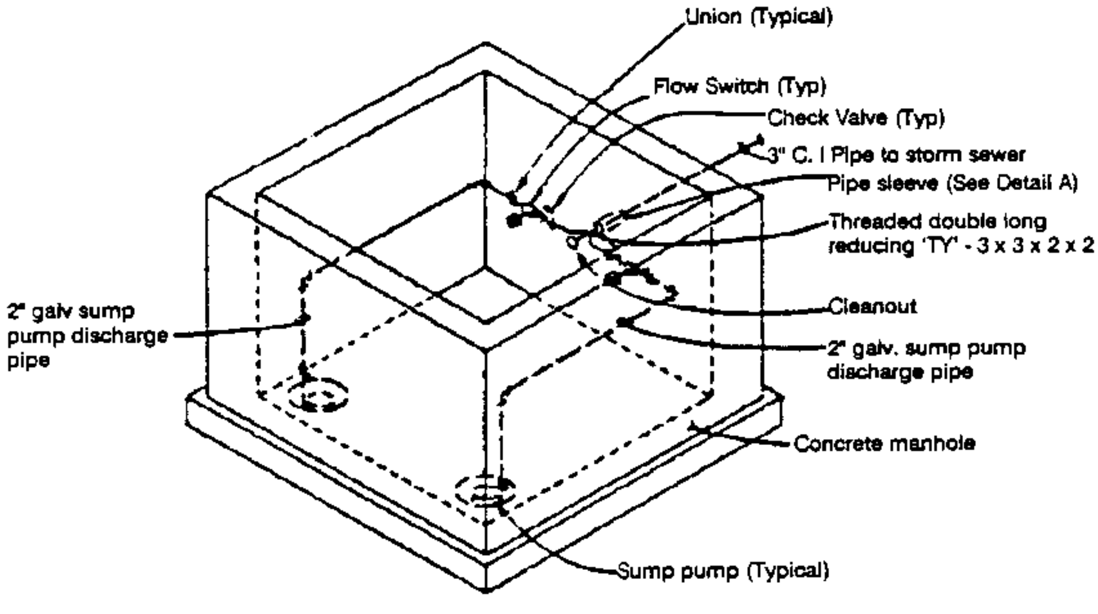
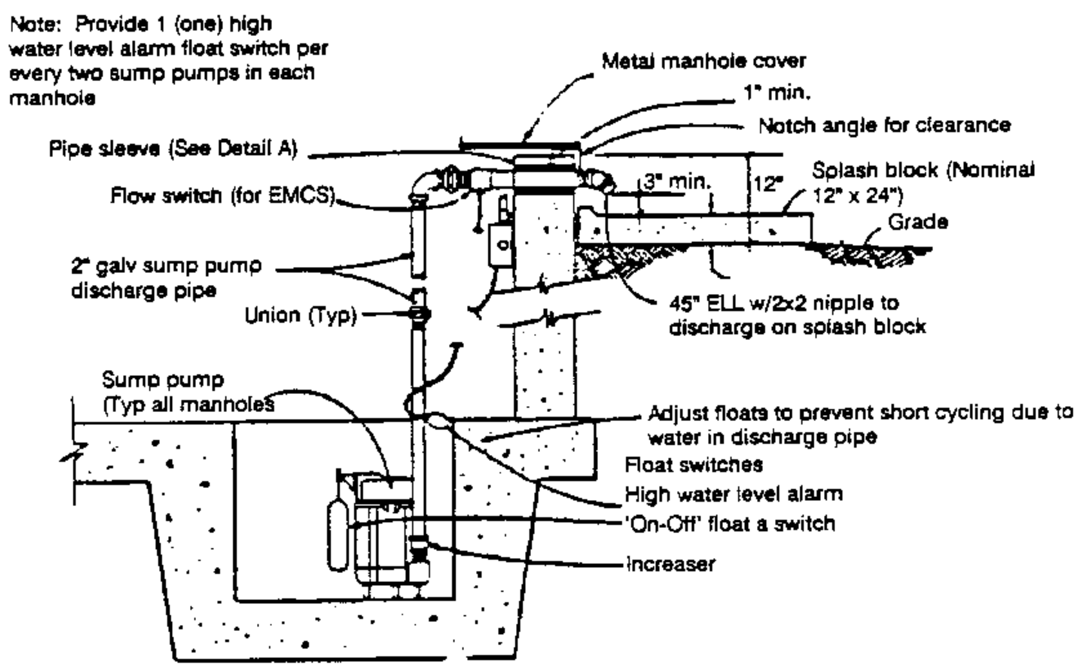


Figure 19
Concrete Shallow Trench Heat Distribution System
Detail 8

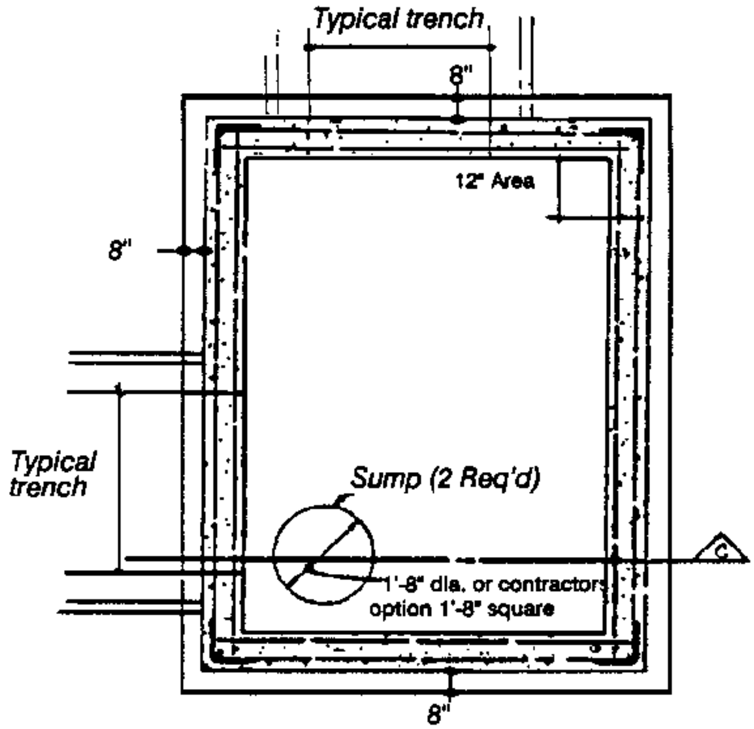


TYPICAL SUMP PUMP PIPING TO STORM SEWER



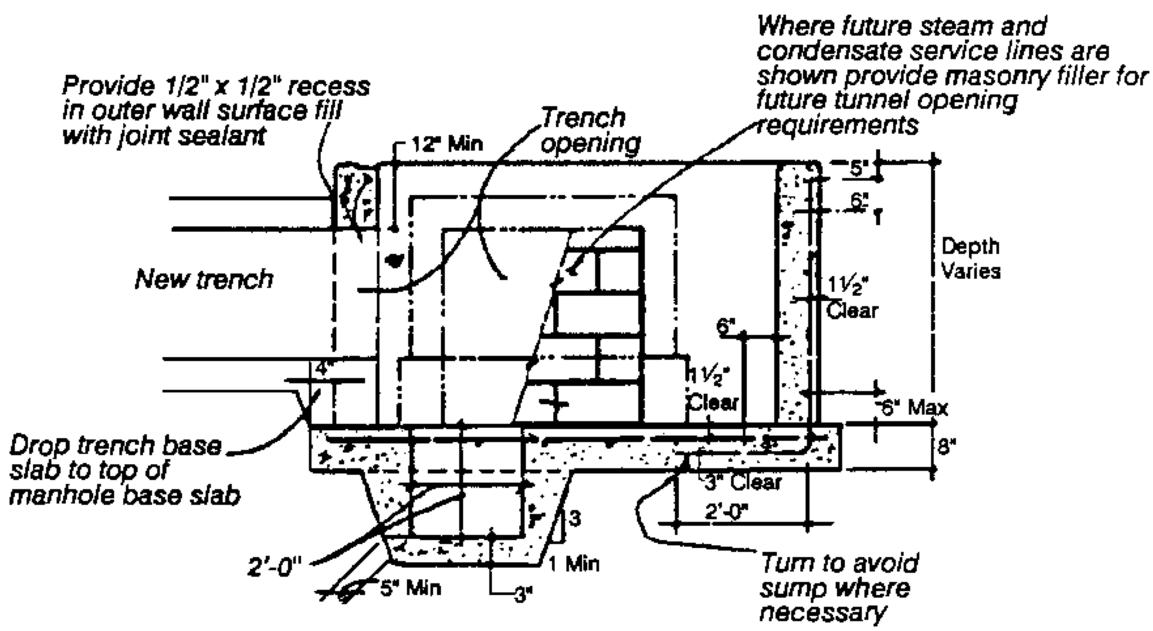
TYPICAL SUMP PUMP PIPING TO SPLASH BLOCK

Figure 20
Concrete Shallow Trench Heat Distribution System
Detail 9



Plan

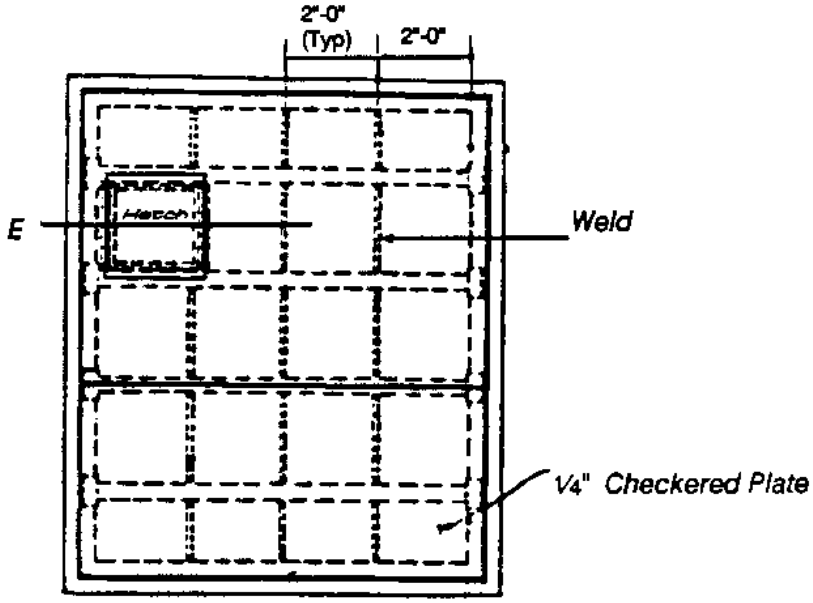
WALL REINFORCING



Section C

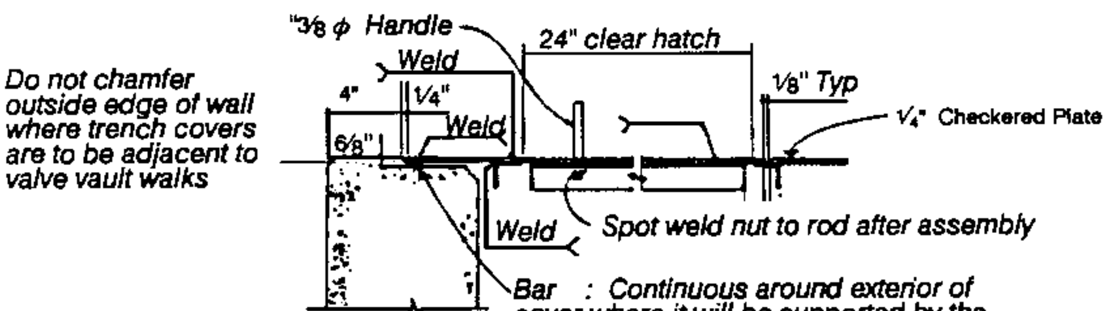
TYPICAL VALVE MANHOLE DETAILS

Figure 21
Concrete Shallow Trench Heat Distribution System
Detail 10

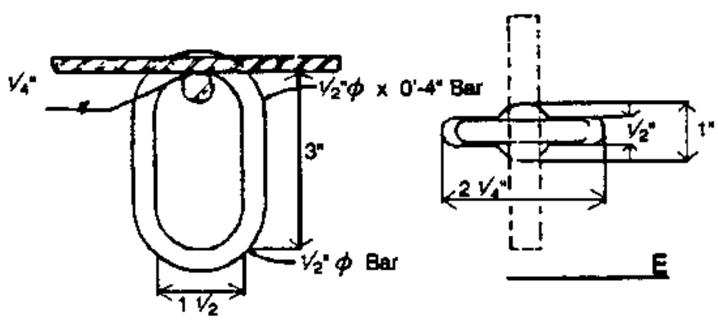


Plan

TYPICAL VALVE MANHOLE COVER IN WALKS



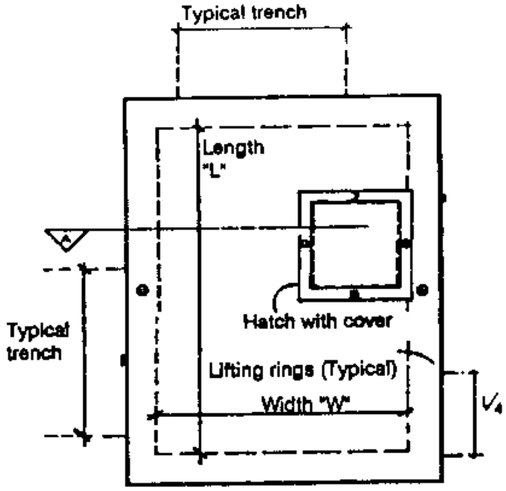
Section E



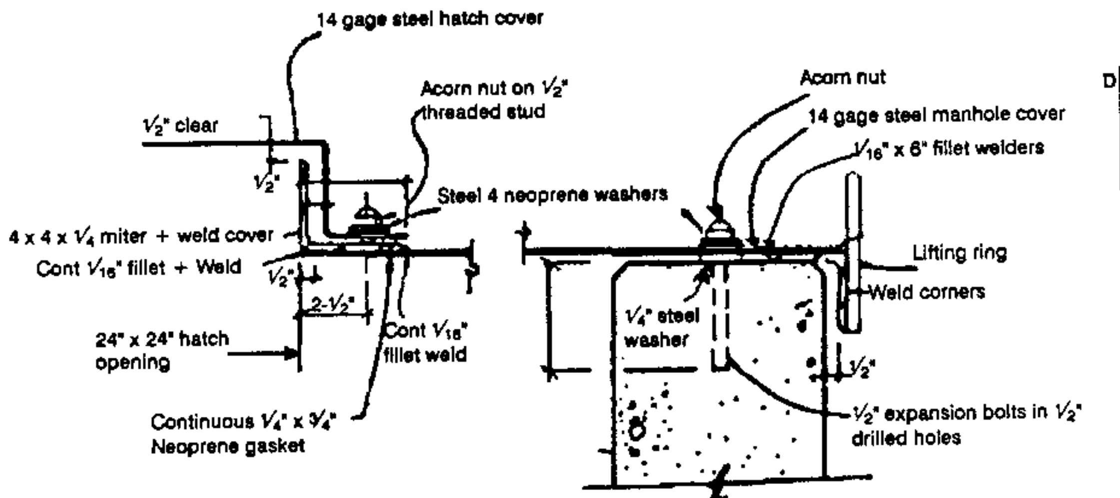
Section E

TYPICAL LIFTING DEVICE FOR VALVE MANHOLE COVER IN WALKS

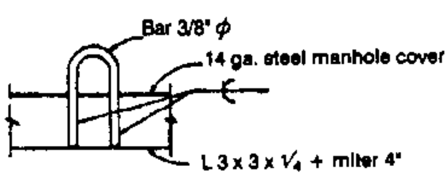
Figure 22
Concrete Shallow Trench Heat Distribution System
Detail 11



TYPICAL STANDARD VALVE MANHOLE COVER



SECTION A



SECTION D

TYPICAL LIFTING RING

Figure 23
Concrete Shallow Trench Heat Distribution System
Detail 12

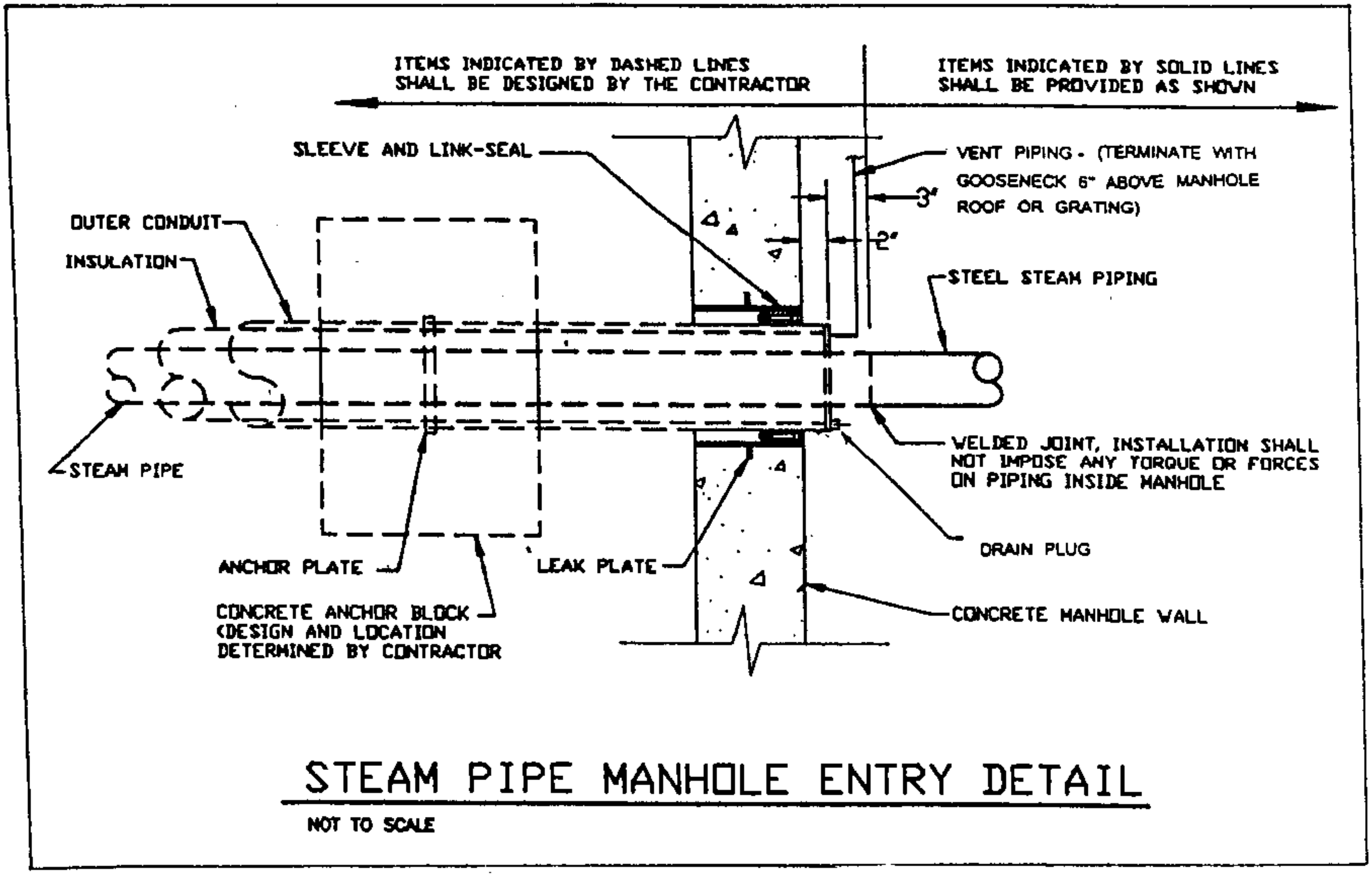


Figure 24
Steel Carrier Piping Manhole Entry Detail
(no scale)

APPENDIX A

HEAT LOSS CALCULATION DATA

PART 1: EARTH THERMAL CONDUCTIVITY FACTORS

The earth thermal conductivity factors (Ke) in Btu-in/(hr) (sq-ft) (degrees F) to be used in the heat loss calculations are as follows:

	TYPE OF SOIL		
Moisture Content of Soil	Sand	Silt	Clay
Low (less than 4% by weight)	2	1	1
Medium (from 4% to 20% by weight)	13	9	7
High (greater than 20% by weight)	15	15	15

Note: Dry soil is exceedingly rare in most parts of the United States, and a low moisture content should be assumed only if the assumption can be proven valid.

APPENDIX A (continued)

PART 2: ENERGY COST AND MAXIMUM PIPE HEAT LOSS

Maximum heat loss, Btu/hr (ft), for each energy cost (EC) in $/1,000,000 Btu shall be based on the following:

$2. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	15	24	32	41	51	61	59	68
1.25	18	27	38	40	49	58	68	78
1.5	19	30	41	53	53	63	74	85
2	22	35	39	50	61	73	85	98
2.5	26	40	55	57	70	83	83	96
3	30	46	63	65	79	80	94	108
4	36	44	60	76	94	83	98	113
5	41	50	69	88	108	129	128	148
6	46	72	98	100	123	147	172	198
8	58	89	96	123	126	151	176	203
10	53	83	113	144	177	177	180	208
12	60	93	127	162	199	201	235	237
14	64	100	136	174	213	254	297	292
16	71	110	150	192	235	239	280	322
18	78	120	164	155	190	227	236	272

$3. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	15	24	27	34	42	50	59	68
1.25	18	27	31	40	49	58	68	78
1.5	19	30	34	43	53	63	74	85
2	18	28	39	50	61	73	66	69
2.5	26	40	44	57	59	71	67	77
3	30	46	50	55	67	80	75	87
4	28	44	60	57	70	83	98	113
5	32	50	69	88	92	97	113	130
6	46	72	78	100	123	108	127	146
8	45	7O	80	103	126	151	137	144
10	53	83	113	121	129	154	180	168
12	60	93	127	137	147	156	183	211
14	64	100	136	174	181	216	219	253
16	71	110	150	163	200	208	217	226
18	78	120	121	155	169	202	215	247

APPENDIX A (continued)

$4. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	15	24	27	34	42	50	59	60
1.25	18	22	31	40	49	58	59	62
1.5	19	24	34	43	53	45	53	61
2	18	28	39	50	43	51	60	69
2.5	26	32	44	48	59	63	67	77
3	30	37	43	55	67	64	75	87
4	28	44	44	57	70	83	98	113
5	32	50	58	75	81	97	113	117
6	46	57	78	74	91	108	114	120
8	45	59	80	103	126	106	125	144
10	53	83	94	105	129	124	146	168
12	60	93	1O7	106	131	156	165	190
14	64	100	136	148	157	187	219	253
16	71	110	128	163	155	167	196	192
18	78	89	121	138	154	183	215	247

$5. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	15	19	27	34	42	44	52	50
1.25	18	22	31	40	38	42	49	57
1.5	15	24	34	31	38	45	53	61
2	18	28	27	35	43	51	60	69
2.5	21	27	38	43	48	57	67	77
3	24	31	43	44	54	64	75	87
4	28	32	44	57	70	69	81	94
5	32	43	51	66	81	87	101	117
6	37	57	58	74	82	89	104	120
8	45	59	80	73	89	106	125	123
10	53	69	82	85	104	124	125	144
12	60	69	83	106	118	130	118	136
14	64	100	100	128	157	151	163	174
16	71	94	99	114	140	142	166	192
18	57	79	108	125	154	183	182	184

APPENDIX A (continued)

$6. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	15	19	27	34	37	44	52	50
1.25	14	22	31	31	35	42	49	57
1.5	16	24	34	31	38	45	53	61
2	18	28	27	35	43	51	60	69
2.5	21	27	34	39	48	57	67	77
3	20	31	34	44	54	64	75	87
4	28	32	44	57	70	69	81	94
5	32	43	51	66	72	87	101	99
6	37	42	58	67	74	89	104	120
8	38	59	63	73	89	106	107	123
10	53	60	82	85	104	115	125	144
12	60	69	83	96	109	100	118	136
14	64	84	100	128	127	139	151	153
16	71	94	89	114	119	142	166	192
18	57	79	98	125	154	155	159	184

$7. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	12	19	27	34	37	44	44	50
1.25	14	22	31	29	35	42	49	57
1.5	16	24	24	31	38	45	53	61
2	18	22	27	35	43	51	60	69
2.5	21	24	30	39	48	57	67	77
3	20	31	34	44	54	64	75	87
4	21	32	44	57	58	69	81	94
5	32	38	51	59	72	87	86	99
6	37	42	58	61	74	89	104	104
8	38	59	57	73	89	91	107	110
10	44	60	66	85	96	106	125	121
12	51	61	83	89	84	100	118	136
14	64	84	100	103	117	129	133	153
16	60	72	89	97	119	142	166	160
18	57	72	98	125	130	136	159	184

APPENDIX A (continued)

$8. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	12	19	27	30	37	37	44	50
1.25	14	22	31	29	35	42	43	57
1.5	16	24	24	31	38	45	53	61
2	18	22	27	35	43	51	60	69
2.5	21	24	30	39	48	57	67	77
3	20	25	34	44	54	64	75	75
4	21	32	44	47	58	69	81	94
5	27	38	51	59	72	87	86	99
6	37	42	52	61	74	89	90	104
8	38	46	57	73	77	91	95	110
10	44	60	66	85	89	106	105	121
12	44	61	75	89	84	100	118	136
14	64	73	100	103	108	113	133	153
16	60	65	89	97	119	142	138	160
18	57	72	98	106	130	136	159	184

$9. EC and Maximum Pipe Heat Loss, Btu/hr (ft)

Pipe Size	Fluid Temperature (Tf), degrees F							
(Inches)	150	200	250	300	350	400	450	500
1	12	19	27	30	31	37	44	50
1.25	14	22	24	29	35	42	49	57
1.5	16	24	24	31	38	45	53	61
2	18	20	27	35	43	51	60	64
2.5	18	22	30	39	48	57	67	72
3	20	25	34	44	54	64	65	75
4	21	32	44	47	58	69	81	94
5	27	38	46	59	72	74	86	99
6	37	42	52	61	74	77	90	98
8	38	46	57	73	77	81	95	110
10	39	48	66	85	89	106	105	121
12	44	61	75	69	84	100	118	136
14	54	73	81	95	108	113	133	153
16	60	65	76	97	119	118	138	160
18	51	72	98	106	114	136	159	173

APPENDIX A (continued)

PART 3: EARTH TEMPERATURES

The earth tempevatures (Te) to be used in the heat loss calculations are listed below. The list presents the average earth temperature from 0 to 10 feet below the surface for the four seasons of the year and for the whole year for the indicated locale. The temperatures were computed on the basis of the method described in the 1965 ASHRAE technical paper entitled "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States" by T. Kusuda and P. R. Achenback (in ASHRAE Transactions, Volume 71, Part 1, p. 61, 1965) using the monthly average air temperatures published by the U.S. Weather Bureau for the listed localities in the United States. Earth temperatures are expressed in Fahrenheit degrees. AP refers to airport data, CO to city office data, COOP to cooperative weather station data, and OBS to observation station data. When data is not available for exact project location, use nearest location shown in following table.

Location	Winter	Spring	Summer	Autumn	Annual
Alabama					
Anniston AP	55	58	7O	67	63
Birmingham AP	54	58	71	68	63
Mobile AP	61	63	74	71	67
Mobile CO	61	64	75	72	68
Montgomery AP	58	61	73	70	65
Montgomery CO	59	62	74	71	66
Arizona					
Bisbee COOP	55	58	70	67	62
Flagstaff AP	35	39	54	50	45
Ft Huachuca (proving ground)	55	58	71	68	63
Phoenix AP	60	64	79	75	69
Phoenix CO	61	65	80	76	70
Prescott AP	46	49	65	61	55
Tuscon AP	59	62	76	73	68
Winslow AP	45	49	65	61	55
Yuma AP	65	69	84	80	75
Arkansas					
Fort Smith AP	52	46	72	68	62
Little Rock AP	53	57	72	68	62
Texarkana AP	56	60	74	71	65

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
California					
Bakersfield AP	56	60	74	70	65
Beaumont CO	53	56	67	64	60
Bishop AP	47	51	65	61	56
Blue Canyon AP	43	46	58	55	50
Burbank AP	58	60	68	66	63
Eureka CO	50	51	54	54	52
Fresno AP	54	58	72	68	63
Los Angeles AP	58	59	64	63	61
Los Angeles CO	60	61	68	66	64
Mount Shasta CO	41	44	57	54	49
Oakland AP	53	54	60	59	56
Red Bluff AP	54	58	72	69	63
Sacramento AP	53	56	67	64	60
Sacramento CO	54	57	68	65	61
Sandberg CO	47	50	63	60	55
San Diego AP	59	60	66	65	62
San Francisco AP	53	54	59	57	56
San Francisco CO	55	55	59	58	57
San Jose COOP	55	57	64	62	59
Santa Catalina AP	57	58	64	62	60
Santa Maria AP	54	55	60	59	57
Colorado					
Alamosa AP	30	35	52	48	41
Colorado Springs AP	39	43	59	55	49
Denver AP	39	43	60	56	50
Denver CO	41	45	61	58	51
Grand Junction AP	39	44	65	60	52
Pueblo AP	41	45	62	58	51
Connecticut					
Bridgeport AP	40	44	61	57	50
Hartford AP	39	43	61	57	50
Hartford AP (Brainer)	39	43	60	56	50
New Haven AP	40	44	60	56	50
Delaware					
Wilmington AP	44	48	64	60	54
Washington D.C.					
Washington AP	47	51	66	63	56
Washington CO	47	51	66	63	57
Silver Hill OBS	46	50	65	61	55

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Florida					
Apalachicola CO	63	65	75	73	69
Daytona Beach AP	65	67	75	74	70
Fort Myers AP	70	71	78	76	74
Jacksonville AP	63	66	75	73	69
Jacksonville CO	64	66	76	73	70
Key West AP	74	75	80	79	77
Key West CO	75	76	81	79	78
Lakeland CO	68	69	77	75	72
Melbourne AP	68	70	77	75	72
Miami AP	72	74	79	78	76
Miami CO	72	73	78	77	75
Miami Beach COOP	74	75	80	78	77
Orlando AP	68	70	77	J5	72
Pensacola CO	62	64	74	72	68
Tallahassee AP	61	64	74	72	68
Tampa AP	68	69	77	75	72
West Palm Beach	71	73	79	77	75
Georgia					
Albany AP	60	63	75	72	67
Athens AP	54	58	71	68	63
Atlanta AP	54	57	70	67	62
Atlanta CO	54	57	70	67	62
Augusta AP	56	59	72	69	64
Columbus AP	56	59	72	69	64
Macon AP	58	61	74	71	66
Rome AP	53	56	70	67	61
Savannah AP	60	63	74	71	67
Thomasville CO	62	64	74	72	68
Valdosta AP	61	64	74	72	68
Idaho					
Boise AP	40	44	62	58	51
Idaho Falls 46 W	30	35	55	50	42
Idaho Falls 42 N W	28	33	54	49	41
Lewiston AP	42	46	63	59	52
Pocatello AP	35	40	59	55	44
Salmon CO	32	37	56	52	44

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Illinois					
Cairo CO	49	53	70	66	60
Chicago AP	38	43	62	57	50
Joliet AP	37	42	61	56	49
Moline AP	38	43	62	58	50
Peoria AP	39	44	63	58	51
Springfield AP	41	45	64	60	52
Springfield CO	43	47	66	62	54
Indiana					
Evansville AP	47	51	67	63	57
Fort Wayne AP	39	43	61	57	50
Indianapolis AP	41	46	64	59	52
Indianapolis CO	43	48	65	61	54
South Bend AP	38	42	61	56	49
Terre Haute AP	42	47	65	60	53
Iowa					
Burlington AP	39	44	64	59	51
Charles City CO	33	38	60	55	46
Davenport CO	39	44	64	59	51
Des Moines AP	37	42	63	58	50
Des Moines CO	38	43	64	59	51
Dubuque AP	34	39	60	55	47
Sioux City	35	40	62	57	49
Waterloo AP	35	40	61	56	48
Kansas					
Concordia CO	42	47	67	62	54
Dodge City AP	43	48	67	62	55
Goodland AP	38	43	62	57	50
Topeka AP	43	47	66	62	55
Topeka CO	44	49	68	63	56
Wichita AP	45	50	68	64	57
Kentucky					
Bowling Green AP	47	51	67	63	57
Lexington AP	44	48	65	61	54
Louisville AP	46	50	67	63	56
Louisville CO	47	51	67	64	57

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Louisiana					
Baton Rouge AP	61	63	74	72	67
Burrwood CO	65	67	77	74	71
Lake Charles AP	61	64	75	73	68
New Orleans AP	63	65	75	73	69
New Orleans CO	64	66	77	74	70
Shreveport AP	58	61	75	72	66
Maine					
Caribou AP	24	29	50	45	37
Eastport CO	33	37	51	48	42
Portland AP	33	38	56	51	44
Maryland					
Baltimore AP	45	49	65	61	55
Baltimore CO	47	51	67	63	57
Frederick AP	44	48	65	61	55
Massachusetts					
Boston AP	41	44	61	57	51
Nantucket AP	41	44	57	54	49
Pittsfield AP	34	38	55	51	44
Worcester AP	36	40	58	54	47
Michigan					
Alpena CO	33	37	54	50	43
Detroit Willow Run AP	38	42	60	56	49
Detroit City AP	38	43	60	56	49
Escanaba CO	30	35	53	49	42
Flint AP	36	40	58	54	47
Grand Rapids AP	36	40	58	54	47
Grand Rapids CO	38	42	60	56	49
East Lansing CO	36	40	58	54	47
Marquette CO	31	35	53	49	42
Muskecon AP	36	40	57	53	47
Sault Ste Marie AP	28	32	51	47	39
Minnesota					
Crookston COOP	25	31	55	49	40
Duluth AP	25	30	52	47	38
Duluth CO	26	31	52	47	39
International Falls	22	27	51	45	36
Minneapolis AP	32	37	60	54	46

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Rochester AP	31	36	58	53	44
Saint Cloud AP	28	33	56	51	42
Saint Paul AP	32	37	60	54	46
Mississippi					
Jackson AP	57	61	73	70	65
Meridian AP	57	60	72	69	64
Vicksburg CO	58	61	74	71	66
Missouri					
Columbia AP	43	48	66	62	55
Kansas City AP	55	49	68	64	56
Saint Joseph AP	42	47	67	72	54
Saint Louis AP	45	49	67	63	56
Saint Louis CO	46	50	68	64	57
Springfield AP	45	49	66	62	56
Montana					
Billings AP	35	40	59	55	47
Butte AP	27	31	50	45	38
Glasgow AP	27	33	56	51	42
Glasgow CO	28	34	57	52	43
Great Falls AP	34	38	56	52	45
Harve CO	31	36	57	52	44
Helena AP	31	36	55	50	43
Helena CO	32	36	55	50	43
Kalispell AP	32	37	54	50	43
Miles City AP	32	37	59	54	45
Missoula AP	33	37	56	51	44
Nebraska					
Grand Island AP	38	43	64	59	51
Lincoln AP	39	44	64	60	52
Lincoln University CO	40	45	65	61	53
Norfolk AP	35	40	62	57	48
North Platte AP	37	42	62	57	49
Omaha AP	39	44	65	60	52
Scottsbluff AP	36	41	60	56	48
Valentine CO	35	40	61	56	48
Nevada					
Elko AP	34	39	57	53	46
Ely AP	35	39	56	52	45

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Las Vegas AP	56	60	78	74	67
Reno AP	40	44	58	55	49
Tonopah	41	56	61	57	51
Winnemucca AP	38	42	60	56	49
New Hampshire					
Concord AP	33	38	56	52	45
Mt Washington COOP	17	21	37	33	27
New Jersey					
Atlantic City CO	45	49	63	60	54
Newark AP	43	47	63	59	53
Trenton CO	43	47	64	60	53
New Mexico					
Albuquerque AP	46	50	67	63	57
Clayton AP	43	47	63	59	53
Raton AP	38	42	58	54	48
Roswell AP	51	54	69	66	60
New York					
Albany AP	36	40	59	54	47
Albany CO	38	43	61	56	49
Bear Mountain CO	38	42	59	55	48
Binghampton AP	34	38	56	52	45
Binghampton CO	38	42	59	55	48
Buffalo AP	37	41	58	54	47
New York AP (La Guardia)	44	48	64	60	54
New York CO	44	47	63	59	53
New York Central Park	44	48	64	60	54
Oswego CO	36	40	58	54	47
Rochester AP	37	41	58	54	47
Schenectady COOP	35	40	59	55	47
Syracuse AP	38	42	60	56	49
North Carolina					
Asheville CO	48	51	64	61	56
Charlotte AP	52	55	69	66	60
Greensboro AP	49	53	67	64	58
Hatteras CO	56	59	70	68	63
Raleigh AP	51	55	69	65	60
Raleigh CO	52	56	70	66	61

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Wilmington AP	56	59	71	69	64
Winston Salem AP	50	53	67	64	58
North Dakota					
Bismarck AP	27	33	56	51	42
Devils Lake CO	24	29	54	48	39
Fargo AP	26	32	56	50	41
Minot AP	25	31	54	49	39
Williston CO	27	33	56	50	41
Ohio					
Akron-Canton AP	39	43	60	56	50
Cincinnati AP	43	47	64	60	54
Cincinnati CO	46	50	66	63	56
Cincinnati ABBE OBS	45	49	65	61	55
Cleveland AP	40	44	61	57	51
Cleveland CO	41	45	62	58	51
Columbus AP	41	46	62	59	52
Columbus CO	43	47	64	60	53
Dayton AP	42	46	63	59	52
Sandusky CC	41	45	62	58	51
Toledo AP	38	43	60	56	49
Youngstown AP	39	43	60	56	50
Oklahoma					
Oklahoma City AP	50	54	71	67	60
Oklahoma City CO	50	55	71	68	61
Tulsa AP	50	54	71	67	61
Oregon					
Astoria AP	47	48	56	54	51
Baker CO	36	40	56	52	46
Burns CO	36	40	58	54	47
Eugene AP	46	48	59	57	52
Meacham AP	34	38	52	49	43
Medford AP	46	49	62	59	54
Pendelton AP	42	46	63	59	53
Portland AP	46	49	60	57	53
Portland CO	48	50	61	59	55
Roseburg AP	47	49	60	57	53
Roseburg CO	48	51	61	59	55
Salem AP	46	49	60	57	53
Sexton Summit	42	44	55	52	48
Troutdale AP	45	48	59	57	52

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Pennsylvania					
Allentown AP	40	44	62	58	51
Erie AP	38	42	58	55	48
Erie CO	40	44	60	56	50
Harrisburg AP	43	47	63	59	53
Park Place CO	36	40	57	53	46
Philadelphia AP	44	48	64	61	54
Philadelphia CO	46	50	66	62	56
Pittsburgh Allegheny	42	46	62	58	52
Pittsburgh GRTR PITT	40	44	61	57	51
Pittsburgh CO	44	48	64	60	54
Reading CO	43	47	64	60	54
Scranton CO	40	44	61	57	50
Wilkes Barre-Scranton	39	43	60	56	49
Williamsport AP	40	44	61	57	51
Rhode Island					
Block Island AP	41	45	59	55	50
Providence AP	39	43	59	56	49
Providence CO	41	45	62	58	51
South Carolina					
Charleston AP	58	61	72	70	65
Charleston CO	60	62	74	71	67
Columbia AP	56	59	72	69	64
Columbia CO	57	60	72	69	64
Florence AP	55	59	72	69	64
Greenville AP	53	56	69	66	61
Spartanburg AP	53	56	70	66	61
South Dakota					
Huron AP	31	37	60	55	46
Rapid City AP	34	39	58	54	46
Sioux Falls AP	32	37	60	55	46
Tennessee					
Bristol AP	48	51	65	62	56
Chattanooga AP	51	55	69	65	60
Knoxville AP	50	54	68	65	59
Memphis AP	52	56	71	68	62
Memphis CO	53	57	72	68	62
Nashville AP	51	54	69	66	60
Oak Ridge CO	49	52	67	64	58
Oak Ridge 8 S	49	52	67	64	58

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Texas					
Abilene AP	55	58	73	70	64
Amarillo AP	47	50	67	63	57
Austin AP	60	63	76	73	68
Big Springs AP	56	59	74	70	65
Brownsville AP	68	70	79	77	74
Corpus Cristi AP	65	68	78	76	72
Dallas AP	57	61	76	72	66
Del Rio AP	62	65	77	75	70
El Paso AP	54	58	72	69	63
Fort Worth AP (Amon Carter)	57	60	75	72	66
Galveston AP	63	66	77	74	70
Galveston CO	63	66	77	74	70
Houston AP	62	65	76	73	69
Houston CO	63	66	77	74	70
Laredo AP	67	70	81	79	74
Lubbock AP	50	54	69	65	59
Midland AP	55	59	73	70	64
Palestine CO	58	62	74	71	66
Port Arthur AP	61	64	75	72	68
Port Arthur CO	63	65	76	74	69
San Angelo AP	58	61	74	71	66
San Antonio AP	61	64	77	74	69
Victoria AP	64	67	78	76	71
Waco AP	58	62	76	73	67
Wichita Falls AP	53	57	73	69	63
Utah					
Blanding CO	39	43	60	56	50
Milford AP	37	42	61	56	49
Salt Lake City AP	40	44	63	59	51
Salt Lake City CO	41	46	65	60	53
Vermont					
Burlington AP	32	37	57	52	44
Virginia					
Cape Henry CO	51	55	68	65	60
Lynchburg AP	48	51	66	62	57
Norfolk AP	51	54	68	64	59
Norfolk CO	52	56	69	66	61

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Richmond AP	48	52	67	63	58
Richmond CO	50	53	68	64	59
Roanoke AP	48	51	66	62	57
Washington					
Ellensburg AP	37	41	59	55	48
Kelso AP	45	47	57	54	51
North Head L H RESVN	47	49	54	53	51
Olympia AP	44	46	56	54	50
Omak 2 mi N W	36	40	59	55	47
Port Angeles AP	45	46	53	52	49
Seattle AP (Boeing Field)	46	48	58	56	52
Seattle CO	47	50	59	57	53
Seattle-Tacoma AP	44	47	57	55	51
Spokane AP	37	41	58	54	47
Stampede Pass	32	35	48	45	40
Tacoma CO	46	48	58	55	52
Tattosh Island CO	46	47	52	51	49
Walla Walla CO	44	48	65	61	54
Yakima AP	40	44	61	57	50
West Virginia					
Charleston AP	47	50	65	61	56
Elkins AP	41	45	59	56	50
Huntington CO	48	52	67	63	57
Parkersburg CO	45	49	65	61	55
Petersburg CO	44	48	63	60	54
Wisconsin					
Green Bay AP	31	36	56	51	44
La Crosse AP	32	38	60	55	46
Madison AP	34	39	59	54	47
Madison CO	34	39	60	55	47
Milwaukee AP	35	40	58	54	47
Milwaukee CO	36	41	59	55	48
Wyoming					
Casper AP	34	38	57	52	45
Cheyenne AP	35	39	55	51	45
Lander AP	31	35	56	51	43
Rock Springs AP	31	35	54	50	42
Sheridan AP	33	37	56	52	44

APPENDIX A (continued)

Location	Winter	Spring	Summer	Autumn	Annual
Hawaii					
Hilo AP	72	72	74	74	73
Honolulu AP	74	75	77	77	76
Honolulu CO	74	74	77	76	75
Lihue AP	72	73	76	75	74
Alaska					
Anchorage PA	25	29	46	42	35
Annette AP	40	42	51	49	46
Barrow AP	4	7	16	14	10
Bethel AP	18	23	41	37	30
Cold Bay AP	33	35	43	41	38
Cordova AP	32	35	45	43	39
Fairbanks AP	14	19	38	34	26
Galena AP	13	18	37	33	25
Gambell AP	15	19	34	30	24
Juneau AP	34	36	47	45	41
Juneau CO	36	39	49	46	42
King Salmon AP	25	28	44	40	34
Kotzebue AP	10	14	31	27	21
McGrath AP	14	18	37	33	25
Nome AP	16	20	37	33	26
Northway AP	12	16	32	29	22
Saint Paul Island AP	31	32	40	38	35
Yakutat AP	33	36	45	43	39
West Indies					
Ponce Santa Isabel AP	75	76	78	78	77
San Juan AP	77	77	79	79	78
San Juan CO	77	77	79	79	78
Swan Island	80	80	82	81	81
Virgin Islands					
St. Croix, V.I. AP	78	78	81	80	79
Pacific Islands					
Canton Island AP	83	84	84	84	84
Koror	81	81	81	81	81
Ponape Island AP	81	81	81	81	81
Truk Moen Island	81	81	81	81	81
Wake Island AP	79	79	81	81	80
Yap	81	81	82	82	82

REFERENCES

NOTE: THE FOLLOWING REFERENCED DOCUMENTS FORM A PART OF THIS HANDBOOK TO THE EXTENT SPECIFIED HEREIN. USERS OF THIS HANDBOOK SHOULD REFER TO THE LATEST REVISIONS OF CITED DOCUMENTS UNLESS OTHERWISE DIRECTED.

FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS, AND NAVFAC GUIDE SPECIFICATIONS:

Unless otherwise indicated, copies are available from Standardization Documents Order Desk, Building 4 D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

SPECIFICATIONS

MILITARY

MIL-P-28584A — Pipe and Pipe Fittings, Glass Fiber Reinforced Plastic for Condensate Return Lines

HANDBOOKS

MIL-HDBK-1002/2 — Loads

MIL-HDBK-1003/6 — Central Heating Plants

MIL-HDBK-1025/2 — Dockside Utilities for Ships Service

NAVFAC GUIDE SPECIFICATIONS

NFGS-02685 — Exterior Fuel Distribution System

NFGS-02685 — Gas Distribution System

NFGS-02693 — Exterior Shallow Trench Heat Distribution System

NFGS-02694 — Exterior Underground Heat Distribution System

NFGS-02695 — Exterior Aboveground Steam Distribution System

NFGS-02696 — Exterior Piping Insulation

NFGS-02697 — Exterior Buried Pumped Condensate Return System

NFGS-02698 — Exterior Buried Preinsulated Water Piping

NFGS-09809	Protection of Buried Steel Piping and Steel Bulkhead Tie Rods
NFGS-15250	Insulation of Mechanical Systems

NAVY MANUALS, DRAWINGS, P-PUBLICATIONS, AND MAINTENANCE OPERATING MANUALS: Available from Commanding Officer, Naval Publications and Forms Center (NPFC), 5801 Tabor Avenue, Philadelphia, PA 19120-5099. To order these documents: government agencies must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP); the private sector must write to NPFC, ATTENTION: Cash Sales, Code 1051, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

DESIGN MANUALS

DM-1.01	Basic Architectural Requirements
DM-3.01	Plumbing Systems
DM-3.03	Heating, Ventilating, Air Conditioning and Dehumidifying Systems
DM-3.5	Compressed Air and Vacuum Systems
DM-3.6	Central Heating Systems (See MIL-HDBK-1003/6 Reference)
DM-7.01	Soil Mechanics
P-272 (Part I)	Definitive Designs for Naval Shore Facilities
P-442	Economic Analysis Handbook

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY (NIST)

NBS Handbook 135	Life-Cycle Cost Manual for the Federal Energy Management Program

Unless otherwise indicated, copies are available from National Technical Information Service (NTIS), Springfield, VA 22161.

NAVAL CIVIL ENGINEERING LABORATORY

NCEL UG-0005	Steam Trap Users Guide

Available from Commanding Officer, Code L08B, Naval Civil Engineering Laboratory, Port Hueneme, CA 93043-5003.

NON-GOVERNMENT PUBLICATIONS:

Crocker and King, Piping Handbook, 5th Edition, available from McGraw-Hill Book Company, Inc., New York, NY 10036.

Keenan, Keyes, Hill and Moore, Thermodynamic Properties of Steam, available from J. Wiley & Sons, NY, Copyright 1969, Library of Congress Catalog, Card No. 68-54568.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B31.1	Power Piping (ANSI/ASME)
ASME B31.8	Gas Transmission and Distribution Piping Systems (ASME/ANSI)

Unless otherwise indicated, copies are available from American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10007.

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR CONDITIONING ENGINEERS (ASHRAE)

ASHRAE	Handbook - Fundamentals
ASHRAE	Handbook - Systems
ASHRAE	Handbook - Applications
ASHRAE Transactions Volume 71, Part 1, p. 61, 1965)	Earth Temperature and Thermal Diffusivity at Selected Stations in the United States

Unless otherwise indicated, copies are available from American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329.

HYDRAULIC INSTITUTE (HI)

Pipe Friction Handbook

Unless otherwise indicated, copies are available from Hydraulic Institute, 712 Lakewood Center North, 14600 Detroit Avenue, Cleveland, OH 44107.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 54	National Fuel Gas Code

Unless otherwise indicated, copies are available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

CUSTODIAN:
NAVY - YD

PREPARING ACTIVITY
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UNIFIED FACILITIES CRITERIA (UFC)

BOILER PLANT INSTRUMENTATION AND CONTROL SYSTEMS

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UNIFIED FACILITIES CRITERIA (UFC)

BOILER PLANT INSTRUMENTATION AND CONTROL SYSTEMS

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-430-11 Boiler Control Systems, dated 02-14-2001.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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UNITED FACILITIES CRITERIA
REVISION SUMMARY SHEET

Document: UFC 3-430-11, *Boiler Plant Instrumentation and Control Systems*

Superseding: UFC 3-430-11 Boiler Control Systems, 14 February 2001.

Description: This document provides criteria for the design of heating plant instrumentation and control systems for heating and process boiler plants.

Reasons for Document:

- This revision incorporates current industry and technology standards to provide an up-to-date document that will serve as a guide for facility planners/designers.

Impact:

- There are no associated cost impacts.

Unification Issues

There are no unification issues.

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FIGURES

TABLES

CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Boiler plant instrumentation and control systems are integral to safe and efficient operation of boiler plants. The Department of Defense adopts American Society of Mechanical Engineers (ASME) and National Fire Protection Association (NFPA) criteria for all boiler applications.

1-2 PURPOSE AND SCOPE.

This Unified Facility Criteria (UFC) provides requirements and guidance for the majority of plants that provide boilers for heating facilities and for process. These boilers are governed by ASME Boiler and Pressure Vessel Code, *Section I, Rules for the Construction of Power Boilers and Section IV, Rules for the Construction of Heating Boilers*. Typically, these are isolated steam plants under 1.0 bar (15 psig), central steam plants over 1.0 bar (15 psig), and isolated and central hot water heating plans.

A heating plant contains one or more boilers. The plant may be an individual boiler serving a single building or a compact group of buildings, or a central plant with several boilers serving many buildings and facilities through an extensive distribution system. The heating plant instrumentation and controls discussed are in general, for a saturated-steam power boiler heating plant. The typical saturated-steam power boiler heating plant discussed will operate at a design steam pressure greater than 1.0 bar (15 psig), with a heating capacity of greater than 422 Megajoule/h (400,000 Btu/h).

Instrumentation is a rapidly changing field. The options available in choosing and designing plant instrumentation are numerous. A boiler plant includes a large number of instrument items, all of which have to be specified in the procurement of a boiler plant. This UFC does not attempt to cover all details. Rather, its purpose is to present general guidelines for selecting and designing instrumentation for boiler plants.

1-3 APPLICABILITY.

This document applies to boiler plant instrumentation and control systems for construction, repair, and maintenance.

The information provided may also be applicable to low, medium, and high temperature hot water heating plants, but does not cover all of the requirements of those plants, such as control of water pressurization and circulation systems. The information may also be applicable to superheated-steam power plants, but does not cover all of the requirements of those plants, such as steam extraction, reheating, steam turbine control, and cooling water controls.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, *Cybersecurity Of Facility-Related Control Systems* and as required by individual Service Implementation Policy.

1-6 GLOSSARY.

APPENDIX A contains acronyms, abbreviations, and terms.

1-7 REFERENCES.

APPENDIX B contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 TYPE OF CONTROLS

2-1 GENERAL.

Control systems may be analog, digital, or a combination of the two. Analog control systems were an industry standard for a short time before quickly being replaced by digital control systems. The present industry standard is for a distributed control system (DCS), a programmable logic controller (PLC), or a direct digital controller (DDC) to provide digital control logic based on information gathered from electronic sensor inputs and responding with electronic control of electric powered valves and dampers. Additional criteria not specific to boiler plants but required for interfacing Facility-Related Control Systems (FRCS) is found in UFC 3-470-01, *Utility Monitoring And Control System (UMCS) Front End And Integration* and UFC 3-410-02, *Direct Digital Control For HVAC And Other Building Control Systems*.

2-2 CONTROL SELECTION.

Choose the type of control that will do the job most economically. This includes total cost over the lifetime of the equipment. Also consider compatibility with controls used in the existing plant, ease of operation and maintenance, and plant personnel familiarity and training. Consider unique situations such as a high EMF (electric magnetic field) where either EMF shielding or fiber optic data transmission are required. Obtaining the latest technology should not be used as the main criteria in the selection of controls.

Use the following as a guideline in selecting the type of control.

- Microprocessor digital type of controls (e.g. PLC, DDC, DCS or combination thereof) should be used for most new designs and in particular where a large number of control loops are involved. Consideration should also be given to using microprocessor digital type controls to replace pneumatic control systems that have exceeded their life expectancy or efficacy.
- Analog logic devices (e.g. electric potentiometer controllers) must not be considered for new designs.
- Consider the environmental conditions (e.g. temperature and humidity) in which the controls will be installed.

2-3 ELECTRICAL CHARACTERISTICS.

2-3.1 Electrical Interface.

The electrical interface between instruments and a digital controller varies depending upon application. Typical analog signal ranges and levels include the following:

- mA direct current (DC) (4-20 mA, 10-50 mA, or 0-100 mA)
- volts DC (0-10 millivolts, 0-100 millivolts, or 0-5 volts)

- temperature (thermocouple in millivolts, or RTD)
- volts alternating current (AC) (120 volts)

Transmitters and control valves commonly use a range of 4-20 mA DC. Switches and solenoid control commonly use a switched level of 120 volts AC. For signal requirements for instrument loops refer to ANSI/ISA-50.00.01, *Compatibility of Analog Signals for Electronic Industrial Process Instruments*.

2-3.2 Communication Data Bus.

Complex boiler control systems may involve multiple digital control systems (e.g. DCS, PLC, or computer controlled smart instruments) linked together by a communication data bus. The communication data bus passes significant data between the digital control systems in a serial format. Refer to UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems* for requirements on incorporating cybersecurity into the design of all FRCS. Only open-protocol standards must be used. Proprietary standards are not permitted per UFC 3-410-02 Direct Digital Control For HVAC And Other Building Control Systems. Typical industry open communication bus standards include:

- DeviceNet: A software protocol that typically uses a Controller Area Network (CAN). DeviceNet is maintained by the Open DeviceNet Vender Association (ODVA) and has been standardized by the International Electrotechnical Commission (IEC).
- Fieldbus: Now technically known as Foundation Fieldbus, is an open hardware and software protocol created by the Fieldbus Foundation, maintained by FieldComm Group and standardized by the International Electrotechnical Commission (IEC) as a part of the Fieldbus family.
- HART: Highway Addressable Remote Transducer protocol is an open hardware and software standard that was originally created and defined by the Rosemount Company, is currently managed by the FieldComm Group, and is standardized by the International Electrotechnical Commission (IEC) as a part of the Fieldbus family. The HART protocol utilizes existing 4-20mA current loop technology by superimposing a low level digital signal on top of the current loop analog signal, which is undetectable by the analog equipment.
- Modbus: An open software protocol that typically uses TIA/EIA-485 and TCP/IP networks. Modbus was originally created and defined by the Modicon Company and is maintained by the Modbus Organization.

2-3.2.2 Communications Between or Among Boilers.

New boiler digital controllers must be of the same manufacturer and product line. Existing boiler plants of different manufacturers with their own proprietary language will need to be translated to a common language through a Gateway or similar device when adding on new boilers.

CHAPTER 3 GENERAL REQUIREMENTS

3-1 GENERAL.

Provide control systems in accordance with applicable codes. Refer to paragraph 3-14 for applicable codes. Design control systems so that the loss of the control medium (e.g. electricity) will leave the controls in a fail-safe position.

3-2 CONTROL LOCATION.

Locate instrument control in the control room as much as practical. Provide local control panels where they are required for equipment start-up.

3-3 TURNDOWN.

Instruments have to cover normal operating as well as upset conditions. Several instruments might have to be provided to cover all of the ranges. It is important that all instruments be reviewed for covering all operating as well as upset conditions during the plant design stage.

3-4 INSTRUMENT RANGES.

Size flow instruments based on a normal operating flow of approximately 70 percent of full scale. For all other instruments set the normal operating point at 50 percent of full scale. Use the following scales:

- Flow: Direct reading
- Pressure: Direct reading
- Temperature: Direct reading
- Level: 0-100% Linear
- Analyzers: Direct reading

Suppressed ranges for temperature and pressure may be used as long as they cover startup and upset conditions.

3-5 ALARMS AND SHUTDOWNS.

Design the plant controls to avoid nuisance shutdowns. These can be caused by excessive complexity, unnecessary items being interlocked into the shutdowns, or lack of provisions in the case of power or instrument air failure. Also design for easy restart in the case of shutdown, especially when caused by non-process type failures such as interruption of power.

3-5.1 Design Criteria.

Use contacts that open on abnormal conditions to alarm or shut down. For all shutdowns provide a pre-alarm that precedes the shutdown. Provide separate devices for alarms and shutdowns. Do not use the same device for an alarm or shutdown as used for control. An electrical power failure must shut off all fuel and require operating personnel attention for a restart.

3-5.2 Testing and Servicing.

Include provisions for the testing and servicing of the shutdown device and related alarms without interfering with plant operation.

3-5.3 Interlock and Safety Requirements.

Safety controls are needed to protect against boiler explosions and implosions. Interlock and other safety requirements for boilers are given in the following American Society of Mechanical Engineers (ASME) and National Fire Protection Association (NFPA) standards.

- ASME CSD-1 Controls and Safety Devices for Automatically Fired Boilers
- NFPA 85 Boiler and Combustion Systems Hazards Code.

3-5.3.2 Safety Interlocks.

Safety interlocks are required but not limited to those listed below.

- Prepurge Interlock – Prevents fuel from being admitted to a furnace until the furnace has been thoroughly air-purged to remove residual combustibles.
- High Steam Pressure Interlock – Fuel is shutoff upon abnormally high boiler steam pressure.
- Low Airflow Interlock – Fuel is shutoff upon loss of airflow from the combustion air fan or blower, the induced draft fan or the forced draft fan.
- Low Fuel Supply Interlock—Fuel is shut off upon loss of fuel supply pressure. The loss of fuel supply pressure would result in unstable flame conditions.
- Loss of Flame Interlock – All fuel is shut off upon loss of flame in the furnace or to an individual burner in the furnace.
- Fan Interlock – Stop forced draft upon loss of induced draft fan.
- Low Water Interlock – Shut off fuel on low water level in boiler drum.
- High Combustibles Interlock (optional) – Shut off fuel on highly combustible content in the flue gases.

- Post Purge Interlock – Continues fan operations to remove residual combustibles from the furnace prior to shutting down the fans.

3-5.3.3 Shutdown Valve Reset.

Safety shutoff valves must be a manual reset type and shall not be operable until all limit controls are in the safe position. Sequence interlocks for start-up and stop must also be provided. Provide annunciator alarms to respond to any safety shutdown.

3-5.3.4 Dedicated Safety System.

The safety shutdown system must be dedicated and independent of the one used for boiler control. For example, if PLC controllers are utilized, the design must contain a PLC for safety shutdown that is separate and independent of the one used for boiler control.

3-5.3.5 Special Considerations.

Special attention should be maintained throughout the boiler design to prevent the following safety hazards.

- Equipment must be designed to protect against electrical shock from exposure to control power.
- Boiler control must assure a sufficient quantity and duration of pre-purge airflow through the boiler prior to ignition to prevent boiler explosions.
- Boiler control must assure a sufficient quantity and duration of post-purge airflow through the boiler during shutdown to prevent boiler explosions.
- Boiler control must assure a sufficient quantity of combustion air and prevent excessive fuel during boiler operation to prevent boiler explosions.
- Boiler control must limit the number of retries when igniting the boiler pilot. The industry standard is to allow three attempts at achieving pilot ignition prior to necessitating a boiler purge cycle.

3-6 HARDWARE.

Hardware standards are defined by NEMA ICS 2, *Industrial Control and Systems Controls, Contactors and Overload Relays Rated 600 Volts.*

3-7 EQUIPMENT RATING AND CLASSIFICATION.

Provide instruments that are rated for the environment. Electrical components must be designed for the anticipated temperature and humidity inside of the enclosure, fungus proofing where required, and vibration. Refer to NEMA ICS 1.1, *Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control* for additional information.

3-7.1 Enclosures.

Enclosures must be certified by the National Electrical Manufacturers Association (NEMA) for the environment where they will be used. NEMA 4 enclosures must be used for outdoor locations. NEMA 4X enclosures must be used in corrosive environments. A space heater is required whenever condensation may occur.

Enclosure ratings are defined by NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*, and NEMA ICS 6, *Industrial Control and Systems: Enclosures*.

3-7.2 Hazardous locations

Hazardous locations are defined by NFPA 70, *National Electric Code*. Enclosures must be rated for the location in which they will be installed. Cost savings may be achieved by relocating an enclosure from a hazardous location to a non-hazardous one. A summary of applicability in reference to NFPA hazardous area classifications follows.

3-7.2.1 Class Definition.

Classes I and II are applicable to boiler plants; Class III is not.

3-7.2.2 Division Definition.

Division 1 is usually not applicable to boiler plants except for coal handling and fuel storage areas. Division 2 is often applicable.

3-7.2.3 Group Definition.

Groups A, B, C, E, and G are not applicable to boiler plants. Groups D and F are applicable.

3-7.3 Special Considerations.

When specifying enclosures note the following:

3-7.3.1 Maintenance.

Class I, Group D, Division 2 can be met by either providing an explosion proof enclosure or by providing a non-explosion proof enclosure and purging it with air. The non-explosion proof enclosure is less expensive (initial cost) but requires an air supply and more attention in that a constant air purge must be maintained. This long-term maintenance is expensive. Therefore, to keep maintenance to a minimum, specify the enclosure as explosion proof. Only exceptionally large equipment should be considered for a Class 1, Group D, Division 2 constant air-purge system, where the life cycle cost of the special enclosure will clearly exceed the life cycle cost of maintenance of the air purge and the effort to provide continuous assurance of safe operation.

3-7.3.2 Specification Completeness.

Include all requirements when specifying explosion-proof enclosures. For example, specify the enclosure as Class I, Group D explosion-proof, not just explosion-proof. An explosion proof enclosure is not necessarily dust tight or suited for an outdoor location. Therefore, both the explosion proof requirement and the weather or dust tight requirement must be specified to define the required enclosure.

3-8 POWER SUPPLIES.

Furnish a power supply that provides clean power to the instruments that is free of disturbances and nuisance shutdowns. The manufacturer should be able to provide equipment specifications and recommend safeguards against severe power disturbances. Refer to NEMA ICS 1.1, *Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control* for additional information. Include the following:

- Provide power supplies that enable the controls, including combustion safeguard systems and other control devices, to operate through an electric power interruption of 20 milliseconds without affecting the operation of the plant.
- Provide an uninterruptible power supply (UPS) system to keep the electronic instrumentation on line in case of a power interruption. The required time depends on the plant and instrumentation, but 30 minutes is often specified. The UPS system must provide a safe plant shutdown in case of a longer power outage. Small UPSs located inside of control panels should be equipped with ventilation fans to remove unwanted heat.
- Connect all trip circuits to the UPS system.

UPS system standards are defined by NEMA PE 1, *Uninterruptible Power Systems*.

3-9 WIRING AND CONDUITS.

Wiring must conform to NFPA 70, *National Electric Code*. Run signal, thermocouple, and power wiring in separate conduits. Wiring for alarm, shutdown, and interlock circuits of the same voltage as the power wiring may be run in the same conduit as the power wiring.

Cable and thermocouple wire must conform to NEMA WC57,*Standard for Control, Thermocouple Extension, and Instrumentation Cables*. Provide high point vents and low point drains for all conduits. Recommended practices for control centers are defined by ISA-RP60.8, *Electrical Guide for Control Centers*.

3-10 TUBING AND PIPING.

Do not bring lines containing process fluids such as water and steam into the control room, control panels or control boards.

3-11 IDENTIFICATION.

Identify all instruments and controls with a stainless steel metal tag permanently mounted on the instrument. Include the instrument number and service in the identification.

3-11.1 Nameplates.

Provide nameplates for all panel instruments on both the front and the rear of the panel. Minimum front panel information must include instrument number, service, scale factors, and units. The rear of panel only requires the instrument number. Use recommended practices on panel nameplates as defined by ISA-RP60.6, *Nameplates, Labels and Tags for Control Centers*.

3-11.2 Terminations.

Identify each electrical and tubing terminal with the instrument item number to which it connects. Tag and number all terminals and the ends of all wires. Identify all electrical conduits as to type of wiring (power, thermocouple, DC signals, or other).

3-11.3 Instruments.

Identify all local instruments such as valves and switches with the item number of the instrument with which it operates.

3-12 INSTRUMENT SPECIFICATION FORMS.

Use instrument specification forms when ordering instruments. Forms and specification checklists for a number of instruments are provided in ISA-S20, *Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves*. Obtain complete information on the instrument from the manufacturer before ordering. Sources of information include manufacturer catalogs, data sheets and other literature. Provide all data required for ordering the instrument. Specify all items including optional selections and deviations from the manufacturer’s standard.

3-13 DRAWINGS.

Use standard symbols. For standard symbols, presentation, and terminology refer to the following industry standards.

- ANSI/ISA S5.1, Instrumentation Symbols and Identification
- ISA S5.3, Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems
- ISA S5.4, Instrument Loop Diagrams

Provide control schematic diagrams, logic diagrams following UFC 3-410-02 control logic diagram overview which is contained in APPENDIX F, and instrument loop diagrams.

3-14 CODE REQUIREMENTS.

The following codes apply.

- ASME, Boiler and Pressure Vessel Code, Section I, Rules for the Construction of Power Boilers, and Section IV, Rules for the Construction of Heating Boilers
- ASME CSD-1, Controls and Safety Devices for Automatically Fired Boilers
- ASME B16.5, Pipe Flanges and Flanged Fitting
- ASME B31.1, Power Piping
- NFPA-70, National Electric Code
- NFPA 85, Boiler and Combustion Systems Hazards Code

3-15 STANDARDIZATION.

Standardize all instrumentation in the boiler plant. Specify that all like instruments, such as all control valves, be provided from the same manufacturer. Avoid having two control valves in identical service from two different manufacturers or from the same manufacturer but of two different model numbers.

3-15.1 Multiple Manufacturers.

Multiple manufacturers are acceptable for different types of instruments. Instruments of the same type, however, must be standardized. For example, controllers can be obtained from one manufacturer, control valves from a second manufacturer, and pressure gauges from a third manufacturer.

3-15.2 Packaged Equipment.

Packaged equipment, which is often furnished with instrumentation included, does not always lead to standardization. Buying the package manufacturers standard, however, might result in considerable cost savings. Even with packaged equipment, however, the instruments should conform to the open architecture and plant standards whenever practical.

3-15.3 Special Considerations.

Also standardize the following for the boiler plant.

3-15.3.1 Signal Amplitude.

Use standard signals. These are 4-20 mA DC for transmitters and control valves and 120 volts AC for switches.

3-15.3.2 Connections.

Use standard types of connections and connection sizes. Avoid non-standard connections.

3-16 ENVIRONMENTAL CONCERNS.

The Environmental Protection Agency (EPA) regulates the maximum allowed emissions from all external combustion sources including boilers. EPA AP-42, *The Compilation of Air Pollutant Emission Factors* contains information associated with the types and quality of emissions and methods used to control them. Allowable emission limits varies by local and state regulations. Consult the Code of Federal Regulations (CFR), Title 40, *Protection of Environment* for regulated limitations and monitoring requirements.

3-17 SAFETY PLAN AND HAZOP STUDY.

Boiler controls must be included in the Safety Plan and Hazardous Operations (HAZOP) Study submitted by the boiler designer.

CHAPTER 4 PANEL INSTRUMENTS

4-1 GENERAL.

This section covers instruments usually located on panels. Non-panel instruments, such as control valves, are covered in Chapter 5.

4-1.1 Types of Control Panels.

Boiler plant panels include panels for boiler control, combustion safeguards, and the control of special equipment such as electrostatic precipitators.

4-1.2 Panel Location.

Panels may be located either in a control room or locally. Both types of panels are covered in this section and are discussed below.

4-1.2.1 Control Room Panels.

The control room is the preferred location for panels. Locate as much of the plant instrumentation in the control room as practical. The central location of panels will simplify both operation and maintenance. The control room is also usually cleaner, has better temperature and humidity control, and has less vibration than other plant locations. These conditions necessitate less stringent instrument enclosure requirements and the instruments will last longer.

4-1.2.2 Local Panels.

Local panels are located in the vicinity of the equipment that they control. This can be either indoors or outdoors. The atmosphere can vary from clean to dusty or corrosive. Local panels must be minimized since more time and effort is required to access and monitor a large number of local panels than a centrally located one.

Restrict local panels to instrumentation that does not require continuous attention and is used extensively for start-up and shutdown of the local equipment. Locate the panel as close to the equipment as practical. Do not locate local panels in front of any access panels or inspection plates where an operator may interfere with boiler inspections or where an explosion may injure an operator.

Provide a panel designed for the environment. Furnish the panel with a rain hood for outdoor locations. Avoid local wall mounted panels which are mounted flush with the wall. These panels may allow wall condensate to enter. The panel must be a self-supporting box type if it is not mounted integrally with the local equipment.

4-1.3 Layout.

Good panel layout requires experienced personnel in panel design and user drawing review. The layout depends on the type of instrumentation to be placed on the panel and how it will be operated. For best results coordinate instrument panel layout with the end user prior to start of panel fabrication. Once the panel is in fabrication changes are expensive and must be kept to a minimum.

Provide a minimum of 10 percent spare panel space for the future expansion of control room panels. Provide 1.52 to 1.83 meters (5 to 6 feet) access clearance between the panel and the wall behind it when possible. Recommended practices on control room and panel layout are defined by ISA-RP60.2, *Control Center Design Guide and Terminology.*

4-1.4 Construction.

The following applies to both control room and local panels.

4-1.4.1 Electrical Components.

Use solid state logic. Do not use relay logic except where only a few logic steps are involved.

Use items that have a long life and do not have to be frequently replaced. A typical example is the use of LED bulbs instead of incandescent bulbs for indicator lights. The LED bulbs have a longer life.

4-1.4.2 Displays.

Use displays that are readily visible to the operator. This might entail specifying LED instead of LCD, although LCD consumes less power.

4-1.4.3 Lighting.

Provide switched vapor tight light fixtures to illuminate the front of the panel. Provide additional switched lights to illuminate the inside of the panel enclosure.

4-1.4.4 Service Outlets.

Provide ground fault interrupt (GFI) protected 120 VAC duplex outlets within each panel enclosure section. Locate outlets not more than 6 feet apart within each section.

4-1.4.5 Steelwork.

Fabricate enclosure panels from 3.04 millimeter (11 gauge (0.1196-inch)) or 3.18 millimeter (1/8-inch) steel plate, powder-coated where corrosion protection is required. Reinforce the panels as required for stiffness. Use 1.52 millimeter (16 gauge (0.0598-inch)) minimum steel plate for doors. Slightly bevel or round all exposed edges. Larger panels are usually fabricated in 3.05 to 3.66 meter (10 to 12 foot) long sections. Make all joints vertical. Horizontal panel joints are not acceptable. Use angle iron at each end of a section to make up vertical butt joints. Preassemble the complete panel in the shop to check for accurate alignment and surface matching. Panel joints passing through an instrument are not acceptable.

4-1.4.6 Prefabrication.

Construct panels in accordance with UL 508A. Specify panels to be complete with all instruments installed, piped, and wired. The only actions that should be necessary to place the panel in service are to connect power and instrument signals.

4-2 INDIVIDUAL ITEM REQUIREMENTS.

4-2.1 Controllers.

Boilers use two types of controllers. These are digital (e.g. microcontroller based) and analog. Use the following guidelines in selecting the type of controller to be used:

- Use the type of controller that is the most economical and reliable.
- For plants with many control loops use digital type of controllers.
- For the expansion of existing digital or analog electronic controls within a plant use the existing technology. This may be either digital or analog electronic controllers.
- When using digital control avoid depending on a single or a few control devices for the entire plant without having a backup. A redundant controller might not be required if only a single controller controls one loop. However, if a single controller controls a large number of loops then provide redundancy so that if the controller fails another controller will automatically take over.

4-2.1.2 Process Controllers.

Process controllers use one or several of the following control modes:

- On-off
- Proportional
- Integral (also called reset)
- Derivative (also called rate)

Most digital controllers have all of the above control modes included. Integral controllers must include anti-integral windup. Analog controllers often do not include all three control modes or anti-integral windup.

4-2.1.2.2 Control Modes.

In general, use the following control modes for the indicated control loop.

- Flow -- Use proportional plus integral.
- Level -- Use proportional plus integral.

- Pressure and Temperature -- Use proportional plus integral. Use proportional plus integral plus derivative (rate) when the application requires a quick response time.

4-2.1.2.3 Testing.

Recommended practices on tests to be conducted on digital controllers are defined by ISA-RP55.1, *Hardware Testing of Digital Process Computers*.

4-2.1.2.4 Controls.

Provide a separate control station for each control loop when using digital controls. Locate critical controls on the front of the panel. Provide the following minimum controls.

- Automatic/manual selection
- Set point adjustment
- Output signal adjustment when on manual control
- Alarm setting

4-2.1.2.5 Alarms.

Provide the following minimum alarms.

- Controller failure
- High-high alarm
- High alarm
- Low alarm
- Low-low alarm

4-2.1.2.6 Displays.

Provide each control station with the following minimum displays

- Process reading
- Set point
- Output signal
- Input signal
- Automatic/Manual indication
- Controller failure indication
- High-high alarm
- High alarm
- Low alarm

- Low-low alarm

4-2.1.2.7 Features.

Provide the following features as a minimum.

- Proportional, integral and derivative control modes
- Anti-integral windup
- Automatic/manual and manual/automatic bumpless transfer
- Change configuration without shutting down the control loop
- Display configuration data without interfering with the operation of the controller.

4-2.1.2.8 Failure Response.

Provide the following minimum actions on controller failure.

- The controller should switch to manual operation, hold its last output signal, and send out an alarm showing controller failure if a backup controller is not provided.
- The control should automatically switch over to the backup controller and send out an alarm showing controller failure if a backup controller is provided.

4-2.1.2.9 Signal Interface.

Digital controllers do not always have dedicated contacts for alarms and shutdowns. If the contacts are not provided, specify a controller where dedicated contacts for each alarm and shutdown condition can be easily added using hardware obtainable from the controller manufacturer. Provide one set of single pole double throw (SPDT) contacts as a minimum.

4-2.1.3 Programmable Logic Controllers.

Programmable logic controllers (PLCs) are usually programmed in the electrical ladder diagram format. Other formats are also used. When specifying PLCs include the following features.

- Provide a controller that can be programmed in the electrical ladder diagram format when many logic steps are involved.
- Include provisions so that the controller can be programmed and the program read without disturbing its operation.

4-2.1.4 Controller Configuration.

Provide a controller that can be programmed in any of the following ways at the programmer’s option.

- From the front of the controller if a separate controller is provided
- From a manual control station if a separate controller is not provided
- From a configuration device manually
- From a configuration device using stored information from a data storage device

Provide either a non-volatile memory or battery back-up for the controller so that the controller configuration memory is not lost due to a power outage.

4-2.2 Recording.

The preferred method of recording data is on non-volatile data storage. This data can later be viewed on a monitor, printed, or plotted.

4-2.3 Totalizers.

Record the data on non-volatile data storage and use a computer program to add up the totals.

4-2.4 Indicators.

Do not specify a dedicated indicator except for critical items when using digital type control systems. Obtain non-critical information from a control station read out or from a monitor.

4-2.5 Status Lights.

Do not specify a dedicated status light except for critical items. When dedicated status lights are required, use LED lights as much as practical. LED lights have lower power consumption and longer life. Use "Push to Test" indicating/status lights to ensure lights are functioning properly.

Obtain the information from a control station read-out or from a monitor whenever practical instead of using status lights for digital type control systems.

4-2.6 Annunciators.

Annunciator standards are defined by ANSI/ISA-18.1, *Annunciator Sequences and Specifications*. Use common trouble alarms instead of dedicated alarms as much as practical. Provide both visual and audible alarms. Provide a dedicated alarm for critical items.

4-2.6.1 Common Alarms.

Provide a dedicated window to contain the common trouble alarms. When possible, include on this display the specific item within the group that caused the alarm.

4-2.6.2 Dedicated Alarms.

Provide a separate window that includes all dedicated alarms associated with an area. Typical dedicated alarms are summarized in Table 6-2.

4-2.6.3 Annunciator Systems.

Include the following minimum items in an annunciator system.

- Solid-state electronic system with first-out sequence.
- Back-lighted windows.
- Acknowledge, test, and reset pushbuttons. Locate the pushbuttons outside of the annunciator cabinet so that the cabinet door does not have to be opened to depress the pushbuttons. Provide a separate audible signal device and separate pushbuttons for each annunciator system.

4-2.6.4 Alarm Indicators.

- The alarm indication is controlled by the annunciator manufacturer. Typical indications for various fault conditions follow.
- Normal - Light off and audible alarm off
- Abnormal - Light flashing, audible alarm on
- Abnormal First Out - Same as above except flashing pattern is different to distinguish it as a first out.
- Acknowledge - Audible alarm off
- Other than first-out - Light steady
- First-out - Light flashing but pattern is different from prior to acknowledgment
- Return to Normal - Light off and audible alarm off.

4-2.7 Selector Switches.

Provide a minimum of SPDT contacts for selector switches. Clearly label all switch positions. Label unused positions as such. Use back-lighted switches for critical items in areas that are not well lit.

Momentary selector switches may be required to electrically sequence equipment to start on emergency diesel generator power following the loss of normal power. This is necessary so as not to overload the emergency power circuit with equipment that has selector switches maintained in the "Run" mode.

4-2.8 Pushbuttons.

Use SPDT contacts as a minimum. Provide recessed or covered pushbuttons for shutdowns to guard against nuisance trips.

4-2.9 Plant Control Stations.

Plant control stations, like panels, can be located either in a main control room or locally. The main control room is the preferred location. Restrict local plant control stations to equipment that require them for start-up or shutdown. In this case locate the control station as close to the equipment as practical.

A typical control station consists of a computer for processing and storing data, a monitor, a keyboard, and a printer. Each of these items is discussed below.

4-2.9.1 Computers.

Furnish the computer with a power supply that provides power that is free of disturbances. The manufacturer should be able to provide power supply specifications and recommend safeguards against severe power disturbances.

4-2.9.1.1 Control Limits.

Limit the ability of the computer to control the plant to those functions that can be safely controlled from the computer and in compliance with applicable codes. Provide an alarm connected to an annunciator to show computer malfunction.

4-2.9.1.2 Data Overflow Limit.

- Provide computers that are used for logging data with an alarm and pop-up annunciator on the operator screen to show the following.
- Data storage capacity is approaching full.
- Data storage capacity has been exceeded.

Provide sufficient memory to log one year of data in a continuous loop without resulting in an overflow condition. Record data in a continuous format so that old data is over-written by new data. Consult with the end user for sampling frequencies.

4-2.9.1.3 Redundancy.

Provide a means by which to automatically take over the logging of critical data in the event of primary computer malfunction.

4-2.9.2 Monitors.

Provide each workstation with two monitors.

4-2.9.3 Keyboards.

Provide sealed-type keyboards to resist liquid spills. Keyboards can be either a standard type or a non-standard with specialized keys. Standard keyboards must be used as much as practical. Mistakes are more likely to be made using a non-standard keyboard than using a standard keyboard. Keyboard replacement is also more difficult with a non-standard type.

4-2.9.4 Printers and Plotters.

Provide an alarm connected to an annunciator to show printer failure for printers receiving critical on-line data. Also, for critical on-line data, provide a back-up printer to take over if the primary printer malfunctions.

4-2.10 Data Logging.

Provide the following minimum data logging for digital type control systems. Print out this information automatically on a dedicated printer.

- Date, time for all data entries
- Device alarmed or shut down
- Identify first out
- Time alarm acknowledged
- Time for return to normal

Include year, day, hours, minutes, and seconds in the date and time. In first out, show the device to alarm first then the device to first shut down the equipment.

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CHAPTER 5 LOCAL DEVICES AND INSTRUMENTATION

5-1 GENERAL.

This chapter covers local instruments. Panel instruments are not included. Instruments that are usually located on panels, such as controllers, are covered in chapter 4.

Instruments should be located where they are accessible. Instruments that must be operated during the start-up or shutdown of equipment should be located as close to the equipment as practical. Some instruments must be accessed continuously for operation, others only during startup and shutdown. The designer must consider whether instrumentation may be needed for both normal, continuous operation and startup and shutdown. In such cases, two sets of instrumentation may be required in two different locations. All instruments must be accessible for calibration and maintenance. Locate instruments using the following order of access preference.

- Grade
- Platform
- Stairs
- Ladder
- Portable ladder

5-2 INDIVIDUAL ITEM REQUIREMENTS.

5-2.1 Valves.

This paragraph covers control valves, pressure regulators, and solenoid valves. Each type is discussed below.

5-2.1.1 Control Valves.

Common types of flow characteristics for control valves include quick opening, linear, and equal percentage. Control valves with equal percentage flow characteristics are specified for most applications. Control valves with linear flow characteristics are hard to tune at low flow and should be avoided. Select the flow characteristic to suit the application. Tolerance criteria for control valves are defined by ISA-75.11.01 *Inherent Flow Characteristic and Rangeability of Control Valves*.

5-2.1.1.1 Control Valve Selection.

There are many items to be considered in control valve selection. Checklists are provided in most manufacturer catalogs. Critical items that are sometimes overlooked include type of shutoff, shutoff pressure, line hydrotest pressure and controllability at turndown conditions. Review all pertinent sizing and selection information including accessories when selecting a control valve.

5-2.1.1.2 Construction.

Use carbon steel body with stainless steel trim. Other materials may be specified when required by unique conditions.

5-2.1.1.3 Sizing.

Size control valves to absorb 30 to 50 percent of the total system pressure drop.

5-2.1.1.4 Maintenance

Provide manual block and bypass valves around control valves to allow for control valve removal and servicing while the system is operational.

5-2.1.1.5 Location.

Locate control valves at grade where practical. Install the control valve near the operating equipment that has to be observed while in local manual control.

5-2.1.2 Pressure Regulators.

Use self-actuated regulators only where the operating pressure is below 10.3 bar (150 psig) and where variations from the control point are acceptable. Use pilot-operated pressure regulators where the operating pressure is equal to or above 10.3 bar (150 psig), or where minimal variations from the control setpoint are required.

5-2.1.3 Solenoid Valves.

Common uses for solenoid valves in a boiler plant include the routing of steam to pilot valves.

Verify solenoid valve sizing to ensure that the valve will open or close within the specified amount of time. Port size might have to be increased to ensure the proper actuation time.

Verify that the proper solenoid valve is used for the intended service. An example of a critical service application is a pilot gas shutoff solenoid valve. Most manufacturer catalogs include checklists on items to be specified. Critical items sometimes overlooked include type of fluid, shutoff and opening pressures, and line test pressure.

5-2.2 Actuators.

Use spring-loaded diaphragm type actuators where practical. Springless operators are acceptable only when spring-loaded type actuators cannot provide the desired performance.

Select the actuator so that the valve or damper that it controls will fail safe. Fail safe is defined as lock in position or take a position (either open or closed) that will result in the least upset.

Furnish positioners for all automatically operated dampers. Furnish positioners for all control valves in critical service and where the variable, such as flow, has to be closely controlled. Specify that the positioner be furnished with the control valve or damper instead of separate procurement.

5-2.3 Dampers.

Dampers can be operated either manually or by means of an actuator. This paragraph covers only actuator-operated dampers. Manually operated dampers are not included in this document.

Specify temperature, pressure, pressure drop, type of shutoff, materials, damper bearings, linkages, damper bearing and linkage lubrication, and other applicable data when selecting dampers.

Provide a hand wheel or lever so that the damper can be manually operated in case of damper actuator failure.

5-2.4 Pressure Relief Valves.

Provide pressure relief valves in accordance with the applicable codes. Refer to paragraph 3-14 for applicable codes.

5-2.5 Rupture Disks.

Use reverse buckling type rupture disks at the inlet of the relief valve in corrosive services.

5-2.6 Level Instruments.

Provide level instruments in accordance with applicable codes. In general, provide separate vessel connections for each level instrument. Provide 13 millimeter (½ -inch) minimum vent and drain valves with plugs for all level instruments.

5-2.6.1 Gauge Glasses.

Complete coverage of total liquid range is not always required. Consult the applicable codes for requirements. Also consider all operating conditions and upsets. Provide gauge glasses to cover and overlap a minimum of 5 centimeters (2 inches) beyond the ranges of displacers and switches.

Gauge glasses should only cover the critical range zone such as high, low, and normal levels when the range is also covered by differential pressure type level transmitters.

Provide illuminators for transparent gauge glasses.

5-2.6.2 Displacer.

Displacer type level instruments can be used for level ranges up to 1.5 meters (60 inches) of fluid height. Avoid use of internal displacers except for open tanks and sumps. Provide carbon steel body material with stainless steel trim as a minimum.

5-2.6.3 Differential Pressure.

Use differential pressure type level instruments instead of displacer type level instruments for ranges over 1.5 meters (60 inches) of fluid height. They may also be used for ranges under 1.5 meters (60 inches).

5-2.6.4 Capacitance Level.

Avoid the use of capacitance type level instruments in boiler plants.

5-2.7 Flow Instruments.

The most commonly used flow element in boiler plants is the orifice plate. There are numerous other flow measuring devices that can be used depending on the application. In alphabetical order these include annubar flowmeters, coriolis type mass flowmeters, elbow meters, flow nozzles, magnetic flowmeters, pitot tubes, pitot-venturi tubes, positive displacement meters, rotameters, target meters, thermal-loss meters (also known as heat-loss meters), turbine meters, ultrasonic flowmeters, venturi tubes, vortex flowmeters, and wedge elements.

Use an orifice plate for most flow measurement applications unless a different type of flow element, such as a flow nozzle or a pitot tube, offers specific advantages. Reasons for using flow elements other than orifice plates include higher accuracy, shorter meter run, lower pressure drop and large line size.

5-2.7.1 Meter Runs.

Flow disturbances as much as 100 pipe diameters upstream of the flow measuring element can affect the accuracy of the flow measurement. Meter run requirements, including pressure tap locations, depend on a number of items. These include type of flow element, beta ratio, and flow disturbances upstream and downstream of the flow element. Flow disturbances result from valves, elbows, enlargers, reducers, and other pipe fittings.

5-2.7.1.1 Requirements.

Obtain complete meter run requirements from the flow measuring device manufacturer to insure accurate measurements. This includes pressure tap locations and other details such as pressure tap size.

5-2.7.1.2 Fabrication.

Do not fabricate meter runs in the field. Fabricate them in a shop qualified in that type of work. Include in the shop fabricated meter run at least 10 pipe diameters of upstream piping and 5 pipe diameters of downstream piping. Straight runs of piping required in addition to the above can be fabricated in the field.

5-2.7.2 Orifice Plates.

Orifice plate types include concentric and eccentric, square edge, quadrant edge, segmental and annular. In general, use concentric, square-edge orifice plates except for the following.

- Use quadrant edge for orifice plates with a Reynolds number of less than 10,000 (based on pipe diameter).
- Do not use concentric orifice plates for horizontal runs flowing wet steam or gas, liquids containing solids, or liquids containing gas or vapor. All of the above will result in inaccurate measurements.
- Solids in the liquid can settle out upstream of the orifice plate. As a first solution use a concentric, square-edge orifice plate but locate it in a vertical run with flow in the downward direction. If locating the orifice plate in a horizontal run cannot be avoided then use a segmental or eccentric orifice plate.
- Use a concentric, square-edge orifice plate located in a vertical run with flow in the upward direction for liquids containing gas or vapor. Use a segmental or eccentric orifice plate with the opening at the top if locating the orifice plate in a horizontal run cannot be avoided.

5-2.7.2.2 Design.

Orifice plates must be a minimum diameter of 5 centimeters (2 inches). Do not use an orifice bore diameter of less than 13 millimeters (½ -inch) due to the possibility of plugging. Do not locate orifices where a liquid is subject to flashing.

Select the orifice plate maximum design flow and meter differential to give a scale reading of approximately 70 percent at normal flow. Use a meter differential of 2.5 meters (100 inches) of water unless not practical.

The orifice plate beta ratio must be between 0.25 and 0.70 and preferably between 0.4 and 0.6. The beta ratio must never be less than 0.20. Do not exceed a beta ratio of 0.70 for gases or steam and 0.75 for liquids.

5-2.7.2.3 Mounting.

Mount the transmitter near the orifice flanges. Use flange taps whenever practical. Specify orifice flange and taps in accordance with ASME B16.36, *Orifice Flanges*. Flange taps are well suited for pipe sizes of 5 centimeters (2 inches) and larger. Provide meter taps at the top of the flange for gas service in horizontal lines. Provide meter taps on the sides of the flange for steam, vapor and liquid service in horizontal lines. Mount the meter below the orifice taps for liquid and steam service and above the orifice taps for gas service. Provide a separate three-valve type manifold for each meter. Provide condensate traps for both the high and low pressure sensing lines for steam and condensate service lines.

5-2.7.2.4 Construction.

Use 304SS material as a minimum for the orifice plate. Provide an identification tab projecting beyond the orifice flange. Show the following minimum information on the tab.

- Actual measured orifice bore
- Pipe inside diameter
- Orifice plate material
- Orifice plate orientation to flow
- Type of fluid

5-2.7.3 Positive Displacement Meters.

Furnish a removable strainer installed upstream of the displacement meter.

5-2.7.4 Turbine Meters.

Refer to ISA-RP31.1, *Specification, Installation, and Calibration of Turbine Flowmeters* for additional information on turbine meters.

5-2.8 Temperature Measurements.

Temperature instruments include thermocouples, resistance-temperature detectors (RTDs), filled bulb systems, and bimetallic thermometers.

5-2.8.1 Thermowells.

Thermowells are used to protect the temperature element from the environment and for personnel protection. Thermowell design varies depending on the application. Items affecting design include temperature, pressure, type of fluid and fluid velocity. In general, thermowells can be classified into two types. These are pressure service and non-pressure service. Thermowells used in non-pressure service are commonly referred to as protective tubes.

Provide thermowells for all temperature elements in pressure service. Use 304 SS material as a minimum. Use the material best suited for the application of protective tubes.

5-2.8.2 Thermocouples.

In general, use the following thermocouples for the different temperature ranges:

- Type T, Copper constantan -- Below –17.8 to 371 degrees C (0 to 700 degrees F)

- Type J, Iron constantan ---17.78 to 593 degrees C (0 to1,100 degrees F)
- Type K, Chromel alumel -- 315 to 1093 degrees C (600 to 2,000 degrees F)

Thermocouple assemblies can be single (one thermocouple) or duplex (two thermocouples). Provide duplex thermocouples for all temperature control loops. Use one thermocouple for control and the other for indication. Thermocouple and thermocouple extension wire specifications are defined in NEMA WC 57, *Standard for Control, Thermocouple Extension, and Instrumentation Cables*.

5-2.8.3 Resistance-Temperature Detectors.

Resistance-temperature detectors (RTDs) are used where accurate temperature or temperature difference measurements are required.

5-2.8.4 Filled Bulb Systems.

Filled bulb systems are used for local temperature indicators and controllers in services where the fluid temperature is below 427 degrees C (800 degrees F). Mercury filled bulb systems are not allowed. Provide armored capillary tubing for all filled bulb systems. Limit capillary length to 15 meters (50 feet) maximum. In all cases provide a thermowell where the filled bulb system is used in pressure service.

5-2.8.5 Bimetallic Thermometers.

Bimetallic thermometers are mostly dial type thermometers used for local temperature indication. In all cases provide a thermowell where the bimetallic thermometer is used in pressure service.

5-2.9 Pressure Measurements.

Pressure instruments include gauges, switches, and transmitters. In general pressure gauges use bourdon tubes to measure pressure greater than 1.0 bar (15 psig), and bellows to measure pressure less than 1.0 bar (15 psig) or differential pressure. Transmitters and switches use diaphragms to measure pressure. Use pulsation dampeners where required.

5-2.9.1 Gauges.

Provide blowout discs for pressure gauges in services with pressures greater than 1.0 bar (15 psig). Provide a safety wall between the dial and the bourdon for service pressures above 68.9 bar (1000 psig). Provide pigtail siphons for all gauges in steam service. Pigtail siphons should be installed perpendicular to the gauge. Provide pulsation dampers and diaphragm seals where required by service conditions and for all gauges in steam and condensate service. Provide a gauge isolation valve for each gauge.

Pressure gauges are usually direct connected and field mounted. The size and range is specified by the user. Locate local gauges so that they are visible from the operating area and are readable from grade or a platform. Local mounted gauges give a “backup” reading and also help operators in determining if equipment or pressure systems are working satisfactorily. Pressure gauges should conform to ASME B40.100, *Pressure Gauges and Gauge Attachments*.

5-2.9.2 Switches.

Pressure switches are used for monitoring alarm conditions and providing safety shutdowns. They are typically mounted directly to the process pipe.

5-2.9.3 Transmitters.

Pressure transmitters convert the measured pressure to an analog or digital signal that is monitored by the control system (e.g. PLC). Provide a three-valve manifold to accomplish block, drain, and test functions for all pressure transmitters. Provide a five-valve manifold to accomplish block, equalize, drain, and test functions for all differential-pressure transmitters. Refer to paragraph 5-2.10 for additional transmitter requirements.

5-2.9.4 Draft.

Pressure instruments for the measurement of draft in furnaces require careful attention as to range and sizing. Note that the draft in a balanced draft boiler furnace is slightly negative, around -2.54 millimeter (-0.1 inch) WC, at the top of the furnace. Too wide an instrument range will result in the loss of accuracy. Too narrow a range will not cover all operating conditions.

Verify that the connections and sensing lines are adequately sized for the low negative pressures. Use larger sizes than for lines sensing positive and high pressures.

5-2.10 Electronic Transmitters.

Electronic transmitters are used to transmit an electronic signal from a local measuring device to a remotely located device such as a panel mounted controller. Typical transmitters include flow, level, pressure and flue gas oxygen. A typical electronic signal is 4-20 mA DC.

Use stainless steel material for all transmitter components in contact with the stream. Provide local indicators for all electronic transmitters. Locate the local indicator at the transmitter for non-controlling loops such as a signal to an indicator. Locate the local indicator at the controlling device for controlling loops such as diaphragm-operated valves. Provide an integrally mounted junction box with a metal cover and a terminal block for blind electronic transmitters to allow for the connection of a plug-in ammeter.

Electronic transmitters with internal microprocessors are known as “smart transmitters”. These transmitters provide on-board sensor linearization, data correction coefficients, measurement ranging, system diagnostics, and instrument configuration. These transmitters communicate to the control system via a communication bus (e.g. HART or Fieldbus).

5-2.11 Electrical Instrument Switches.

Typical applications for electrical instrument switches are alarms and shutdowns. Contacts must open to alarm or shut down for fail safe operation. Provide switches that are suited for the environment. Provide switches that are dust tight and vibration proof for all locations. Provide NEMA 4 rated switches for outdoor locations with non-corrosive atmospheres and NEMA 4X rated switches for corrosive atmospheres. Provide SPDT contacts as a minimum.

5-2.12 Analyzers.

Include all analyzers necessary to meet federal, state, and local environmental monitoring requirements. Analyzers used in a boiler plant include the following:

- In-line
- Sample diverted from the stream to the analyzer and then returned to the stream
- Sample diverted from the stream to the analyzer and then discharged to the atmosphere or a drain.

5-2.12.1 General Guidelines.

Use in-line analyzers where practical. As a second choice use an analyzer where the sample is diverted to the analyzer and then returned to the stream. Use an analyzer where the sample is discharged to the atmosphere or drain as a last choice. Provide a relatively constant differential pressure device, such as a pump, as a bypass to divert a sample that is to be returned to the stream. Do not bypass around a control valve.

5-2.12.1.1 Calibration.

Where practical use a self-calibrating analyzer that provides zero and full span in the range in which the analyzer will be operating. Provide automatic calibration at power-up, at manual command, and at preprogrammed intervals.

5-2.12.1.2 Application.

When to use analyzers and what type of analyzer to use depends upon environmental and value engineering concerns for a given boiler size. These issues are discussed in paragraph 6-4. Analyzers should be used for trim or alarms. Avoid using analyzers as a sole means of control or shutdown.

5-2.12.1.3 Packaging.

It is possible to obtain multiple analyzers packaged in one system. For example, flue gas analyzers are available that combine oxygen, combustibles and methane measurement in one package. This packaging concept would reduce installation complexity and may provide cost savings.

When practical obtain the analyzer from the manufacturer completely packaged in a housing, wired, piped and with the sample system installed. Specify the analyzer to be free standing unless it is mounted on the equipment.

5-2.12.2 Oxygen Analyzer.

Oxygen analyzers in a boiler plant are used for oxygen measurement to provide an indication of excess air in the flue gas. Use the analyzer for alarms and trim. Do not use it as the sole instrument for the control of combustion air.

Probe location is not critical for forced draft type or pressurized boilers since leakage is flue gas out of the boiler. Probe location is critical, however, for balanced draft boilers (which have induced draft fans), since leakage is typically tramp air into the boiler from flue ductwork. Locate the oxygen probe so as to keep the effect of tramp air on the oxygen reading at a minimum. This usually entails locating the probe as close to the furnace as practical.

5-2.12.3 Combustibles Analyzer.

Combustibles analyzers in a boiler plant are used for carbon monoxide measurement, hydrogen measurement or both to provide an indication of incomplete combustion in the flue gas. Use the analyzer for alarms and trim. Do not use it as the sole instrument for the control of combustion air.

5-2.12.3.1 Carbon Monoxide Analyzer.

Carbon monoxide (CO) analyzers used in a boiler plant may utilize a catalytic element, wet electrochemical cell, or non-dispersive infrared absorption.

Install the CO analyzer in a clean gas stream that is downstream of the particulate removal system.

A CO analyzer permits firing at lower oxygen levels than without it. A minimum air requirement is established by decreasing oxygen in the stack gas until a large increase in the CO reading occurs. A CO analyzer is also useful in boiler start-up. During start-up monitor the CO analyzer closely for unsafe firing conditions. High CO readings indicate incomplete combustion, which implies potentially unsafe conditions in the furnace.

5-2.12.3.2 Hydrogen Analyzer.

Hydrogen (H_2) analyzers used in a boiler plant are on line monitors that employ a catalytic element.

Like the CO analyzer, a H_2 analyzer permits firing at lower oxygen levels than without it. A minimum air requirement is established by decreasing oxygen in the stack gas until a large increase in the H_2 reading occurs. A H_2 analyzer is also useful in boiler start-up. During start-up monitor the H_2 analyzer closely for unsafe firing conditions. High H_2 readings indicate incomplete combustion, which implies potentially unsafe conditions in the furnace.

5-2.12.4 Stack Opacity Analyzer.

Stack opacity analyzers are used in a boiler plant to monitor particulate emissions. Their main use is in coal and heavy oil fired boilers. Stack opacity monitors are generally not required for gas fired boilers; however, state and federal regulations should be consulted. Also, most large boilers are dual fuel which may be a combination of gas and oil.

5-2.12.5 Conductivity Analyzer.

Conductivity analyzers are used in boiler plants to monitor dissolved solids in the boiler drum. Use a conductivity analyzer for adjusting boiler blowdown. Do not use it as the sole device for boiler blowdown control.

5-2.12.6 Methane Analyzer.

Methane analyzers in a boiler plant are used for methane measurement to provide an indication of a completed purge cycle prior to boiler ignition or during boiler shutdown. Note that this analyzer must be used in conjunction with and not as a substitute for the minimum purge time requirements stated in the applicable codes.

5-2.13 Flame Detectors.

Provide the flame detector best suited for the fuel and flame. For gas fired boilers always use an ultraviolet (UV) self-checking flame scanner.

Do not use a flame detector that is activated by hot refractory.

Provide a separate flame detector for each burner. Locate the flame detector so that it will be activated only by its own burner and not by an adjacent burner or hot refractory.

5-2.14 Continuous Emission Monitoring (CEM).

Provide all necessary equipment to meet federal, state, and local environmental analysis and documentation requirements.

CHAPTER 6 RECOMMENDED BOILER INSTRUMENTATION

6-1 BOILER CONTROL PANEL INDICATORS AND TOTALIZERS.

The instrumentation in Table 6-1 represents the minimum recommended requirements for a boiler plant. This instrumentation selection is based primarily on boiler operation safety concerns. Refer to NFPA 85 *Boilers and Combustion Systems Hazards Code* for further instrumentation concerns for boiler plants in the 13.18 gigajoule/h (12,500,000 Btu/h) or above range and ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers* for boiler plants below 13.18 gigajoule/h (12,500,000 Btu/h). The indicators can be either dedicated or shared devices. Totalizers must be dedicated devices. Shared device selection may be either by means of pushbuttons, a selector switch, or by entering commands on a keyboard. Provide the following in the display of information associated with a shared device:

- Name of process variable
- Instrument number
- Units
- Process variable value

Store the process data in a storage device such as a computer disk or non-volatile memory. Label the data storage as to process variable, instrument number, date, time, and units. The time label must include hours, minutes, and seconds. Store the data so that it can be retrieved selectively. In selective retrieval as a minimum include the name of process variable, instrument number, date and desired time interval. Include maximum and minimum points and alarms with the data to be recorded. Provide a dedicated printer or printer/plotter on which the recorded and totalized data can be presented on paper on demand. Data storage, retrieval, and printing must meet federal, state, and local environmental documentation requirements.

6-2 BOILER CONTROL PANEL ALARMS AND SHUTDOWNS.

The alarms and shutdowns in Table 6-2 represents the minimum recommended requirements for a boiler plant. These were selected based primarily on boiler operation safety concerns. Refer to NFPA 85 *Boiler and Combustion Systems Hazards Code* for further information for boiler plants in the 13.18 gigajoule/h (12,500,000 Btu/h) or above range and ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers* for boiler plants below 13.18 gigajoule/h (12,500,000 Btu/h). Provide a separate window in an annunciator system for each dedicated alarm. Provide a dedicated common trouble alarm window to which the non-dedicated alarms are wired. Include a first-out listing to show which device connected to the common trouble alarm tripped first. Provide instrumentation to show which device shut the equipment down first during a system shutdown. Refer also to paragraphs 3-5 and 4-2.6.

6-3 BOILER CONTROL PANEL CONTROLLERS.

Provide controllers as required for the proper operation of the boiler plant. Controllers required for a typical boiler plant include steam header pressure (plant master and boiler master), boiler drum water level (feedwater flow), fuel flow, and combustion air flow and boiler furnace draft.

6-4 VALUE ENGINEERING.

There are many cost tradeoffs associated with the design of a boiler. The use of an oxygen trim system is one example. The installation of an oxygen trim system in a boiler design will provide fuel savings. The analyzer that provides this function, however, is costly to buy and maintain. Therefore, oxygen trim systems should only be used on large boilers where the cost of fuel savings outweighs the cost of the analyzer.

Table 6-1 Boiler Control Panel Indicators, Recorders and Totalizers

(X shows instrumentation item required)

INSTRUMENT	INDICATOR	TRENDING	TOTALIZER
Levels			
Boiler drum water 1	X	X	
Flows			
Boiler steam 1	X	X	X
Boiler feedwater 1	X	X	X
Combustion air 1	X	X	
Fuel gas 1	X	X	X
Fuel oil 1	X	X	X
Pressures			
Boiler steam drum	X		
Steam outlet header	X	X	
Boiler feedwater	X		
FD fan outlet	X		
Pilot gas	X		
Fuel gas	X		
Fuel oil	X		
Atomizing steam	X		
Draft			
Boiler furnace	X	X	
ID fan inlet	X		
Differential pressures			
Air preheater air	X		
Air preheater flue	X		
Temperatures			
Steam			
Steam drum	X		
Superheater inlet	X	X	
Superheater outlet	X	X	
Steam header	X	X	
Feedwater			
Supply header	X	X	
Economizer inlet	X	X	

Economizer outlet	X	X	
INSTRUMENT	**INDICATOR**	**TRENDING**	**TOTALIZER**
Fuel oil	X	X	
Combustion air			
Air preheater inlet	X	X	
Air preheater outlet	X	X	
Flue gas			
Superheater outlet	X		
Boiler outlet	X		
Economizer inlet	X	X	
Economizer outlet	X	X	
Air preheater inlet	X	X	
Air preheater outlet	X	X	
ID fan inlet	X	X	
Flue gas stack	X	X	
Viscosity			
Fuel oil	X	X	
Flue gas oxygen [1]	X	X	
Stack opacity [1]	X	X	
Current in amps			
ID fan	X		
FD fan	X		

1. These records shall be maintained separately and not shared in storage.

Table 6-2 Boiler Control Panel Alarms and Shutdowns
(X shows instrumentation item required)

INSTRUMENT	ALARMS	SHUTDOWNS
Levels		
Boiler drum water		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Flows		
Combustion air		
Low	X	
Low-low	X	X
Pressures		
Boiler feedwater header		
Low	X	
Boiler steam drum		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Steam header		
Low	X	
High	X	
Pilot gas		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Fuel gas		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Fuel oil		
Low	X	
Low-low	X	X
High	X	
High-high	X	X

INSTRUMENT	ALARMS	SHUTDOWNS
Atomizing steam		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Atomizing air		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Instrument air		
Low	X	
Low-low	X	X
Scanner air		
Low	X	
Boiler furnace	X	
High	X	
High-high	X	X
Draft		
Boiler furnace		
High	X	
High-high	X	X
Differential pressure		
Atomizing steam to oil		
Low	X	
Low-low	X	X
Temperatures		
Boiler feedwater		
Low	X	
Fuel oil		
Low	X	
Low-low	X	X
High	X	
High-high	X	X
Flue gas		
Economizer outlet		
Low	X	
High	X	

INSTRUMENT	ALARMS	SHUTDOWNS
Stack	X	
High	X	
High-high	X	X
Fan bearings		
High [1]	X	
Boiler water solids		
High	X	
Oxygen		
Low	X	
High	X	
Smoke		
High	X	
Flame scanner failure	X	X
Failure to establish flame	X	X
Flame failure	X	X
Burner valves not closed		
Following trip	X	X
Equipment failure		
FD fan	X	X
ID fan	X	X
Oxygen analyzer	X	
Power failure		
Control	X	X
Equipment	X	X
Boiler shutdown		
Automatic	X	X
Manual	X	X

[1] Provide one thermocouple at each bearing.

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CHAPTER 7 CONTROL SCHEMES

7-1 GENERAL.

Provide controls in accordance with applicable codes. Refer to paragraph 3-14 for applicable codes. The codes take precedence over the control requirements shown in this UFC.

7-2 CONTROL LOOPS.

A control loop consists of all components necessary to control a process variable to maintain its setpoint. Typical process variables for boilers are pressure, temperature, flow, and liquid level.

Control loops have three main components which are a sensor(s), a controller, and a final control element. The sensor is made up of a sensing element and transmitter. The controller monitors the sensor transmissions and transmits a control signal based on the sensor values and setpoint. The final control element receives the control signal and modulates a process value.

7-2.1 Pressure.

Pressure control loops may be used for the control of boiler drum pressure or fuel oil pressure. For the control of boiler pressure, the final control element regulates fuel flow to the boiler in response to boiler steam pressure. For the control of fuel oil pressure, the final control element is usually a pressure reducing control valve that regulates in response to downstream pressure. A typical pressure control loop is shown in Figure 7-1.

7-2.2 Temperature.

Temperature control loops may be used for the control of steam temperature from boilers or fuel oil temperature from fuel oil heaters. A typical temperature control loop is shown in Figure 7-2.

7-2.3 Liquid Level.

Liquid level control loops may be used for the control of boiler drum water level. A typical liquid level control loop is shown in Figure 7-3.

7-2.4 Flow.

Flow control loops may be used for the control of fuel flow into the boiler burners, burner draft airflow, feed water into a boiler, or steam flow out of a boiler. A typical flow control loop is shown in Figure 7-4.

7-3 AIR TO FUEL RATIO.

Furnish controls to automatically provide the proper fuel to air ratio over the entire boiler operating range from maximum turndown to Maximum Continuous Rating (MCR). Provide cross-limited (lead-lag) controls between air and fuel to increase airflow before increasing fuel flow and to decrease fuel flow before decreasing airflow.

7-3.1 Control Type.

Consider full metering controls, which measure directly both airflow and fuel flow, for all boilers with capacities greater than 5.28 gigajoule/h (5,000,000 Btu/h). Consider an oxygen analyzer, for trim only, for all boilers with capacities greater than 25.3 gigajoule/h (24,000,000 Btu/h). Consider CO trim for all boilers with capacities greater than 52.8 gigajoule/h (50,000,000 Btu/h), especially coal fired boilers. Evaluate the energy savings of these measures and provide all those that are life cycle cost effective per UFC 3-401-01, Mechanical Engineering. A typical cross-limited (lead-lag) boiler control system with oxygen trim for a single fuel is shown in Figure 7-5.

7-3.2 Control Configuration.

Configure the controls so that the air to fuel ratio does not have to be manually reset or reprogrammed when switching from one fuel to another or from one combination of fuels to another. Provide an 8-point minimum fuel to air characterization curve for each fuel or combination of fuels. Provide controls so that the air to fuel ratio is automatically adjusted to the proper proportions for all of the following:

- Load change (between minimum firing and MCR)
- Fuel change (either change in fuels or same fuel but different specifications)
- Fuel ratio change (more than one fuel firing)

7-3.3 Fuel Changeover.

Accomplish the switch over from one fuel to another without shutting down the boiler. Configure the controls so that the changeover from one fuel to another can be made by either a selector switch, pushbuttons, or by entering commands on a keyboard.

7-3.4 Simultaneous Fuel Firing.

Provide automatic controls for maintaining the proper fuel ratio and fuel to air ratio to compensate for load changes when firing several fuels at the same time. Do not allow multiple attempts to switch fuels without a full post-purge and pre-purge after each unsuccessful fuel switch attempt.

7-3.5 Alarms.

Furnish alarms to announce the approach of unsafe conditions. Provide shutdowns to shut the equipment down under unsafe conditions.

7-4 BOILER DRUM LEVEL.

Provide controls to always maintain the boiler drum level within the boiler manufacturer's specifications under all operating conditions. Two typical types of control systems used in boiler plants are single element control and three element control based. Two element control based systems are available but are not permitted. Two element control is not needed for steady loads and they are not adequate enough for most variable loads.

7-4.1 Single Element Control.

A single element control system, Figure 7-6, utilizes just a level transmitter to maintain control of the boiler drum water level. Use a single element control system only for boilers operating at steady loads.

7-4.2 Two Element Control (Not Permitted).

Two Element Control is not permitted. A two element control system, Figure 7-7, utilizes a level transmitter and the amount of steam flow from the boiler to maintain control of the boiler drum water level. A two element control system provides some compensation for variable loads. It does not adequately correct for the expansion of water within a boiler due to the decreased boiler pressure that occurs when a large amount of steam is required or the contraction of heated water in a boiler due to the addition of cold feedwater.

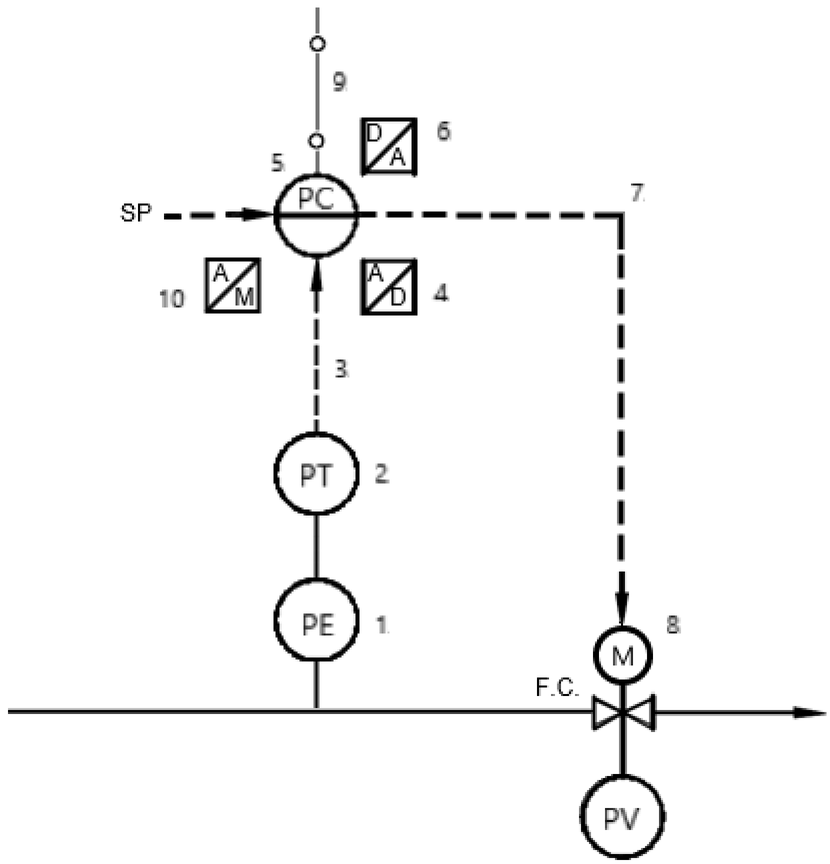
7-4.3 Three Element Control.

A three element control system, Figure 7-8, utilizes a level transmitter, the amount of steam flow from the boiler and the amount of water into the boiler to maintain control of the boiler drum water level. Note that although not shown, the steam flow from the boiler is usually compensated for pressure and temperature. A three element control system corrects the problems associated with a two element control system and provides the best method of compensating for variable loads.

7-5 MULTIPLE BOILERS.

The output of multiple boilers is accomplished by routing the steam from each individual boiler into a common plant output header. The pressure measured at this plant output header will be fed back into each individual boiler control loop. Control is maintained by the plant master cascading the output of the boiler masters to achieve the desired steam output. A typical multiple boiler control loop is shown in Figure 7-9. Dual Pressure Indicating Transmitters (PIT) are shown feeding their output signals into a High Signal Selector. This redundancy may be provided for plants with three or more boilers to allow continued plant operations during maintenance or failure of one PIT.

Figure 7-1 Typical Pressure Control Loop

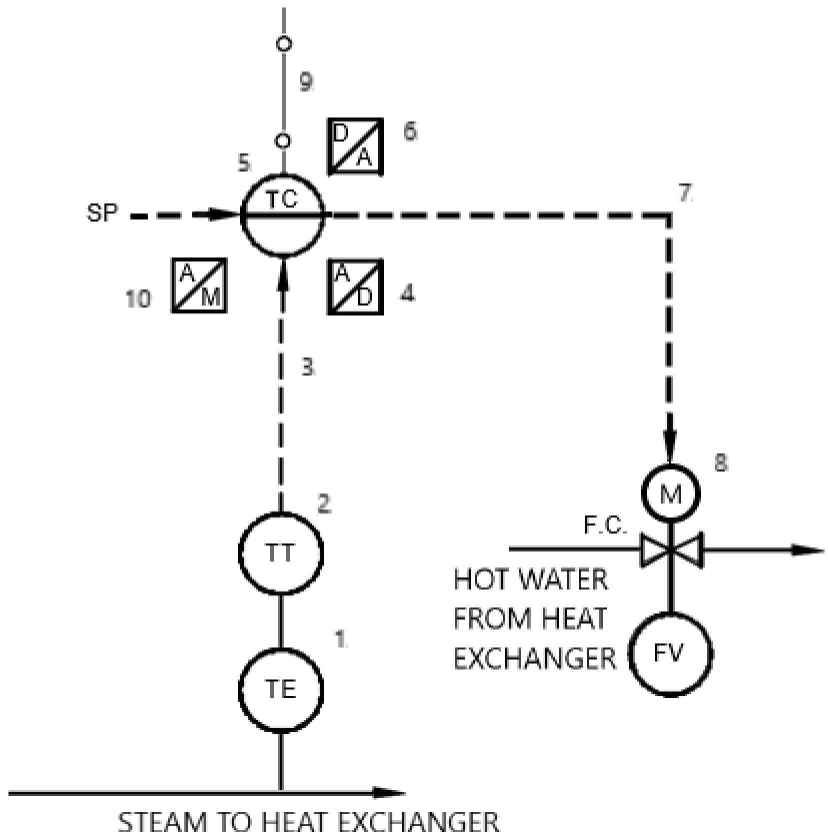


LEGEND:

1. PRESSURE ELEMENT
2. PRESSURE TRANSMITTER
3. 4-20 mA SENSOR SIGNAL
4. ANALOG TO DIGITAL CONVERTER
5. PRESSURE CONTROLLER
6. DIGITAL TO ANALOG CONVERTER
7. 4-20 mA CONTROL SIGNAL
8. PRESSURE VALVE, FAIL CLOSE
9. DATA BUS
10. AUTOMATIC-MANUAL FUNCTION

SYMBOLS PER ANSI/ISA-S5.1

Figure 7-2 Typical Temperature Control Loop

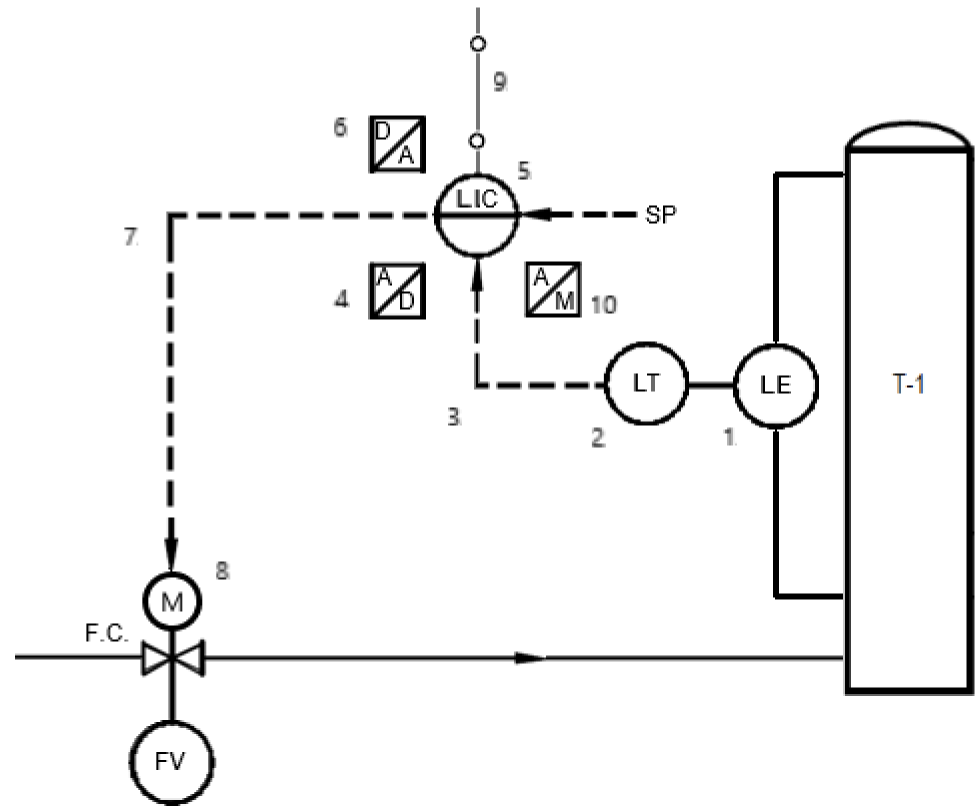


LEGEND:

1. TEMPERATURE ELEMENT
2. TEMPERATURE TRANSMITTER
3. 4-20 mA SENSOR SIGNAL
4. ANALOG TO DIGITAL CONVERTER
5. TEMPERATURE CONTROLLER
6. DIGITAL TO ANALOG CONVERTER
7. 4-20 mA CONTROL SIGNAL
8. FLOW VALVE, FAIL CLOSE
9. DATA BUS
10. AUTOMATIC-MANUAL FUNCTION

SYMBOLS PER ANSI/ISA-S5.1

Figure 7-3 Typical Level Control Loop

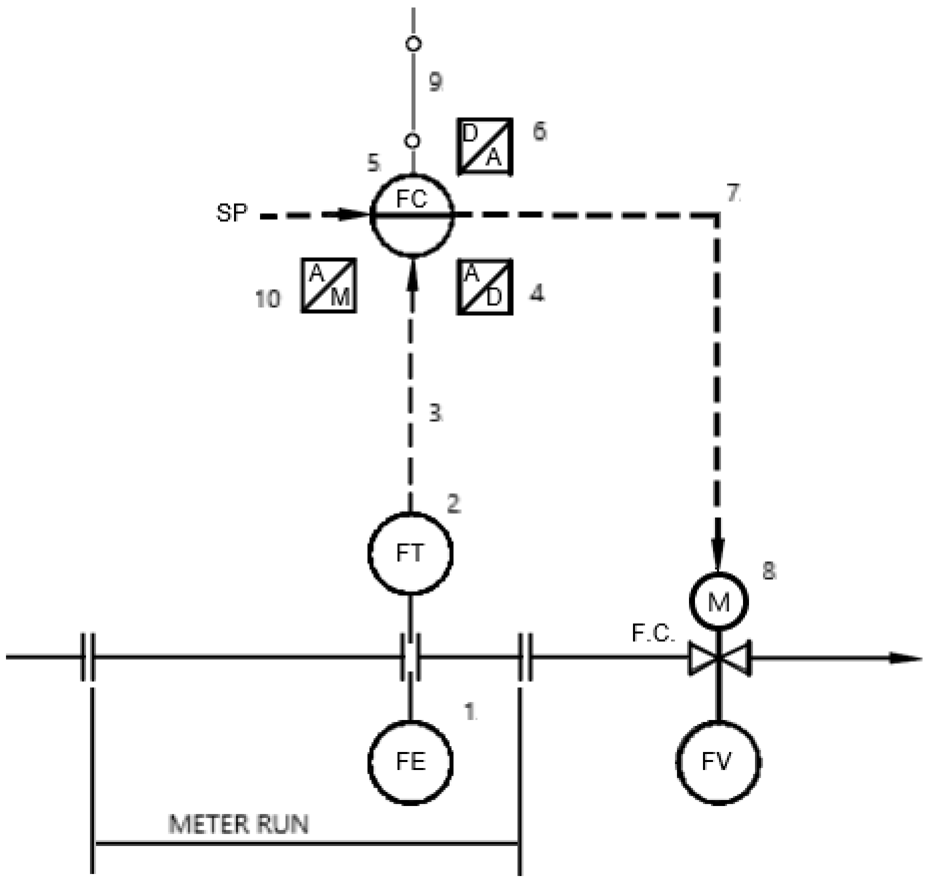


LEGEND:

1. LEVEL ELEMENT
2. LEVEL TRANSMITTER
3. 4-20 mA SENSOR SIGNAL
4. ANALOG TO DIGITAL CONVERTER
5. LEVEL INDICATING CONTROLLER
6. DIGITAL TO ANALOG CONVERTER
7. 4-20 mA CONTROL SIGNAL
8. FLOW VALVE, FAIL CLOSE
9. DATA BUS
10. AUTOMATIC-MANUAL FUNCTION

SYMBOLS PER ANSI/ISA-S5.1

Figure 7-4 Typical Flow Control Loop



LEGEND:

1. FLOW ELEMENT
2. FLOW TRANSMITTER
3. 4-20 mA SENSOR SIGNAL
4. ANALOG TO DIGITAL CONVERTER
5. FLOW CONTROLLER
6. DIGITAL TO ANALOG CONVERTER
7. 4-20 mA CONTROL SIGNAL
8. FLOW VALVE, FAIL CLOSE
9. DATA BUS
10. AUTOMATIC-MANUAL FUNCTION

SYMBOLS PER ANSI/ISA-S5.1

Figure 7-5 Typical Cross-Limited (Lead-Lag) Boiler Control System for a Single Fuel Using Full Metering with Oxygen Trim

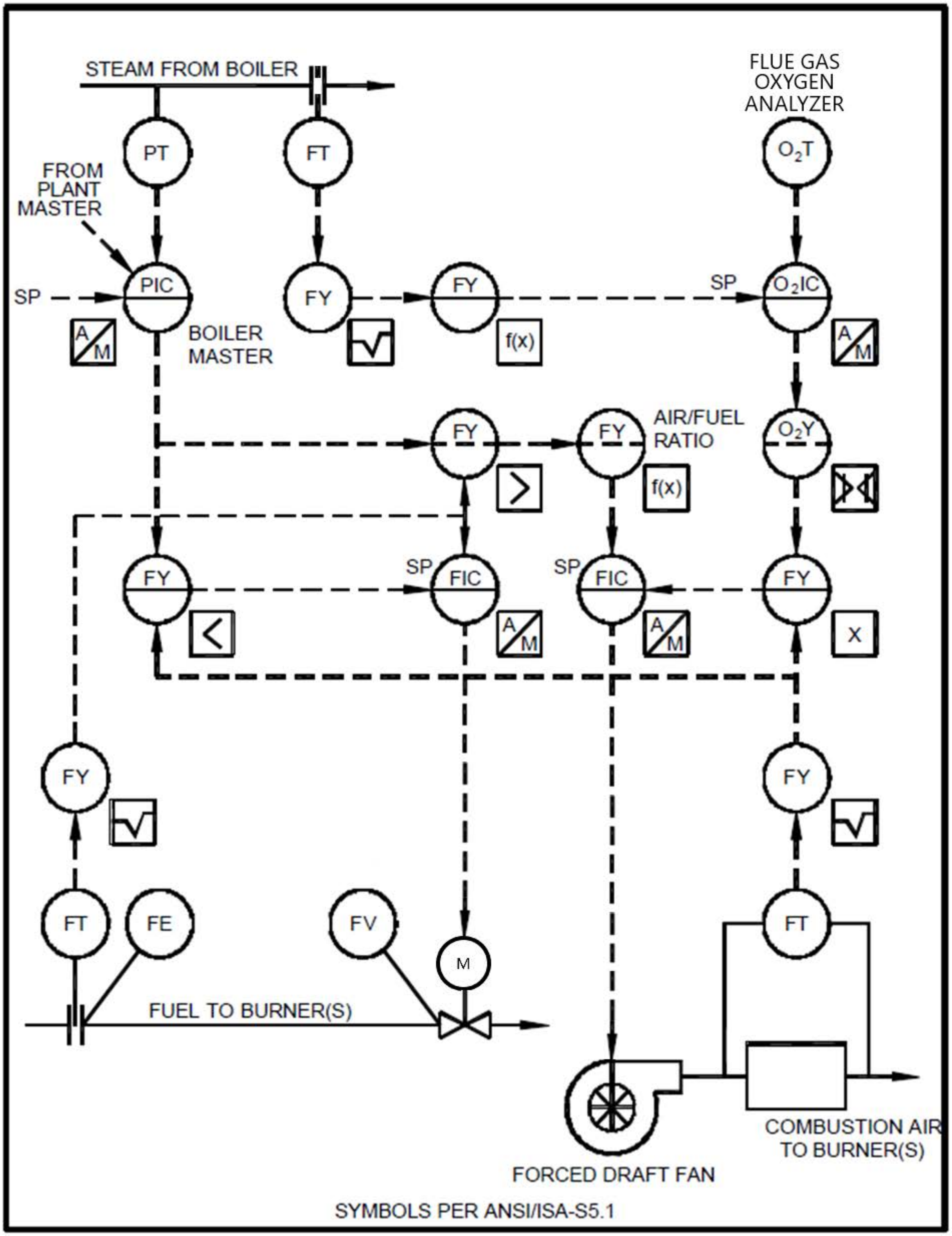


Figure 7-6 Single Element Drum Level Control System

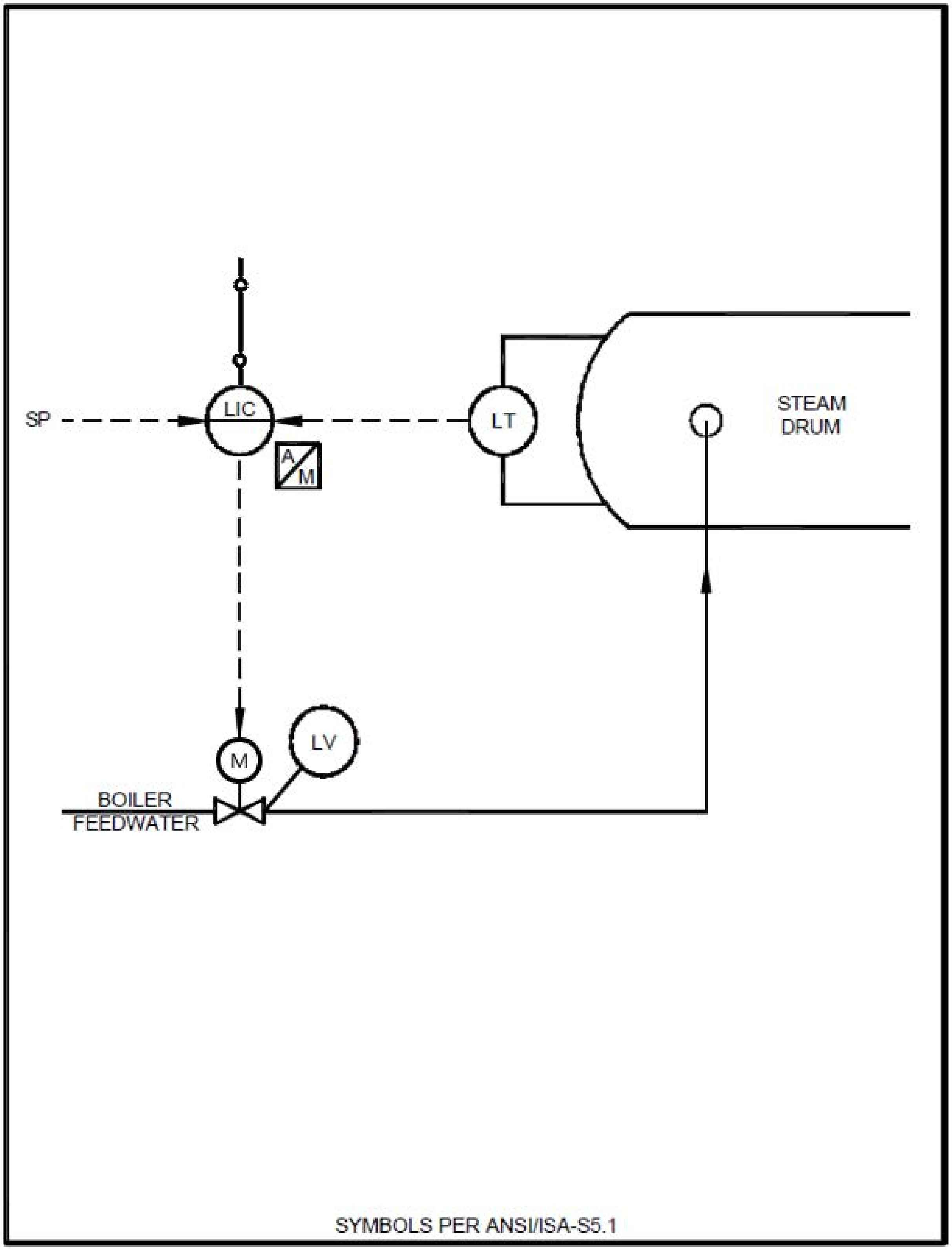


Figure 7-7 Two Element Drum Level Control System (Not Permitted)

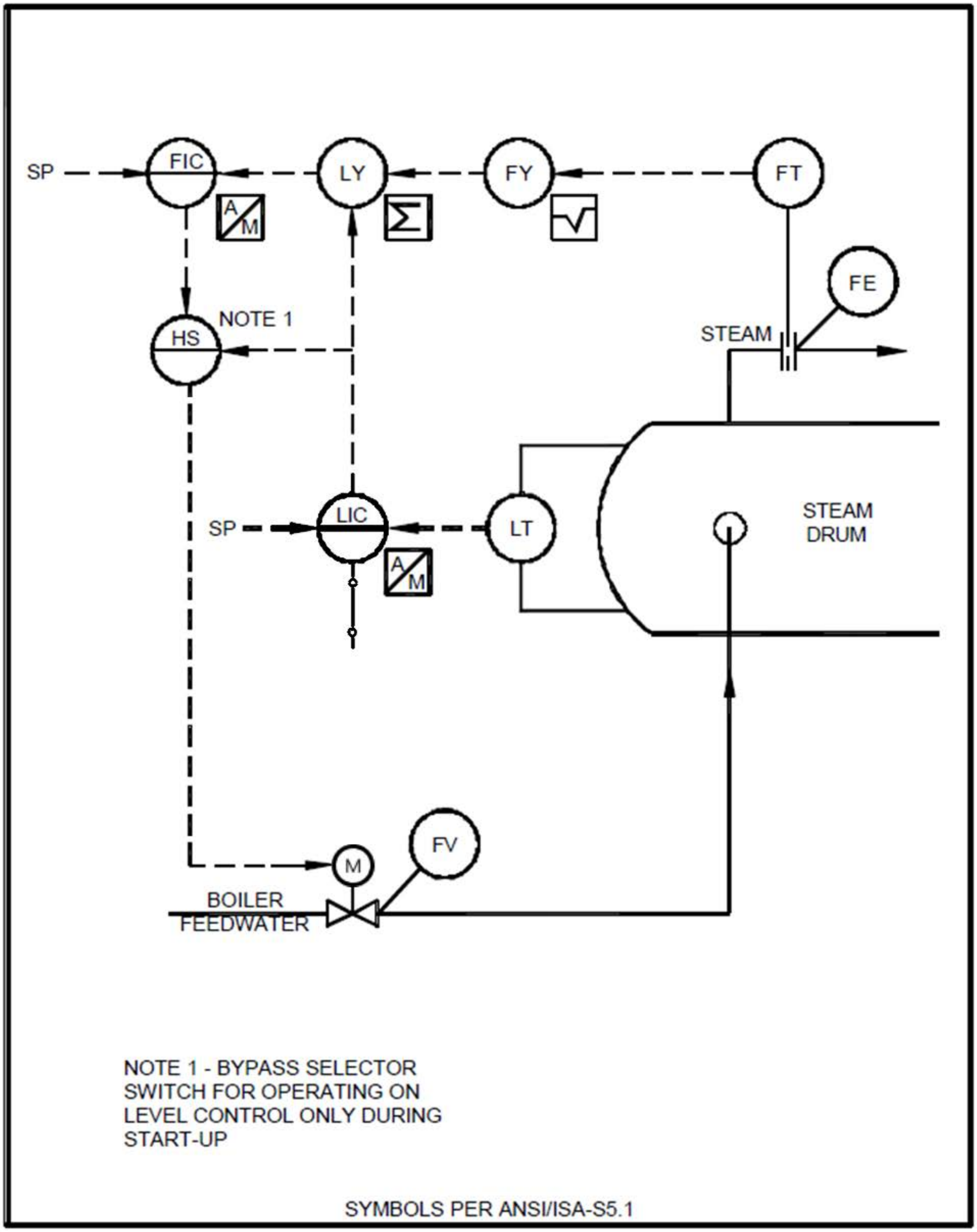


Figure 7-8 Three Element Drum Level Control System

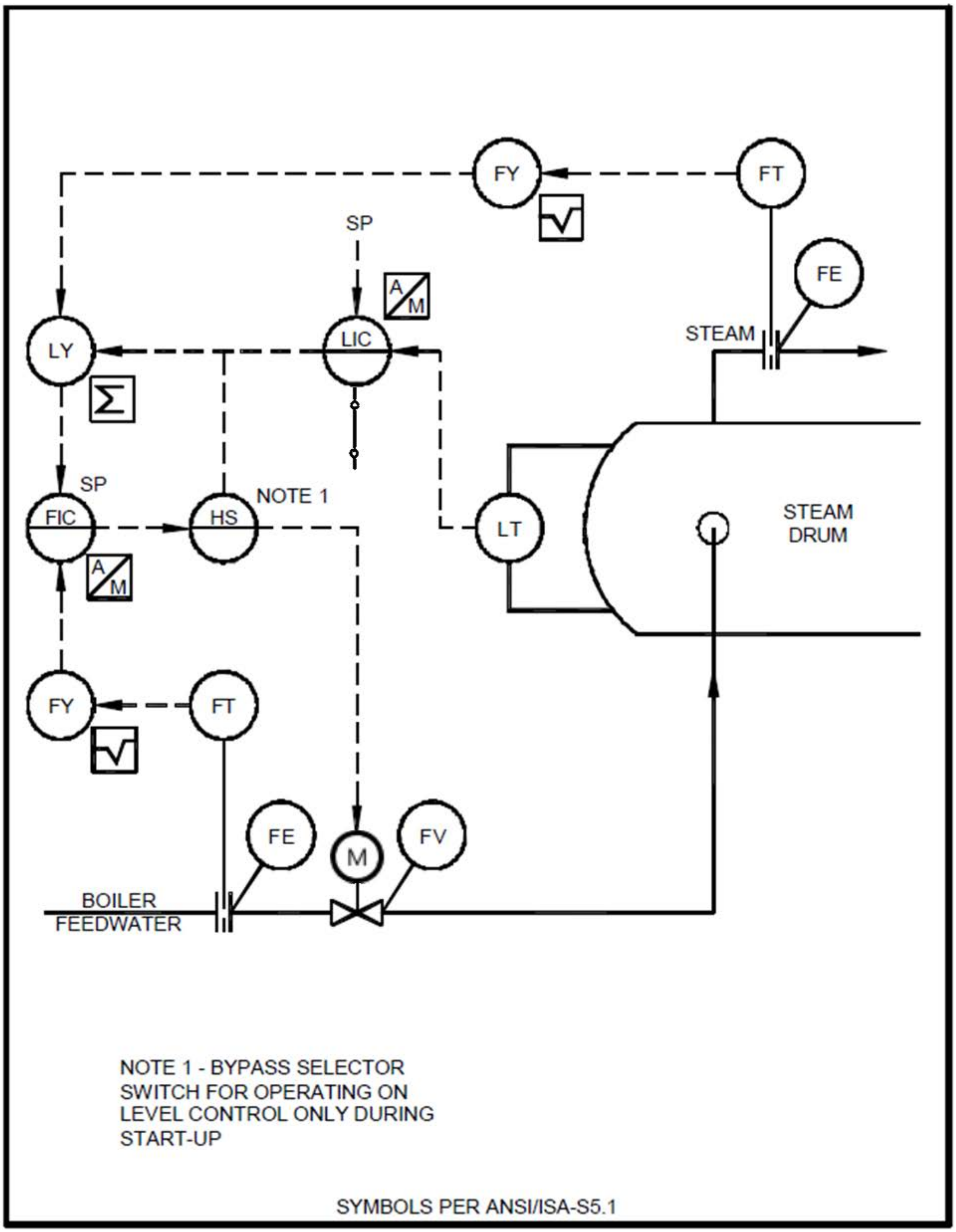
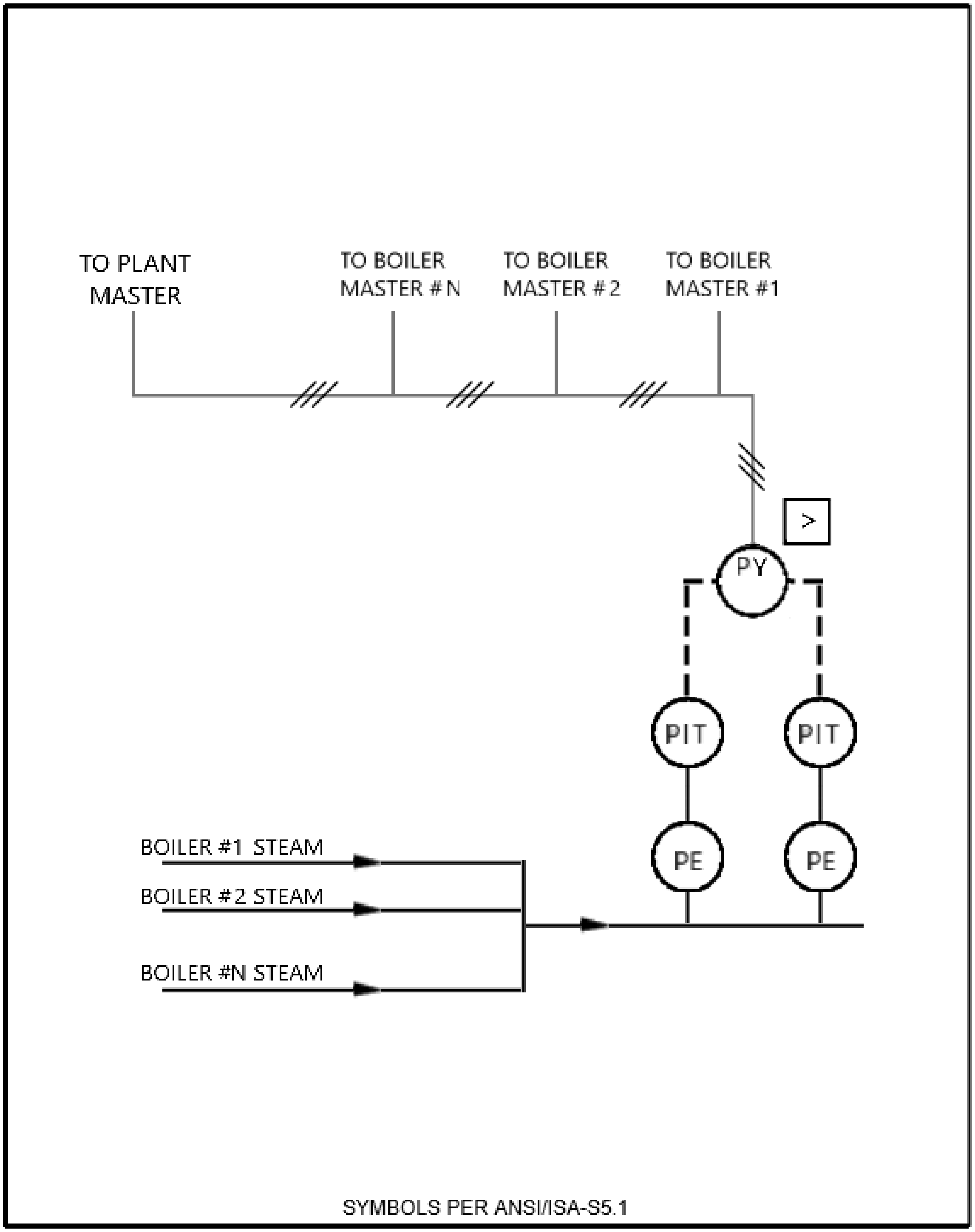


Figure 7-9 Multiple Boiler Control Loop – Plant Master



APPENDIX A GLOSSARY

A-1 ACRONYMS

AC	Alternating Current
AFCEC	Air Force Civil Engineer Center
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BIA	Bilateral Infrastructure Agreement
BPVC	Boiler and Pressure Vessel Code
Btu	British Thermal Unit
C	Celsius
CEM	Continuous Emission Monitoring
CO	Carbon Monoxide
CSD	Controls and Safety Devices
DoD	Department of Defense
DC	Direct Current
DCS	Distributed Control System
DDC	Direct Digital Controller
EIA	Electronic Industries Alliance
EMF	Electric Magnetic Field
EPA	Environmental Protection Agency
F	Fahrenheit
GFI	Ground Fault Interrupt
h	Hour
H2	Hydrogen

HAZOP	Hazardous Operations
HTW	High Temperature Hot Water
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
HVAC	Heating, Ventilation, and Air Conditioning
ICS	Industrial Control and Systems
ISA	Instrument Society of America
LED	Light Emitting Diode
LCD	Liquid Crystal Display
LTW	Low Temperature Hot Water
mA	Milliampere or milliamp
MCR	Maximum Continuous Rating
MTW	Medium Temperature Hot Water
NAVFAC	Naval Facilities Engineering Command
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
RTD	Resistance-Temperature Detector
ODVA	Open DeviceNet Vender Association
PIC	Pressure Indicating Controllers
PIT	Pressure Indicating Transmitters
PLC	Programmable Logic Controller
PSI or PSIG	Pounds per Square Inch, the unit of pressure measurement; gauge pressure above atmospheric
SOFA	Status of Forces Agreements
SPDT	Single Pole Double Throw
TIA	Telecommunication Industries Association

UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
UMCS	Utility Monitoring and Control Systems
UPS	Uninterruptible Power Supply
U.S.	United States
USC	United States Code
UV	Ultraviolet
VAC	Volts of Alternating Current
WC	Water Column (inches wc, millimeter wc)

A-2 DEFINITION OF TERMS

Bumpless Transfer: A transfer from Automatic Mode to Manual Mode or from Manual mode to Automatic Mode that does not interrupt the control loop and controlled process.

Heating Boiler: A boiler rated in accordance with ASME BPVC, Section IV. This is typically a steam boiler for operation at pressures not exceeding 1.0 bar (15 psig) or a hot water boiler for operation at pressures and temperatures, not exceeding 11.0 bar (160 psig) and 120°C (250°F), respectively.

Non-Volatile Data Storage: Storage that does not require power to retain data.

Power Boiler: A boiler rated in accordance with ASME BPVC, Section I. This is typically a steam boiler for operation at pressures exceeding 1.0 bar (15 psig) or a hot water boiler for operation at pressures and/or temperatures, exceeding 11.0 bar (160 psig) and 120°C (250°F), respectively.

APPENDIX B REFERENCES

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME).

ASME Boiler and Pressure Vessel Code, *Section I, Rules for the Construction of Power Boilers and Section IV, Rules for the Construction of Heating Boilers*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

ASME B16.36, *Orifice Flanges*

ASME B31.1, *Power Piping*

B40.100, Pressure Gauges and Gauge Attachments

ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers*

CODE OF FEDERAL REGULATIONS

CFR Title 40, *Protection of Environment*

ELECTRONIC INDUSTRIES ALLIANCE (EIA).

TIA/EIA-485, Characteristics of Generators & Receivers for Use in Balanced Digital Multipoint Systems

ENVIRONMENTAL PROTECTION AGENCY (EPA).

AP-42, *The Compilation of Air Pollutant Emission Factors*

INSTRUMENT SOCIETY OF AMERICA (ISA).

ANSI/ISA S5.1, *Instrumentation Symbols and Identification*

ISA S5.3, *Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems*

ISA S5.4, Instrument Loop Diagrams

ANSI/ISA-18.1, Annunciator Sequences and Specifications

ISA-S20, *Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves*

ISA-RP31.1, *Specification, Installation, and Calibration of Turbine Flowmeters*

ANSI/ISA-50.00.01, *Compatibility of Analog Signals for Electronic Industrial Process Instruments*

ISA-RP55.1, *Hardware Testing of Digital Process Computers*

ISA-RP60.2 *Control Center Design Guide and Terminology*

ISA-RP60.6, *Nameplates, Labels and Tags for Control Centers*

ISA-RP60.8, *Electrical Guide for Control Centers*

ISA-75.11.01, *Inherent Flow Characteristic and Rangeability of Control Valves*

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA).

NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NEMA ICS 1.1, *Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control*

NEMA ICS 2, *Industrial Control and Systems Controllers, Contactors and Overload Relays Rated 600 Volts*

NEMA ICS 6, *Industrial Control and Systems: Enclosures.*

NEMA PE 1, *Uninterruptible Power Systems*

NEMA WC 57, *Standard for Control, Thermocouple Extension, and Instrumentation Cables*

NATIONAL FIRE PROTECTION AGENCY (NFPA).

NFPA 70, *National Electrical Code*

NFPA 85, *Boiler and Combustion Systems Hazards Code*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *DoD Building Code*

UFC 3-410-02*, Direct Digital Control For HVAC And Other Building Control Systems*

UFC 3-470-01, *Utility Monitoring And Control System (UMCS) Front End And Integration*

UFC 4-010-06, *Cybersecurity Of Facility-Related Control Systems*

UNDERWRITER'S LABORATORY

UL 508A STANDARD FOR SAFETY Industrial Control Panels

UFC 3-440-01
01 July 2015

UNIFIED FACILITIES CRITERIA (UFC)

FACILITY-SCALE RENEWABLE ENERGY SYSTEMS

UNIFIED FACILITIES CRITERIA (UFC)

FACILITY-SCALE RENEWABLE ENERGY SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-440-01, dated 14 June 2002 and UFC 3-440-04N, dated 16 January 2004.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *General Building Requirements*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-440-01, *Facility-Scale Renewable Energy Systems*

Superseding: UFC 3-440-01, *Active Solar Preheat Systems* and UFC 3-440-04N, *Solar Heating of Buildings and Domestic Hot Water*

Description: This new UFC 3-440-01 consolidates into one Tri-Service document the renewable energy criteria applicable to solar thermal energy that was in the superseded documents, and new solar photovoltaic electrical energy generation. This UFC applies to facility-scale renewable energy systems and is not intended for utility-scale energy generation.

Reasons for Document:

- To provide unified Department of Defense renewable energy power generation criteria and create more consistency in DoD designs.

Impact:

This uniform effort will result in the more effective use of DoD funds in the following ways:

- Standardized guidance of facility-scaled renewable energy power production planning, design, construction, and operations and maintenance among the Services.
- The consolidation of the UFC 3-440-01 will positively impact the project costs incurred, as a result of the following direct benefits:
    - Reduction in ambiguity and the need for interpretation reduces the potential for design and construction conflicts.
    - The reduction in the number of documents and the use of industry standards improves the ease of updating the revising this reference document as better information becomes available.

Unification Issues:

The Air Force does not allow paralleling facility-level renewable energy systems with any standby power regardless of whether it is for emergency, Critical Operations Power Systems (COPS), or other purposes.

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TABLES

CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE

This UFC is issued to provide guidance for designing and installing facility-scale renewable energy systems. The criteria contained herein are intended to ensure durable, efficient, and reliable systems and installations. Guidelines apply to facility-scale applications. A facility-scale project has the interconnection point at the facility's service entrance equipment and generally provides electricity for the facility. A utility-scale project has the interconnection point directly to the utility distribution grid. Facility-scale projects are typically less than 1 megawatt, and utility-scale projects are usually greater than 1 megawatt. For renewable energy systems designed to generate power on a utility-scale, and privately-financed projects, see UFC 3-540-08 (Draft).

Future revisions of this UFC will address additional renewable energy system technologies and components that can be applied on a facility-scale level, such as geothermal energy, wind energy, and on-site energy storage (batteries). Whenever unique conditions and problems are not specifically covered by this UFC, use the applicable referenced industry standards and other documents for design guidance.

Note that this document does not constitute a detailed technical design, maintenance or operations manual, and is issued as a general guide to the considerations associated with design of economical, efficient and environmentally acceptable facility-scale renewable energy systems.

1-2 ORGANIZATION

This UFC is comprised of three sections. Chapter 1 provides an introduction and a general reference to other documents closely related to the subject. Chapter 2 provides general criteria for the design of solar thermal systems. Chapter 3 provides general criteria for the design of solar photovoltaic power generation systems.

1-3 APPLICABLITY

This UFC applies to all planning, design and construction, renovation, repair, maintenance and operation, and equipment installation in new and existing facilities and installations, regardless of funding source that result in DoD real property assets. The designs developed in this document are targeted for new construction, although most are also appropriate for renovation applications.

1-4 GENERAL BUILDING REQUIREMENTS

Comply with UFC 1-200-01, *General Building Requirements*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

Comply with UFC 3-560-01, *Electrical Safety, O&M*, for electrical safety requirements applicable to the installation and operation of electrical systems.

1-5 LIFE-CYCLE COST ANALYSIS (LCCA)

Provide a Life Cycle Cost Analysis in accordance with UFC 1-200-02, paragraph entitled " LIFE CYCLE COST ANALYSIS (LCCA)".

1-6 AIRSPACE COORDINATION

Comply with UFC 3-260-01 when evaluating renewable power generation systems and equipment to be sited near an airfield or related facilities and equipment used to sustain flight operations. Submit plans to site renewable power generation systems and equipment near an airfield to the airfield manager and safety officer (among other stakeholders) for approval.

1-6.1 Military Training Route and DoD Siting Clearinghouse

The Military Training Route (MTR) program is a joint venture by the Federal Aviation Administration (FAA) and the DoD to develop routes for the purpose of conducting low-altitude, high-speed testing and training activities. Improper site planning can negatively affect the MTR program. Contact the DoD Siting Clearinghouse (http://www.acq.osd.mil/dodsc/) during initial planning, and prior to applying for permits on any federal or non-federal lands, for project site vetting. Provide applicable data items required for the DoD Siting coordination.

1-6.2 FAA Requirements

FAA requires early planning coordination for structures and assessment of glare from solar panels. For structure assessment, complete FAA Form 7460. Glare assessments are covered under FAA interim policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports. This interim policy requires use of the Solar Glare Hazard Analysis Tool (SGHAT). Provide both FAA Form 7460 and SGHAT report to the DoD Siting Clearinghouse.

1-7 CYBERSECURITY

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

1-8 REFERENCES

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-9 BEST PRACTICES

Appendix B contains background information and best practices for accomplishing certain renewable energy design and engineering services.

1-10 GLOSSARY

Appendix C contains acronyms, abbreviations, and terms.

1-11 ADDITIONAL RESOURCES

For additional resources on renewable energy applications and systems, refer to the Whole Building Design Guide (WBDG) Internet site: http://www.wbdg.org/resources/.

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CHAPTER 2 SOLAR THERMAL TECHNICAL REQUIREMENTS

2-1 GENERAL REQUIREMENTS

2-1.1 Economic Feasibility Study

As required in UFC 1-200-02, Section 523 of the Energy Independence and Security Act (EISA) 2007 requires that at least 30% of the domestic hot water demand for each new federal building (or major renovations to existing federal buildings) be met through the use of solar water heating, if life cycle cost-effective.

Perform a life-cycle cost analysis for all new military construction to determine whether the use of renewable forms of energy will result in a net monetary savings to the government. The methodologies and parameters required for Federal energy project feasibility studies are mandated by Federal law (10 CFR 436). Provide a solar thermal energy system when life-cycle cost effective.

2-1.2 Screening Procedures

Perform the initial evaluation for solar hot water system viability. Generate a final report containing at least the solar hot water system size, system cost, annual energy savings, annual cost savings, savings-to-investment ratio (SIR), simple payback, solar fraction, and annual greenhouse gas reduction. See Appendix B for recommended tools.

2-1.3 Detailed Analysis and Study

If the results of the screening procedure indicate that a solar hot water system is a viable consideration, then perform a detailed life-cycle cost analysis (LCCA) to determine the most effective design alternative to develop. Perform LCCA calculations and reports. See Appendix B for recommended tools. Budget constraints, maintenance capabilities of customer, system complexities, and other factors in addition to the LCCA influence the final selected system design.

2-1.4 System Applications

2-1.4.1 Domestic Hot Water

For domestic hot water systems (DHW) without combined space heating, provide lined, insulated, pressurized tanks similar to the conventional water heater. Provide appropriate temperature and pressure relief valves. Provide a tempering or mixing valve. To size the collectors and storage tank it is necessary to estimate or measure the hot water consumption of the facility or building. See Appendix B for recommended estimating tools.

2-1.4.2 Hydronic Space Heating Combined with Domestic Hot Water

Size the collectors and storage tank to provide the greater loads of space heating plus domestic hot water. A heat delivery system is added to the domestic hot water system. Provide an auxiliary heating source to supply heat when the solar system cannot supply sufficient heat. Provide corrosion and freeze protection through the use of a closed collector loop and heat exchanger.

2-1.5 Solar Thermal Basis of Design

At a preliminary design stage equivalent to 35% design, the designer of record must provide a basis of design which covers the general facility design requirements in accordance with UFC 1-200-01 and its referenced documents. In addition to the UFC 3-401-01 requirements for preliminary basis of design and follow-on submittals, provide the following general system specific analysis information:

- Narrative
  - FY Year, Project Number, and project location.
  - Briefly state scope, project description, references, and calculation method used.
  - Geographic and operating environment, including coastal locations/corrosive conditions, humidity, altitude, seismic zones, and ambient temperature extremes.
  - Type of solar energy system (domestic hot water, space heating).
- Life Cycle Cost Effectiveness
  - Life Cycle Cost Analysis results.
  - Solar energy system design cost (study and design costs itemized).
  - Average annual energy savings and fuel used.
  - Fuel costs provided in the study.
  - Percent energy contribution from solar energy system.
  - Savings to investment ratios (SIR).
  - Estimate of solar energy system installed costs [exclusive of supervision, inspection and overhead (SIOH) and contingency].
  - Initial year O&M costs and requirements.
- Design Feasibility
  - Schematic of system layout.
  - Structural design considerations (roof mounting discussion, life span of roof, structural adequacy).
  - Type and area of collectors.
  - Description of freeze and high temperatures and pressure protection.

- o Description of control sequence.
- o Description of operating sequence.
  - Startup procedures.
  - Shut off procedures.
  - Normal positions of valves, controls.
  - Typical temperatures at key locations.
- o Calculations used: input data, analysis, method used.

2-2 SYSTEM SELECTION

2-2.1 Standard System Types

2-2.1.1 Closed-Loop (Indirect) System

Closed-loop circulation systems circulate a heat transfer fluid through the solar collectors and implement a heat exchanger to heat potable water. While the closed loop solar energy system can provide reliable service in any climate, take certain design precautions:

- Closed-loop circulation systems must be pressurized. Drainback systems are prohibited.
- Provide a check valve in the collector loop to prevent reverse thermosiphoning. Locate check valves so that the fluid in the collector loop can be drained if necessary.
- Use non-ferrous piping and components. Size the expansion tank and pressure relief valves to prevent loss of solution and opening of the collector loop in the event of high pressure stagnation. See Expansion Tank Paragraph for expansion tank design. Provide for the collection and recovery of freeze protection solution in the event of pressure relief.
- Do not use the cold-water leg between the mixing valve and the cold water supply to the solar storage tank for connection to any other fixture.

2-2.1.2 Open-Loop (Direct) Circulation System

Direct circulation systems circulate potable water through the solar collectors and do not implement a separate heat exchanger. Direct circulation systems must be active. Drain-down systems are prohibited. Limit use of direct circulation systems to locations where there are no freezing days, and where the water supply is of sufficiently high quality, between 0-0.015 oz/gallon (0-120 mg/L) calcium carbonate. Obtain water supply quality information from the local water authority. Where the water supply is of poor quality, it is necessary to treat the incoming water supply so that it is within quality limits using a mechanical water softener, water conditioner, or ion-exchange device.

2-2.1.3 Thermosiphon and Integral Storage Collector Systems

Mount the bottom of the thermosiphon system tank approximately 2 feet (0.6 meters) higher than the highest point of the collector. Test integral storage collector (ISC) units as whole systems and using the method given in ASHRAE Standard 95. Only install ISC systems in areas where temperatures rarely fall below freezing. The results of system tests on these models are reported in the Directory of SRCC Ratings: http://www.solar-rating.org.

2-2.2 Mount Types

2-2.2.1 Roof Mounting

Comply with UFC 3-301-01 for requirements related to wind and seismic loads on rooftop solar thermal arrays. Use rooftop mounting systems of the same manufacturer for the entire project array.

2-2.2.2 Ground Mounting

Comply with UFC 3-301-01 for requirements related to the foundation, soil stability, and seismic analysis. Use ground mounting systems of the same manufacturer for the entire project array. The system must withstand the expected wind loads for the location. Complete an environmental impact assessment for the site. Foundation must be either concrete, concrete pad ballast, driven pile, or helical pile.

2-2.3 Collector Types

Solar thermal system collectors are either flat plate or evacuated tube. Use flat plate collectors in ASHRAE Climate Zones 1-3. Use evacuated tube collectors in ASHRAE Climate Zones 4 and above or within zones 1-3 when water heating above 140 degrees F (60 degrees C) is required.

2-2.3.1 Flat Plate Selective Surfaces

Use Collector surface of highly selective black absorber coating, which absorbs the high frequency incoming solar radiation and emits low frequency infrared radiation poorly, with a minimum absorptivity of 0.85.

2-2.3.2 Flat Plate Collector Insulation

Use Collector insulation that is not flammable, has a low thermal expansion coefficient, will not melt or outgas at collector stagnation temperatures 300 degrees F – 400 degrees F (149 degrees C – 204 degrees C), and contains reflective foil to reflect thermal radiation back to the absorber.

2-2.3.3 Flat Plate Collector Housings

Construct housing of powder-coated aluminum. Do not use wood as a structural member, spacer, or anchor for panels due to its susceptibility to deterioration and flammability. Provide adequate room for expansion of the internal manifold and absorber plate assembly within the collector housing.

2-2.3.4 Evacuated Tubes

The evacuated tube collector's individual tubes must be easily replaceable, and made of low emissivity borosilicate glass with a highly selective coating.

2-2.3.5 Collector Gaskets & Sealants

Provide gaskets and seals that:

- Withstand significant expansion and contraction without destruction.
- Adhere effectively to all surfaces.
- Resist ultraviolet degradation.
- Resist outdoor weathering.
- Do not harden or become brittle.
- Withstand temperature cycling from -30 degrees F to 400 degrees F (-34 degrees C to 204 degrees C).
- Do not outgas at high temperatures.

2-2.3.6 Fill Ports and Drains

Provide fill ports and drains that are tamper-resistant.

2-2.4 Fluid Types

Provide heat transfer fluid that is nonionic, high dielectric, nonreactive, noncorrosive, and stable with temperature and time. If system design requirement mandates the use of toxic fluid, receive approval from the installation. The closed-cup flashpoint must be provided by the heat transfer fluid manufacturer and determined using the methods described in NFPA 30. To reduce the risk of fire, the closed-cup flashpoint of the liquid heat transfer fluid must equal or exceed the highest temperature determined from below:

- A temperature of 50 degrees F (28 degrees C) above the design maximum flow temperature of the fluid in the solar system; or
- A temperature of 50 degrees F (28 degrees C) above the maximum no-flow temperature to be reached by the fluid in the collector.
- 100 degrees F (56 degrees C) greater than the maximum expected collector temperature.

To minimize the probability of contamination of potable water systems, address the following items:

- Use tags, color coding, and different pipe connections to preclude the possibility of cross connection of potable water piping with heat transfer fluid piping is required. Use of double-wall separation is required.
- Hydrostatic testing of system to find leaks.
- Color indicators in heat transfer fluid to find leaks.
- Safe designs for heat exchangers.
- Determine toxicity classification of heat transfer fluids.

2-2.4.2 Hydrocarbon Oils

Hydrocarbon oil must have a closed-cup flashpoint 100 degrees F (38 degrees C) higher than maximum expected collector temperature. Provide synthetic hydrocarbon oils.

2-2.4.3 Glycol/Water Mixture

Mixtures must be either a 50/50 or 60/40 glycol-to-water ratio. Circulate glycol/water liquids in a closed loop with a double wall heat exchanger between the collector loop and the storage tank. Maintain the pH between 6.5 and 8.0. Replacement of the glycol/water solution may be as often as every 12-24 months or even sooner in high temperature systems. The glycol manufacturer specifies the expected life of the solution and the amount of monitoring required. Consider the cost of periodic fluid replacement and monitoring in the economic analysis.

2-3 SYSTEM DESIGN

For potable water systems, all components must meet potable water requirements of UFC 3-420-01.

2-3.1 Checklist

2-3.1.1 Schematic

Appendix D provides a checklist of items to consider as part of system planning and design.

2-3.1.2 Component Connections

Provide isolation valves on all major system components, such as the collector banks, storage tank, heat exchanger, and circulation pumps, for removal, cleaning, repair, or replacement.

2-3.1.3 Roof Penetrations

Design roof penetrations for the array supply and return piping and sensor wiring conduit to prevent leaking and to account for movement due to thermal expansion.

2-3.2 Collector Sub-System

2-3.2.1 Array Tilt Angle

For annual loads, tilt collectors to the value of the local latitude. To accommodate for seasonal load variation, tilt the array to the latitude minus an offset up to 10 degrees (to favor summer energy output) or to the latitude plus an offset up to 10 degrees (to favor winter energy output). It should be noted that as the tilt angle increases, the minimum spacing between rows due to shading must be increased due to shading, requiring a larger area.

Anticipate any future structures or vegetation (trees) that could block future solar access, and generally keep the collectors out of the shade between 9 a.m. and 3 p.m., when the bulk of the energy collection occurs.

2-3.2.2 Array Azimuth Angle

Consider the orientation of a collector (i.e. the direction the collector faces). For optimum performance, orient the collector true south, however slightly west of south (azimuth angle of true south plus 10 degrees) may be preferable in some locations if an early morning haze or fog is a regular occurrence. Design the array’s azimuth angle within plus or minus 20 degrees from due south.

2-3.2.3 Pressure Drop

2-3.2.3.1 The 30 Percent Rule

To ensure uniform flow through the piped collector bank array, the ratio of a manifold's pressure drop to its riser pressure drop should be designed to be around 10 percent, and under no circumstances exceed 30 percent (for a pressure drop ratio of 30 percent, the flow in any riser should not deviate from the average riser flow rate by more than plus or minus 5 percent).

2-3.2.3.2 Pressure Drop Across Banks and Rows

Determine the pressure drop across a bank of collectors in order to calculate the pipe sizes necessary to achieve balanced flow in the array. Once the array layout is determined and assuming that the pressure drop across each collector unit at the recommended flow rate is known, the pressure drop associated with each branch extending from a manifold can be determined.

2-3.2.4 Collector Grouping

Group internal-manifold collectors into banks ranging from four to seven collectors, with each bank containing the same number of collectors to maintain uniform flow throughout the array and minimize thermal expansion.

2-3.2.5 Minimum Array Row Spacing

Calculate the minimum row spacing for multi-row arrays. Base north-south spacing of collector banks on no shading of the array on the “worst” solar day of the year (21

December, when the sun is lowest in the sky in the northern hemisphere) for the designated time period of 10 a.m. to 2 p.m. solar time.

2-3.2.5.1 Roof Pitch

If the roof pitch does not allow flush mounting of the collectors, or if the tilt angle must be fixed, coordinate the array design with the roof pitch so that the collectors are raised at one end to give a tilt per paragraph entitled “Array Azimuth Angle.”

2-3.2.5.2 Array Layout

Determine the array layout keeping the piping length minimized while geometric symmetry is maintained, so that banks contain as many collectors as possible, and the array layout is rectangular in area with an even number of banks installed in multiple rows.

2-3.2.5.3 Array Support Structure

Meet all code requirements and coordinate design with, or review by, a licensed professional structural engineer. Design stepped arrays with elevated walkways for maintenance personnel. Coordinate with roof design and coordinate with support structure manufacturer to identify materials options. Use galvanic barrier when design uses incompatible metals. Comply with UFC 3-575-01 for utilizing lightning protection requirements.

2-3.2.5.4 Lightning Protection Requirements

Comply with UFC 3-501-01 for requirements related to providing a lightning risk assessment.

If lightning protection is a design requirement, provide UL listed lightning arrestor and comply with UFC 3-575-01 for requirements related to providing a lightning protection system. Provide side flash calculations as required by NFPA 780.

2-3.2.6 Collector Selection

Provide a collector with a minimum Clear C of 0.98 kBtu/(ft^2·day) (11 MJ/(m^2·day)) as reported by the Solar Rating and Certification Corporation (SRCC): http://www.solar-rating.org/. To validate that the array size and layout is a viable option, information required by the designer and to be submitted by the manufacturer on the shop drawings includes the net aperture area; ranges of overall dimensions of length or height and width; the manufacturer's recommended collector flow rates and the pressure drop across the collector at that flow rate; the internal manifold tube diameter; and the collector weight when filled. Note on the drawings the number of collectors per bank and whether the manufacturer recommends a maximum number of collectors per bank less than seven.

2-3.2.7 Collector Sub-System Piping

2-3.2.7.1 Manifolds

Each collector must have internal manifolds. External manifolds are not permitted.

2-3.2.7.2 Flow Balancing

Design the array plumbing for passive flow balancing, so that uniform flow will occur as naturally as possible in the array. Provide flow control balancing valves on the outlet of each bank to adjust for any flow imbalances after construction.

2-3.2.7.3 Reverse-Return Piping Layout – Diagonal Attachment Rule

The reverse-return strategy of providing approximately equal length flow paths for supply and return pipes attached to the array at any two opposite diagonal corners of the array must be used for all projects.

2-3.2.7.4 Reverse-Return Piping Design

Use the corner closest to the pipe roof penetrations as the return point since this will result in the shortest pipe length for the heated fluid. If the pipe roof penetrations are near the centerline of a multiple row, multiple column array with an even number of columns, save pipe length by feeding the array on the outside and returning the heated fluid from the center of the array.

2-3.2.7.5 Stepped Collector Rows

Although a true reverse-return design is not possible for stepped collector rows, use the same diagonal attachment strategy and the pipe length for each elevation must be accounted for in the pressure drop/pump sizing calculation.

2-3.2.7.6 Array Layout and Piping Schematic

Note the array layout and piping schematic in the construction drawings to pipe the array exactly as that shown to ensure flow balance.

2-3.2.8 Pipe Sizing

Flow throughout the array must be in balance at the proper flow rates, while maintaining a maximum velocity limit of 5 ft/s (1.5 m/s).

2-3.2.9 Volumetric Flow Rates

Use the manufacturer's recommended collector flow rate and the piping schematic to determine the design flow rates throughout the collector sub-system. The total array flow rate is determined by multiplying the collector flow rate by the actual number of collectors. Bank flow rates and row or other branch flow rates are determined by multiplying the collector flow rate by the number of collectors per bank or per row.

2-3.2.10 Pressure Drop Models and the Fluid Velocity Constraints

The design operating temperature of the collector loop inlet (return, entering the collector) should be between 60 and 90 degrees F (15 and 32 degrees C), with the 60 degrees F (15 degrees C) value preferred because it is the lowest temperature (thus highest viscosity and pressure drop) that steady-state operation could be expected. If a higher temperature is to be used, the designer should apply the standard temperature corrections for water before correcting for the use of propylene glycol.

2-3.2.11 Collector Sub-System Plumbing Details

The collector banks must be able to be valved off for maintenance, repair, or replacement. Use ball valves for collector bank isolation. Manually operated, calibrated balancing valves must be located at the outlet to each collector bank to adjust for any flow imbalances present after construction. Drain valves must be located at all low points in the collector sub-system to allow the collectors to be drained if necessary. Pressure relief valves must be located on each collector bank. Manual air vents must be located at the high points of the collector loop to allow air to escape during the filling process. The differential expansion between the system flow paths and the system and the support structure must be considered in the design.

2-3.2.12 Thermal Expansion

When long pipe runs are required, ensure that the resulting expansion or contraction will not harm system components or cause undue stress on the system or the building. Provide pipe anchors, supports, guides, and expansion loops to allow freedom of movement in the direction of motion.

2-3.3 Storage Sub-System

2-3.3.1 Supplementary Heat

Supplementary heat sources are required and shall supply 100% of the system required loads. Operate the auxiliary heater automatically as needed, use the most economical fuel, and share a common heat delivery system with the solar system.

2-3.3.2 Location

Design the equipment room to house the solar storage tank, pumps, heat exchangers, controls, and all system components except the solar collectors.

2-3.3.3 Legionella or Legionnaire's Disease

For domestic use, heat the water in the storage tank to a minimum of 140 degrees F (60 degrees C) in order to avoid any potential source of Legionnaire's disease. For additional information on Legionnaire's disease refer to: http://www.wbdg.org/pdfs/legionella.pdf.

2-3.3.4 Tank Support and Floor Loads

Provide reinforced concrete pads and footings to ensure that the weight of the tank does not endanger the structural integrity of the building. The design load calculation must take into account the estimated weight of the empty tank, the water to be stored in the tank, the insulation, and the tank support structure.

2-3.3.5 Storage Tank Construction

Insulate solar storage tanks to a minimum value of R-30. The storage tank must be equipped with a minimum of four pipe connections, two located near the top of the tank and two located near the bottom. To take advantage of storage tank stratification, pipes supplying the collector array and the cold-water inlet must be connected to the bottom penetrations, and the pipes returning to the tank from the collector array and hot water supplied to the load must be connected to the penetrations near the top. Instrumentation openings will be required as well as openings for relief valves, and drains. Since copper is to be used for all system plumbing, a dielectric coupling must be included in the design of any necessary penetrations of the storage tank**.**

2-3.3.6 Storage Tank Sizing

Specify the solar storage tank based on the sizing criteria that the volume is between 1.5 to 2 gals per square foot (61 to 82 L per square meter) of total array collector area.

2-3.3.7 Storage Sub-System Flow Rate

To ensure that the storage loop can accept the energy available, the thermal capacity on the storage side of the heat exchanger (the product of the mass flow rate and constant pressure specific heat) must be greater than or equal to the thermal capacity on the collector side of the heat exchanger. The storage sub-system volumetric flow rate must be at least 0.9 times that of the total array volumetric flow rate.

2-3.4 Heat Exchanger

2-3.4.1 Sizing

Size the heat exchanger to a minimum effectiveness of 0.5.

2-3.4.2 Specification

The heat exchanger area and pressure drop must be indicated on the drawings and provided by the designer. All materials used in the heat exchanger must be compatible with the fluids used.

2-3.5 Piping

Design piping for low pressure drop. All exposed piping must be well-insulated with approved weather-resistant insulation. Use dielectric unions at connections between dissimilar metals. Provide thermal expansion for all piping.

2-3.5.1 Materials

Piping materials must be copper or steel. Only tin-antimony (Sn-Sb) solders are allowed (Sb5, Sn94, Sn95, and Sn96). Lead solders are forbidden in any part of the potable water system.

2-3.5.2 Insulation

Coordinate insulation requirements with specification UFGS 23 07 00. Insulation must withstand temperatures up to 400 degrees F (204 degrees C) within 1.5 ft. (457 mm) of the collector absorber surface, and 250 degrees F (121 degrees C) at all other locations. Insulation exposed to the outside environment must be weatherproof and protected against ultraviolet degradation. A minimum of R-4 insulation must be specified on all piping.

2-3.6 Expansion Tank

2-3.6.1 Location

Locate the expansion tank in the equipment room or existing mechanical room on the suction side of the pump.

2-3.6.2 Determination of Acceptance Volume

Size the expansion tank to account for the displacement of all the fluid contained in the collector array that is subject to vaporization. During stagnation conditions, only the volume of fluid located in the collector array and associated piping above the lowest point of the collectors is subject to vaporization. The required acceptance volume is determined by adding the total volume of all collectors plus the volume of any piping at or above the elevation of the collector inlets.

2-3.6.3 Determination of Design Pressures

The air-side of closed expansion tanks must be precharged by the manufacturer. This initial or precharged pressure (P_i) must be determined, along with the collector loop fill pressure (P_f) and the maximum relief pressure allowed in the system (P_r). The maximum pressure in the collector loop should be 125 psi (862 kPa). The system-fill pressure should result in a +10 to +15 psi (+69 to +103 kPa) pressure at the highest point of the system. The expansion tank precharge pressure should be equal to the fill pressure at the expansion tank inlet, minus 5 to 10 psi (35 to 69 kPa). This initial condition allows fluid to be contained within the expansion tank at the time of filling and will provide positive pressure in the event of the system operating at temperatures below that occurring when the system is filled.

2-3.6.4 Sizing and Specification

The designer must specify operating modes and freeze/over-temperature protection methods.

2-3.7 Fittings

Valves, other than seasonal or emergency shut-off valves, should be electrically operated and located out of the weather or well-protected. A vent must be provided at the high point in liquid systems to eliminate entrapped air and it should also serve as a vacuum breaker to allow draining of the system. To avoid multiple venting, systems should be piped to avoid having more than one high point. Pressure relief must be provided in each flow circuit. Add check valves to prevent thermally induced gravity circulation. A flow-check valve (used in the hydronic heating industry) will also accomplish the same purpose. Mixing valves should be used to protect DHW systems from delivering water hotter than specified [usually 120–140 degrees F (49–60 degrees C)].

2-3.7.1 Isolation Valves

Use gate valves only in locations where only on/off operation is required. Ball valves must be used at locations where partial flow may be required, such as on the outlet side of the collector banks. These valves are manually operated and must have a key or special tool to prevent unauthorized tampering. Isolation valve locations must ensure that system pressure relief cannot be valved off accidentally. Globe-type valves must not be used.

2-3.7.2 Thumb Valves

Thumb valves also function as on/off valves and only for smaller sized tubing [1/4 inch (6 mm) or less], used to manually open pressure gauges or flow indicators to local flow and are not meant for constant use.

2-3.7.3 Drain Valves

Drain valves are required at all system low points. Specifically, these locations include the low points of the collector banks, the bottom of the storage tank, and two at the bottom of the collector loop between the expansion tank and the pump. The latter two drain valves are used for filling and draining and must be separated by a gate valve.

2-3.7.4 Check Valves

Locate a spring-type check valve in the system between the pump and the collector array, on the supply side.

2-3.7.5 Pressure Relief Valves

A pressure relief valve is required in any line containing a heat source that can be isolated (such as a collector row) and also must be provided between the heat exchanger and the suction side of the collector loop pump. Pressure relief for solar systems must be set at 125 psi (862 kPa) (maximum system design pressure). The discharge from pressure relief valves must be either routed to an appropriate floor drain or captured as required by either local or state regulatory requirements. The discharge must be piped to avoid personnel injury from the hot fluid.

2-3.7.6 Temperature-Pressure Relief Valves

Install temperature-pressure relief valves on the solar storage tank and set for 125 psi (862 kPa) or 210 degrees F (99 degrees C).

2-3.7.7 Balancing Valve

Provide balancing valve with taps to read flow across outlet of each collector bank.

2-3.7.8 Manual Air Vents

Locate manual air vents at the high point(s) of the system where air will accumulate.

2-3.7.9 Strainers

Locate a strainer before the pump to test for system flush.

2-3.8 Pumps

2-3.8.1 Operation

Circulation pumps in both the collector and storage loops must be activated simultaneously by the control sub-system when it has been determined that net energy collection can occur.

2-3.8.2 Pump Sizing and Specification

Select the pump using the manufacturer's standard tables and graphs. After the selected pump is installed and the system is started, balance the system. Provide ECM pump. Comply with UFC 3-420-01 for requirements related to potable water systems.

2-3.9 Control Sub-System

The differential temperature controller (DTC) and all solar thermal system control components must be compatible with the building automation system (BAS) controls specified in the project.

2-3.9.1 Control Strategy

Specify operating modes and freeze/over-temperature protection methods. Connect the control sub-system to the BAS to access at a minimum the following:

- BTU meter in storage loop to measure and record thermal energy sent to storage tank.
- Indicate and record elapsed time of activated pumps.
- Activation of conventional system in event of solar thermal system failure.

Specify at a minimum the following control sequences:

- DTC--activates solar loop pump at preset temperature delta between collector and storage.

- Simultaneous activation of storage loop pump and collector loop pump after input from DTC.

Specify at a minimum the following control points:

- Collector temperature sensor (located at manufacturer's recommendation).
- Storage temperature tank sensor (located in coolest section of tank).
- Heat exchanger temperature sensors at inlet and outlet.
- Pressure indicators at supply and discharge sides of storage loop pump and collector loop pump.
- Pressure indicators at inlet and outlet of heat exchanger.
- Pressure indicator at storage tank.
- Flow indicator in collector loop.
- Flow indicator in storage loop.

2-3.9.2 Location of Controls

Panel-mount electronic displays and visual pressure and temperature gauges together in the mechanical room.

2-3.9.3 Differential Temperature Control Unit (DTC)

The DTC must include a solid-state design with an integral transformer. The DTC must allow the on and off set-points to be variable, and must allow the instantaneous temperatures of the collector and storage tank to be displayed by the system operator or maintenance personnel. The DTC must be able to diagnose and flag open or short circuits.

Using the DTC, the collector and storage loop pumps must be energized whenever the difference between the absorber plate and storage tank temperatures is greater than the high setpoint differential temperature, typically 15 to 25 degrees F (8 to 14 degrees C). The pumps must stay on until that temperature difference is less than the low setpoint differential temperature, usually 5 to 8 degrees F (3 to 4 degrees C).

2-3.9.4 Temperature Sensors and Locations

Provide sensors that are platinum resistance temperature detectors (RTDs) or 10 K-ohm thermistors. Sensors must be easily accessible for calibration and servicing.

2-3.9.4.1 Collector Temperature Sensor

To determine when sufficient energy is available for collection, locate one sensor on the collector array, either in the fluid stream (on a nearby collector bank and in the top internal manifold piping between two collectors) or fastened directly to the absorber plate (only if the collector manufacturer provides this service at the factory). Do not use threaded wells that consist of ferrous materials due to material compatibility with glycol heat transfer fluid. Cover the sensor assembly with a weatherproof junction box.

2-3.9.4.2 Storage Tank Sensor

Locate the storage tank sensor within a well protruding into the storage tank near the outlet to the heat exchanger.

2-3.9.4.3 Sensor Wiring

Locate wiring from the controller to the collector and storage sensors within metal conduit. Keep color-coding consistent from the controller to the sensor, and do not locate junctions or pull boxes in concealed areas.

2-3.9.5 Monitoring Equipment

2-3.9.5.1 Pressure Indicators

Install pressure gauges on the supply and discharge sides of both pumps, on all inlets and outlets of the heat exchanger, and on the storage tank. Duplex gauges can be used or single pressure gauges can be connected to supply and discharge pipe with small plug valves installed in the gage lines. Pressure gauges must be rated for 150 psi (1,034 kPa) and 210 degrees F (99 degrees C) operation.

2-3.9.5.2 Temperature Indicators

Provide thermometers at the heat exchanger inlets and outlets and at the top and bottom of the solar storage tank.

2-3.9.5.3 Flow Indicators

Specify a flow indicator in the collector loop and in the storage loop, after the pump(s). Use venturi-type flow meters to quantify flow measurement with flow indicator components made of brass, bronze, or other compatible non-ferrous material. Install flow devices at least five pipe diameters downstream of any other fittings. Connect flow indicators to the building automation system.

2-3.9.5.4 Elapsed Time Monitor

Record operating time of each circulation pump with an elapsed time monitor.

2-3.9.5.5 BTU Meter

When the solar energy system performance is monitored, specify a BTU meter, and install according to the manufacturer’s recommendation.

2-3.10 Design Precautions

2-3.10.1 Collector Loop Check Valve

Locate check valves so that the fluid in the collector loop can be completely drained.

2-3.10.2 Mixing Valves

Ensure that the cold water leg between the mixing valve and the cold water supply to the solar storage tank is not used for connection to any other fixture.

2-3.11 Safety Features

2-3.11.1 Fall Protection

Design equipment to minimize work at heights and minimize fall hazards during maintenance, repair, and inspection or cleaning. Design must include prevention systems, such as guardrails, catwalks, and platforms, and anchor points compatible with the job tasks and work environment.

2-3.11.2 Equipment Lockout and Disconnect

Machinery and equipment layout must ensure safe access to lockout devices and provide equipment with independent disconnects. All equipment and utilities must have lockout capability and any replacement, major repair, renovation, or modification of equipment must still accept lockout devices. Emergency and non-emergency shutoff controls must be located in the equipment room and have easy access and usability.

2-3.12 Coordination

The system designer is responsible for ensuring the requirements below are coordinated appropriately between the architect and structural engineer.

2-3.12.1 Roof Requirements

Provide a minimum space of 4 inches (100 mm) between the collector and the roof. Provide a roof design with penetrations near the array for collector supply and return lines. Other architectural requirements for roof design include designing the array support structure and provide calculations assuring that the roof structure is adequate to support the added loading and point loading from the new system; allowing adequate access to the array for maintenance; including access to the roof for personnel path (and equipment); including fire path access; and including walkways around the array and between adjacent arrays. Coordinate with paragraph entitled “Fire Safety Design” Requirements herein.

2-3.12.2 Equipment Room

There must be an equipment room for the solar energy system hardware in one location, and it must contain the storage tank, heat exchanger, expansion tank, pumps, control system, and related plumbing. The equipment room must be configured and sized to allow personnel easy access to maintain and replace equipment. A floor drain must be provided near the storage tank relief valve. Control panels must be installed in an accessible area within line of sight of the equipment room door.

2-3.12.3 Maintenance and Accessibility

Do not use protective mesh screens to cover collectors. Collectors and mounts must withstand expected wind and snow loads. Collector design must allow for rapid replacement of glass covers. Pumps, pipes, and controls must be accessible to allow for repair or replacement. Water pumps must be located so that leakage does not cause serious damage. The operations and maintenance (O&M) manual must be developed by the contractor for the specific design of the solar system.

CHAPTER 3 SOLAR PHOTOVOLTAIC TECHNICAL REQUIREMENTS

3-1 GENERAL REQUIREMENTS

3-1.1 Economic Feasibility Study

As required in UFC 1-200-02, provide on-site renewable energy systems in accordance with ASHRAE 189.1 Section 7.4.1.1 (On-Site Renewable Energy Systems), if life cycle cost-effective. ASHRAE 189.1 requires a minimum annual renewable energy production requirement based on the size of the total roof area. This result refers to the rated DC nameplate capacity of the system.

Perform a life-cycle cost analysis for all new military construction to determine whether the use of renewable forms of energy will result in a net monetary savings to the government. The methodologies and parameters required for Federal energy project feasibility studies are mandated by Federal law (10 CFR 436). Provide a solar photovoltaic energy system when life-cycle cost effective.

3-1.2 Screening Procedures

Perform the initial evaluation for solar photovoltaic system viability. Generate a final report containing at least the solar photovoltaic system size, system cost, annual energy savings, annual cost savings, savings-to-investment ratio (SIR), simple payback, solar fraction, and annual greenhouse gas reduction. The utility rate used for calculating savings must be the burdened rate. See Appendix B for recommended tools.

3-1.3 Detailed Analysis and Study

If the results of the screening procedure indicate that a solar photovoltaic system is a viable consideration, then the next step will be to perform a detailed life-cycle cost analysis (LCCA) to determine the most effective design alternative to develop. Perform LCCA calculations and reports. Include evaluation of tracking array. See Appendix B for recommended tools.

3-1.4 Energy Security Risk Mitigation

On-site renewable energy system designs must include the following requirements in accordance with UFC 3-501-01 in order to limit the risk to energy security:

a. Direct interconnection of system to installation-wide electrical system (grid):

  - o For renewable energy systems that include a tie-in by a direct connection to the primary distribution system, provide a cumulative renewable energy load analysis of both the direct connection and building renewable power systems.
  - o Evaluate the proposed systems and verify there are no adverse effects on the installation-wide electrical system frequency control, voltage

regulation, and power quality. See Appendix B for issues that should be considered.

b. Direct interconnection of system to buildings that utilize engine generators that may operate in parallel with the renewable energy generation[1]:

  - Evaluate the proposed systems and verify there are no adverse effects on the generator's ability to maintain frequency control, voltage regulation, and power quality. See Appendix B for issues that should be considered.
  - If the stability of the combined systems cannot be confirmed, then design system to automatically disconnect renewable power generation when the backup generator is in operation.

c. Direct interconnection of system to buildings that either do not utilize engine generators or have backup power systems that would never operate in parallel with the renewable energy generation, such as a backup generator supplying power via an automatic transfer switch:

  - Provide analysis validating that the electrical system design addresses the electrical characteristics (real and reactive power output) of the renewable energy system.

3-1.5 Solar Photovoltaic Basis of Design

At a preliminary design stage equivalent to 35% design unless stated otherwise, the designer of record must provide a basis of design which covers the general facility design requirements in accordance with UFC 1-200-01 and its referenced documents. In addition to the UFC 3-501-01 requirements for preliminary basis of design and follow-on submittals, provide the following general system specific analysis information:

- Narrative
  - FY Year, Project Number, and project location.
  - Project acquisition: Design-Bid-Build or Design-Build.
  - Briefly state scope, project description, references, and calculation method used.
  - Geographic and operating environment, including coastal locations/corrosive conditions, humidity, altitude, seismic zones, and ambient temperature extremes.
  - Type of solar PV system (BIPV, ground mount, roof mount, tracking).
- Life Cycle Cost Effectiveness
  - Life Cycle Cost Analysis results.
  - Solar PV system design cost (study and design costs itemized).

[1] The Air Force does not allow paralleling facility-scale renewable energy systems with any standby power regardless if it is emergency, Critical Operations Power Systems (COPS), or other.

- Average annual energy savings and fuel used.
- Fuel costs provided in the study.
- Percent energy contribution from solar PV system.
- Savings to investment ratios (SIR).
- Estimate of solar PV system installed costs [exclusive of supervision, inspection and overhead (SIOH) and contingency].
- Initial year O&M costs and requirements.

- Design Feasibility
  - Consideration must be taken to avoid shadowing from nearby structures and vegetation.
  - Schematic of system layout.
  - Structural design considerations (roof mounting discussion, life span of roof, structural adequacy).
  - Type and area of solar PV modules.
  - Tracking or fixed solar PV array.
  - Azimuth angle of solar PV modules.
  - Tilt angle of solar PV modules.
  - Calculations used: input data, analysis, method used.
- Connection to Facility (50% Design) in accordance with NFPA 70
  - Ground fault protection.
  - Overcurrent protection.
  - Arc-fault circuit protection.
  - Disconnecting means.
  - System grounding.
  - Grounding electrode system.
  - Rating of AC interconnection panel/switchboard and potential for source to exceed busbar rating. Where the busbar rating would be exceeded, provide design alternative for grid interconnection.
  - Calculations used: input data, analysis, method used.
- Solar PV system schedule (50% Design).
  - Solar PV module technology (crystalline-silicon, thin film).
  - Solar PV module wattage.
  - Solar PV source circuits voltage, current, wattage.
  - Solar PV combiner box output circuit voltage, current, wattage.
  - Inverter input and output voltage, current, wattage.

- Description of operating sequence (90% Design).
  - Startup procedures.
  - Shut off procedures (rapid shutdown of PV systems on buildings).

3-2 SYSTEM SELECTION

3-2.1 Photovoltaic Modules

Solar photovoltaic (PV) modules generate direct current (DC) electrical power from semiconductors when they are excited by sunlight. There are a number of solar PV technologies commercially available and can be categorized into crystalline silicon, ribbon sheet, and thin film. See Appendix E for a discussion on each solar PV technology. Select one commercially-available PV module type based on LCCA, required energy production, site location environmental conditions, and maintainability.

3-2.2 Inverter Types

A micro-inverter converts the DC power to AC at each individual solar module. A string inverter converts the DC power to AC for a series of solar modules. Use either micro-inverters mounted on each individual solar PV module, micro-inverters mounted on racking, or string inverters that serve a series of solar PV modules.

NOTE: Utility-size systems in UFC 3-540-08 (Draft) require reactive power; however this is not necessary for facility-size systems. As regulations are enacted and standards evolve, more inverters will feature reactive power adjustment, but currently very few do.

3-2.3 Mount Types

3-2.3.1 Roof Mounting

Comply with UFC 3-110-03 for requirements related to rack-mounted photovoltaic systems. Design mounting systems in accordance with UFC 3-301-01. For racking requirements dependent upon the roof type, comply with NRCA Guidelines for Roof Systems with Rooftop Photovoltaic Components. Use rooftop mounting systems of the same manufacturer for the entire project array.

3-2.3.1.1 Asphalt Shingle Roof Systems

Comply with CEIR PV Racking and Attachment Criteria for Effective Asphalt Shingle Roof System Integration for requirements related to attaching the mounting system to an asphalt shingle roof system.

3-2.3.1.2 Low-Slope Roof Systems

Comply with CEIR PV Racking and Attachment Criteria for Effective Low-Slope Roof System Integration for requirements related to attaching the mounting system to a low-slope roof system.

3-2.3.1.3 Metal Panel Roof Systems

Comply with CEIR PV Racking and Attachment Criteria for Effective Low-Slope Metal Panel Roof System Integration for requirements related to attaching the mounting system to a low-slope metal panel roof system.

3-2.3.2 Ground Mounting

Design mounting systems in accordance with UFC 3-301-01. Foundation must be either concrete, driven pile, or helical pile. Complete an environmental impact assessment for the site.

3-2.3.3 Tracking Array System

Design for solar PV tracking system in accordance with IEC 62727. See Appendix E for tracking system pros and cons.

3-2.4 DC Input Voltage

Maximum DC string input voltage must not exceed 1,000 VDC.

3-2.5 System Warranty

Provide a warranty in the event of component failure due to workmanship, defective components or assemblies for the entire solar PV system at a minimum one year parts and labor. Coordinate all warranty requirements with the LCCA.

3-2.5.1 PV Module Warranty

Provide PV module warranty of minimum 10 years for workmanship material and manufacturing defects from the date of manufacture. Concerning performance, PV module warranty must include manufacturer written guarantee for minimum continuous, linear power output of 80 percent for 25 years.

3-2.5.2 Inverter Warranty

Provide inverter warranty of minimum 15 years.

3-2.5.3 Mounting System Warranty

Provide PV mounting system warranty of minimum 15 years.

3-2.6 Standard Test Conditions

All compliance testing must be completed under Standard Test Conditions (STC) which are defined as 92.9 W/ft^2 (1,000 W/m^2) insolation, 68 degrees F (25 degrees C) cell temperature, and 2.2 mph (1 m/s) average wind velocity. Modules must be supplied with original current/voltage maximum power measurement data.

3-3 SYSTEM DESIGN

Installation must meet requirement based on roof area although it does not have to be installed on the roof (it can be ground-mounted).

3-3.1 Array Tilt Angle

Tilt the array to the latitude plus or minus 10 degrees. It should be noted that as the tilt angle increases, the minimum spacing between rows must be increased due to shading, requiring a larger roof area. Do not allow inter-row shading between 9 a.m. and 3 p.m., when the bulk of the energy collection occurs.

3-3.2 Array Azimuth Angle

For optimum performance, orient the module true south, however slightly west of south (azimuth angle of true south plus 10 degrees) may be preferable in some locations if an early morning haze or fog is a regular occurrence. Design the array's azimuth angle off of due south as coordinated with the Basis of Design.

3-3.3 PV Module Design

The solar photovoltaic module must comply with UL 1703. The backsheet and encapsulent must be specified in accordance with UFGS 26 31 00 with a guarantee of their construction submitted by the manufacturer.

3-3.3.1 Insulation

All module circuitry must be insulated from external surfaces and withstand open-circuit system voltage of 1,000 VDC.

3-3.4 Inverter and Array Design

3-3.4.1 Network Communication

Provide inverter capable of network communication to allow for PV array performance monitoring.

3-3.4.2 Inverter Location

Locate the string inverter(s) in the electrical equipment room or outdoors with appropriate personnel safety to prevent unauthorized access. If a ventilated enclosure is not available, provide enclosure in accordance with UFC 3-501-01, paragraph entitled "Corrosive and High Humidity Areas."

3-3.4.3 Micro-Inverter Systems

For micro-inverter systems, coordinate the maximum number of micro-inverters per branch circuit and overcurrent protection size with the inverter manufacturer. The maximum number will be dependent on the AC system voltage, AC output power, and conductor size of the interconnection cable. Design the array to the best power output using best practices in Appendix B.

3-3.5 Metering and Monitoring

Coordinate revenue metering requirements with the utility provider and DoD installation regarding interconnection-specific data and guidelines, utilizing metering specifications UFGS 26 27 13.10 30 (Air Force only) and UFGS 26 27 14.00 20 (Navy only). Coordinate with Activity for requirements and plan of action to manage excess energy, including the utilization of net metering.

Provide communication and annunciator panel. Monitoring must be module-based if micro-inverters are implemented, otherwise monitoring must be string-inverter based. Provide monitoring based on inverter type utilized (i.e. string inverter or micro-inverter).

3-3.6 Wiring

Provide UL 4703 listed PV wiring. Provide grounding in accordance with NFPA 70.

3-3.7 Sensors and Locations

Provide sensors that are easily accessible for calibration and servicing, and relevant to affecting PV output.

3-3.7.1 Ambient Temperature Sensor

The ambient temperature sensor must be located near the array but not on it, such that it will not cast a shadow on the array, is at the same mean height as the array, and is exposed to the same hours of sunlight as the majority of the array panels.

3-3.7.2 Panel Temperature Sensor

The panel temperature sensor must be located on the array, fastened directly to the center of the back side of a solar panel. Sensors must be either thermocouple platinum or digital, and fully encapsulated including a minimum 3/8 inch (10 mm) thick insulation block.

3-3.7.3 Insolation Sensor

The solar insolation sensor must be located in the plane of the array, fastened directly to the front side of a solar panel frame but must not cast a shadow on the panel cells, and constructed of UV-resistant material.

3-3.7.4 Wind Speed Sensor

Locate the wind speed sensor near the array but not on it, such that it will not cast a shadow on the array, and away from tall obstructions. Wind speed sensor is necessary for solar tracking PV systems to prevent damage.

3-3.7.5 Sensor Wiring

Comply with NFPA 70 for requirements related to sensor wiring.

3-3.8 Lightning and Surge Protection

3-3.8.1 Lightning Protection

Comply with UFC 3-501-01 for requirements related to providing a lightning risk assessment.

If lightning protection is a design requirement, comply with UFC 3-575-01 for requirements related to providing a lightning protection system. Provide side flash calculations as required by NFPA 780.

3-3.8.2 Overcurrent Protection

Provide overcurrent protection in accordance with NFPA 70. Show locations of overcurrent protective device on drawings.

3-3.8.3 Surge Protection

Provide surge protection in accordance with NFPA 780. Comply with UFC 3-520-01 for requirements related to providing surge protection. Show locations of surge protective device on drawings.

3-3.9 System Grounding

Comply with NFPA 70 for requirements related to general system grounding.

3-3.10 Utility Interconnection

Coordinate with local transmission and interconnection services provider for specific procedures in accordance with the provider’s pro forma Open Access Transmission Tariff (OATT). Where the busbar rating would be exceeded, provide design alternatives for interconnection to the grid. Comply with all IEEE 1547 requirements regarding the interconnection technical and testing requirements necessary for electrical systems to operate under normal conditions without degradation. Prior to interconnect, provide proper documentation and certifications for all generation equipment, installation, operation, and maintenance to show that the system is in compliance with IEEE 1547.

3-3.11 Safety Features

3-3.11.1 Emergency Shutdown

Provide system rapid shutdown equipment in accordance with NFPA 70.

3-3.11.2 Fall Protection

Comply with UFC 3-110-03 for requirements related to elimination, prevention, or control of fall hazards. Design equipment to minimize work at heights and minimize fall hazards during maintenance, repair, and inspection or cleaning. Design must include prevention systems, such as guardrails, catwalks, and platforms, and anchor points compatible with the job tasks and work environment.

3-3.12 Fire Safety Design Requirements

Comply with UFC 3-600-01 and all requirements in NFPA 1 related to "Photovoltaic Systems" with the following modifications.

3-3.12.1 Buildings Other Than One- and Two-Family Dwellings and Townhouses.

3-3.12.1.1 Access

Provide a minimum 6 ft (1.8 m) wide clear perimeter around the edges of the roof for all buildings.

3-3.12.1.2 Single Story Smoke Ventilation

Ventilation options shall be provided as required by NFPA 1. It is preferable to provide skylights (that can be manually opened) or manually operated smoke vents in lieu of the "venting cutout options".

3-3.12.1.3 Multistory Smoke Ventilation

Increased pathway width or venting cutout options are not required. The minimum width of any pathway must be 4 ft (1.2 m).

Provide a roof access hatch or skylight above every enclosed stairway. The hatch or skylight must not be less than 16 square ft (1.5 square m) in area and having a minimum dimension of 2 ft (6.1 m).

3-4 COORDINATION

3-4.1.1 Roof Requirements

Architectural requirements for roof design include providing roof penetrations near the array for conduit; designing the array support structure; allowing adequate access to the array for maintenance; including access to the roof for personnel (and equipment); and including walkways around the array.

3-4.1.2 Equipment Locations

Coordinate equipment locations with the system design, and consider the best practices in Appendix B. Design to minimize conductor cable distances. Provide panels in easily accessible areas and clearly visible.

Accommodate the inverters, meters, and subpanels in the electrical equipment room or other designated equipment area. Size area to allow personnel to move about freely and have easy access to replace equipment as necessary in accordance with NFPA 70.

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APPENDIX A REFERENCES

AMERICAN SOCIETY OF HEATING, REFERIGERATING AND AIR CONDITIONING ENGINEERS (ASHRAE)
http://www.ashrae.org/

ASHRAE 93, Methods of Testing to Determine the Thermal Performance of Solar Collectors

ANSI/ASHRAE/USGBC/IES Standard 189.1 (ASHRAE 189.1), Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings

CENTER FOR ENVIRONMENTAL INNOVATION IN ROOFING (CEIR)
http://roofingcenter.org/main/Initiatives/pv

PV Racking and Attachment Criteria for Effective Asphalt Shingle Roof System Integration

PV Racking and Attachment Criteria for Effective Low-Slope Roof System Integration

PV Racking and Attachment Criteria for Effective Low-Slope Metal Panel Roof System Integration

FEDERAL AVIATION ADMINISTRATION (FAA)

Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, October 23, 2013, https://www.federalregister.gov/articles/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports#h-11

Technical Guidance for Evaluating Selected Solar Technologies on Airports, http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 62727, Photovoltaic Systems – Specification for Solar Trackers

MODBUS ORGANIZATION, INC (MODBUS)

Modbus Application Protocol Specification

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA C12.20, Electricity Meters – 0.2 and 0.5 Accuracy Classes

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 1, Fire Code

NFPA 30, Flammable and Combustible Liquids Code

NFPA 70, National Electrical Code

NFPA 780, Standard for the Installation of Lightning Protection Systems

NATIONAL ROOFING CONTRACTORS ASSOCIATION (NRCA)
http://www.nrca.net/

Guidelines for Roof Systems with Rooftop Photovoltaic Components

NORTH AMERICAN BOARD OF CERTIFIED ENERGY PRACTITIONERS
http://www.nabcep.org/

NABCEP Solar Heating Installer Resource Guide

NABCEP PV Installation Professional Resource Guide

UNDERWRITERS LABORATORIES
http://ulstandards.ul.com/

UL 1703, Flat-Plate Photovoltaic Modules and Panels

UNITED STATES DEPARTMENT OF DEFENSE

DoD Instruction 8500.01, Cybersecurity, March 14, 2014, http://www.dtic.mil/whs/directives/corres/ins1.html

DoD Instruction 8510.01, Risk Management Framework (RMF) for DoD Information Technology (IT), March 12, 2014, http://www.dtic.mil/whs/directives/corres/ins1.html

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA PROGRAM
http://dod.wbdg.org/

UNIFIED FACILITIES CRITERIA (UFC)

UFC 1-200-01, General Building Requirements

UFC 1-200-02, High Performance and Sustainable Building Requirements

UFC 3-110-03, Roofing

UFC 3-260-01, Airfield and Heliport Planning and Design

UFC 3-301-01, Structural Engineering

UFC 3-401-01, Mechanical Engineering

UFC 3-420-01, Plumbing Systems

UFC 3-501-01, Electrical Engineering

UFC 3-520-01, Interior Electrical Systems

UFC 3-540-08, Utility-Scale Renewable Energy Systems (Draft)

UFC 3-560-01, Electrical Safety, O&M

UFC 3-575-01, Lightning and Static Electricity Protection Systems

UFC 3-600-01, Fire Protection Engineering for Facilities

UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

UFGS 23 07 00, Thermal Insulation for Mechanical Systems

UFGS 23 09 23, LonWorks Direct Digital Control for HVAC and Other Building Control Systems

UFGS 23 09 23.13 20, BACnet Direct Digital Control Systems for HVAC

UFGS 25 10 10, Utility Monitoring and Control System (UMCS) Front End and Integration

UFGS 26 27 13.10 30, Electric Meters

UFGS 26 27 14.00 20, Electricity Metering

UFGS 26 31 00, Solar Photovoltaic (PV) Components

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APPENDIX B BEST PRACTICES

This appendix identifies background information and practices for accomplishing certain renewable energy design and engineering services. The Designer of Record (DoR) is expected to review and interpret this guidance and apply the information according to the needs of the project. If a Best Practices document has guidelines or requirements that differ from the UFGS or UFC, the UFGS and the UFC must prevail. If a Best Practices document has guidelines or requirements that are not discussed in the UFGS or UFC, the DoR must submit a list of the guidelines or requirements being used for the project with sufficient documentation to the Government Engineer for review and approval prior to completing design.

B-1 WHOLE BUILDING DESIGN GUIDE.

The Whole Building Design Guide (www.wbdg.org) provides additional information and discussion on practice and facility design, including a holistic approach to integrated design of facilities.

The WBDG provides access to Construction Criteria Base (CCB) criteria, standards and codes for the DoD Military Departments, National Aeronautics and Space Administration (NASA), and others. These include, UFC, UFGS, Performance Technical Specifications (PTS), design manuals, and specifications.

B-2 RENEWABLE ENERGY SYSTEMS AND ENERGY SECURITY.

Designs should address the following issues concerning the utilization of renewable energy (RE) systems:

B-2.1 Low Energy Security Risk RE Systems.

Waste-to-energy, geothermal, or biomass, are low energy security risk RE systems and are highly desirable.

- No power quality issues.
- Stable, reliable, easily controllable.
- Easily integrated into microgrid topology.
- Straightforward, easily implemented IEEE 1547 standard.

B-2.2 High Energy Security Risk RE Systems.

Photovoltaic and wind renewable energy (RE) systems are high energy security risk due to their possible adverse effect on electric grid frequency control, voltage regulation, and power quality.

B-2.2.1 Wind Energy Generators Systems.

- Consume reactive power – cannot provide reactive power to meet needs of base.

- Lower utility power factor (PF) during operation – creates risk of utility power factor penalty charges or power outages.
- Electromagnetic interference.
- Implementation of IEEE 1547 standard is more complex.

B-2.2.2 Solar PV Energy Systems.

- Provide near unity PF – little to no reactive power.
- Lower utility PF during operation.
- Unstable effect on system frequency control.
- Additional stress on emergency generators supporting critical facilities if operated in parallel.
- Implementation of IEEE 1547 standard is more complex.

B-3 SOLAR THERMAL BEST PRACTICES.

B-3.1 Tools.

B-3.1.1 Screening Tools.

B-3.1.1.1 Solar Hot Water System Calculator.

Use the Solar Hot Water System Calculator developed by the Federal Energy Management Program (FEMP) for the initial evaluation for solar hot water system viability: http://apps1.eere.energy.gov/femp/solar_hotwater_system/.

B-3.1.1.2 System Advisor Model (SAM).

Use the System Advisor Model, a performance and financial model designed to facilitate decision-making for those involved in the renewable energy industry: https://sam.nrel.gov/.

B-3.1.2 Shading Analysis Tools.

B-3.1.2.1 Solar Pathfinder.

Use the Solar Pathfinder tool to determine the most economical and efficient solar thermal array location and position: http://www.solarpathfinder.com/.

B-3.1.2.2 Solmetric SunEye.

Use the Solmetric SunEye tool to determine the most economical and efficient solar thermal array location and position: http://www.solmetric.com/.

B-3.1.2.3 Manual Calculation.

Manual calculations may be an acceptable approach for more experienced designers. Perform calculations justifying the basis of shadowing exclusion areas.

B-3.1.3 LCCA Tools.

B-3.1.3.1 Economic Analysis Package (ECONPACK).

Perform LCCA calculations and reports by utilizing a service's economic analysis program, such as the Economic Analysis Package (ECONPACK): http://www.wbdg.org/tools/econpack.php.

B-3.1.3.2 Building Life-Cycle Cost (BLCC).

Perform LCCA calculations and reports by utilizing a service's economic analysis program, such as the Building Life-Cycle Cost (BLCC) Program: http://www1.eere.energy.gov/femp/information/download_blcc.html.

B-3.1.4 Domestic Hot Water.

The FEMP Solar Hot Water System Calculator (http://apps1.eere.energy.gov/femp/solar_hotwater_system/) incorporates hot water demand estimates for several types of buildings: barracks, dormitory, food service, hospital, motel, office, residence, and school. Other required inputs are: number of persons, cold water temperature, and hot water temperature. The outputs are the total calculated load and estimated system size.

B-3.2 Solar Thermal Heat Transfer Fluids.

Observe the cautions regarding toxic heat transfer fluids as given here: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12930.

B-3.2.1 Hydrocarbon Oils

Hydrocarbon oils are for systems susceptible to regular freezing or stagnation temperatures, usually in ASHRAE Climate Zones 6 and above. Hydrocarbon must have a minimum closed-cup flashpoint 100 degrees F (38.7 degrees F) higher than the maximum expected collector temperature. Use oxygen scavenger additives when unsaturated hydrocarbons are used as heat transfer fluids. Some non-synthetic hydrocarbons thicken at low temperatures and the resultant higher viscosity can cause pumping problems. Synthetic hydrocarbon oils retain low viscosity at low temperatures, and therefore are required.

B-3.2.2 Distilled Water

Due to distilled water being subject to freezing and boiling, add an anti-freeze/anti-boil agent such as glycol.

B-3.3 Hydronic Heating Combined with Domestic Hot Water

Water-to-air heat exchangers may be placed in existing ductwork, in which case, an unpressurized, unlined tank may be used and represents a minimum heating system. The following is guidance for baseboard heaters:

- Most baseboard heaters have comparatively small surface areas, so they require higher temperatures, typically about 180 degrees F (82.2 degrees C). If larger heat transfer areas are available as in older or modified hot water systems, temperatures of 120 degrees F (48.9 degrees C) may be sufficient. Temperatures of 100 degrees F (37.8 degrees C) are adequate for the system which uses entire floors, walls, and ceilings as radiator surfaces.
- During the winter, typical liquid-type solar systems are seldom operated at delivery temperatures above 150 degrees F (65.6 degrees C). The use of solar heated water in standard baseboard heaters is impractical. Only modified baseboard heaters of adequate size or radiant panels shall be used in hydronic systems which use solar heated water.

B-3.4 Solar Thermal Collector Sub-System Array Design.

Select a specific collector for the detailed design before the actual array size is determined.

B-3.5 Reverse-Return Piping Layout – Diagonal Attachment Rule.

The reverse-return strategy of providing approximately equal length flow paths for supply and return pipes attached to the array at any two opposite diagonal corners of the array must be used for all projects.

B-3.6 Solar Thermal Pressure Drop Across Banks and Rows.

When internal-manifold collectors are banked together in groups of seven or less, it can be assumed that the pressure drop across the entire bank is equal to the pressure drop across a single collector.

B-3.7 Draindown and Drainback Systems.

Draindown (closed-loop) and drainback (open-loop) systems are prohibited due to additional maintenance required over the approved systems.

B-3.8 Over-Temperature Protection.

Over-temperature protection of the collector loop in the event of stagnation is provided through expansion tank sizing, and therefore there are no additional control requirements. The pressure-temperature relief valve located on the storage tank supplies over-temperature protection of the storage loop. If a direct circulating system is supplying water for domestic use, protection is provided through relief and mixing valves.

B-3.9 Heat Exchanger.

Effectiveness is a relatively complex term to calculate. Two methods of heat exchanger analysis are used in design: the log mean temperature difference (LMTD) method and the effectiveness-number of transfer units (e-NTU) method. The LMTD method is used most often for conventional HVAC systems and requires knowledge of three of the four inlet and outlet temperatures. This method cannot be applied directly to solar systems because the inlet temperatures to the heat exchangers from both the collectors and storage are not constant. Since the goal of the solar system heat exchanger is to transfer as much energy as possible, regardless of inlet and outlet temperatures, the e-NTU method should be used. However, a complete e-NTU analysis can be avoided by considering the impact of the heat exchanger on the overall system performance. The annual system solar fraction is decreased by less than 10 percent as heat exchanger effectiveness is decreased from 1.0 to 0.3. By setting a minimum acceptable effectiveness of 0.5, the e-NTU method can be used to generate the temperatures required by the LMTD method. These temperatures and the corresponding flow rates can then be used to size the heat exchanger according to the LMTD method, with the resulting heat exchanger satisfying the minimum effectiveness of 0.5.

Consult manufacturer’s representatives and catalogued data to size heat exchangers. A 120 degrees F (49 degrees C) solar loop exit temperature yields an effectiveness of 0.5, and increasing the exit temperature decreases effectiveness. To ensure an effectiveness greater than 0.5 is achieved, the designer provides the following recommended temperatures and flow rates:

- Solar loop inlet temperature = 140 degrees F (60 degrees C)
- Solar loop exit temperature = 120 degrees F (49 degrees C) or less
- Storage side inlet temperature = 100 degrees F (38 degrees C)
- Solar loop flow rate = Average flow rate (AFR)
- Storage loop flow rate = 1.25 × AFR.

B-4 SOLAR PHOTOVOLTAIC (PV) BEST PRACTICES.

B-4.1 Tools.

B-4.1.1 Screening Tools.

B-4.1.1.1 Solar Insolation Map.

Determined with a solar insolation map, sites with an average solar radiation rate above 5.0 kWh/m^2 per day must be carefully considered for solar photovoltaic energy.

B-4.1.1.2 PVsyst.

Consider using the PVsyst software package for preliminary design, project management, and data simulation: http://www.pvsyst.com.

B-4.1.1.3 PVWatts.

Consider using the PVWatts web application, developed to estimate the electricity production of a grid-connected roof- or ground-mounted photovoltaic system based on a few simple inputs: http://www.nrel.gov/rredc/pvwatts/.

B-4.1.1.4 Solar Prospector.

Use the Solar Prospector tool for mapping direct normal irradiance (DNI), developed by the National Renewable Energy Laboratory (NREL) for the initial evaluation for solar photovoltaic system viability: http://maps.nrel.gov/node/10/.

B-4.1.1.5 System Advisor Model (SAM).

Use the System Advisor Model, a performance and financial model designed to facilitate decision-making for those involved in the renewable energy industry: https://sam.nrel.gov/.

B-4.1.2 Shading Analysis Tools.

B-4.1.2.1 Solar Pathfinder.

Consider using the Solar Pathfinder tool to determine the most economical and efficient solar thermal array location and position: http://www.solarpathfinder.com/.

B-4.1.2.2 Solmetric SunEye.

Consider using the Solmetric SunEye tool to determine the most economical and efficient solar thermal array location and position: http://www.solmetric.com/.

B-4.1.2.3 Manual Calculation.

Experienced designers who may be more comfortable with using manual tools such as a tape measure is also an acceptable approach. Provide calculations justifying the basis of shadowing exclusion areas.

B-4.1.3 LCCA Tools.

B-4.1.3.1 Economic Analysis Package (ECONPACK).

Perform LCCA calculations and reports by utilizing a service's economic analysis program, such as the Economic Analysis Package (ECONPACK): http://www.wbdg.org/tools/econpack.php.

B-4.1.3.2 Building Life-Cycle Cost (BLCC).

Perform LCCA calculations and reports by utilizing a service's economic analysis program, such as the Building Life-Cycle Cost (BLCC) Program: http://www1.eere.energy.gov/femp/information/download_blcc.html.

B-4.2 Warranty.

Note that specific system components can have warranties that vary with each manufacturer. Typically, PV module warranty ranges from 5-10 years. Concerning performance, PV module warranty includes manufacturer written guarantee for minimum continuous power output of 80 percent for 20 years. Warranties for inverters have a typical range of 10-25 years depending on the manufacturer and technology. In addition, the PV mounting system warranty typically varies between 5-10 years.

B-4.3 Array Tilt Angle.

Anticipate any future structures or vegetation (trees) that could block future solar access, and keep the modules out of the shade between 9 a.m. and 3 p.m. when the bulk of the energy collection occurs.

B-4.4 Inverter and Array Design.

For string-inverter and micro-inverter systems, because the inverter must be sized for a system to last 20 years, the PV-to-inverter (DC-to-AC) size ratio must be between 1.1 and 1.4, or according to the microinverter manufacturer if microinverters are used. The ideal ratio must be determined by the designer using simulation software. Consider designing the system using smaller inverters so that less power is lost in the event one fails.

B-4.4.1 Maximum Panels for Inverter.

The temperature-corrected open-circuit voltage calculation used in determining the maximum number of panels for the inverter must not use the location record low temperature but rather refer to the Extreme Annual Mean Minimum Design Dry Bulb Temperature data published in ASHRAE Handbook – Fundamentals. The recommended method is to calculate the temperature-corrected, minimum expected module maximum power voltage, Vminmp = Vmp + ((T_rise + T_max – T_stc) X TCVmp), where,

- Vminmp = Minimum expected module maximum power voltage
  - Vmp = Module maximum power voltage
- T_rise = Temperature rise resulting from mounting conditions
- T_max = Average high ambient temperature
- T_stc = Temperature at Standard Test Conditions
- TCVmp = Temperature coefficient at maximum power voltage.

B-4.4.2 Minimum Panels for Inverter.

To determine the minimum number of panels in the string for the inverter, use the equation Nmin = Vmininv / Vmin, where:

- Nmin = Minimum number of panels per inverter string

- Vmininv = Minimum inverter voltage
- Vminmp = Minimum expected module maximum power voltage.

B-4.5 PV Array Zone Labeling.

On the as-built plans, label PV arrays into zones to match with corresponding inverters and combiner boxes. Labeling will help in identifying locations for troubleshooting and repair.

B-4.6 PV Modules and Hot Roofs.

Design for an air gap between continuous rows of PV modules for ventilation.

B-4.7 Equipment Locations.

Depending on the system design, equipment may be located indoors or outdoors. Equipment indoors adds generated heat to the building, but also adds longevity. Equipment outdoors may be subjected to a harsh environment. If equipment is in a desert environment, in addition to the proper NEMA enclosure, it must also be provided with a shading structure.

APPENDIX C GLOSSARY

C-1 ACRONYMS.

AC	Alternating Current
AFR	Average Flow Rate
BAS	Building Automation System
BIA	Bilateral Infrastructure Agreement
BTU	British Thermal Unit
CCB	Construction Criteria Base
CIS/CIGS	Copper Indium [Gallium] (di)Selenide
DC	Direct Current
DoR	Designer of Record
DHW	Domestic Hot Water
DTC	Differential Temperature Controller
ECM	Electronically Commutated Motor
EISA	Energy Independence and Security Act
FEMP	Federal Energy Management Program
HNFA	Host Nation Funded Construction Agreements
ISC	Integral Storage Collector
kW	Kilowatt
kWh	Kilowatt-Hour
LCCA	Life Cycle Cost Analysis
MTR	Military Training Route
NFPA	National Fire Protection Association
NREL	National Renewable Energy Laboratory
O&M	Operation & Maintenance
PV	Photovoltaic

RTD Resistance Temperature Detector

SAM System Advisor Model

SGHAT Solar Glare Hazard Analysis Tool

SIOH Supervision, Inspection, and Overhead

SIR Savings-to-Investment Ratio

SRCC Solar Rating and Certification Corporation

WBDG Whole Building Design Guide

C-2 DEFINITION OF TERMS.

Albedo: The fraction of solar radiation that is reflected from the ground, ground cover, and bodies of water on the surface of the earth.

Anemometer: An instrument that measures wind speed.

Azimuth Angle: The angle between the horizontal direction (of the sun, for example) and a reference direction (usually North).

Dry-Bulb Temperature: Air temperature measured with a thermometer, similar to ambient temperature.

Fixed-Tilt Array: An array of solar power collectors that do not pivot to follow the track of the Sun in the sky. In the Northern Hemisphere, they are usually mounted with a southern tilt that will maximize the amount of energy that they can receive.

Flat-Plate Collector: A solar power collector that absorbs the Sun's energy on a flat surface without concentrating or refocusing it.

Insolation: The amount of solar energy that arrives, at a specific area of a surface during a specific time interval. A typical unit is W/m^2.

Nadir: Straight down (toward the center of the Earth)

Net Metering: A service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.

Orientation: The direction that a solar energy collector faces. The two components of orientation are tilt angle (the angle the collector makes from the horizontal) and the aspect angle (the angle the collector makes from North)

Parabolic Collector Trough: A system that tracks the path of the sun by pivoting on one axis (typically East-West or North-South), using shiny parabolic troughs to heat the collector fluid that passes through a tube at the focus

Photovoltaic: Technology for converting sunlight directly into electricity, usually with photovoltaic cells

Solar Absorber: A sheet of metal, usually copper, aluminum, or steel, which forms the surface of a solar collector. It collects and retains solar radiation, which is passed to a heat transfer medium

Tracking Collector/Module: Any collector that changes its orientation throughout the day in order to follow the path of the sun in the sky. Two-axis trackers continually face the sun, while one-axis trackers rotate on one axis so that collectors receive the maximum amount of circumsolar radiation that strikes the axis.

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APPENDIX D EXAMPLE SOLAR THERMAL DRAWINGS AND SCHEDULE CHECKLIST

D-1 PURPOSE.

The drawings and schedule checklist provides the solar thermal system designer, project manager, and quality assurance personnel with a list of those items that are called out by the guide specification to appear on the drawings, or are strongly suggested based on experience with solar thermal system design problems. The designer is encouraged to annotate the drawings to ensure that design changes are properly accounted for, to provide a record of system settings and performance criteria, and to ensure that important details are not overlooked during construction. The following items should be included as part of the system drawings and schedule.

D-2 SUGGESTED DRAWINGS AND SCHEDULE.

D-2.1 Collector Array Layout (No Scale).

The collector array layout will be in accordance with the guidance defined in Chapter 2. As a minimum define the layout, number of collectors, bank sizes, rows (if applicable), and required fittings.

D-2.2 System Schedule.

The job specific system schedule includes the following:

- Note the collector parameters around which the system was designed:
    - Collector net aperture area.
    - Collector fluid volume.
    - Collector gross dimensions (length, width, and thickness).
    - Collector design flow rate (CFR, recommended by manufacturer).
    - Pressure drop at design flow rate.
    - Internal manifold diameter.
- Note the following system parameters:
    - System calculated net aperture area.
    - System (collector loop) flow rate required (AFR = CFR × Number of collectors).
    - Storage loop flow rate = 1.25 × AFR.
    - Propylene glycol concentration required in collector loop.
    - Minimum pressure drop throughout piping loop, corrected for propylene glycol solution, if necessary.
- Note the following information about the heat transfer fluid:

- Recommend only food-grade propylene glycol/distilled water solutions as the heat transfer fluid.
- Percent concentration required (30 percent or 50 percent).
- Tamper-resistant resistant seals are required at all fill ports or drains.

- Note the heat exchanger recommended minimum performance requirements to achieve an effectiveness of 0.5, although this may vary due to the system design and environment:
  - Solar loop (hot) inlet = 140 degrees F (60 degrees C).
  - Storage loop (cold) inlet = 100 degrees F (38 degrees C).
  - Solar loop (hot) outlet = 120 degrees F (49 degrees C), or less.
  - Solar loop (hot) flow rate = AFR.
  - Storage loop (cold) flow rate = 1.25 × AFR.
  - Solar (hot) fluid: 30 percent or 50 percent propylene glycol/water solution.
  - Storage (cold) fluid: water.
  - Note required pipe diameters.
  - Locate expansion tanks near pump inlets.
  - Require expansion tank bladders to be compatible with propylene glycol/water solutions.
  - Require a check valve in the collector loop in order to prevent reverse thermosiphoning.
  - Require isolation valves around the collector banks and all major components.
  - Require pressure relief shown on all banks.
  - Require calibrated balancing valves at all bank outlets.
  - Require drain valves at low points of each collector bank or row.
  - Require thumb valves (if required) to manually open and close pressure gauges and flow indicators not meant for constant use.
  - Require two drain valves, with gate in between, at all low points in the system to allow for filling.
  - Require 125 psi/210 degrees F (862 kPa/99 degrees C), pressure/temperature relief valve on the storage tank.
  - Require manual air vents at all high points of the system plumbing.
  - Locate collector temperature sensor on a nearby collector bank and in the top internal manifold piping between two collectors; or on the collector absorber plate, only if installed by manufacturer.

- o Locate a storage sensor in the thermal well at the bottom of the storage tank.
- o Require sensor wiring be installed in a conduit.
- o Require pressure gauges, rated for 125 psi (862 kPa), on both sides of pump(s), on all ports of the heat exchanger, and on the storage tank.
- o Require thermometers on all ports of the heat exchanger and at the top and bottom of the storage tank.
- o Require flow indicators or meters in each loop to allow either visual or quantified flow measurements to be observed.
- o Require an elapsed time meter be installed on circulation pump(s).
- o Require BTU meter be located across the heat exchanger on the storage side (if needed).

D-2.3 Roof Plan (To Scale Unless Noted).

- For Navy projects, coordinate with FC 1-300-09N.
- Collector groupings in banks and rows as designed.
- Minimum row spacing shown and noted.
- Orientation with respect to due south shown and noted.
- Rooftop mounted equipment, vents, and system penetrations shown and noted.
- Reverse-return piping shown and noted (not to scale).
- Expansion loops (if required) shown and noted.
- Manual air vents, pressure relief, valves and drains shown.
- Walkway, catwalk, or other array access shown and noted.

D-2.4 System Elevation.

- Pipe pitches for positive draining shown and noted.
- Piping elevations from equipment room to system and throughout array shown and system elevation head noted.
- Required collector tilt angle shown and noted.
- Mechanical chase shown between equipment room and roof.
- Array support structure shown.
- Walkway, catwalk, or other array access shown and noted.

D-2.5 Equipment Room Layout.

- Storage tank, pump(s), piping, control panel, heat exchanger, expansion tank, and drain shown.

- Backup water heating unit shown.
- Access is available to all equipment by maintenance personnel for repair, replacement, or monitoring.

D-2.6 Additional Schedules and Instructions.

- Schedule of operation. The operating characteristics (including the on/off temperature differential) of the system should be indicated.
- Installation instructions. Instructions should be provided regarding important installation details. These details include the use of Sb5, Sn94, or Sn96 solder for copper piping and on-site insulating instructions for equipment and piping.
- Design information schedule. Include the system design parameters into a drawing schedule(s).
- System filling and start-up instructions. Instructions on mixing the propylene glycol solution and filing the system will be provided. System fill pressure will be stated.
- Equipment schedule (standard).

D-2.7 Details.

- Storage tank.
  - Minimum of two tank penetrations each shown at both top and bottom of tank shown and noted.
  - Minimum insulation value of R-30 (factory or on-site application) shown and noted.
  - Storage sensor located in thermal well bottom of storage tank shown and noted.
  - Show and note that incoming water supply and outlet to solar system are connected to bottom of storage tank; inlet from solar thermal system and outlet to backup heating unit are connected to top of tank.
  - Dielectric couplings will be used on all piping connections.
  - Note that tank is to be lined with epoxy, glass, or cement.
  - If outdoors, weather protection and added insulation should be shown and noted.
  - Storage tank weight when filled should be noted.
  - Proper foundation for storage tank should be shown and noted.
- Heat exchanger (optional): For shell-in-tube heat exchangers, indicate the access areas allotted for tube bundle removal (to allow cleaning). Indicate that materials in the heat exchanger must be compatible with propylene glycol.
- Array support structure (typical).

- Collector mounting to support detail at proper tilt (within 10 degrees of site latitude) shown.
- Support mounting to roof detail shown.
- Aluminum structure with stainless steel hardware noted.
- Design loads noted.

- Collector temperature sensor mounting details. Detail showing mounting of the collector array temperature sensor should be provided. The sensor should show either mounting in the upper manifold piping between two collectors or should show mounting by the manufacturer directly to the absorber plate.
- Building piping penetrations. Design of piping penetration is weather tight and will withstand temperature expansion variations from 350 degrees F (177 degrees C) to the design low temperature of the project location.
- Pipe support. Pipe support design allows for temperature expansion variations from 350 degrees F (177 degrees C) to the design low temperature of the project location.

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APPENDIX E SOLAR PHOTOVOLTAIC TECHNOLOGIES

E-1 TECHNOLOGY.

This appendix identifies various solar PV technology alternatives and their main differences, to help the designer select the technology most appropriate for the project.

E-2 CRYSTALLINE SILICON.

Crystalline silicon PV is the most widely used to date with an approximate market share of 85%. There are two types of crystalline silicon: mono-crystalline and poly-crystalline.

E-2.1 Mono-Crystalline Silicon.

Most PV cells are mono-crystalline type. Silicon is purified, melted, and crystallized into ingots, which are then sliced into thin wafers or individual cells. The cells have a uniform color, usually blue or black and all cells in a module are cut from the same silicon ingot. Mono-crystalline possesses the highest conversion efficiency of approximately 18% and are more expensive than poly-crystalline silicon.

E-2.2 Poly-Crystalline Silicon.

Poly-crystalline silicon PV cells are manufactured and operated similar to the mono-crystalline type. The main difference is the usage of silicon that is of lower cost and quality, which results in a conversion efficiency lower than mono-crystalline, of approximately 14%. The surface of poly-crystalline cells has random patterns of crystal borders due to cells in the module cut from different ingots.

E-3 RIBBON SHEET SILICON.

Ribbon sheet cells are produced by growing a ribbon from molten silicon. These cells operate the same manner as mono- and poly-crystalline cells. The surface of these cells is coated with an anti-reflective material giving off a prismatic rainbow appearance.

E-4 THIN FILM.

Thin film technology emerged through successful efforts to reduce the amount of silicon per watt of PV energy generation and to improve the efficiency of cells manufactured when compared to crystalline silicon. Thin film technology is generally classified into three major categories: Amorphous silicon (a-Si), Cadmium Telluride (CdTe), and Copper Indium (Gallium) (di)Selenide (CIS/CIGS).

E-4.1 Amorphous Silicon Film.

Amorphous silicon cells have no particular shape and are deposited on a variety of substrates. Despite having a low conversion efficiency of 6-8%, the cells possess a reliable output in low-light conditions.

E-4.2 Cadmium Telluride Film.

Cadmium Telluride cells are formed from depositing four layers of material onto transparent glass as a substrate. This technology is manufactured at a relatively low cost with a production of 9-10% conversion efficiency.

E-4.3 Copper Indium (Gallium) (di) Selenide Film.

Copper Indium (Gallium) (di) Selenide (CIGS) film has the highest efficiency among thin film technologies. CIGS cells utilize either a rigid or flexible substrate coated with multiple layers of materials with an antireflective coating. Typical conversion efficiency is approximately 10-12%.

E-5 PROS-CONS: PV TECHNOLOGIES AND APPLICATIONS.

Refer to the Table E-1 for guidance on how to select the most appropriate PV technology.

Table E-1 PV Technologies Pros and Cons

Technology/Application	Pros	Cons
Mono-Crystalline Silicon	Crystalline silicon is more widely-used, proven technology. Highest conversion efficiency. Non-toxic to the environment.	Considerably more expensive than poly-crystalline at only marginally higher conversion efficiency.
Poly-Crystalline Silicon	Crystalline silicon is more widely-used, proven technology. More affordable than mono-crystalline. Non-toxic to the environment.	Lower conversion efficiency than mono-crystalline due to overall lower-quality silicon.
Ribbon Sheet Silicon	Manufacturing process yields less waste, more environmentally-friendly. Conversion efficiency similar to poly-crystalline.	Few vendors. Manufacturing method yields inconsistent thickness, yields conversion efficiency similar or worse than poly-crystalline.
Thin Film	Lower weight than crystalline silicon. Better wind resistance. Durable to foot traffic. Versatile. Affordable modules. Withstands high heat. Can use indirect light.	Much worse conversion efficiency and quicker performance degradation than crystalline silicon. Contains toxic materials.

Amorphous Silicon Film	Affordable modules. Flexible. Withstands high heat and partial shading.	Much worse conversion efficiency and quicker performance degradation than crystalline silicon.
Cadmium Telluride Film	Layered design allows module to capture more of the sunlight spectrum for more energy generation.	Cadmium is an exotic metal and toxic substance that may pose problems at the end of the life-cycle for disposal. Few vendors. Less efficient and more expensive than crystalline-silicon.
Copper Indium (Gallium) (di)Selenide Film	Layered design allows module to capture more of the sunlight spectrum for more energy generation.	Cadmium is an exotic metal and toxic substance that may pose problems at the end of the life-cycle for disposal. More difficult to manufacture than Cadmium Telluride. Few vendors. Less efficient and more expensive than crystalline-silicon.
BIPV [roof (i.e. solar shingles), façade]	Architecturally blends into structure, more aesthetically pleasing. Covers maximum surface area for more energy generation. Building itself is support structure.	Much worse conversion efficiency and quicker performance degradation than crystalline silicon. Difficult to repair and replace due to components beneath roof membrane.
BAPV	Architecturally blends into structure, more aesthetically pleasing. Covers more surface area for more energy generation. Building itself is support structure.	Much worse conversion efficiency and quicker performance degradation than crystalline silicon. Difficult to repair and replace.

E-6 PROS-CONS: PV TRACKING ARRAYS

E-6.1 PV Tracking Array Pros:

- Captures more solar irradiance energy than fixed-tilt arrays, increasing system output by up to 50% in the summer and 20% in the winter.

- Passive designs do not consume additional energy.

E-6.2 PV Tracking Array Cons:

- More expensive upfront than fixed-tilt arrays by up to 25%.
- Motorized designs consume energy for tracking mechanism to operate.
- Moving parts and more complicated design than fixed-tilt arrays.
- Heavier than fixed-tilt arrays.
- Higher maintenance costs than fixed-tilt arrays.
- A failed tracking mechanism can leave the array at an angle where it collects almost no sun.

APPENDIX F EXAMPLE SOLAR PV DRAWINGS AND SCHEDULE CHECKLIST

F-1 PURPOSE.

The drawings and schedule checklist provides the solar PV system designer, project manager, and quality assurance personnel with a list of those items that are called out by the guide specification to appear on the drawings, or are strongly suggested based on experience with solar PV system design problems. The designer is encouraged to annotate the drawings to ensure that design changes are properly accounted for, to provide a record of system settings and performance criteria, and to ensure that important details are not overlooked during construction. The following items should be included as part of the system drawings and schedule.

F-2 SUGGESTED DRAWINGS AND SCHEDULE.

F-2.1 PV Array Layout (No Scale).

The PV array layout will be in accordance with the guidance defined in Chapter 3. As a minimum define the layout, number of modules, string sizes, rows (if applicable), and required balance of system components. Coordinate with site plan to anticipate any future structures or vegetation (trees) that could block future solar access.

F-2.2 System Schedule.

The job specific system schedule includes the following:

- Note the module parameters around which the system was designed:
  - Module technology.
  - Module tilt and azimuth angle.
  - Racking type.
- Note the following system parameters:
  - System wattage and voltage.

F-2.3 Roof Plan (To Scale).

- Module groupings in strings and rows as designed.
- Minimum row spacing shown and noted.
- Orientation with respect to due south shown and noted.
- Tilt angle.
- Combiner boxes shown and noted.
- Rooftop mounted equipment, vents, and system penetrations shown and noted.
- Rooftop conduit shown and noted.
- Walkway, catwalk, or other array access shown and noted.

F-2.4 System Elevation.

- Required module tilt angle shown and noted.
- Conduit run shown between equipment room and roof.
- Array support structure shown.
    - Collector mounting to support detail at tilt shown.
    - Support mounting to roof detail shown.
    - Structure with hardware noted.
    - Design loads noted.
- Walkway, catwalk, or other array access shown and noted.

F-2.5 Equipment Area Layout.

- Inverters, disconnects, conduits, meters, main panel, and any subpanels shown.
- Access is available to all equipment by maintenance personnel for repair, replacement, or monitoring.
- Adequate working and personnel safety clearance distances must be indicated on the plans.

F-2.6 Additional Schedules and Instructions.

- Schedule of operation. The operating characteristics of the system should be indicated.
- Schedule of labels.

UNIFIED FACILITIES CRITERIA (UFC)

NOISE AND VIBRATION CONTROL

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UNIFIED FACILITIES CRITERIA (UFC)

NOISE AND VIBRATION CONTROL

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 3-450-01, dated 15 May 2003 and TM 5-805-4, dated 26 May 1995.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Mil Standard 3007G and UFC 1-300-01 requires the Tri-service community to achieve conformance to the Defense Standardization Program format and provide guidance consistent with current industry standards and incorporate best practices where applicable.

Noise and Vibration is a critical engineering feature to address in the design and construction of Tri-Service projects. UFC 3-450-01 (2003) is a unified document that includes ARMY TM 5-805-4/AFJAM 32-1090 (26 May 1995) Noise and Vibration Control. As written, ARMY TM 5-805-4/AFJAM 32-1090 is principally a technical "How To" manual to address Noise and Vibration control on projects.

1-2 REISSUES AND CANCELS.

This UFC updates and supersedes UFC 3-450-01 (May 2003).

1-3 INCORPORATES AND CANCELS.

This UFC incorporates salient features of and cancels ARMY TM 5-805-4/AFJAM 32-1090 (26 May 1995) Noise and Vibration Control.

1-4 PURPOSE.

This UFC provides qualified designers the criteria required for design and construction of those features related to noise and vibration control of electro-mechanical, mechanical, ductwork, and plumbing systems most commonly encountered in government facilities.

1-5 SCOPE.

This UFC applies to all new construction and to major alteration of existing structures. US government facilities that require higher standards because of special functions or missions are not covered in this document; criteria for these and other exceptions are normally contained in a design directive. If standards given in this UFC and its referenced documents do not provide all the needs of a project, recognized construction practices and design standards must be used.

1-6 DUCT LINING ATTENUATION.

Internal duct lining is prohibited. Prior to any design or construction, any consideration for its use must first be approved by exemption.

1-7 NOISE ESTIMATES.

Noise level estimates have been derived for various types of mechanical equipment, and in some cases graded for power or speed variations of the noise-producing machines. Noise data in the form of sound power levels per octave band must be obtained from the manufacturer to have the most acoustical accuracy, but these noise estimates can be used as a reference for typical expected noise levels across the frequency range. Data and recommendations are given for mechanical equipment installations on-grade and in upper-floor locations of steel and concrete buildings. Data and recommendations are also given for the analysis of noise in the surrounding neighborhood caused by mechanical equipment, such as cooling towers. On-site power plants driven by reciprocating and gas turbine engines have specific sound and vibration problems, which are considered separately, and their requirements are exclusive of this UFC.

1-8 SAFETY.

In addition to the subjective or perceived effects of noise, the requirements and information outlined in this document also consider the well-being of occupants in the facilities as pertaining to noise exposure. This accounts for avoiding long-term hearing damage or injury from loud noises to the occupants. The Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.95 covers the requirements for occupational noise exposure limits within a building or facility. The requirements listed within this document are established as not to exceed limits from the OSHA standard(s).

1-9 ENGLISH METRIC UNITS.

English units are used throughout this manual. Where applicable, metric units are listed in parentheses alongside the corresponding English units. Metric units are used in special applications where the United States has joined with the International Standards Organization (ISO) in defining certain acoustic standards, such as 20 microPascal (µPa) as the reference base for sound pressure level.

1-10 GLOSSARY.

APPENDIX B contains acronyms and terms.

1-11 REFERENCES.

APPENDIX E contains a list of references used in this document.

CHAPTER 2 PROJECT REQUIREMENTS AND DOCUMENTATION

2-1 GENERAL.

This chapter outlines the expected applications and minimum expectations of an acoustical review for a facility in-design or an existing facility. In addition, guidance is given for expected documents/deliverables that will display the results and recommendations needed for the acoustical review. This chapter must be followed by the engineer/consultant carrying out the analysis.

2-2 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design, and construction of DoD facilities worldwide. Where conflicts in requirements appear between sections of any UFC or applicable codes, the AHJ is the responsible party for determining the most restrictive requirement.

Refer to UFC 1-200-01 applicability paragraph for additional applicability guidance.

2-3 REQUIREMENTS FOR ACOUSTICAL REVIEWS.

When carrying out an acoustical review of a facility, there are several primary fields to analyze and report. These include, but are not limited to, HVAC noise & vibration control, interior sound isolation, and reverberant noise control. Criteria must be established for these fields. It is important to note that the fields included in an acoustical review are dependent on scoping for each individual facility project.

Calculations must be made for each of these fields to test for criteria compliance. The methods for completing these calculations must be determined by the engineer/consultant (computer software calculations, handwritten calculations, or similar). There are sample calculations and best practice techniques listed in Appendix A through Appendix C of this document.

2-4 DELIVERABLES FOR ACOUSTICAL DESIGN REVIEWS.

Documents that list the analysis results must be created by the engineer/consultant to report the acoustical review. At minimum, the deliverable must report the following for each acoustical field that is being reviewed:

1. Establish and list the acoustical design criteria. The standards used must be cited in the deliverable.
2. Supporting calculations and results of the analysis must also be included in the deliverable.
3. Provide recommendations for any fields that do not meet the established criteria. This is not needed if the facility has full criteria compliance.

The specific number of reports needed throughout the design process is dependent on the scope for each facility. For guidance in preparing an acoustical analysis report, please refer to the Sample Acoustical Analysis Report which can be found on the Whole Building Design Guide (https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-450-01).

2-5 DELIVERABLES FOR ACOUSTICAL MEASUREMENTS.

If on-site acoustical measurements are required at a facility, provide a report that outlines the corresponding measurement findings. The scope of the measurements is dependent on each individual facility. At minimum, the deliverable must report the following for each acoustical field that was measured:

1. Establish the methods used for the measurements. This must include the equipment used, measurement locations, and compliance with the measurements criteria listed in Chapter 8 of this document.
2. Report the existing conditions and list the acoustical design criteria for the fields that were analyzed. The standards used must be cited in the deliverable.
3. Report the measurement results for each analyzed field and compare to the existing conditions. These can be listed in tables, charts, or similar.
4. Provide recommendations for any fields that do not meet the established criteria. This is not needed if there were no deficiencies indicated in the measurement results.

The specific number of measurement reports required is dependent on the scope for each facility.

CHAPTER 3 NOISE CRITERIA

3-1 GENERAL.

This chapter includes data and discussions on generally acceptable indoor noise criteria for acceptable living and working environments. This criterion can be used to evaluate the suitability of existing indoor spaces and spaces under design.

3-2 NOISE CRITERIA IN BUILDINGS.

3-2.1 Evaluation Criteria.

Noise Criteria (NC) and Room Criterion (RC) are two widely recognized criteria used in the evaluation of the suitability of intrusive mechanical equipment noise into indoor occupied spaces. The Speech Interference Level (SIL) is used to evaluate the adverse effects of noise on speech communication.

3-2.2 NC Criteria.

For typical facility spaces (refer to Table 2-1 and Table 2-2 of UFC 3-101-01). Table 3-1 in this document must be used for spaces not covered under the referenced UFC 3-101-01 tables.

3-2.3 Strict Interpretation.

The sound levels of the mechanical equipment or ventilation system under design must be equal to or be lower than the selected NC target curve in all octave bands to meet the design goal. An estimation of the NC Level within a given space can be made using the following procedure:

1. Use Fig 3-1 to plot the sound pressure levels (dB) at each octave band frequency. The levels used can either be measured or calculated data. Methods for calculating sound pressure levels from known sound power levels are discussed in Appendix C.
2. Follow paragraph 3-2.2 Tangent Rating Procedure to determine the NC level curve for the space.

Refer to ASHRAE Applications (2019) Chapter 49 for further analysis and procedures. Additionally, Chapter 49 provides a Balanced Noise Criteria Method (NCB) used to specify or evaluate room noise.

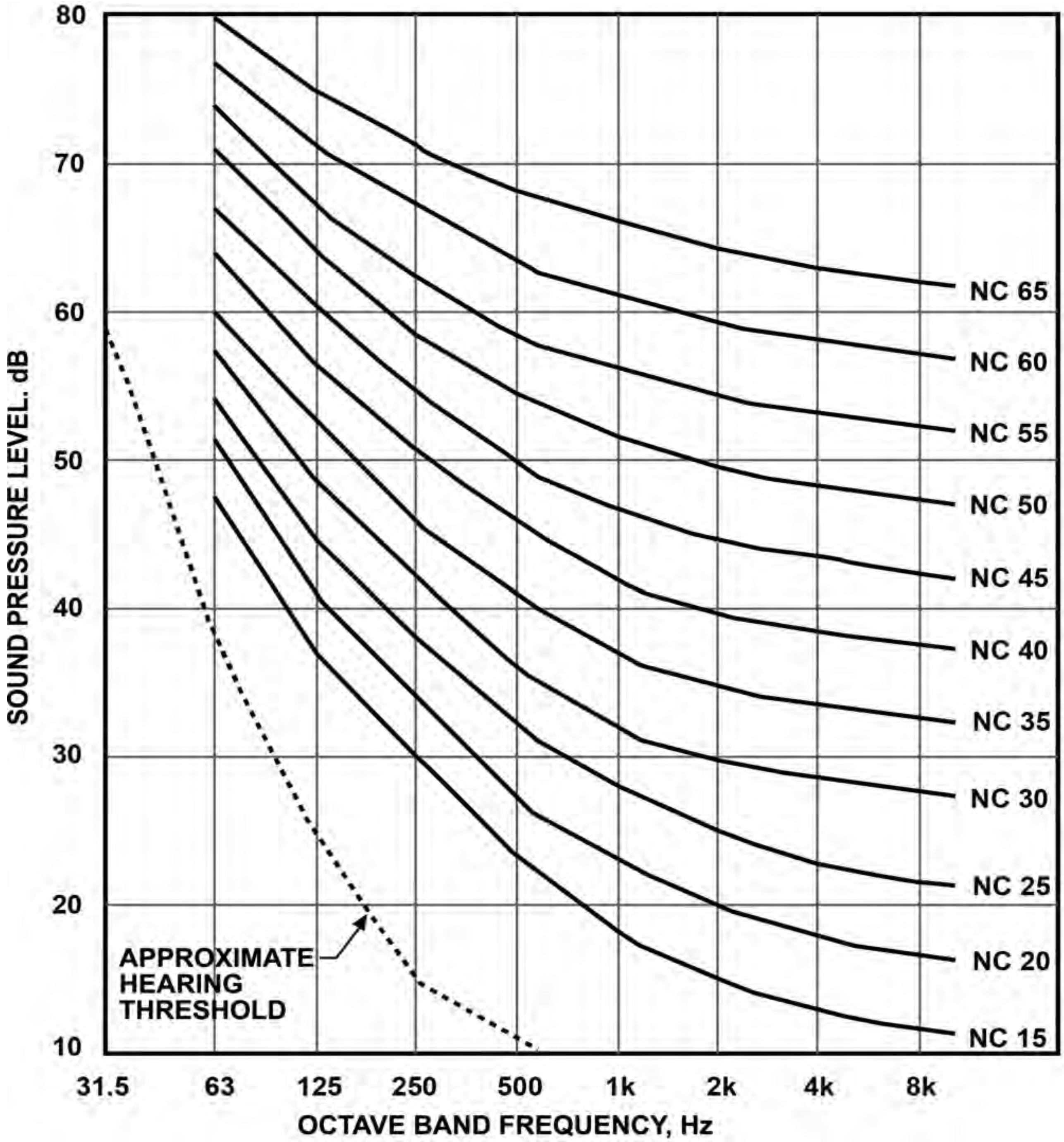
Table 3-1 Design Guidelines for HVAC-related Background Sound in Rooms

Space Types		NC Design Goal	Approximate Overall dBA	Sound Pressure Level dBC
Rooms with Outdoor Noise Intrusion	Traffic Noise	N/A	45	70
	Aircraft Flyovers	N/A	45	70
Office Buildings	Executive & Private Offices	30	35	60
	Conference Rooms	30	35	60
	Teleconference Rooms	25	30	55
	Open-plan Offices	40	45	65
	Corridors & Lobbies	40	45	65
Courtrooms	Unamplified Speech	30	35	60
	Amplified Speech	35	40	60
Performing Arts Spaces	Concert & Recital Halls	20	25	50
	Music Teaching Studios	25	30	55
	Music Practice Rooms	30	35	60
Hospitals & Clinics	Patient Rooms	30	35	60
	Wards	35	40	60
	Operating & Procedure Rooms	35	40	60
	Corridors & Lobbies	40	45	65
Laboratories	Testing/Research w/ minimal speech	50	55	75
	Extensive speech & phone use	45	50	70
	Group Teaching	35	40	60
Places of Worship	General assembly w/ critical music program	25	30	55
Schools	Classrooms	30	35	60
	Large Lecture Hall w/ speech amplification	30	35	60
	Large Lecture Hall w/o speech amplification	25	30	55
	Libraries	30	35	60
Indoor Stadiums/ Gymnasiums	Gymnasiums and Natatoriums	45	50	70
	Large-seating-capacity Spaces w/ speech amplification	50	55	75

3-2.4 Noise-Criterion (NC) Curves.

Figure 3-1 presents the NC curves. NC curves have been used to set or evaluate suitable indoor sound levels resulting from the operation of building mechanical equipment. These curves give sound pressure levels (SPLs) as a function of the octave frequency bands. The curves within this total range may be used to set desired noise level goals for almost all normal indoor functional areas.

Figure 3-1 Noise Criterion (NC) Curves.



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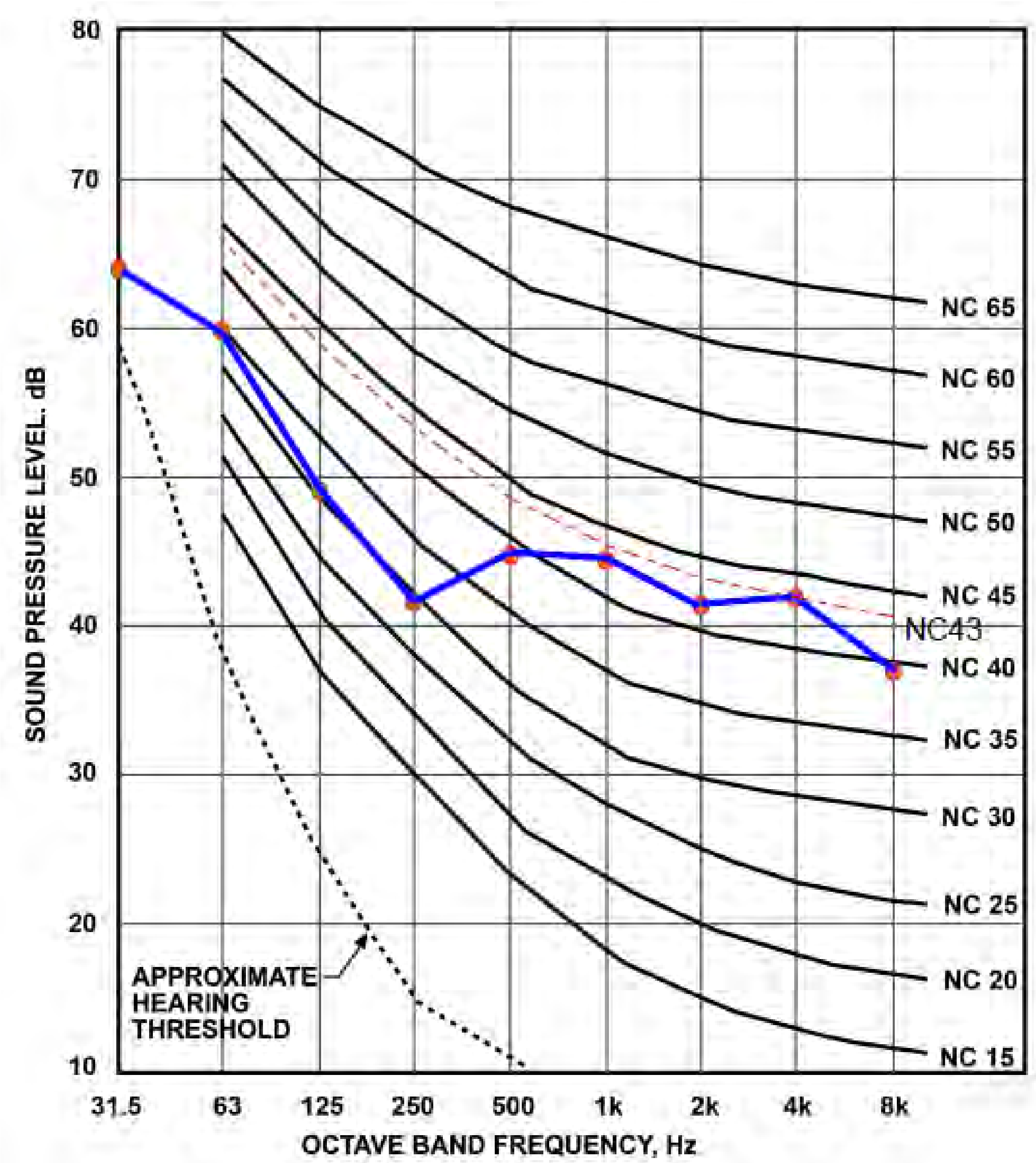
3-2.5 TANGENT Rating Procedure.

NC: Noise Criteria Method. The NC method for rating noise (described in Chapter 8 of the 2017 ASHRAE Handbook-Fundamentals) has been used for more than 50 years. It is a single-number rating that is somewhat sensitive to the relative loudness and speech interference properties of a given noise spectrum. The method consists of a family of criterion curves, shown in Figure 3-2, extending from 63 to 8000 Hz, and a tangency rating procedure. The criterion curves define the limits of octave band spectra that must not be exceeded to meet occupant acceptance in certain spaces. The rating is expressed as NC followed by a number (in example, NC 40). The octave mid-band frequency of the point at which the spectrum is tangent to the highest NC curve must also be reported (in example NC 43 [4k Hz]). The NC values are formally defined only in 5 dB increments, with intermediate values determined by discretionary interpolation. Widely used and understood, the NC method is sensitive to level but has the disadvantage that the tangency method used to determine the rating does not require that the noise spectrum precisely follow the balanced shape of the NC curves. Thus, sounds with different frequency content can have the same numeric rating, but rank differently based on sound quality. With the advent of VAV systems, low-frequency content (in other words, below the 63 Hz octave band) is prevalent, and the NC rating method fails to properly address this issue (Ebbing and Blazier 1992). Consequently, if the NC method is chosen, sound levels at frequencies below 63 Hz must be evaluated by other means.

In HVAC systems that do not produce excessive low-frequency noise and strong discernible pure tones, the NC rating correlates relatively well with occupant satisfaction if sound quality is not a significant concern. NC rating is often used because of its simplicity.

Figure 3-2 Noise Criterion (NC) Curves Tangent Plot.



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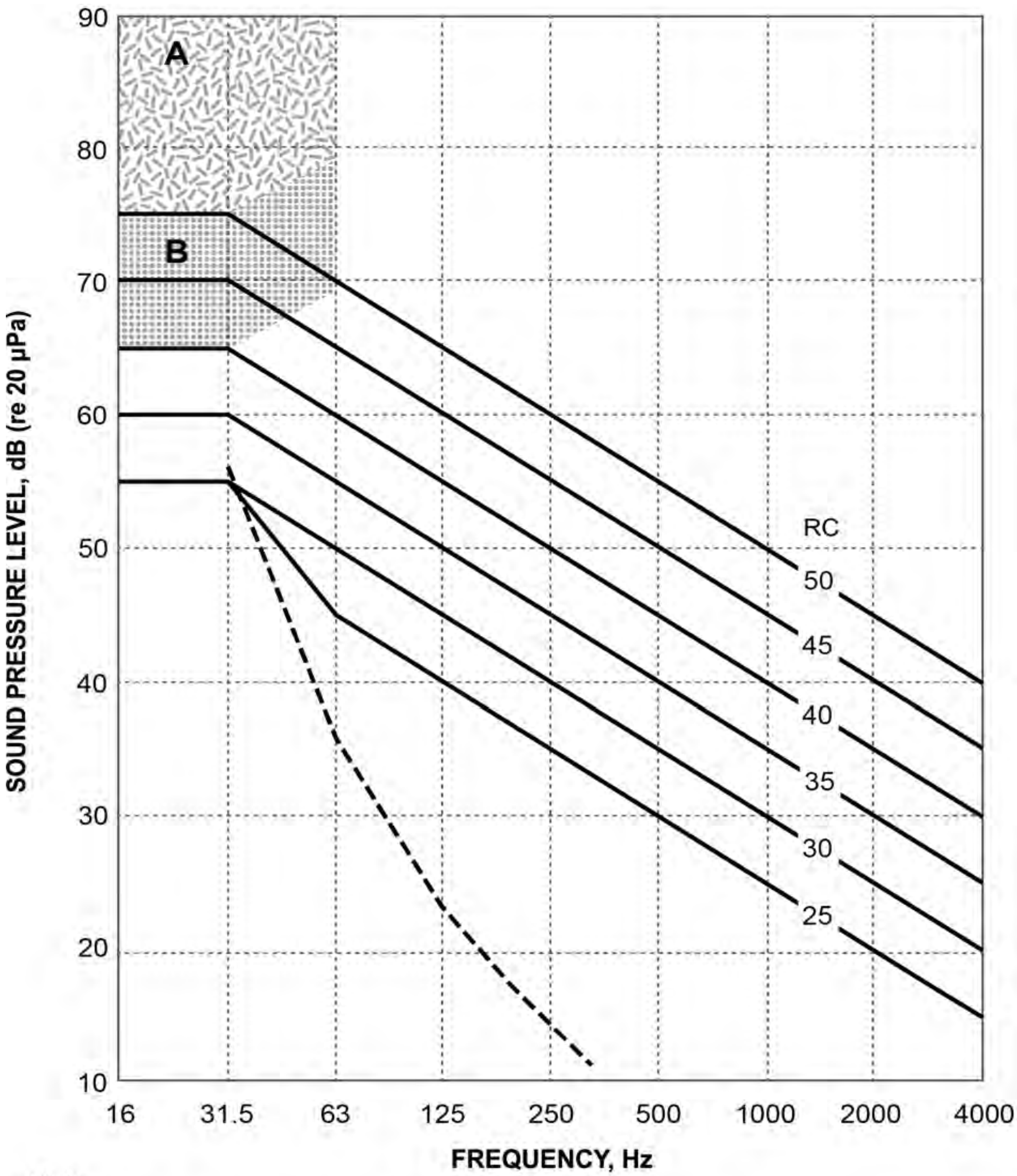
Hz	31.5	63	125	250	500	1000	2000	4000	8000
dB	64	60	49	42	45	45	42	43	37

Figure 3-3 Fig 3-3 Room Criterion (RC) Curves, Mark II



Note:

- Noise levels for lightweight wall and ceiling constructions:
  - In shaded region B are likely to generate vibration that may be perceptible. There is a slight possibility of rattles in light fixtures, doors, windows, etc.
  - In shaded region A have a high probability of generating easily perceptible noise-induced vibration. Audible rattling in light fixtures, doors, windows, etc. may be anticipated.

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3-3 ROOM CRITERION (RC) CURVES.

3-3.1 Evaluation.

Figure 3-3 presents the Room Criterion (RC) curves. RC curves, like NC curves, are currently being used to set or evaluate indoor sound levels resulting from the operation of mechanical equipment.

The evaluation of the RC curves is different than that for the NC curves. ASHRAE HVAC Applications (2019), Chapter 49 provides the RC Mark II method for RC analysis. The RC Mark II method has three parts:

1. A family of criterion curves (Figure 3-2)
2. A procedure for determining the RC numerical rating and the noise spectral balance (quality)
3. A procedure for estimating occupant satisfaction when the spectrum does not have the shape of an RC curve (quality assessment index)

Refer to Appendix C-14 for a detailed example of the RC Mark II rating procedure.

3-3.2 Rating.

The rating is expressed as RC followed by a number and a letter (in example, RC 35[N]). The number is the arithmetic average rounded to the nearest integer of sound pressure levels in the 500, 1000, and 2000 Hz octave bands (the main speech frequency region) and is known as the preferred speech interference level (PSIL). The letter is a qualitative descriptor that identifies the sound's perceived character: (N) for neutral, (LF) for low-frequency rumble, (MF) for midfrequency roar, and (HF) for high-frequency hiss. There are also two subcategories of the low-frequency descriptor: (LFB), denoting a moderate but perceptible degree of sound-induced ceiling/wall vibration, and (LFA), denoting a noticeable degree of sound-induced vibration.

Also indicated on the RC curves (Fig 3-3) are two regions where low frequency sound, with the octave band levels indicated, can induce feelable vibration or audible rattling in light weight structures. *Refer to ASHRAE Applications (2019) Chapter 49 for procedure in determining the RC Mark II rating for a system.*

3-4 SPEECH INTERFERENCE LEVELS.

The speech interference level (SIL) of a noise is the arithmetic average of the SPLs of the noise in the 500-, 1000-, 2000- and 4000-Hz octave bands. The approximate conditions of speech communication between a speaker and listener can be estimated from Table 3-2 when the SIL of the interfering noise is known. Table 3-2 provides “barely acceptable” speech intelligibility, which implies that a few words or syllables will not be understood but that the general sense of the discussion will be conveyed or that the listener will ask for a repetition of portions missed.

Table 3-2 Speech Interference Levels (SIL) That Permit Barely Acceptable Speech Intelligibility at the Distances and Voice Levels Shown

Distance (ft.)	Voice Level			
	Normal	Raised	Very Loud	Shouting
1/2	74	80	86	92
1	68	74	80	86
2	62	68	74	80
4	56	62	68	74
6	53	59	65	71
8	50	56	62	68
10	48	54	60	66
12	46	52	58	64
16	44	50	56	62

SIL is arithmetic average of noise levels in the 500-, 1000-, 2000-and 4000-Hz octave frequency bands. SIL values apply for average male voices (reduce values 5 dB for female voice), with speaker and listener facing each other, using unexpected work material. SIL values may be increased 5 dB when familiar material is spoken. Distances assume no nearby reflecting surface to aid the speech sounds.

The quality of telephone usage is related to SIL approximately as follows:

SIL Range (dB) for Telephone Usage

- 30-45 Satisfactory
- 45-60 Slightly difficult
- 60-75 Difficult
- Above 75 Unsatisfactory

3-5 LIMITATIONS.

The indoor noise criteria considered above assume that the noise is almost continuous and of a steady nature (not enough modulating or fluctuating up and down in level or frequency to attract attention), and there are no raucous, unpleasant sounds or strong tonal sounds. If any of these assumptions are not met, the sound level criteria must be even lower than the criteria normally considered applicable. The criteria given above is intended to be illustrative; any occupied or habitable area not identified in the list can be assigned to one of these categories based on similarity to the types of areas already listed. Generally, where a range of criteria is given, the lower values must be used for the more critical spaces in the category and for non-government areas outside the control of the facility; the higher of the range of criteria may be used for the less critical spaces in the category. Some short-term infrequent sounds (such as the weekly testing of a fire pump or an emergency power generator) may be allowed to exceed normal criteria in relatively noncritical areas if the normal functions of these areas are not seriously restricted by the increase in noise.

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CHAPTER 4 VIBRATION CONTROL

4-1 GENERAL.

This chapter includes data and requirements of indoor vibration criteria for acceptable living and working environments. This criterion can be used to evaluate the suitability of existing indoor spaces and spaces under design.

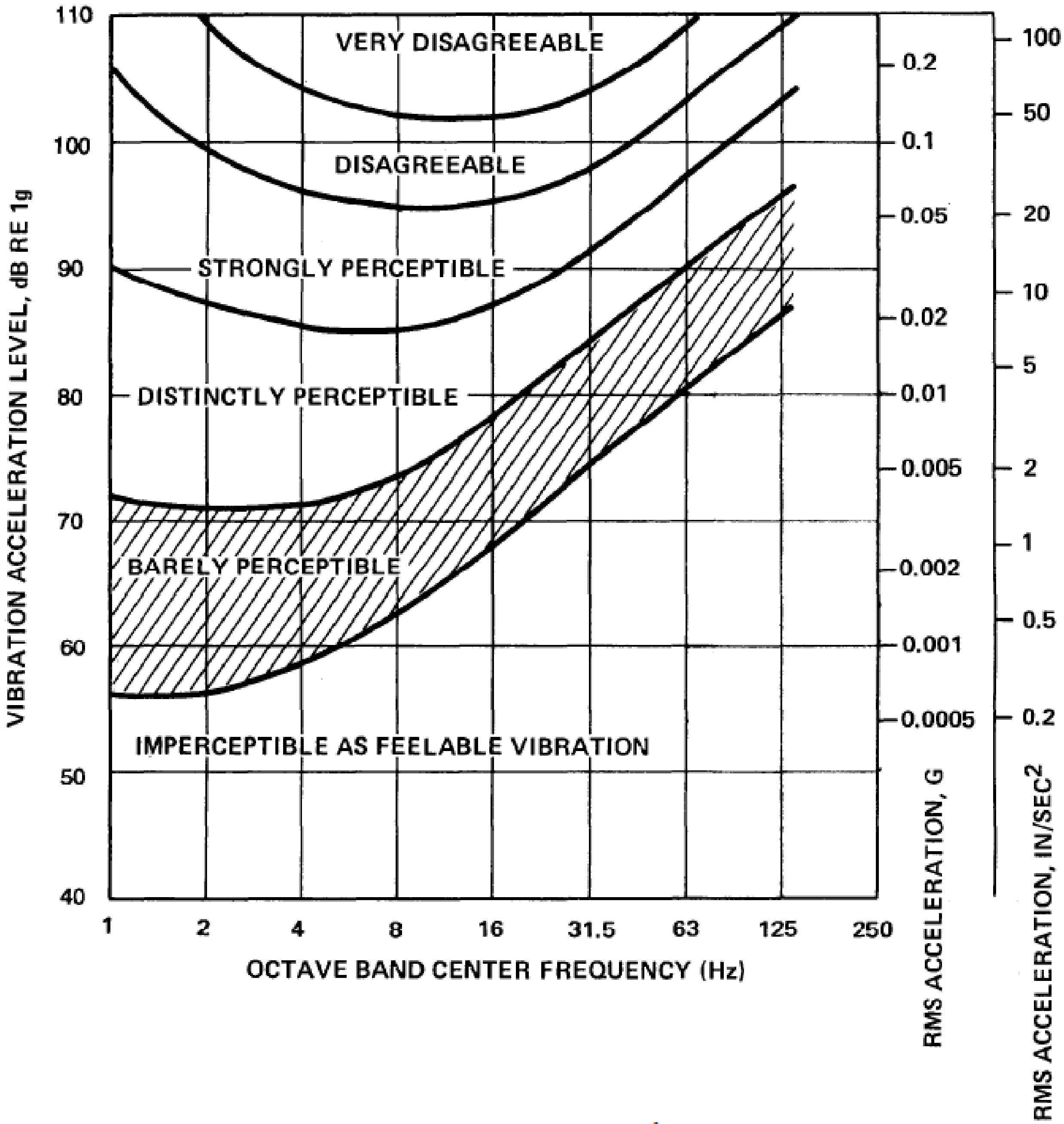
4-2 VIBRATION CRITERIA IN BUILDINGS.

Structural vibration in buildings, which results in feelable vibration, produces structural or superficial damage of building components, or interferes with equipment operation is unacceptable. In addition. large building components that vibrate can produce unacceptable sound levels.

4-3 VIBRATION CRITERIA FOR OCCUPANTS.

Figure 4-1 shows the approximate occupant response to building vibration levels. An approximation of the “threshold of sensitivity” of individuals to feelable vibration is shown by the shaded area of Figure 4-1, labeled “barely perceptible.” Other typical responses of people to vibration are indicated by the other zones in Figure 4-1. These reactions or interpretations may vary over a relatively wide range for different individuals and for different ways in which a person might be subjected to vibration (standing, seated, through the fingertips). The choice of a vibration criteria, for annoyance due to feelable vibration, will be determined by the usage of the space and the perceived sensitivity of the occupants. There will likely not be a problem with perceptible vibration when levels are 6 to 8 dB are below the “barely perceptible” range of Figure 4-1.

Figure 4-1 Approximate Sensitivity - Response of People to Feelable Vibration

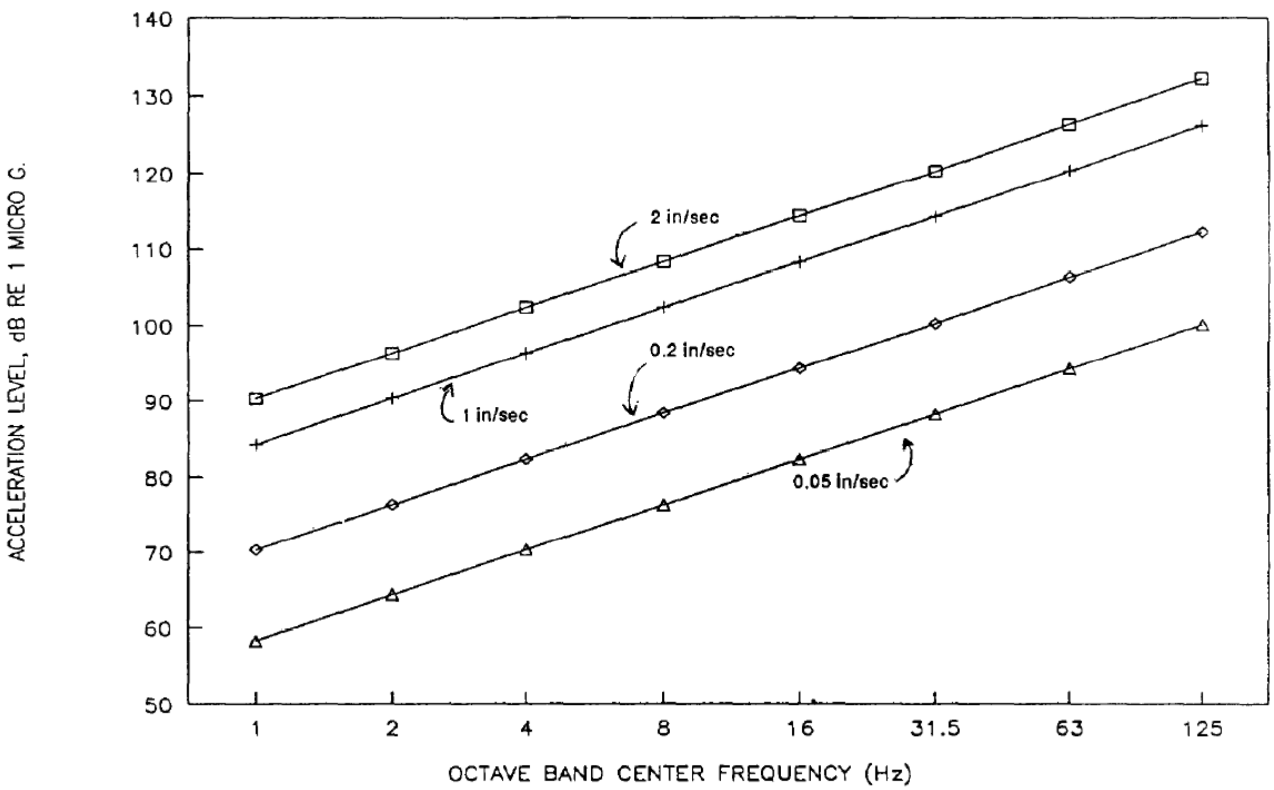


4-4 VIBRATION CRITERIA FOR BUILDING STRUCTURES.

A structural vibration velocity of 2.0 in/sec (0.0508 m/sec) has commonly been used as an upper safe limit for building structures, and vibrations above this value will have adverse environmental impact. A vibration velocity of 1.0 in/sec (0.0254 m/sec) must be used as a normally safe vibration upper limit with respect to structural damage. Vibrations with a velocity level greater than 1.0 in/sec must be avoided and measures must be implemented to reduce vibrations to 1.0 in/sec or less. Even with a vibration level of 1.0 in/sec (0.0254 m/sec) superficial damage may occur in isolated instances.

Superficial damage can consist of small cracking in brittle facades such as plaster. To ensure that the possibility of superficial damage is minimized a vibration criterion of 0.2 in/sec (0.00508 m/sec) has been recommended. And finally, for very old structures an even lower level of 0.05 in/sec (0.00127 m/sec) is recommended. The way the level is to be determined is a function of the type of vibration expected or experienced. For continuous vibration the RMS level must be used. For impulsive vibration the Peak value is to be used. See Appendix B for a discussion of Peak and RMS vibration. On Figure 4-2 the vibration limits mentioned above have been plotted in terms of acceleration level in dB re 1 micro-G.

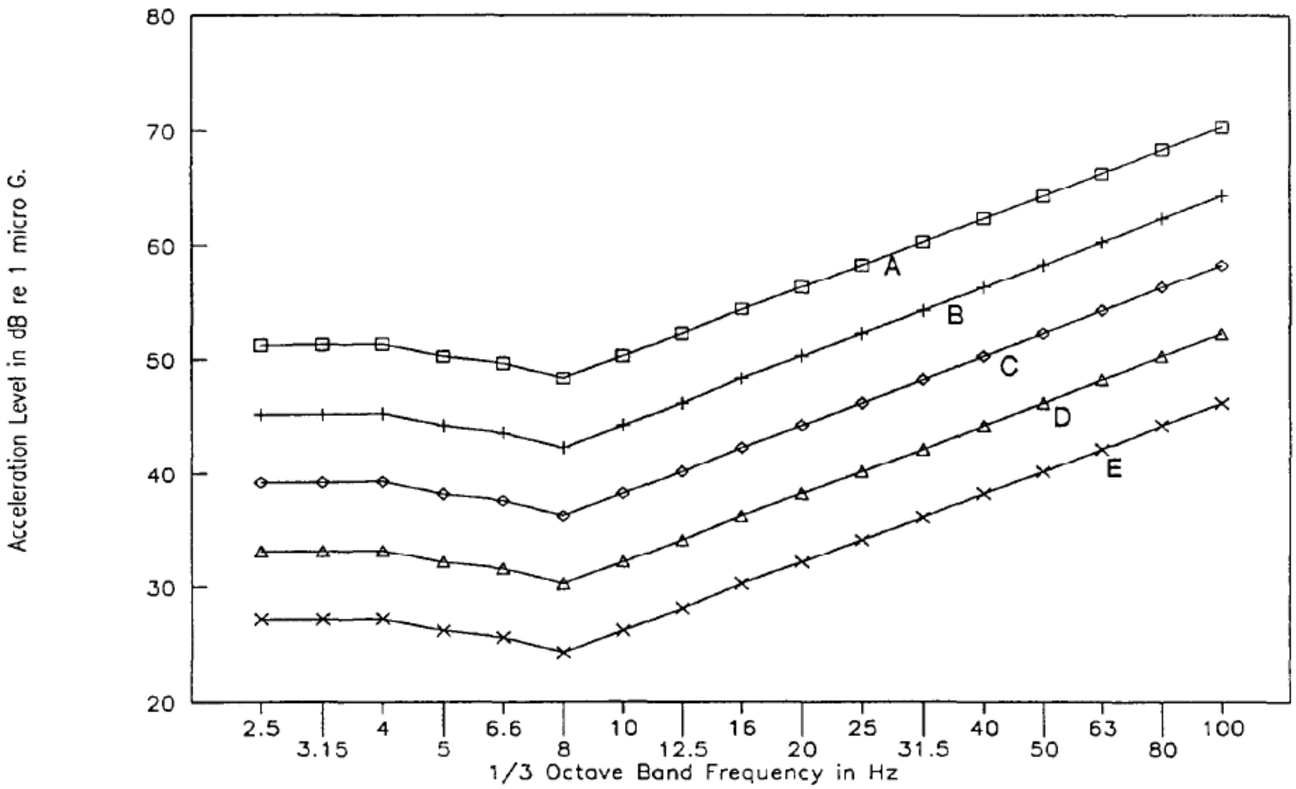
Figure 4-2 Vibration Criteria for Damage Risk to Buildings.



4-5 VIBRATION CRITERIA FOR SENSITIVE EQUIPMENT.

Building vibration may be disturbing to the use or proper operation of vibration-sensitive equipment, such as electron microscopes and other special chemical, medical, or industrial instruments or processes. Figure 4-3 shows vibration criteria for some sensitive equipment types. To achieve these low-level vibration levels special building construction, mechanical equipment selection and isolation, and vibration isolation for the sensitive equipment are required.

Figure 4-3 Vibration Criteria for Sensitive Equipment in Buildings.

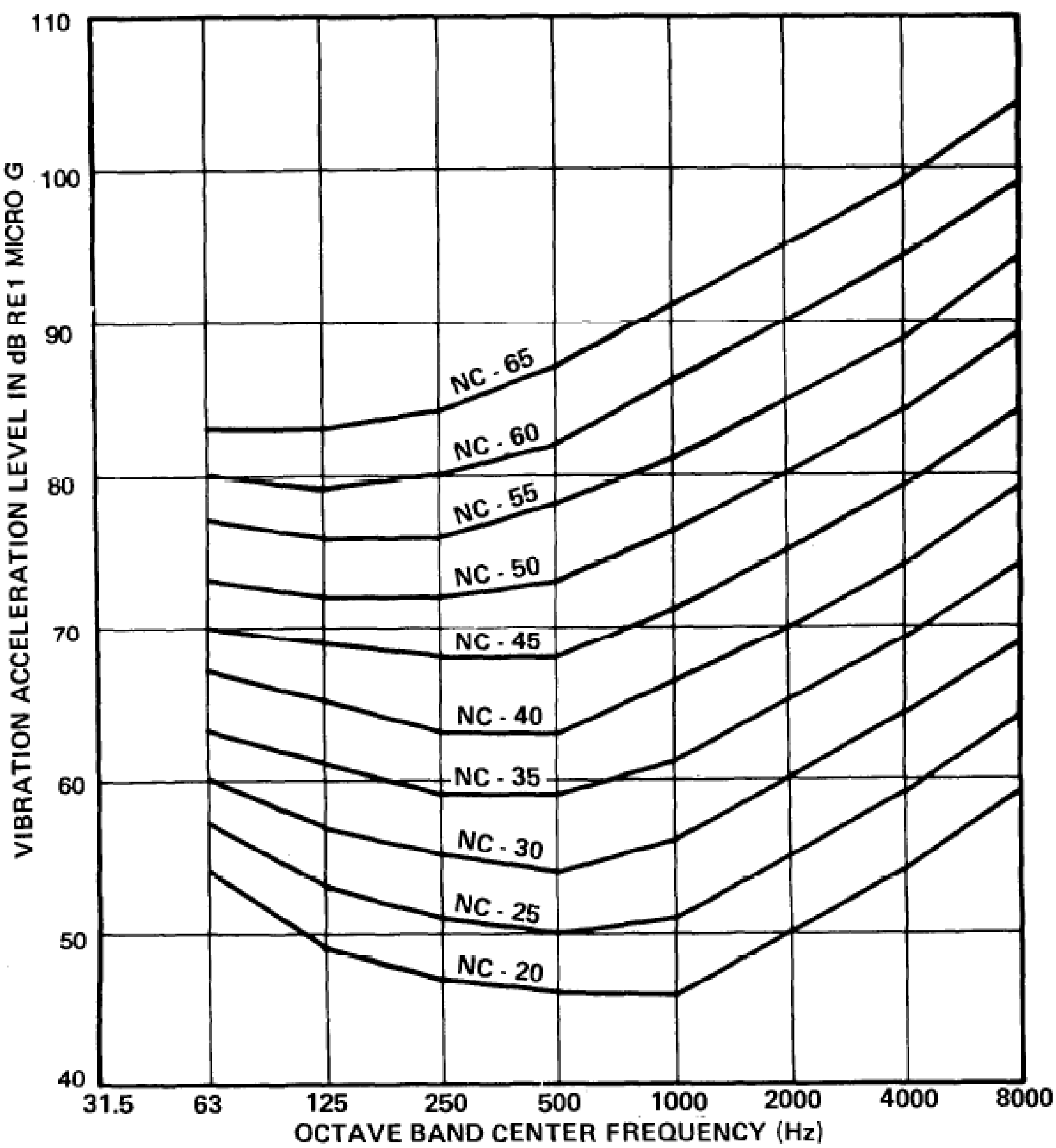


Note:
a. 100 X Microscopes.
b. 500 X Microscopes.
c. 1,000 X Microscopes.
d. Electron Beam Microscopes to 0.3 micrometer geometries.
e. Anticipated Adequate for future low submicron geometries.

4-6 VIBRATION CRITERIA FOR SOUND CONTROL.

Vibrating building components will produce sound radiation which may be unacceptable. Figure 4-4 shows “NC-equivalent” sound level curves as a function of acceleration level of a large surface. These NC-equivalent curves show the vibration acceleration levels of a large vibrating surface (such as a wall, floor, or ceiling of a room) that will produce radiated sound having approximately the octave band sound pressure levels of the NC curves (shown earlier in Figure 3-1).

Figure 4-4 Vibration Acceleration Levels of a Large Vibrating Surface that Will Produce Radiated Sound Levels into a Room Approximating the Sound Levels of the NC Curves



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CHAPTER 5 SOUND ISOLATION BETWEEN ROOMS

5-1 OBJECTIVE.

This chapter provides data and procedures for estimating the changes in sound levels as one follows the "energy flow" path from a sound source to a receiver, through building components, such as walls, floors, doors and similar items. First, the sound pressure levels in the room containing the source drop off as one moves away from the source. Then, at the walls of the room, some sound is absorbed, some is reflected back into the room, and some is transmitted by the walls into the adjoining rooms (this also occurs at the floor and ceiling surfaces). The combined effects of this absorption, reflection, and transmission are the subject of this chapter.

5-2 SOUND TRANSMISSION LOSS (TL) AND SOUND TRANSMISSION CLASS (STC).

With the knowledge of the acoustical isolation provided by walls and floors, it is possible to select materials and designs to limit noise intrusion from adjacent mechanical equipment rooms to acceptable levels. The degree of sound that is transmitted is influenced by the noise isolation properties of the demising construction, the area of the demising wall, floor or ceiling and the acoustical properties in the quiet room. Definitions for Transmission Loss (TL) and Sound Transmission Class (STC) are listed below. See Appendix C for additional information on sound transmission.

- Transmission Loss (TL): The TL of a wall is the ratio, expressed in decibels, of the sound intensity transmitted through the wall to the airborne sound intensity incident upon the wall.
- Sound Transmission Class (STC): A one-number weighting of transmission losses at various frequencies used to rate partitions, doors, windows, and other acoustic dividers in terms of their relative ability to provide privacy against intrusion of speech or noise.

5-3 SOUND TRANSMISSION LOSS CRITERIA FOR INTERIOR PARTITIONS.

Refer to UFC 3-101-01 (Table 2-1 and Table 2-2) for sound transmission criteria of partitions and doors at typical spaces that must be followed. In the case where criterion is dependent on the privacy requirements of the occupants, Table 5-1 in this document must be used to determine the appropriate STC design criteria for rooms of varied privacy levels. When rooms of differing privacy levels are adjacent to each other, the higher of the two STC requirements must be used at the dividing partition.

Table 5-1 STC Requirements based on Room Privacy Level

Room Privacy Level	Typical Adjacency	Sound Isolation Requirement
Private	Occupied Space	STC 45 - 50
	Corridor	STC 40 - 45
	Stairwell	STC 45 - 50
Confidential	Occupied Space	STC 50 - 55
	Corridor	STC 45 - 50
	Stairwell	STC 50 - 55
Classified	Occupied Space	STC 50 - 55
	Corridor	STC 50 - 55
	Stairwell	STC 50 - 55
Collaborative/Multi-use	Occupied Space	STC 35 - 40
	Corridor	STC 35 - 40
	Stairwell	STC 35 - 40
Mechanical Room	Occupied Space	STC 60 - 65
Restroom	Occupied Space	STC 50 - 55

5-4 DEFINITIONS OF ROOM PRIVACY LEVEL CATEGORIES.

The following lists defines each of the Room Privacy Levels listed in Table 5-1 and includes examples of typical spaces in each category.

1. Private: this covers rooms where moderate speech privacy is required. Speech intelligibility and concentration are preferred, but not critical for these rooms. Typical "Private" spaces such as private offices, exam rooms, group study rooms, and similar.
2. Confidential: this covers rooms where critical speech privacy is required. Speech intelligibility and concentration are of high priority in these rooms

and are essential for the occupants. Typical "Confidential" spaces can include conference rooms, classrooms, consultation rooms, and similar.

3. Classified: this covers rooms where critical speech privacy is required. Speech intelligibility and concentration are of critical priority in these rooms and are essential for the occupants. Typical "Classified" spaces can include conference rooms, classrooms, consultation rooms, and similar. with teleconferencing capabilities.

4. Collaborative/Multi-use: these are occupiable spaces where speech privacy is not critical. These rooms are generally occupied by multiple occupants. Typical "Collaborative/Multi-use" spaces include open offices, research laboratories, and similar.

5. Mechanical Room: any room designated for mechanical equipment servicing the HVAC systems of the building. The requirements must be followed for any room, housing air handler units, chillers, or other equipment with significant noise generation.

6. Restroom: any single or multi-occupant restrooms where plumbing noise is expected.

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CHAPTER 6 AIRBORNE SOUND CONTROL

6-1 INTRODUCTION.

This chapter draws together much of the factual content of the earlier chapters and presents a systematic approach for evaluating noise data and arriving at design decisions for controlling reverberation within noise-critical rooms, as well as the noise of electrical and mechanical equipment transmitted between room within a building and to other nearby structures. The chapter concludes with discussions of the various noise control treatments that are practical and available for solution of equipment noise problems. Almost all sound analysis problems can be divided into considerations of the; 1) Source; 2) Path and 3) Receiver Noise and vibration for specific problems may be reduced by using the following system approach:

1. Reduce noise and vibration at the source by using quieter equipment or noise-reducing modifications.
2. Prevent noise transmission by using barriers and prevent vibration transmission by using vibration isolators.
3. Relocate the receiver.

Sources of mechanical equipment sound are provided in Appendix B. Criteria for acceptable sound is given in Chapter 3. Chapter 7 provides a similar discussion for sound transmitted via air distribution systems in buildings. Considerations for vibration control of mechanical equipment are given in Chapter 8.

6-2 REVERBERENT NOISE CONTROL.

The interior acoustics of a room often refers to the overall noise within the space and the effects it has on the occupants. One driving factor of the “acoustical quality” within a space in the reverberant noise levels. When sound travels within a room, the energy can either be redirected by a reflective surface or distributed by diffusive/absorptive materials. When a room has little to no absorptive or diffusive surface materials, reverberant noise buildup can occur. This will lead to lower speech intelligibility within the room. To counteract this, a noise-critical room must be strategically designed with finishes and treatments to prevent excessive reverberant noise buildup.

Reverberation time (RT_{60}) is a metric used to quantify the reverberant noise within a room, measured in seconds. RT_{60} is the amount of time (in seconds) it takes for a given noise source to dissipate 60 dB across each frequency band. It is important to note that sound from the given source can take longer to dissipate at different frequencies. An overall RT_{60} can be determined from a weighted average of the RT_{60} at each band.

6-2.1 Reverberation Time (RT_{60}) Design Criteria.

The RT_{60} requirements for noise-critical spaces are a factor of the volume of the room and the intended application. If speech intelligibility is critical for a given space (in other words, classrooms, teleconferencing rooms, and similar.), the space must be designed to meet a specific overall RT_{60} criteria. Refer to UFC 3-101-01 (Table 2-1 and Table 2-2) for reverberation time criteria of typical facility spaces which must be followed.

6-3 INDOOR SOUND ANALYSIS.

6-3.1 Suggested Approach.

Essentially a flow diagram of sound from source to receiver, following certain prescribed steps.

1. The SPL or PWL values are obtained for each noise source (from Appendix B or other available source date).
2. The acoustic conditions inside the MER source room and in the receiving rooms are calculated.
3. The SPL values of all equipment sources are extrapolated to the interior MER walls and surfaces of interest (Appendix C).
4. Noise criteria are selected for all the receiving rooms of interest (Chapter 2).
5. Wall and floor designs are selected to permit acceptable amounts of equipment noise into the adjoining spaces (refer to Chapter 5 and APPENDIX C for additional guidance.)
6. Additional material in paragraph C-10.2.4 is considered if special noise control treatments are required. The procedures offered here are simple and relatively easy to follow, while designs are still on paper. Remedial treatments are difficult, expensive, time-consuming, and frequently less effective after the completed designs are fixed in steel and concrete. In some cases, it is found that the normally used walls or floors are not adequate, and improved versions must be substituted. Three additional factors must be considered in an overall acoustic design; these factors are aimed at finding the best mixture of practicality and total economy. One involves the possibility of using noise specifications to limit the amount of noise produced by noise-dominating equipment, the second involves use of noise control treatments on particularly noisy equipment, and the third involves building layout and equipment arrangement.

6-3.2 Use of Noise Specifications.

The use of noise specifications is presented in Chapter 7. It must be kept in mind that the noise levels quoted represent the 80- to 90-percentile range of the data studied and it can reasonably be expected that many suppliers of equipment can furnish products that are a few decibels quieter without burdening the job with excessive costs. Therefore, when it becomes apparent that one or two pieces of equipment stand out above all others in noise levels and dictate the need for unusually heavy walls or floors, it is good engineering to prepare noise-level specifications on those pieces of equipment and require that they be brought under reasonable noise limits. When this approach is used successfully, reduced noise can be achieved, and less expensive building designs can be used. It would be reasonable, first, to specify sound levels that range about 3 dB below the levels quoted in the manual. Such specifications would not seriously limit the availability of equipment, but they would weed out the noisiest equipment.

6-3.3 Use of Noise Control Treatments.

This subject is discussed in paragraph C-10.2.4. For some types of equipment, a noise control treatment may be more practical and less expensive than the problems of accommodating the untreated noisy equipment with strengthened building structures.

6-3.4 Building Layout Alternatives.

Many noise problems can be reduced during the design stage. In the building layout, critical spaces must be moved away from the mechanical rooms and, where possible, “buffer zones” be placed between the noisy and the quiet rooms. In the mechanical equipment rooms (MER), the noisiest equipment must be placed away from the common walls that join the critical rooms; and when reverberant sound levels pervade the entire MER and control the design, sound absorption may be applied to reduce those reverberant levels.

6-4 OUTDOOR SOUND PROBLEM AND ANALYSIS.

The basic procedure here, also, is to follow the sound path from the source to the receiver, applying certain adjustments and calculations along the way.

1. The SPL or PWL values must be determined for each source that can radiate noise outdoors.
2. The outdoor sound propagation factors of distance, air absorption, and anomalous excess attenuation must be applied for the prevailing temperature and humidity conditions.
3. Proper adjustments must be made for terrain, vegetation, and barrier effects encountered by the sound.
4. All the pertinent data are collected and summarized, and the outdoor and indoor SPLs are estimated for the various neighbors of interest.
5. The expected neighbor reaction to the outdoor noise is estimated and the expected indoor SPLs are compared against the indoor noise criterion applicable to the neighbor’s building.
6. Available noise control treatments and operational changes are considered if noise reduction is required to achieve satisfactory response of the neighbors to the outside noise.

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CHAPTER 7 MECHANICAL NOISE SPECIFICATIONS

7-1 OBJECTIVE.

Once noise and vibration control has been determined it is then necessary to specify the performance and materials for the noise control treatments. This chapter covers specifications for specialized acoustical products commonly used in building mechanical systems. Manufacturers can also provide guidance for acoustical products. Commonly used noise control products include attenuators in ducting systems and vibration isolation products. In addition, a noise level limit may be imposed on the equipment to be used, in which case it is the responsibility of the manufacturer to provide suitable noise or vibration control which will meet the criteria.

7-2 GENERAL CONSIDERATION.

All noise control specifications must include some common information. This includes:

- A statement as to the purpose for the noise control treatment. Although it may not be the responsibility of the supplier to meet the overall objective, if they know the overall objective, they may be able to provide guidance on the application of their product to aid in achieving the overall objective.
- Materials of construction that will be acceptable. This can be stated specifically, or it can be given in general terms.
- Conditions under which the material or items will be used. This mainly pertains to the environmental conditions (such as temperature, flow velocity, pressure, and similar).
- Acoustical performance that is expected. This can be the specific performance of a noise control item, or it can be the overall performance.
- How the acoustical performance is to be evaluated. This is the most important and difficult portion of any specification. This may take the form of a laboratory test or a test in the field under actual operating conditions. The references provide ASTM, ARI and ASHRAE standards commonly used to evaluate acoustical performance in the laboratory and in the field.
- What action is expected if the specified performance is not met.

7-3 PARTITIONS AND ENCLOSURES.

The performance specification of partitions and enclosures usually includes the sound isolation properties. The most common method is to specify the sound transmission loss (TL) required. The laboratory procedure is given in ASTM E90. ASTM standards E336 and E966 provide procedures for on-site evaluations of building partitions and building facades, respectively. For machinery enclosures the interior sound absorptive properties also need to be specified. ASTM standard C423 and E795 provides methods for mounting and measuring sound absorptive properties in the laboratory. ASTM standard E596 provides a laboratory method of rating the noise reduction of sound isolating enclosures. In addition, there are standards for the installation of partitions which are intended to provide sound isolation, such as ASTM E497.

7-4 ATTENUATORS AND DUCT LINING FOR DUCTED VENTILATION SYSTEMS.

Internal duct lining is prohibited. Prior to any design or construction, any consideration for its use must first be approved by exemption.

The acoustical performance for duct lining and attenuators is typically specified to be made in accordance with ASTM Standard E477. Note: this is a laboratory standard and includes insertion loss and regenerated noise (for attenuators). All suppliers of prefabricated duct attenuators are required to submit attenuator performance in accordance with this standard. In addition, many suppliers of duct attenuators will also provide guidance on how actual field installation may modify the laboratory performance.

CHAPTER 8 NOISE AND VIBRATION MEASUREMENTS

8-1 OBJECTIVE.

In the event that demonstration of compliance with noise or vibration criteria is required, sound or vibration measurements will be required. Within the scope of this manual, sound and vibration measurements and instrumentation might be involved in two types of situations: noise and vibration in buildings, and community noise or measurements. This chapter discusses these subjects.

8-2 SOUND AND VIBRATION INSTRUMENTATION.

8-2.1 Instrumentation.

Measuring sound and vibration vary widely in complexity and capability. However most sound and vibration level measurements for building mechanical equipment systems can be obtained with hand-held, battery operated meters. A basic sound level meter consists of a microphone, electronic circuits, and a display. Vibration measurements can be made with a sound level meter if the microphone is replaced with a vibration transducer. The most common vibration transducer is an accelerometer. With the use of an accelerometer the meter will display acceleration level in dB. Many sound level meters are equipped with “internal calibration” capabilities. While this is adequate for checking the internal electric circuits and display, the internal calibration does not check the operation of the microphone or accelerometer. Therefore, it is highly recommended that all sound level meter systems be equipped with a separate calibrator. Sound level calibrators generate a known sound level and vibration calibrators generate a known vibration signal. As a minimum, the sound level meter must be equipped with internal filters providing the capability octave band levels from 16 to 8,000 Hz. Many sound level meters have the capability to “A-weight” the octave band levels. The use of A-weighting is not appropriate for evaluating building mechanical systems.

8-2.2 Sound Level Meters.

The American National Standards Institute (ANSI) provides specifications for the acoustical and electrical response of sound level meters. ANSI Standard S1.4 specifies four types of sound level meters:

- Type 1 Precision (recommended for detailed analysis)
- Type 2 General Purpose
- Type 3 Survey
- Type S Special Purpose

The Type 1 Sound Level Meter has the capability to perform at least 1/1 octave and 1/3 octave frequency bands analysis, the tightest specification on frequency response, precision and stability. This meter is fitted with a microphone; it has a stable amplifier, controllable attenuators, and a meter that permits reading of sound levels over a wide range of values, such as from 30 decibels to 130 decibels sound pressure level (SPL) or more. The accuracy of the reading may be expected to be within 1 to 1.5 dB of the true SPL. This instrument also has the A-, C-, and Z- weighted filters that are held to within specified tolerances, and the meter has a “slow” and a “fast” response. At the “slow” setting, the meter in effect integrates the sound pressure level fluctuations of the last half second (approximately) and shows the “average” of that fluctuating signal. The “slow” setting is used for readings of “continuous” noise, in other words, noise that is produced by a continuing sound source without any noticeable periodic change (a fan would be considered a “continuous” source of noise, a pile drive would not). The “fast” response integrates the fluctuations of the last 1/8 second (approximately); thus, the needle jumps back and forth over a wider range of the meter face as it attempts to follow all short-term instantaneous changes. The Type 2 Sound Level Meter has slightly less stringent specifications than apply to the Type 1 meter. The A-, C-, and Z-weighted networks and the directionality limits of the microphone are slightly relaxed. The Type 3 Sound Level Meter is for general survey applications, where still less accuracy is acceptable. The Type 3 instrument is not acceptable for OSHA use, nor for any noise level application involving compliance with noise codes, ordinances, or standards. The Type S Sound Level Meter may be a simplified version of any of the Type 1, 2, or 3 instruments. It is a special purpose meter that may have, for example, Type 1 accuracy and only an A-weighted filter. In this case, it would be described as Type S1A (“S” indicates Special, “1” indicates Type 1 accuracy, and “A” indicates A-weighted filter). The Type S meter must carry a designation that describes its function (such as Type S1A or Type S2C, and similar), and must be constructed to meet the appropriate specification applicable to that special combination.

8-2.3 Octave Band Filters.

ANSI standards also exist on the frequency limits and tolerances of octave band and one-third octave band sound and vibration analyzers (ANSI S1.11). These filters are given a Class 1, 2 or 3 designations. Class 3 filters have the highest frequency discrimination and Class 1 have the lowest. It is recommended that all octave band filter sets used for the evaluation of noise in buildings, with respect to compliance with noise or vibration specifications, have a Class 2 or higher designation. For cursory evaluation a Class 1 will be sufficient.

8-2.4 Microphones.

Microphones are categorized by their frequency response, level sensitivity and directionality. Most provided microphones will provide suitable frequency response (10 to 10,000 Hz) and level sensitivity (30 to 130 dB) for the evaluation of mechanical equipment in buildings. The microphone directionality is important, however. Measurement microphones directionality is typically given as “free-field” or “random incidence”. Free field microphones are intended for use outdoors and the microphone must be aimed at the sound source under investigation. Random incidence microphones are used indoors where the reverberant sound is significant. There are adapters that can be applied to a free field microphone when used indoors.

8-2.5 Accelerometers.

Due to their small size, durability and extended frequency response, accelerometers are the most common vibration transducers. As a rule, the sensitivity of an accelerometer is directly proportional to the physical size (as such, larger accelerometers usually can measure lower vibration levels). The frequency response is inversely proportional to the sensitivity (as such, accelerometers with an extended frequency response may be limited in measuring low vibration levels.) In general, use a low-sensitivity accelerometer to measure high amplitude signals and a high-sensitivity accelerometer to measure low amplitude signals. Some accelerometers require an external power supply to operate a pre-amp that is incorporated into the accelerometer casing. There exists a large variety of accelerometers which to choose. Once the intended purpose is ascertained, a vendor/manufacturer can provide guidance on the most appropriate type and model of accelerometer to select.

8-3 MEASUREMENT OF NOISE AND VIBRATION IN BUILDINGS.

Noise measurements in buildings are commonly made either to determine if RC or NC curves have been met or to search for the cause of their not having been met. Conducting measurements after the equipment has been turned off is extremely helpful. A comparison of the measurement with and without the equipment in operation will indicate if the measurements are indicative of the equipment or another extraneous source. If the level decreases after the equipment have been turned off, then the measurements are indicative of the equipment under evaluation. If the sound level does not decrease after the equipment is turned off, then the measured level is not indicative of the equipment under evaluation. If the decrease is more than 2 dB but less than 10 dB, the measured levels after the equipment has been shut down can be subtracted from the levels with the equipment (see Appendix C). For the most accurate results, conduct these measurements at night or when the building is not in use. At these times it is easier to turn on and off equipment and extraneous sources are at a minimum.

8-3.1 Procedures.

For various indoor measurement types, the following procedures must be followed if these indoor measurement types are required for on-site testing:

- For background noise measurements, follow the guidelines from ASTM E1574
- For sound isolation measurements, follow the guidelines from ASTM E336
- For reverberant noise measurements, follow the guidelines from ASTM C423 (4.1 and 5.5)

8-4 MEASUREMENT OF NOISE AND VIBRATION OUTDOORS.

The consideration for measuring noise and vibration outdoors is identical to that for indoor measurements. The most significant factor is the environmental influence on the transmission of the sound. Environmental factors, such as wind, humidity and temperature gradients can produce significant (such as 5, 10 dB or greater) variations in the measured sound level. Therefore, it is important to document the environmental conditions at the time of the measurements. Ideally, take measurements under neutral conditions (such as no wind, cloudy overcast day).

8-4.1 Procedures.

For various outdoor measurement types, the following procedures must be followed if these outdoor measurement types are required for on-site testing.

- For outdoor noise measurements, follow the guidelines from ASTM E1014.
- For outdoor-to-indoor noise measurements, follow the guidelines from ASTM E966.

APPENDIX A BASICS OF ACOUSTICS

A-1 INTRODUCTION.

This Appendix presents the basic quantities used to describe acoustical properties. For the purposes of the material contained in this document perceptible acoustical sensations can be generally classified into two broad categories, these are:

A-1.1 Sound.

A disturbance in an elastic medium resulting in an audible sensation. Noise is by definition “unwanted sound”.

A-1.2 Vibration.

A disturbance in a solid elastic medium which may produce a detectable motion. Although this differentiation is useful in presenting acoustical concepts, sound and vibration are often interrelated. That is, sound is often the result of acoustical energy radiation from vibrating structures and, sound can force structures to vibrate. Acoustical energy can be completely characterized by the simultaneous determination of three qualities. These are:

A-1.2.1 Level or Magnitude.

This is a measure of the intensity of the acoustical energy.

A-1.2.2 Frequency or Spectral Content.

This is a description of an acoustical energy with respect to frequency composition.

A-1.2.3 Time or Temporal Variations.

This is a description of how the acoustical energy varies with respect to time. The subsequent material in this chapter defines the measurement parameters for each of these qualities that are used to evaluate sound and vibration.

A-2 DECIBELS.

The basic unit of level in acoustics is the “decibel” (abbreviated dB). In acoustics, the term “level” is used to designated that the quantity is referred to some reference value, which is either stated or implied.

A-2.1 Definition and Use.

The decibel (dB), as used in acoustics, is a unit expressing the ratio of two quantities that are proportional to power. The decibel level is equal to 10 times the common logarithm of the power ratio; or

Equation A-1. Decibel Level

$$\mathbf{dB = 10\log\frac{P_1}{P_2}}$$

Where:
dB = decibel
P_1 = absolute value of the power under evaluation (units vary)
P_2 = absolute value of a power reference quantity (same units as P_2)

In this equation P_1 is the absolute value of the power under evaluation and P_2 is an absolute value of a power reference quantity with the same units. If the power P_2 is the accepted standard reference value, the decibels are standardized to that reference value. In acoustics, the decibel is used to quantify sound pressure levels that people hear, sound power levels radiated by sound sources, the sound transmission loss through a wall, and in other uses, such as simply “a noise reduction of 15 dB” (a reduction relative to the original sound level condition). Decibels are always related to logarithms to the base 10, so the notation 10 is usually omitted. It is important to realize that the decibel is in reality a dimensionless quantity (somewhat analogous to “percent”). Therefore, when using decibel levels, reference needs to be made to the quantity under evaluation and the reference level. It is also instructive to note that the decibel level is primarily determined by the magnitude of the absolute value of the power level. That is, if the magnitude of two different power levels differs by a factor of 100 then the decibel levels differ by 20 dB.

A-2.2 Decibel Addition.

A-2.2.1 Example.

In many cases cumulative effects of multiple acoustical sources have to be evaluated. In this case the sum the individual sound levels. Decibel levels are added logarithmically and not algebraically. For example, 70 dB plus 70 dB does not equal 140 dB, but only 73 dB. A very simple, but usually adequate, schedule for obtaining the sum of two decibel values is:

When two decibel values differ by	Add the following amount to the higher value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

Use Equation A-2 when several decibel values are to be added.

Equation A-2. Decibel Addition

$$\mathbf{L_{sum}} = \mathbf{log}\left[\mathbf{10^{\frac{L_{p1}}{10}}} + \mathbf{10^{\frac{L_{p2}}{10}}} + \cdots + \frac{\mathbf{10^{L_{pn}}}}{\mathbf{10}}\right]$$

Where:
L_{sum} = cumulative decibel level
L_p = decibel level (each level to be added is notated by 1, 2,… n)

A-2.2.2 Special Case.

In the special case where decibel levels of equal magnitudes are to be added, the cumulative level can be determined with Equation A-3.

Equation A-3. Addition of Decibels with Equal Magnitudes

$$\mathbf{L_{sum}} = \mathbf{L_p} + \mathbf{10\ log(n)}$$

Where:
L_{sum} = cumulative decibel level
L_p = common decibel level
n = number of levels with equal magnitude

where n is the number of sources, all with magnitude L_p.

A-2.3 Decibel Subtraction.

In some case it is necessary to subtract decibel levels. For example, if the cumulative level of several sources is known, what would the cumulative level be if one of the sources were reduce? Decibel subtraction is given by Equation A-4.

Equation A-4. Decibel Subtraction

$$\mathbf{L_{diff}} = \mathbf{10\ log}[\mathbf{10^{\frac{L_{p1}}{10}}} - \mathbf{10^{\frac{L_{p2}}{10}}}]$$

Where:
Ldiff = cumulative decibel level
Lp1 = first decibel level
Lp2 = second decibel level

A-2.4 Decibel Averaging.

Strictly speaking decibels, average logarithmically not arithmetically. Use Equation A-5 for decibel averaging.

Equation A-5. Decibel Averaging

$$L_{avg} = 10\log\left[\frac{10^{\frac{L_{p1}}{10}} + 10^{\frac{L_{p2}}{10}} + \cdots + 10^{\frac{L_{pn}}{10}}}{n}\right]$$

Where:
Lavg = average decibel level
Lp = decibel level (each level to be added is notated by 1, 2,… n)

A-3 SOUND PRESSURE LEVEL (LP OR SPL).

The ear responds to sound pressure. Sound waves represent tiny oscillations of pressure just above and below atmospheric pressure. These pressure oscillations impinge on the ear, and sound is heard. A sound level meter is also sensitive to sound pressure.

A-3.1 Definition, sound pressure level.

The sound pressure level (in decibels) is defined by:

Equation A-6. Sound Pressure Level Format 1

$$L_p = 10\log[(\frac{p}{Pref})^2]$$

Where:
L_p = sound pressure level (in dB)
P = sound pressure (Pa)
Pref = reference sound pressure (20 µPa)

Where p is the absolute level of the sound pressure and Pref is the reference pressure. Unless otherwise stated the pressure, p, is the effective root mean square (rms) sound pressure. This equation is also written as:

Equation A-7. Sound Pressure Level Format 2

$$L_p = 20\log\left[\left(\frac{p}{Pref}\right)\right]$$

Where:
L_p = sound pressure level (in dB)
P = sound pressure (Pa)
Pref = reference sound pressure (20 µPa) (microPascal)

Although both formulas are correct, it is instructive to consider sound pressure level as the log of the pressure squared (Equation A-6). This is because when combining sound pressure levels, in almost all cases, it is the square of the pressure ratios (in other words, $\{p/P_{ref})^2\}$'s) that must be summed not the pressure ratios (in other words, not the {p/Pref}'s). This is also true for sound pressure level subtraction and averaging.

A-3.2 Definition, Reference Pressure.

Sound pressure level, expressed in decibels, is the logarithmic ratio of pressures where the reference pressure is 20 microPascal or 20 µPa (Pascal, the unit of pressure, equals 1 Newton/m2). This reference pressure represents approximately the faintest sound that can be heard by a young, sensitive, undamaged human ear when the sound occurs in the frequency region of maximum hearing sensitivity, about 1000 Hertz (Hz). A 20 µPa pressure is 0 dB on the sound pressure level scale. In the strictest sense, a sound pressure level must be stated completely, including the reference pressure base, such as "85 decibels relative to 20 µPa." However, in normal practice and in this document the reference pressure is omitted, but it is nevertheless implied.

A-3.3 Abbreviations.

The abbreviation SPL is often used to represent sound pressure level, and the notation Lp is normally used in equations, both in this document and in the general acoustics - literature.

A-3.4 Limitations on the Use of Sound Pressure Levels.

Sound pressure levels can be used for evaluating the effects of sound with respect to sound level criteria. Sound pressure level data taken under certain installation conditions cannot be used to predict sound pressure levels under other installation conditions unless modifications are applied. Implicit in these modifications is a sound power level calculation.

A-4 SOUND POWER LEVEL (LW OR PWL).

Sound power level is an absolute measure of the quantity of acoustical energy produced by a sound source. Sound power is not audible like sound pressure. However, they are related (see Section A-5). It is the way the sound power is radiated and distributed that determines the sound pressure level at a specified location. The sound power level, when correctly determined, is an indication of the sound radiated by the source and is independent of the room containing the source. The sound power level data can be used to compare sound data submittals more accurately and to estimate sound pressure levels for a variety of room conditions. Thus, there is technical need for the generally higher quality sound power level data.

A-4.1 Definition, sound power level.

The sound power level (in decibels) is defined by:

Equation A-8. Sound Power Level

$$L_w = 10 \log \frac{P}{Pref}$$

Where:
L_W = sound power level (in dB)
P = sound power (W)
Pref = reference sound power (10^{-12} W)

Where P is the absolute level of the sound power and Pref is the reference power. Unless otherwise stated the power, P, is the effective root mean square (rms) sound power.

A-4.2 Definition, Reference Power.

Sound power level, expressed in decibels, is the logarithmic ratio of the sound power of a source in watts (W) relative to the sound power reference base of 10-12 W. Before the US joined the IS0 in acoustics terminology, the reference power in this country was 10-13 W, so it is important in using old data (earlier than about 1963) to ascertain the power level base that was used. If the sound power level value is expressed in dB relative to 10-13 W, it can be converted to dB relative to 10-12 W, by subtracting 10 dB from the value. Special care must be used not to confuse decibels of sound pressure with decibels of sound power. It is often recommended that power level values always be followed by the notation "dB re 10-12 W." However, in this document this notation is omitted, although it will always be made clear when sound power levels are used.

A-4.3 Abbreviations.

The abbreviation PWL is often used to represent sound power level, and the notation L_W normally used in equations involving power level. This custom is followed in the document.

A-4.4 Limitations of Sound Power Level Data.

There are two notable limitations regarding sound power level data: Sound power cannot be measured directly but are calculated from sound pressure level data, and the directivity characteristics of a source are not necessarily determined when the sound power level data are obtained.

A-4.4.1 PWL Calculated, Not Measured.

Under the first of these limitations, accurate measurements and calculations are possible, but nevertheless there is no simple measuring instrument that reads directly the sound power level value. The procedures involve either comparative sound pressure level measurements between a so-called standard sound source and the source under test (in example, the "substitution method"), or very careful acoustic qualifications of the test room in which the sound pressure levels of the source are measured. Either of these procedures can be involved and requires quality equipment and knowledgeable personnel. However, when the measurements are carried out properly, the resulting sound power level data generally are more reliable than most ordinary sound pressure level data.

A-4.4.2 Loss of Directionality Characteristics.

Technically, the measurement of sound power level considers the fact that different amounts of sound radiate in different directions from the source, but when the measurements are made in a reverberant or semi-reverberant room, the actual directionality pattern of the radiated sound is not obtained. If directivity data are desired, measurements must be made either outdoors, in a totally anechoic test room where reflected sound cannot distort the sound radiation pattern, or in some instances by using sound intensity measurement techniques. This restriction applies equally to both sound pressure and sound power measurements.

A-5 SOUND INTENSITY LEVEL (LI).

Sound intensity is sound power per unit area. Sound intensity, like sound power, is not audible. It is the sound intensity that directly relates sound power to sound pressure. Strictly speaking, sound intensity is the average flow of sound energy through a unit area in a sound field. Sound intensity is also a vector quantity, that is, it has both a magnitude and direction. Like sound power, sound intensity is not directly measurable, but sound intensity can be obtained from sound pressure measurements.

A-5.1 Definition, Sound Intensity Level.

The sound intensity level (in decibels) is defined by:

Equation A-9. Sound Intensity Level

$$\mathbf{L_i = 10\log\frac{I}{I_{ref}}}$$

Where:
L_i = sound intensity level (in dB)
I = sound intensity (W/m^2)
I_{ref} = sound intensity reference (10^{-12} W/m^2)

Where I is the absolute level of the sound intensity and I_{ref} is the reference intensity. Unless otherwise stated the intensity, I, is the effective root mean square (rms) sound intensity.

A-5.2 Definition, Reference Intensity.

Sound intensity level, expressed in decibels, is the logarithmic ratio of the sound intensity of at a location, in watts/square meter (W/m^2) relative to the sound power reference base of 10^{-12} W/m^2.

A-5.3 Notation.

The abbreviation Li is often used to represent sound intensity level. The use of IL as an abbreviation is not recommended since this is often the same abbreviation for "Insertion Loss" and can lead to confusion.

A-5.4 Computation of Sound Power Level from Intensity Level.

The conversion between sound intensity level (in dB) and sound power level (in dB) is as follows:

Equation A-10. Sound Power Level from Intensity Level Format 1

$$\mathbf{L_w = 10\log\left[A\left(\frac{I}{I_{ref}}\right)\right]}$$

Where:
L_W = sound power level (in dB)
A = area of average intensity (m^2)
I = sound intensity (W/m^2)
I_{ref} = sound intensity reference (10^{-12} W/m^2)

where A is the area over which the average intensity is determined in square meters (m^2). Note this can also be written as:

Equation A-11. Sound Power Level from Intensity Level Format 2

$$\mathbf{L_w = L_i + 10\log\{A\}}$$

Where:
L_W = sound power level (in dB)
L_i = sound intensity level (in dB)
A = area of average intensity (m^2)

if A is in English units (sq. ft.) then Equation A-11 can be written as:

Equation A-12. Sound Power Level from Intensity Level (English Units)

$$\mathbf{L_w = L_i + 10\log\{A\} - 10}$$

Where:
L_W = sound power level (in dB)
L_i = sound intensity level (in dB)
A = area of average intensity (ft^2)

Note, when the area A completely closes the sound source, these equations can provide the total sound power level of the source. However, care must be taken to ensure that the intensity used is representative of the total area. This can be done by using an area weighted intensity or by logarithmically combining individual Lw's.

A-5.5 Determination of Sound Intensity.

Although sound intensity cannot be measured directly, a reasonable approximation can be made if the direction of the energy flow can be determined. Under free field conditions where the energy flow direction is predictable (outdoors for example) the magnitude of the sound pressure level (L_p) is equivalent to the magnitude of the intensity level (L_i). This result because, under these conditions, the intensity (I) is directly proportional to the square of the sound pressure (p^2). This is the key to the relationship between sound pressure level and sound power level. This is also the reason that when two sounds combine the resulting sound level is proportional to the log of the sum of the squared pressures (in example, the sum of the p^2's) not the sum of the pressures (in example, not the sum of the p's). That is, when two sounds combine it is the intensities that add, not the pressures. Recent advances in measurement and computational techniques have resulted in equipment that determine sound intensity directly, both magnitude and direction. Using this instrumentation sound intensity measurements can be conducted in more complicated environments, where fee field conditions do not exist and the relationship between intensity and pressure is not as direct.

A-6 VIBRATION LEVELS.

Vibration levels are analogous to sound pressure levels.

A-6.1 Definition, Vibration Level.

The vibration level (in decibels) is defined by:

Equation A-13. Vibration Level

$$L_a = \log\left[\left(\frac{a}{a_{ref}}\right)^2\right]$$

Where:
L_a = vibration level (in dB)
a = acceleration level (micro-G)
a_{ref} = acceleration level reference (1 micro-G)

Where a is the absolute level of the vibration and a_{ref} is the reference vibration. In the past different measures of the vibration amplitude have been utilized, these include, peak-to-peak (p-p), peak (p), average and root mean square (rms) amplitude. Unless otherwise stated the vibration amplitude, a, is the root mean square (rms). For simple harmonic motion these amplitudes can be related by:

rms value	=	0.707 x peak
average value	=	0.637 x peak
rms value	=	1.11 x average
peak-to peak	=	2 x peak

In addition, vibration can be measured with three different quantities, these are, acceleration, velocity and displacement. Unless otherwise stated the vibration levels used in this document are in terms of acceleration and are called "acceleration levels". For simple harmonic vibration at a single frequency the velocity and displacement can be related to acceleration by:

$$\text{velocity} = \text{acceleration}/(2\pi f)$$

$$\text{displacement} = \text{acceleration}/\ (2\pi f)^2$$

Where f is the frequency of the vibration in hertz (cycles per second). For narrow bands and octave bands, the same relationship is approximately true where f is the band center frequency in hertz.

A-6.2 Definition, Reference Vibration.

In this document, the acceleration level, expressed in decibels, is the logarithmic ratio of acceleration magnitudes where the reference acceleration is 1 micro-G (10-6), where G is the acceleration of gravity (32.174 ft/sec^2 or 9.81 m/s^2). Note: other reference acceleration levels are in common use, these include, 1 micro m/s^2,10 micro m/s^2 (approximately equal to 1 micro-G) and 1 G. Therefore, when stating an acceleration level, it is customary to state the reference level, such as "60 dB relative to 1 micro G."

A-6.3 Abbreviations.

The abbreviation VAL is sometimes used to represent vibration acceleration level, and the notation La is normally used in equations, both in this document and in the general acoustics literature.

A-7 FREQUENCY.

Frequency is analogous to "pitch." The normal frequency range of hearing for most people extends from a low frequency of about 20 to 50 Hz (a "rumbling" sound) up to a high frequency of about 10,000 to 15,000 Hz (a "hissy" sound) or even higher for some people. Frequency characteristics are important for the following four reasons: People have different hearing sensitivity to different frequencies of sound (generally, people hear better in the upper frequency region of about 500-5000 Hz and are therefore more annoyed by loud sounds in this frequency region); high-frequency sounds of high intensity and long duration contribute to hearing loss; different pieces of electrical and mechanical equipment produce different amounts of low-, middle-, and high-frequency noise; and noise control materials and treatments vary in their effectiveness as a function of frequency (usually, low frequency noise is more difficult to control; most treatments perform better at high frequency).

A-7.1 Frequency Unit, Hertz, Hz.

When a piano string vibrates 400 times per second, its frequency is 400 vibrations per second or 400 Hz. Before the US joined the IS0 in standardization of many technical terms (about 1963), this unit was known as "cycles per second."

A-7.2 Discrete Frequencies, Tonal Components.

When an electrical or mechanical device operates at a constant speed and has some repetitive mechanism that produces a strong sound, that sound may be concentrated at the principal frequency of operation of the device. Examples are the blade passage frequency of a fan or propeller, the gear-tooth contact frequency of a gear or timing belt, the whining frequencies of a motor, the firing rate of an internal combustion engine, the impeller blade frequency of a pump or compressor, and the hum of a transformer. These frequencies are designated "discrete frequencies" or "pure tones" when the sounds are clearly tonal in character, and their frequency is usually calculable. The principal frequency is known as the "fundamental," and most such sounds also contain many "harmonics" of the fundamental. The harmonics are multiple of the fundamental frequency, in other words, 2, 3, 4, 5, and the other times the fundamental. For example, in a gear train, where gear tooth contacts occur at the rate of 200 per second, the fundamental frequency would be 200 Hz, and it is very probable that the gear would also generate sounds at 400, 600, 800, 1000, 1200 Hz and so on for possible 10 to 15 harmonics. Considerable sound energy is often concentrated at these discrete frequencies, and these sounds are more noticeable and sometimes more annoying because of their presence. Discrete frequencies can be located and identified within a general background of broadband noise (noise that has all frequencies present, such as the roar of a jet aircraft or the water noise in a cooling tower or waterfall) with the use of narrowband filters that can be swept through the full frequency range of interest.

A-7.3 Octave Frequency Bands.

Typically, a piece of mechanical equipment, such as a diesel engine, a fan, or a cooling tower, generates and radiates some noise over the entire audible range of hearing. The amount and frequency distribution of the total noise is determined by measuring it with an octave band analyzer, which is a set of contiguous filters covering essentially the full frequency range of human hearing. Each filter has a bandwidth of one octave, and nine such filters cover the range of interest for most noise problems. The standard octave frequencies are given in Table A-1. An octave represents a frequency interval of a factor of two. The first column of Table A-1 gives the band width frequencies, and the second column gives the geometric mean frequencies of the bands. The latter values are the frequencies that are used to label the various octave bands. For example, the 1000-Hz octave band contains all the noise falling between 707 Hz (1000/square root of 2) and 1414 Hz (1000 x square root of 2). The frequency characteristics of these filters have been standardized by agreement (ANSI S1.11 and ANSI S1.6). In some instances, reference is made to "low", "mid" and "high" frequency sound. This distinction is somewhat arbitrary, but for the purposes of this document low frequency sound includes the 31 through 125 Hz octave bands, mid frequency sound includes the 250 through 1,000 Hz octave bands, and high frequency sound includes the 2,000 through 8,000 Hz octave band sound levels. For finer resolution of data, narrower bandwidth filters are sometimes used; for example, finer constant percentage bandwidth filters (such as half-octave, third octave, and tenth-octave filters), and constant width filters (such as 1 Hz, 10 Hz, and similar). The spectral information presented in this document in terms of full octave bands. This has been found to be a sufficient resolution for most engineering considerations. Most laboratory test data is obtained and presented in terms of 1/3 octave bands. A reasonably approximate conversion from 1/3 to full octave bands can be made (see d. below). In certain cases, the octave band is referred to as a “full octave” or "1/1 octave” to differentiate it from partial octaves such as the 1/3 or 1/2 octave bands. The term “overall” is used to designate the total noise without any filtering.

Table A-1 Bandwidth and Geometric Mean Frequency of Standard Octave and 1/3 Octave Bands.

Frequency, Hz					
Octave			One-third octave		
Lower band limit	Center	Upper band limit	Lower band limit	Center	Upper band limit
11	16	22	14.1	16	17.8
			17.8	20	22.4
			22.4	25	28.2
22	31.5	44	28.2	31.5	35.5
			35.5	40	44.7
			44.7	50	56.2
44	63	88	56.2	63	70.8
			70.8	80	89.1
			89.1	100	112
88	125	177	112	125	141
			141	160	178
			178	200	224
177	250	355	224	250	282
			282	315	355
			355	400	447
355	500	710	447	500	562
			562	630	708
			708	800	891
710	1,000	1,420	891	1,000	1,122
			1,122	1,250	1,413
			1,413	1,600	1,778
1,420	2,000	2,840	1,778	2,000	2,239
			2,239	2,500	2,818
			2,818	3,150	3,548
2,840	4,000	5,680	3,548	4,000	4,467
			4,467	5,000	5,623
			5,623	6,300	7,079
5,680	8,000	11,360	7,079	8,000	8,913
			8,913	10,000	11,220
			11,220	12,500	14,130
11,360	16,000	22,720	14,130	16,000	17,780
			17,780	20,000	22,390

Where TLob is the resulting octave band transmission loss and TL1, TL2 & TL3 are the 1/3 octave band transmission losses.

A-7.4 Octave Band Levels (1/3).

Each octave band can be further divided into three 1/3 octave bands. Laboratory data for sound pressure, sound power and sound intensity levels may be given in terms of 1/3 octave band levels. The corresponding octave band level can be determined by adding the levels of the three 1/3 octave bands using (lower, middle, and upper) Equation A-2. There is no method of determining the 1/3 octave band levels from octave band data. However, as an estimate one can assume that the 1/3 octave levels are approximately 4.8 dB less than the octave band level. Laboratory data for sound transmission loss is commonly given in terms of 1/3 octave band transmission losses. To convert from 1/3 octave band transmission losses to octave band transmission losses use Equation A-14.

Equation A-14. 1/3 Octave Bands to Octave Band Conversion

$$\mathbf{TL_{ab} = 4.77 - 10\log\left[10^{\frac{-TL_{lower}}{10}} + 10^{\frac{-TL_{middle}}{10}} + 10^{\frac{-TL_{upper}}{10}}\right]}$$

Where:

TL_{ab} = octave band transmission loss (in dB)
TL_{lower} = lower 1/3 octave band transmission loss (in dB)
TL_{middle} = middle 1/3 octave band transmission loss (in dB)
TL_{upper} = upper 1/3 octave band transmission loss (in dB)

A-7.5 A-, C-, & Z-Weighted Sound Levels.

Sound level meters are usually equipped with "weighting circuits" that tend to represent the frequency characteristics of the average human ear for various sound intensities. The frequency characteristics of the A-, C-, and Z-weighting networks are shown in Figure A-1. Table A-2 lists the uncompensated electrical frequency responses for A-, C-, and Z- weightings. The relative frequency response of the average ear approximates the A curve when sound pressure levels of about 20 to 30 dB are heard. For such quiet sounds, the ear has fairly poor sensitivity in the low-frequency region, the C curve shows the almost flat frequency response of the ear for loud sounds in the range of about 90 to 100 dB, and the Z-curve indicates unweighted or "linear" frequency responses. Annoyance usually occurs when an unwanted noise intrudes into an otherwise generally quiet environment. At such times, the ear is listening with a sensitivity resembling the A curve. Thus, judgment tests are often carried out on the loudness, noisiness, annoyance, or intrusiveness of a sound or noise related to the A-weighted sound level of that sound. The correlation is generally quite good, and it is a generally accepted fact that the high-frequency noise determined from the A- weighted sound level is a good indicator of the annoyance capability of a noise. Thus, noise codes and community noise ordinances are often written around A-weighted sound levels. For example: "The sound level at the property line between a manufacturing or industrial plant and a residential community must not exceed 65 dB(A) during daytime or 55 dB(A) during nighttime." Of course, other sound levels and other details might appear in a more complete noise code. Sound levels taken on the A-, C-, and Z-weighted networks have usually been designated by dB(A), dB(C), and dB(Z), respectively. The parentheses are sometimes omitted, as in dBA. The weighting networks, in effect, discard some of the sound, so it is conventional not to refer to their values as sound pressure levels, but only as sound levels-as in “an A-weighted sound level of 76 dB(A).” High-intensity, high-frequency sound is known to contribute to hearing loss, so the A-weighted sound level is also used as a means of monitoring factory noise for the hearing damage potential. It is very important, when reading or reporting sound levels, to identify positively the weighting network used, as the sound levels can be quite different depending on the frequency content of the noise measured. In some cases, if no weighting is specified, A-weighting will be assumed. This is very poor practice and is discouraged.

Figure A-1 Approximate Electrical Frequency Response of the A-, C-, and Z-weighted Networks of Sound Level Meters.

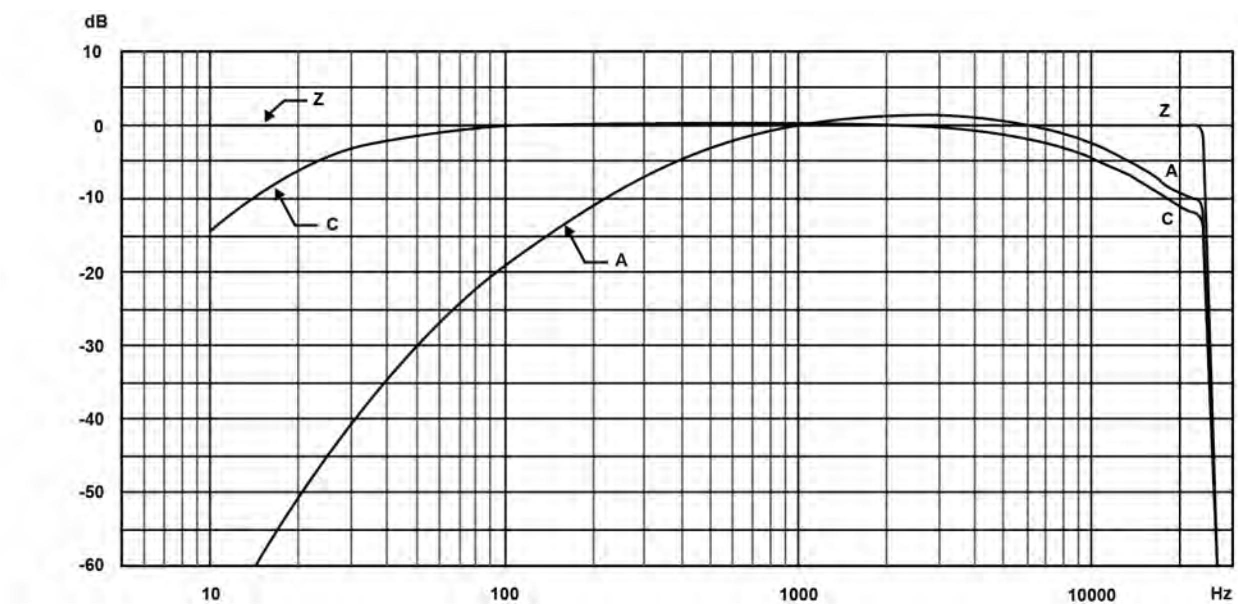


Table A-2 Uncompensated Electrical Frequency Responses for A-, C-, and Z-Weightings

(Continues on next page)

Nominal Frequency (Hz)	Exact Frequency (6 digits) (Hz)	Electrical Response (dB)	Add to Acoustical Responses (dB)	Nominal Frequency (Hz)	Exact Frequency (6 digits) (Hz)	Electrical Response (dB)
		A-weighting	C-weighting	Z-weighting	A-weighting	C-weighting
63	63.0957	-26.20	-0.82	0.00	-26.20	-0.82
80	79.4328	-22.50	-0.50	0.00	-22.51	-0.50
100	100	-19.14	-0.30	0.00	-19.14	-0.30
125	125.893	-16.10	-0.17	0.00	-16.10	-0.17
160	158.489	-13.35	-0.08	0.00	-13.35	-0.08
200	199.526	-10.87	-0.03	0.00	-10.87	-0.03
250	251.189	-8.63	0.00	0.00	-8.63	0.00
315	316.228	-6.61	-0.02	0.00	-6.61	0.02
400	398.107	-4.81	-0.03	0.00	-4.81	0.03
500	501.187	-3.23	-0.03	0.00	-3.23	0.03
630	630.957	-1.90	-0.03	0.00	-1.90	0.03
800	794.328	-0.82	-0.02	0.00	-0.82	0.02
1000	1000	0.00	0.00	0.00	0.00	0.00
1060	1059.25	0.17	-0.01	0.00	0.17	-0.01
1120	1122.02	0.32	-0.01	0.00	0.32	-0.01
1180	1188.50	0.46	-0.02	0.00	0.46	-0.02
1250	1258.93	0.59	-0.03	0.00	0.59	-0.03
1320	1333.52	0.71	-0.04	0.00	0.71	-0.04
1400	1412.54	0.81	-0.06	0.00	0.81	-0.06
1500	1496.24	0.90	-0.07	0.00	0.90	-0.07
1600	1584.89	0.98	-0.09	0.00	0.98	-0.09
1700	1678.80	1.05	-0.10	0.00	1.05	-0.10
1800	1778.28	1.11	-0.12	0.00	1.11	-0.12
1900	1883.65	1.16	-0.15	0.00	1.16	-0.14
2000	1995.26	1.20	-0.17	0.00	1.20	-0.17
2120	2113.49	1.23	-0.20	0.00	1.23	-0.20
2240	2238.72	1.25	-0.23	0.00	1.25	-0.23
2360	2371.37	1.26	-0.26	0.00	1.27	-0.26
2500	2511.89	1.27	-0.30	0.00	1.27	-0.30
2650	2660.73	1.26	-0.35	0.00	1.27	-0.34
2800	2818.38	1.25	-0.40	0.00	1.25	-0.39

3000	2985.38	1.22	-0.45	0.00	1.23	-0.45
3150	3162.28	1.19	-0.51	-0.01	1.20	-0.51
3350	3349.65	1.15	-0.58	-0.01	1.16	-0.57
3550	3548.13	1.10	-0.65	-0.01	1.10	-0.65
3750	3758.37	1.03	-0.74	-0.01	1.04	-0.73
4000	3981.07	0.96	-0.83	-0.01	0.97	-0.82
4250	4216.97	0.87	-0.93	-0.01	0.88	-0.92
4500	4466.84	0.77	-1.04	-0.01	0.79	-1.03
4750	4731.51	0.66	-1.17	-0.01	0.67	-1.16
5000	5011.87	0.54	-1.31	-0.01	0.55	-1.29
5300	5308.84	0.39	-1.46	-0.01	0.41	-1.45
5600	5623.41	0.23	-1.63	-0.02	0.25	-1.61
6000	5956.62	0.06	-1.81	-0.02	0.07	-1.80
6300	6309.57	-0.14	-2.02	-0.02	-0.12	-2.00
6700	6683.44	-0.35	-2.24	-0.02	-0.33	-2.22
7100	7079.46	-0.59	-2.48	-0.02	-0.57	-2.46
7500	7498.94	-0.85	-2.74	-0.02	-0.82	-2.72
8000	7943.28	-1.13	-3.03	-0.02	-1.10	-3.00
8500	8413.95	-1.43	-3.34	-0.03	-1.41	-3.31
9000	8912.51	-1.76	-3.67	-0.03	-1.74	-3.64
9500	9440.61	-2.12	-4.03	-0.03	-2.09	-4.01
10000	10000	-2.51	-4.42	-0.03	-2.48	-4.39
10600	10592.5	-2.92	-4.84	-0.03	-2.89	-4.81
11200	11220.2	-3.36	-5.28	-0.03	-3.34	-5.25
11800	11885.0	-3.84	-5.76	-0.03	-3.81	-5.73
12500	12589.3	-4.34	-6.26	-0.02	-4.31	-6.24
13200	13335.2	-4.87	-6.80	-0.02	-4.85	-6.77
14000	14125.4	-5.43	-7.36	-0.02	-5.42	-7.34
15000	14962.4	-6.02	-7.95	-0.01	-6.01	-7.94
16000	15848.9	-6.64	-8.56	-0.01	-6.63	-8.56
17000	16788.0	-7.27	-9.20	0.00	-7.27	-9.20
18000	17782.8	-7.92	-9.85	0.00	-7.92	-9.85
19000	18836.5	-8.56	-10.49	0.00	-8.56	-10.49
20000	19952.6	-9.17	-11.10	0.00	-9.16	-11.09
21200	21134.9	-9.71	-11.64	-0.02	-9.69	-11.62
22400	22387.2	-10.13	-12.06	-0.05	-10.08	-12.01

A-7.6 Calculation of A-Weighted Sound Level.

For analytical or diagnostic purposes, octave band analyses of noise data are much more useful than sound levels from only the weighting networks. It is always possible to calculate, with a reasonable degree of accuracy, an A-weighted sound level from octave band levels. This is done by subtracting the decibel weighting from the octave band levels and then summing the levels logarithmically using Equation A-2. But it is not possible to determine accurately the detailed frequency content of a noise from only the weighted sound levels. In some instances, it is considered advantageous to measure or report A-weighted octave band levels. When this is done the octave band levels must not be presented as “sound levels in dB(A)“but must be labeled as “octave band sound levels with A-weighting”, otherwise confusion will result.

A-8 TEMPORAL VARIATIONS.

Both the acoustical level and spectral content can vary with respect to time. This can be accounted for in several ways. Sounds with short term variations can be measured using the meter averaging characteristics of the standard sound level meter as defined by ANSI S1.4. Typically, two-meter averaging characteristics are provided, these are termed “Slow” with a time constant of approximately 1 second and “Fast” with a time constant of approximately 1/8 second. The slow response is useful in estimating the average value of most mechanical equipment noise. The fast response if useful in evaluating the maximum level of sounds which vary widely.

A-9 SPEED OF SOUND AND WAVELENGTH.

The speed of sound in air is given by Equation A-15 (Imperial units) and Equation A-16 (S.I. units):

Equation A-15. Speed of Sound (ft/s)

$$\mathbf{c = 49.03\ x\ (460 + t_F)^{1/2}}$$

Where:

c = speed of sound (ft/s)
*c = SQRT(k*gc*R*T/MW) ft/sec*
c = 49.02 x SQRT(T°R) ft/sec (air only)
k is specific heat ratio (dimensionless) for air k = 1.4
gc is gravitational conversion constant = 32.174 lbm.ft/(lbf.sec^2)
R is universal gas constant = 1545.4 ft.lbf/(lbm.°R) or 8314 J/(kmol.°K)
MW is Molecular Weight lbm/lbmol, MW for air is 28.965 lbm/lbmol or 28.965 kg/kmol
t_F = air temperature (degrees F)

Equation A-16. Speed of Sound (m/s)

$$\mathbf{c = 20.05 \ x \ (273 + t_C)^{1/2}}$$

Where:

c = speed of sound (m/s)
*c = SQRT(k*R*T/MW) m/sec*
t_F = air temperature (degrees C)

A-9.1 Temperature Effect.

For most normal conditions, the speed of sound in air can be taken as approximately 1120 ft./sec. (341.38 m/sec.). For an elevated temperature of about 1000 deg. F (537.78 deg. C), as in the hot exhaust of a gas turbine engine, the speed of sound will be approximately 1870 ft./sec. (569.98 m/sec.). This higher speed becomes significant for engine muffler designs, as will be noted in the following paragraph.

A-9.2 Wavelength.

The wavelength of sound in air is given by Equation A-17.

Equation A-17. Wavelength

$$\boldsymbol{\gamma = c/f}$$

Where:

γ = wavelength (ft)
c = speed of sound (ft/s)
f = frequency (Hz)

where γ is the wavelength in ft., c is the speed of sound in air in ft./sec, and f is the frequency of the sound in Hz. Over the frequency range of 50 Hz to 12,000 Hz, the wavelength of sound in air at normal temperature varies from 22 feet (6.71 meters) to 1.1 inches (0.02794 meters), a relatively large spread. The significance of this spread is that many acoustical materials perform well when their dimensions are comparable to or larger than the wavelength of sound. Thus, a l-inch thickness of acoustical ceiling tile applied directly to a wall is quite effective in absorbing high-frequency sound but is of little value in absorbing low-frequency sound. At room temperature, a 10-feet-long (3.05 meters) dissipative attenuator is about 9 wavelengths long for sound at 1000 Hz and is therefore quite effective but is only about 0.4 wavelength long at 50 Hz and is therefore not very effective. At an elevated exhaust temperature of 1000 deg. F (537.78 deg. C), the wavelength of sound is about 2/3 greater than at room temperature, so the length of a corresponding attenuator must be about 2/3 longer in order to be as effective as one at room temperature. In the design of noise control treatments and the selection of noise control materials, the acoustical performance will frequently be found to relate to the dimensions of the treatment compared to the wavelengths of sound. This is the basic reason why it is generally easier and less expensive to achieve high-frequency noise control (short wavelengths) and more difficult and expensive to achieve low-frequency noise control (long wavelengths).

A-10 LOUDNESS.

The ear has a wide dynamic range. At the low end of the range, one can hear very faint sounds of about 0 to 10 dB sound pressure level. At the upper end of the range, one can hear with clarity and discrimination loud sounds of 100-dB sound pressure level, whose actual sound pressures are 100,000 times greater than those of the faintest sounds. People may hear even louder sounds, but in the interest of hearing conservation, exposure to very loud sounds for significant periods of time must be avoided. It is largely because of this very wide dynamic range that the logarithmic decibel system is useful; it permits compression of large spreads in sound power and pressure into a more practical and manageable numerical system. For example, a commercial jet airliner produced 100,000,000,000 times the sound power of a cricket. In the decibel system, the sound power of the jet is 110 dB greater than that of the cricket (110 = 10 log 1011). Humans judge subjective loudness on a still more compressed scale.

A-10.1 Loudness Judgments.

Under controlled listening tests, humans judge that a 10 dB change in sound pressure level, on the average, represents approximately a halving or a doubling of the loudness of a sound. Yet a 10-dB reduction in a sound source means that 90 percent of the radiated sound energy has been eliminated. Table A-3 shows the approximate relationship between sound level changes, the resulting loss in acoustic power, and the judgment of relative loudness of the changes. Toward the bottom of the table, it becomes clear that tremendous portions of the sound power must be eliminated to achieve impressive amounts of noise reduction in terms of perceived loudness.

Table A-3 Relationship Between Changes in Sound Level, Acoustic Energy Loss, and Approximate Relative Loudness of a Sound

Sound Level Change	Acoustic Energy Loss	Relative Loudness
0 dB	0%	Reference
-3 dB	50%	Perceptible Change
-10 dB	90%	Half as loud
-20 dB	99%	1/4 as loud
-30 dB	99.9%	1/8 as loud
-40 dB	99.99%	1/16 as loud

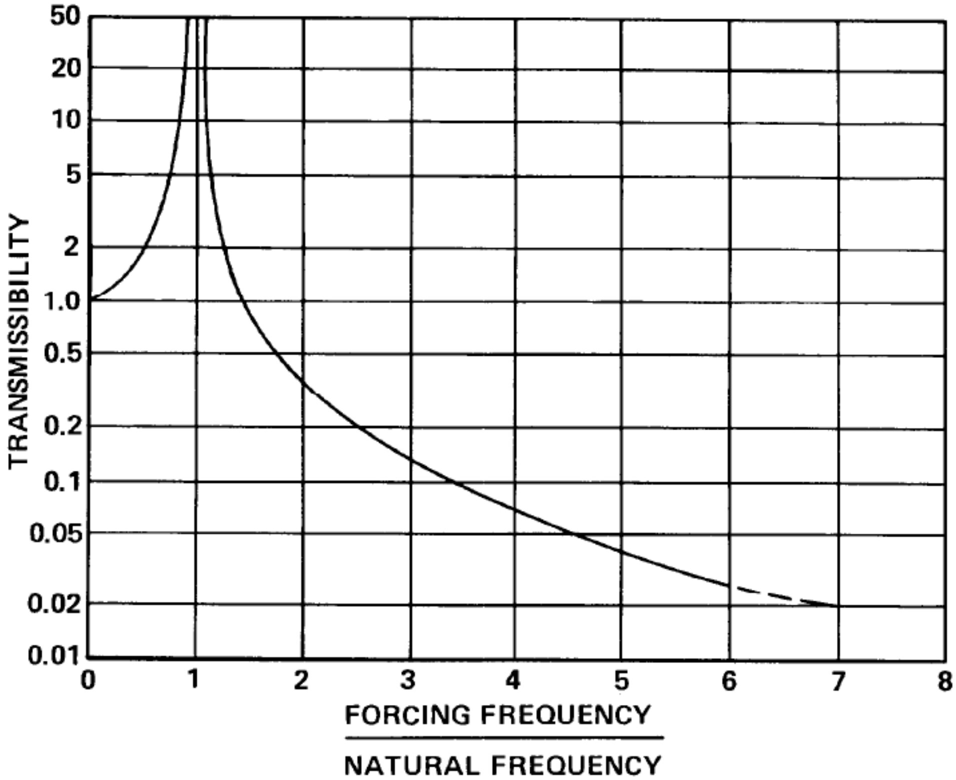
A-10.2 Sones and Phons.

Sones and phons are units used in calculating the relative loudness of sounds. Sones are calculated from nomograms that interrelate sound pressure levels and frequency, and phons are the summation of the sones by a special addition procedure. The results are used in judging the relative loudness of sounds, as in “a 50-phon motorcycle would be judged louder than a 40-phon motorcycle.” When the values are reduced to phon ratings, the frequency characteristics and the sound pressure level data have become detached, and the noise control analyst or engineer has no concrete data for designing noise control treatments. Sones and phons are not used in this document, and their use for noise control purposes is of little value. When offered data in sones and phons, the noise control engineer must request the original octave or 1/3 octave band sound pressure level data, from which the sones and phons were calculated.

A-11 VIBRATION TRANSMISSIBILITY.

A transmissibility curve is often used to indicate the general behavior of a vibration-isolated system. Transmissibility is roughly defined as the ratio of the force transmitted through the isolated system to the supporting structure to the driving force exerted by the piece of vibrating equipment. Figure A-2 is the transmissibility curve of a simple undamped single-degree-of-freedom system. The forcing frequency is usually the lowest driving frequency of the vibrating system. For an 1800-rpm pump, for example, the lowest driving frequency is 1800/60 = 30 Hz. The natural frequency, in Figure A-2, is the natural frequency of the isolator mount when loaded. An isolator mount might be an array of steel springs, neoprene-in-shear mounts, or pads of compressed glass fiber or layers of ribbed or waffle-pattern neoprene pads. When the ratio of the driving frequency to the natural frequency is less than about 1.4, the transmissibility goes above 1, which is the same as not having any vibration isolator. When the ratio of frequencies equals 1, that is, when the natural frequency of the mount coincides with the driving frequency of the equipment, the system may go into violent oscillation, to the point of damage or danger, unless the system is restrained by a damping or snubbing mechanism. Usually, the driver (the operating equipment) moves so quickly through this unique speed condition that there is no danger, but for large, heavy equipment that builds up speed slowly or runs downs slowly, this is a special problem that must be handled. At higher driving speeds, the ratio of frequencies exceeds 1.4 and the mounting system begins to provide vibration isolation, that is, to reduce the force reduce the force transmitted into the floor or other supported structure. The larger the ratio of frequencies, the more effective the isolation mount.

Figure A-2 Transmissibility of a Simple Undamped Single Degree-of-Freedom System.



A-11.1 Isolation Efficiency.

An isolation mounting system that has a calculated transmissibility, say, of 0.05 on Figure A-2 is often described as having an "isolation efficiency" of 95 percent. A transmissibility of 0.02 corresponds to 98 percent isolation efficiency, and so on. Strict interpretation of transmissibility data and isolation efficiencies, however, must be adjusted for real-life situations.

A-11.2 Transmissibility Limitations.

The transmissibility curve implies that the mounted equipment (in example, equipment plus the isolators) are supported by a structure that is infinitely massive and infinitely rigid. In most situations, this condition is not met. For example, the deflection of a concrete floor slab under static load may fall in the range of 1/4 inch to 1/2 inch (0.635 cm to 1.27 cm). This does not qualify as being infinitely rigid. The isolation efficiency is reduced as the static floor deflection increases. Therefore, the transmissibility values of Figure A-2 must not be expected for any specific ratio of driving frequency to natural frequency.

A-11.2.1 Adjustment for Floor Deflection.

In effect, the natural frequency of the isolation system must be made lower or the ratio of the two frequencies made higher to compensate for the resilience of the floor. This fact is especially true for upper floors of a building and is even applicable to floor slabs poured on grade (where the earth under the slab acts as a spring). Only when equipment bases are supported on large extensive portions of bedrock can the transmissibility curve be applied directly.

A-11.2.2 Adjustment for Floor Span.

This interpretation of the transmissibility curve is also applied to floor structures having different column spacings. Usually, floors that have large column spacing, such as 50 to 60 feet (15.24 to 18.29 meters), will have larger deflections that floors of shorter column-spacing, such as 20 to30 feet (6.1 to 9.14 meters). To compensate, the natural frequency of the mounting system is usually made lower as the floor span increases. All of these factors are incorporated into the vibration isolation recommendations in this chapter.

A-11.2.3 Difficulty of Field Measurement.

In field situations, the transmissibility of a mounting system is not easy to measure and check against a specification. Yet the concept of transmissibility is at the heart of vibration isolation and must not be discarded because of the above weakness. The material that follows is based on the valuable features of the transmissibility concept but added to it are some practical suggestions.

A-12 VIBRATION ISOLATION EFFECTIVENESS.

With the transmissibility curve as a guide, three steps are added to arrive at a fairly practical approach toward estimating the expected effectiveness of an isolation mount.

A-12.1 Static Deflection of a Mounting System.

The static deflection of a mount is simply the difference between the free-standing height of the uncompressed, unloaded isolator and the height of the compressed isolator under its static load. This difference is easily measured in the field or estimated from the manufacturer’s catalog data. An uncompressed 6-inch-high (15.24 cm) steel spring that has a compressed height of only 4 inches (10.2 cm) when installed under a fan or pump is said to have a static deflection of 2 inches (5.08 cm). Static deflection data are usually given in the catalogs of the isolator manufacturers or distributors. The data may be given in the form of “stiffness” values. For example, a stiffness of 400 lb/in (71.65 kg/cm) means that a 400 lb (181.44 kg) load will produce a 1-inch (2.54 cm) static deflection, or that an 800 lb (362.87 kg) load will produce a 2-inch (5.08 cm) deflection, if the mount has freedom to deflect a full 2 inches (5.08 cm).

A-12.2 Natural Frequency of a Mount.

The natural frequency of steel springs and most other vibration isolation materials can be calculated approximately from the formula in Equation A-18 (Imperial units) and Equation A-19 (S.I. units).

Equation A-18. Natural Frequency of Vibration Isolation Materials (Imperial)

$$\mathbf{f_n = 3.13\ x\ \sqrt{\frac{1}{SD}}}$$

Where:
f_n = natural frequency (Hz)
SD = static deflection (in)

Equation A-19. Natural Frequency of Vibration Isolation Materials (S.I.)

$$\mathbf{f_n = 0.5\ x\ \sqrt{\frac{1}{SD}}}$$

Where:
f_n = natural frequency (Hz)
SD = static deflection (m)

A-12.2.1 Example, Steel Spring.

Suppose each steel springs has a static deflection of 1- inch (0.0254 meters) when placed under each corner of a motor-pump base. The natural frequency of the mount is approximately:

Equation A-20. Example Natural Frequency of a Steel Spring Mount (Imperial)

$$\mathbf{f_n = 3.13\ x\ \sqrt{\frac{1}{1}} = 3.13\ Hz}$$

Where:
f_n = natural frequency (Hz)

A-12.2.2 Example, Rubber Pad.

Suppose a layer of 3/8-inch-thick (0.953 cm) ribbed neoprene is used to vibration isolate high-frequency structure borne noise or vibration. Under load, the pad is compressed enough to have a 1/16-inch (0.159 cm) static deflection. The natural frequency of the mount is approximately:

Equation A-21. Example Natural Frequency of a Neoprene Pad (Imperial)

$$f_n = 3.13 \text{ x } \sqrt{\frac{1}{\frac{1}{16}}}$$

$$= 3.13 \text{ x } \sqrt{16}$$

$$= 3.13 \text{ x } 4 = 12 \text{ Hz}$$

Where:
f_n = natural frequency (Hz)

This formula usually has an accuracy to within about plus or minus 20 percent for material such as neoprene-in-shear, ribbed or waffle-pattern neoprene pads, blocks of compressed glass fiber, and even pads of cork and felt when operating in their proper load range.

A-12.3 Application Suggestions.

Table A-4 provides a suggested schedule for achieving various degrees of vibration isolation in normal construction. The table is based on the transmissibility curve but suggests operating ranges of the ratio of driving frequency to natural frequency. The terms “low,” “fair,” and “high” are merely word descriptors, but they are more meaningful than such terms as 95 or 98 percent isolation efficiency which are clearly erroneous when they do not consider the mass and stiffness of the floor slab. Vibration control recommendations given in this chapter are based on the application of this table.

Table A-4 Suggested Schedule for Estimating Relative Vibration Isolation Effectiveness of a Mounting System

Ratio of Driving Frequency of Source to Natural Frequency of Mount	Degree of Vibration Isolation
Below 1.4	Amplification
1.4 - 3	Negligible
3 - 6	Low
6 - 10	Fair
Above 10	High

A-12.3.1 Example.

Suppose an 1800-rpm motor-pump unit is mounted on steel springs having 1-inch (2.54 cm) static deflection (as in the example above). The driving frequency of the system is the shaft speed, 1800 rpm or 30 Hz. The natural frequency of the mount is 3 Hz, and the ratio of driving frequency to natural frequency is about 10. Table A-4 shows that this would provide a “fair” to “high” degree of vibration isolation of the motor pump at 30 Hz. If the pump impeller has 10 blades, for example, this driving frequency would be 300 Hz, and the ratio of driving to natural frequencies would be about 100; the isolator would clearly give a “high” degree of vibration isolation for impeller blade frequency.

A-12.3.2 Caution.

The suggestion on vibration isolation offered in the document are based on experiences with satisfactory installations of conventional electrical and mechanical HVAC equipment in buildings. The concepts and recommendations described here may not be suitable for complex machinery, with unusual vibration modes, mounted on complex isolation systems. For such problems, assistance must be sought from a vibration specialist.

APPENDIX B SOUND LEVEL DATA FOR MECHANICAL AND ELECTRICAL EQUIPMENT

B-1 INTRODUCTION.

This appendix contains sound pressure and sound power data for mechanical equipment commonly found in many commercial buildings. Where possible, the noise data have been correlated with some of the more obvious noise influencing parameters, such as type, speed, power rating, and flow conditions. The noise levels quoted in the UFC are suggested for design uses; these noise levels represent approximately the 80 to 90 percentile values. That is, based on these sample sizes, it would be expected that the noise levels of about 80 to 90 percent of a random selection of equipment would be equal to or less than the design values quoted in the document, or only about 10 to 20 percent of a random selection would exceed these values. This is judged to be a reasonable choice of design values for typical uses. Higher percentile coverage, such as 95 percent, would give increased protection in the acoustic design, but at greater cost in weight and thickness of walls, floors, columns, and beams. On-site power plants driven by reciprocating and gas turbine engines have specific sound and vibration problems, which are considered separately in the inactive UFC 3-450-02 Power Plant Acoustics.

B-2 SOUND PRESSURE AND SOUND POWER LEVEL DATA.

In the collection of data, most noise levels were measured at relatively close-in distances to minimize the influence of the acoustic conditions of the room and the noise interference of other equipment operating in the same area.

B-2.1 Normalized Conditions for SPL Data.

Note: All measurements were normalized to a common MER condition by selecting a distance of 3 feet (0.914 meters) and a Room Constant of 800 ft^2 (74.32 m^2) as representative. SPL data measured at other distances and Room Constants were brought to these normalized conditions by using the procedures of Chapters 3 and 6.

B-2.2 Sound Power Level Data.

For equipment normally located and used outdoors, outdoor measurements were made, and sound power level data are given. To use these data, one may procedures of Chapter 3 and 6. Usually, more measurements and a more detailed estimate of the measurement conditions were involved in deriving the PWL data, so they are believed to have a slightly higher confidence level than the normalized SPL data.

B-2.3 A-Weighted Sound Levels.

In the tables and figures that follow, A-weighted sound levels are also given. Where sound pressure levels are given, the A-weighted sound level is in pressure; where sound power levels are given, the A-weighted value is in sound power. A-weighted sound levels are useful for simply comparing the noise output of competitive equipment. For complete analysis of an indoor or outdoor noise problem, however, octave band levels must be used.

B-2.4 Manufacturers' Noise Data.

Whenever possible, and especially for new types of equipment, the manufacturer must be asked to provide sound level data on their equipment. If the data show remarkably lower noise output than competitive models or are significantly lower than the data quoted in the document, the manufacturer must be asked to give guarantees of the noise data and to specify the conditions under which the data were measured and/or computed.

B-3 PACKAGED CHILLERS WITH RECIPROCATING COMPRESSORS.

These units' range in size from 15-ton to 200-ton (8.8 kW to 703.4 kW) cooling capacity. The noise levels have been reduced to the normalized 3-foot (.914 m) distance from the acoustic center of the assembly. In terms of noise production, the measured compressors are divided into two groups: up to 50 tons (175.8 kW) and over 50 tons (175.8 kW). The suggested 80- to 90-percentile noise level estimates are given in Figure B-1 and in Table B-1 for the two size ranges selected. Although major interest is concentrated here on the compressor component of a refrigeration machine, an electric motor is usually the drive unit for the compressor. The noise levels attributed here to the compressor will encompass the drive motor most of the time, so these values are taken to be applicable to either a reciprocating compressor alone or a motor-driven packaged chiller containing a reciprocating compressor.

Figure B-1 Sound Pressure Levels Reciprocating Compressors at 3-ft (.914 m) Distance

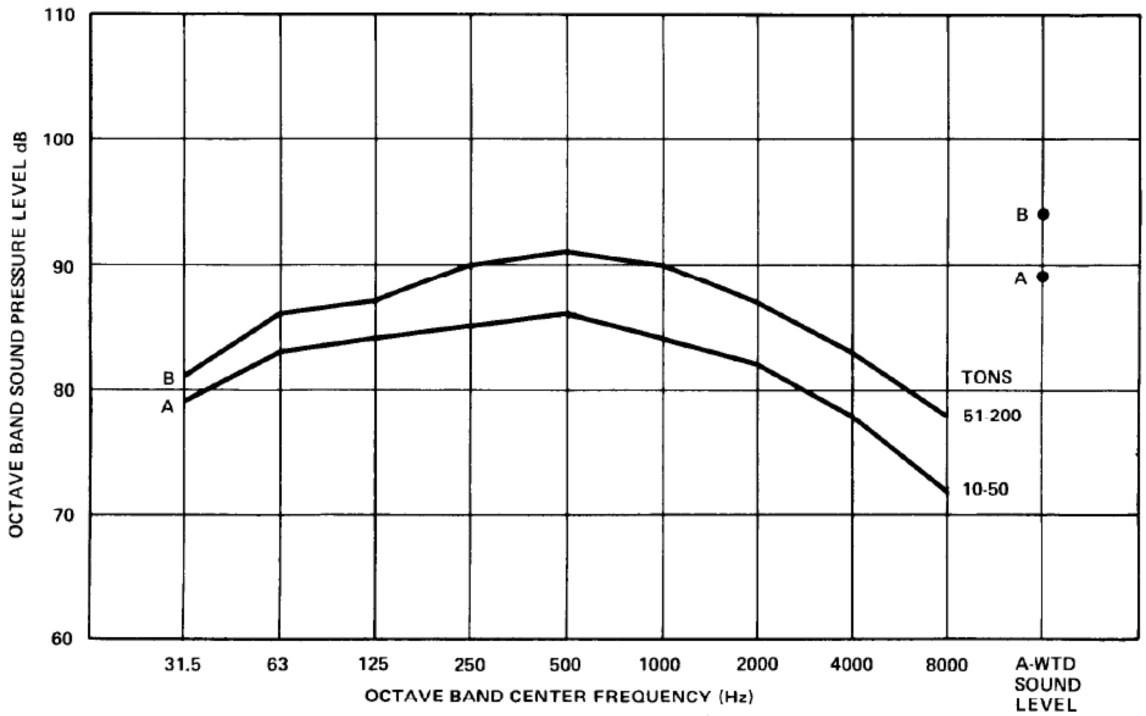


Table B-1 Sound Pressure Levels (in dB at 3-ft (.914 m) distance) for Packaged Chillers With Reciprocating Compressors

Octave Frequency Band (Hz)	Sound Pressure Level, dB	
	10-50 Tons Cooling Capacity	51-200 Tons Cooling Capacity
31	79	81
63	83	86
125	84	87
250	85	90
500	86	91
1000	84	90
2000	82	87
4000	78	83
8000	72	78
A-weighted, dB(A)	89	94

B-4 PACKAGED CHILLERS WITH ROTARY-SCREW COMPRESSORS.

The octave band sound pressure levels (at 3-foot (0.914 m) distance) believed to represent near-maximum noise levels for rotary-screw compressors are listed in Table B-2. The data applies for the size range of 100- to 300-ton cooling capacity, operating at or near 3600 RPM

Table B-2 Sound Pressure Levels (in dB at 3-ft. (0.914 m) Distance) for Packaged Chillers With Rotary Screw Compressors

Octave Frequency Band (Hz)	Sound Pressure Level, dB 100-300 Tons Cooling Capacity
31	70
63	76
125	80
250	92
500	89
1000	85
2000	80
4000	75
8000	73
A-weighted, dB(A)	90

B-5 PACKAGED CHILLERS WITH CENTRIFUGAL COMPRESSORS.

These compressors range in size from 100 tons to 4000 tons (351.8 kW to 14067.4 kW) and represent the leading manufacturers. The noise levels may be influenced by the motors, gears, or turbines, but the measurement positions are generally selected to emphasize the compressor noise. The noise levels given in Figure B-2 and Table B-3 represent the 80- to 90- percentile values found when the units were divided into the two size groups: under 500 tons (1758.4 kW) and 500 or more tons (1758.4 kW). The low-frequency noise levels reflect the increased noise found for off-peak loads for most centrifugal machines. This data may be used for packaged chillers, including their drive units. For built-up assemblies, this data must be used for the centrifugal compressor only and the suggestions of paragraph B-5 followed for combining the noise of other components.

Figure B-2 Sound Pressure Levels, Centrifugal Compressors at 3-ft.(0.914 m)Distance

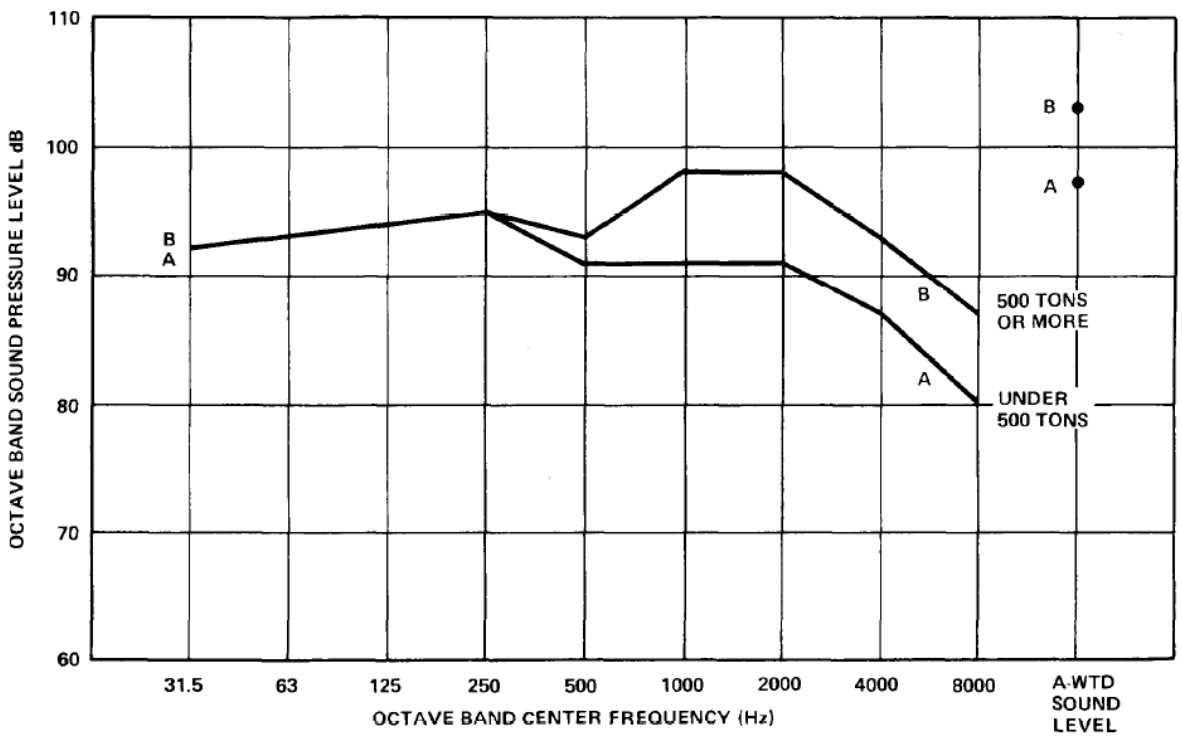


Table B-3 Sound Pressure Levels (in dB at 3-ft. Distance) for Packaged Chillers With Centrifugal Compressors

Octave Frequency Band (Hz)	Sound Pressure Level, dB	
	Cooling Capacity Under 500 Tons	Cooling Capacity 500 Tons or More
31	92	92
63	93	93
125	94	94
250	95	95
500	91	93
1000	91	98
2000	91	98
4000	87	93
8000	80	87
A-weighted, dB(A)	97	103

B-6 BUILT-UP REFRIGERATION MACHINES.

The noise of packaged chillers, as presented in the preceding paragraphs, includes the noise of both the compressor and the drive unit. If a refrigeration system is built up of separate pieces, then the noise level estimate must include the noise of each component making up the assembly. Compressor noise levels must be taken from the packaged chiller data. Sound level data for the drive units (motors, gears, steam turbines) must be taken from the appropriate tables in the document or obtained from the manufacturers. Use decibel addition to determine each octave band sum from the octave band levels of the various components. Assume the acoustic center to be at the approximate geometric center of the assembly, and distances must be extrapolated from that point. For very close distances (such as 2 to 3 feet or 0.61 to 0.914 meters) to each component, assume the total sound levels apply all around the equipment at distances of 3 feet (0.914 meters) from the approximate geometric centers of each component, although this assumption will not provide exact close-in sound levels.

B-7 ABSORPTION MACHINES.

These units are normally masked by other noise in a mechanical equipment room. The machine usually includes one or two small pumps; steam flow noise or steam valve noise may also be present. The 3-foot (0.914 meters) distance SPLs for most absorption machines used in refrigeration systems for buildings are given in Table B-4.

Table B-4 Sound Pressure Levels (dB at 3-ft (.914 m) Distance) for Absorption Machines

Octave Frequency Band (Hz)	Sound Pressure Level, dB All Sizes
31	80
63	82
125	82
250	82
500	82
1000	81
2000	78
4000	75
8000	70
A-weighted, dB(A)	86

B-8 BOILERS.

B-8.1 Noise Data.

The estimated noise levels given in Table B-5 are believed applicable for all boilers, although some units will exceed these values and, certainly, many units will be much lower than these values. These 3-foot (0.914 meters) noise levels apply to the front of the boiler, so when other distances are of concern, the distance must always be taken from the front surface of the boiler. Noise levels are much lower off the side and rear of the typical boiler. The wise variety of blower assemblies, air and fuel inlet arrangements, burners, and combustion chambers provides such variability in the noise data that it is impossible simply to correlate noise with heating capacity.

Table B-5 Sound Pressure Levels (dB at 3-ft (.914 m) Distance from the Front of Boilers

Octave Frequency Band (Hz)	Sound Pressure Level, dB 50-2000 BHP
31	90
63	90
125	90
250	87
500	84
1000	82
2000	80
4000	76
8000	70
A-weighted, dB(A)	88

B-8.2 Boiler Rating.

Heating capacity of boilers may be expressed in different ways: sq. ft.(m^{2}) of heating surface, BTU/hour (kW), Lb (kG) of steam/hour, or bhp boiler horsepower (kW)). To a first approximation, some of these terms are interrelated as follows:

33,500 BTU/hour = 1 bhp   33 lb of steam/hour = 1 bhp.   1 bhp = 0.745 kW

All ratings have been reduced to equivalent bhp.

B-9 STEAM VALVES.

Estimated noise levels are given in Table B-6 for a typical thermally insulated steam pipe and valve. Even though the noise is generated near the orifice of the valve, the pipes on either side of the valve radiate a large part of the total noise energy that is radiated. Hence, the pipe is considered, along with the valve, as a part of the noise source. Valve noise is largely determined by valve type and design, pressure and flow conditions, and pipe wall thickness. Some valve manufacturers can provide valve noise estimated for their products.

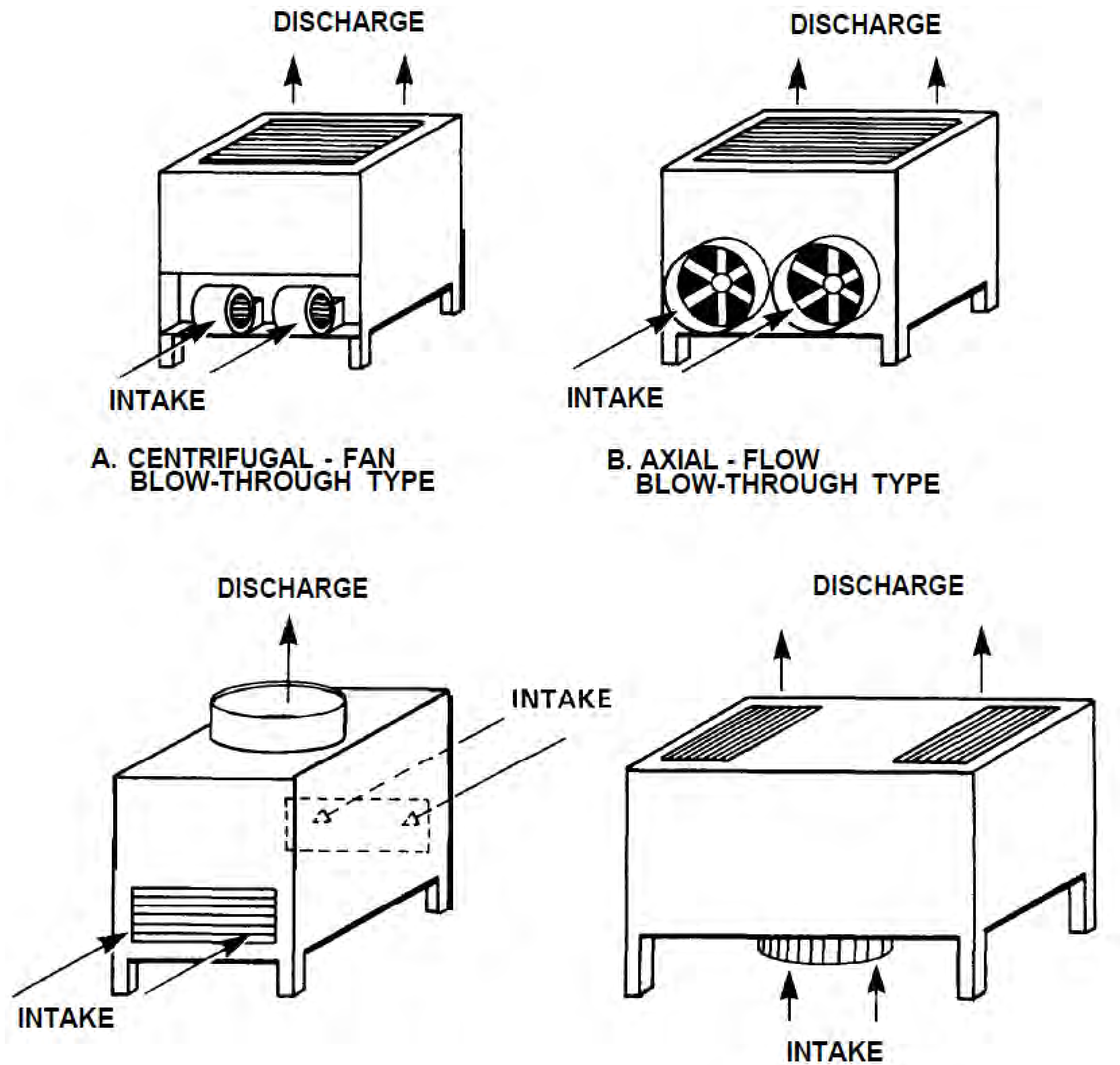
Table B-6 Sound Pressure Levels (dB at 3-ft (.914 m) Distance) for High-Pressure Thermally Insulated Steam Valves and Nearby Piping

Octave Frequency (Hz)	Sound Pressure Level (dB)
31	70
63	70
125	70
250	70
500	75
1000	80
2000	85
4000	90
8000	90
A-weighted, dB(A)	94

B-10 COOLING TOWERS AND EVAPORATIVE CONDENSERS.

The generalizations drawn here may not apply exactly to all cooling towers and condensers, but the data are useful for laying out cooling towers and their possible noise control treatments. It is desirable to obtain from the manufacturer actual measured noise levels for all directions of interest, but if these data are not forthcoming, it is essential to be able to approximate the directional pattern of the cooling tower noise. For aid in identification, four general types of cooling towers are sketched in Figure B-3: A.) The centrifugal-fan blow-through type; B.) The axial-flow blow-through type (with the fan or fans located on a side wall); C.) The induced-draft propeller type; and D.) The “underflow” forced draft propeller type (with the fan located under the assembly).

Figure B-3 Principal Types of Cooling Towers.



B-10.1 Sound Power Level Data.

Sound power level data are given for both propeller-type and centrifugal-fan cooling towers.

B-10.1.1 Propeller-type Cooling Tower.

The approximate overall and A-weighted sound power levels of propeller-type cooling towers are given by Equations B-1 and B-2, respectively: for overall PWL (propeller-type),

Equation B-1. Sound Power Levels of Propeller-Type Cooling Towers

$$\mathbf{Lw} = \mathbf{95 + 10\log(fan\ hp)}$$

Where:
Lw = sound power level (in dB)
fan hp = horsepower of cooling tower fan motor

and for A-weighted PWL,

Equation B-2. A-Weighted Sound Power Levels of Propeller-Type Cooling Towers

$$\mathbf{Lw_a} = \mathbf{86 + 10\log(fan\ hp)}$$

Where:
Lw_a = sound power level (in dBA)
fan hp = horsepower of cooling tower fan motor

where “fan hp” is the nameplate horsepower rating of the motor that drives the fan. Octave band PWLs can be obtained by subtracting the values of Table B-7 from the overall PWL.

Table B-7 Frequency Adjustments (in dB) for Propeller-Type Cooling Towers

Octave Frequency Band (Hz)	Value to be Subtracted From Overall PWL (dB)
31	8
63	5
125	5
250	8
500	11
1000	15
2000	18
4000	21
8000	29
A-weighted, dB(A)	9

B-10.1.2 Centrifugal Fan Cooling Tower.

The approximate overall and A-weighted sound power levels of centrifugal-fan cooling towers are given by Equations B-3 and B-4, respectively: for overall PWL (centrifugal-fan),

Equation B-3. Sound Power Levels of Centrifugal-Fan Cooling Towers

$$\mathbf{Lw = 85 + 10\log(fan\ hp)}$$

Where:
L_W = sound power level (in dB)
fan hp = horsepower of cooling tower fan motor

For A-weighted PWL,

Equation B-4. A-Weighted Sound Power Levels of Centrifugal-Fan Cooling Towers

$$\mathbf{L_a = 78 + 10\log(fan\ hp)}$$

Where:
L_a = sound power level (in dBA)
fan hp = horsepower of cooling tower fan motor

When more than one fan or cooling tower is used, "fan hp" is the total motor-drive hp of all fans or towers. Octave band PWLs can be obtained by subtracting the values of Table B-8 from the overall PWL.

Table B-8 Frequency Adjustments (in dB) for Centrifugal-Fan Cooling Towers

Octave Frequency Band (Hz)	Value to be Subtracted From Overall PWL (dB)
31	6
63	6
125	8
250	10
500	11
1000	13
2000	12
4000	18
8000	25
A-weighted, dB(A)	7

B-10.2 SPLs at a Distance.

To obtain the average outdoor SPL at any distance, use equation C-11 and obtain the value of the "distance term" from Tables C-24 or C-25 in Appendix C. Cooling towers usually radiate different amounts of sound in different directions, and the directional corrections of Table B-9 must be made to the average SPL. These corrections apply to the five principal directions from a cooling tower, in other words, in a direction perpendicular to each of the four sides and to the top of the tower. If it is necessary to estimate the SPL at some direction other than the principal directions, it is common practice to interpolate between the values given for the principal directions.

Table B-9 Correction to Average SPLs for Directional Effects of Cooling Towers

Octave Band (Hz)	31	63	125	250	500	1000	2000	4000	8000
CENTRIFUGAL-FAN BLOW-THROUGH TYPE									
Front (Fan inlet)	+3	+3	+2	+3	+4	+3	+2	+2	+2
Side (Enclosed)	0	0	0	-2	-3	-4	-5	-5	-5
Rear (Enclosed)	0	0	-1	-2	-3	-4	-5	-6	-6
Top (Discharge)	-3	-3	-2	0	+1	+2	+3	+4	+5
AXIAL-FLOW BLOW-THROUGH TYPE									
Front (Fan inlet)	+2	+2	+4	+6	+6	+5	+5	+5	+5
Side (Enclosed)	+1	+1	+1	-2	-5	-5	-5	-5	-4
Rear (Enclosed)	-3	-3	-4	-7	-7	-7	-8	-11	-8
Top (Discharge)	-5	-5	-5	-5	-2	0	0	+2	+1
INDUCED-DRAFT PROPELLER-TYPE									
Front (Air inlet)	0	0	0	+1	+2	+2	+2	+3	+3
Side (Enclosed)	-3	-3	-3	-3	-3	-3	-4	-5	-6
Top (Discharge)	+3	+3	+3	+3	+3	+4	+4	+3	+3
“UNDERFLOW” FORCED-DRAFT PROPELLER-TYPE									
Any side	-1	-1	-1	-2	-2	-3	-3	-4	-4
Top	+2	+2	+2	+3	+3	+4	+4	+5	+5

B-10.3 Close-in SPLs.

Sound power level data usually will not give accurate calculated SPLs at very close distances to large-size sources, such as cooling towers. The data of Table B-10 may be used where it is required to estimate close-in SPLs at nearby walls, floors, or in closely confined spaces (at 3 to 5-foot or 0.914 meter to 1.524-meter distances from inlet and discharge openings).

Table B-10 Approximate Close-In SPLs (in dB) Near the Intake and Discharge Openings of Various Cooling Towers (3- to 5ft. distance (0.914 to 1.524 m))

Octave Band (Hz)	31	63	125	250	500	1000	2000	4000	8000
CENTRIFUGAL-FAN BLOW-THROUGH TYPE									
Intake	85	85	85	83	81	79	76	73	68
Discharged	80	80	80	79	78	77	76	75	74
AXIAL-FLOW BLOW-THROUGH TYPE (INCLUDING "UNDERFLOW" TYPE)									
Intake	97	100	98	95	91	86	81	76	71
Discharged	88	88	88	86	84	82	80	78	76
PROPELLER-FAN INDUCED-DRAFT TYPE									
Intake	94	96	94	92	88	83	78	72	65
Discharged	99	103	99	95	90	85	81	76	70

B-10.4 Half-speed Operation.

When it is practical to do so, the cooling tower fan can be reduced to half speed in order to reduce noise; such a reduction also reduces cooling capacity. Half-speed produces approximately two-thirds cooling capacity and approximately 8- to 10-dB noise reduction in the octave bands that contain most of the fan-induced noise. For half-speed operation, the octave band SPLs or PWLs of full-speed cooling tower noise may be reduced by the following amounts, where fB is the blade passage frequency and is calculated from the relation fB = No. of fan blades x shaft RPM/GO.

Octave band that contains:	Noise reduction due to half-speed:
1/8 fB	3 dB
1/4 fB	6 dB
1/2 fB	9 dB
fB	9 dB
2 fB	9 dB
4 fB	6 dB
8 fB	3 dB

If the blade passage frequency is not known, it may be assumed to fall in the 63-Hz band for propeller type cooling towers and in the 250-Hz band for centrifugal cooling towers. Waterfall noise usually dominates in the upper octave bands, and it would not change significantly with reduced fan speed.

B-10.5 Limitations.

B-10.5.1 Design Variations.

The data given here represent a reasonable summary of cooling tower noise, but it must still be expected that noise levels may vary from manufacturer to manufacturer, and from model to model as specific design changes take place. Whenever possible, request the manufacturer to supply the specific noise levels for the specific needs.

B-10.5.2 Enclosed Locations.

Most of the preceding discussion assumes that cooling towers will be used in outdoor locations. If they are located inside enclosed mechanical equipment rooms or within courts formed by several solid walls, the sound patterns will be distorted. In such instances, the PWL of the tower (or appropriate portions of the total PWL) can be placed in that setting, and the enclosed or partially enclosed space can be likened to a room having certain estimated amounts of reflecting and absorbing surfaces. Because of the limitless number of possible arrangements, this is not handled in a general way, so the problem of partially enclosed cooling towers is not treated here. In the absence of a detailed analysis of cooling tower noise levels inside enclosed spaces, it is suggested that the close-in noise levels of Table B-10 be used as approximations.

B-10.5.3 Evaporative Condensers.

Evaporative condensers are somewhat like cooling towers in terms of noise generation. A few evaporative condensers have been included with the cooling towers, but not enough units have been measured to justify a separate study of evaporative condensers alone. In the absence of noise data on specific evaporative condensers, it is suggested that noise data be used for the most nearly similar type and size of cooling tower.

B-10.6 Air-cooled Condensers.

For some installations, an outdoor air-cooled condenser may serve as a substitute for a cooling tower or evaporative condenser. The noise of an air-cooled condenser is made up almost entirely of fan noise and possibly air-flow noise through the condenser coil decks. In general, the low-frequency fan noise dominates. Since most of the low-frequency noise of a typical cooling tower is due to the fan system, in the absence of specific data on air-cooled condensers, it is suggested that noise data be used for the most nearly similar type and size of cooling tower.

B-10.7 Ejector-type Cooling Tower.

This is a fan less-type cooling tower that induces air flow using nozzles of high-pressure water spray. Noise levels are generally lower for the ejector cooling tower than for cooling towers using fans to produce air flow. Adequate vibration isolation of the drive pump, piping, and tower are necessary, although the elimination of the fan reduces the severity of tower vibration.

B-11 PUMPS.

The overall and A-weighted 3-foot SPLs given in Table B-11. The pump power rating is taken as the nameplate power of the drive motor. This is easily determined in field measurements, whereas actual hydraulic power would be unknown in a field situation. For pump ratings under 100 hp (74.6 kW), the radiated noise increases with the function (10 log hp), but about 100 hp the noise changes more slowly with increasing power, hence, the function (3 log hp). Octave band SPLs are obtained by subtracting the values of Table B-12 from the overall SPLs of Table B-11. Pumps intended for high-pressure operation have smaller clearances between the blade tips and the cutoff edge and, as a result, may have higher noise peaks than shown in Tables B-11 and B-12 (by 5 dB, sometimes 10 dB) in the octave bands containing the impeller blade passage frequency and its first harmonic. These would usually fall in the 1,000 and 2,000 Hz octave bands. The data of Tables B-11 and B-12 are summarized in Figure B-4.

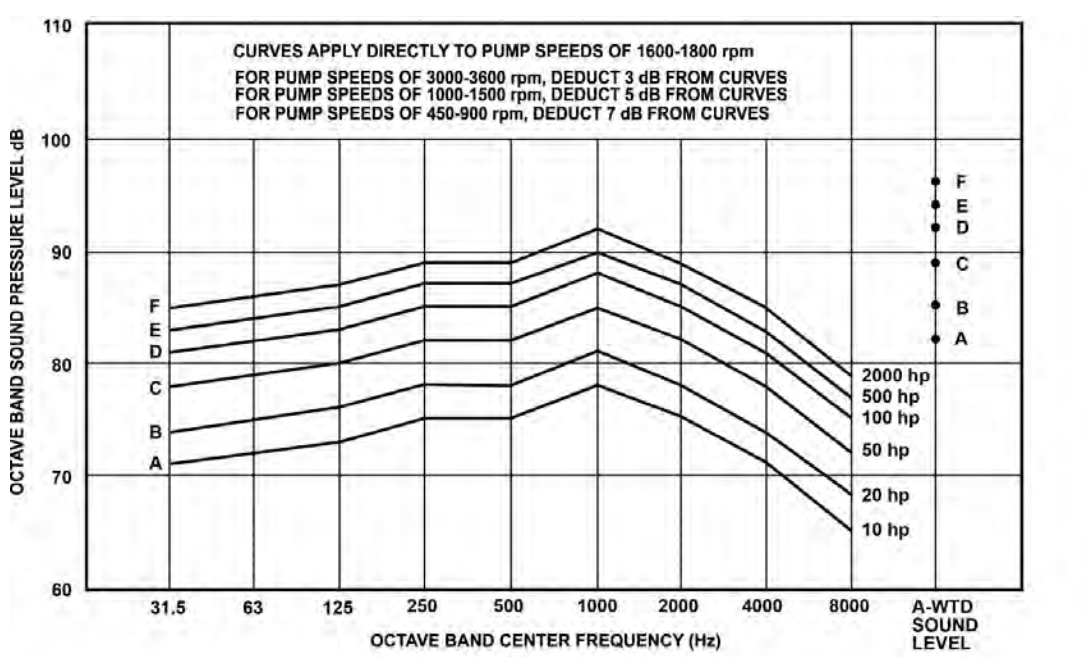
Table B-11 Overall and A-Weighted Sound Pressure Levels (dB and dB(A) at 3-ft (0.914 m) Distance) for Pumps

Speed Range rpm	Drive Motor Nameplate Power Under 100 hp	Above 100 hp
Overall sound messure level, dB:		
3000-3600	71+10 log hp	85+3 log hp
1600-1800	74+10 log hp	88+3 log hp
1000-1500	69+10 log hp	83+3 log hp
450- 900	67+10 log hp	81+3 log hp
A-weighted sound level, dB(A):		
3000-3600	69+10 log hp	82+3 log hp
1600-1800	72+10 log hp	86+3 log hp
1000-1500	67+10 log hp	81+3 log hp
450- 900	65+10 log hp	79+3 log hp

Table B-12 Frequency Adjustments in dB) for Pumps

Octave Frequency Band (Hz)	Value to be Subtracted from Overall SPL (dB)
31	13
63	12
125	11
250	9
500	9
1000	6
2000	9
4000	13
8000	19
A-weighted, dB (A)	2

Figure B-4 Sound Pressure Levels of Pumps at 3-ft (.914 m) Distance



B-12 FANS.

B-12.1 In-duct Noise.

Recent issues of ASHRAE publications provide updated methods for estimating the in-duct noise of ventilating fans. Manufacturers also furnish in-duct PWL data of their fans on request. A current ASHRAE estimation is given by Equation B-5:

Equation B-5. In-Duct Sound Power Level

$$\mathbf{Lw = Kw + 10\log Q + 20\ \log P + BFI + C}$$

Where:
Lw = sound power level (in dB)
Kw = sound power level of specific fan design (dB)
Q = volumetric flow rate (cfm)
P = static pressure of the fan (inches of water)
BFI =blade frequency increment (dB)
where Lw the in-duct sound power level of the fan at either the inlet or discharge end of the fan, Kw the specific sound power level for the particular fan design, Q is the volume flow rate in cfm (ft^3/min.) (lps), and P is the static pressure produced by the fan (inches (cm) of water gage). Values of Kw for the octave bands and for various basic fan blade designs are given in part A of Table B-13. The blade passage frequency of the fan is obtained from

$$\mathbf{fan\ \ RPM\,x\ no.of\ blades/60}$$

and the “blade frequency increment” BFI (in dB) is added to the octave band sound power level in the octave in which the blade passage frequency occurs. It is best to obtain the number of blades and the fan rotational speed from the manufacturer to calculate the blade passage frequency. In the event this information is not available, part B of Table B-13 provides the usual blade passage frequency. The estimates given by this method assume ideal inlet and outlet flow conditions and operation of the fan at its design condition. The noise is quite critical to these conditions and increases significantly for deviations from ideal.

Part C of Table B-13 provides a correction factor for off-peak fan operation.

Table B-13 Specific Sound Power Levels Kw (in dB), Blade Frequency Increments (in dB) and Off-Peak Correction for Fans of Various Types, for Use in Equation B-5.

(for table below: for metric convert inches to cm: multiply by 2.54)

Fan & Blade Type	Size & Operation	Octave Band Center Frequency - Hz								
		63	125	250	500	1000	2000	4000	8000	BFI
CENTRIFUGAL- Airfoil, Backward Curved and Inclined	Over 30 in . dia.	37	37	36	31	27	20	16	14	3
	Under 30 in. dia.	42	42	40	36	31	25	21	16	3
CENTRIFUGAL- Forward Curved	All sizes	50	50	40	33	33	28	23	18	2
CENTRIFUGAL- Radial	Low Pressure, SP 4" to 10"									
	Over 40 in. dia.	53	44	40	36	34	29	28	23	7
	Under 40 in. dia.	64	58	50	40	30	36	31	28	7
	Mild Pressure, SP 10" to 20"									
	Over 40 in. dia.	55	51	42	30	35	30	28	23	8
	Under 40 in. dia.	65	60	48	45	43	38	34	31	8
	High Pressure, SP 20" to 60"									
	Over 40 in. dia.	58	55	50	45	43	41	38	35	8
	Under 40 in. dia.	65	60	48	45	43	38	34	31	8
VANEAXIAL	Hub Ratio 0.3 to 0.4	46	40	40	45	43	41	38	35	6
	Hub Ratio 0.4 to 0.6	48	40	43	40	38	33	27	25	6
	Hub Ratio 0.6 to 0.8	56	40	48	48	48	44	40	37	8
TUBEAXIAL	Over 40 in. dia.	48	43	44	48	44	43	36	34	7
	Under 40 in. dia.	45	44	46	50	49	48	40	37	7
PROPELLER	All sizes	45	48	55	53	52	46	43	39	5

Note – Kw for inlet or outlet level, add 3dB for total level.

Part B. Octave band in which blade frequency increment (BFI) occurs.

Fan Type	Octave Band in Which BFI occurs
Centrifugal	
Airfoil, backward curved & backward inclined	250 Hz
Forward curved	500 Hz
Radial blade	125 Hz
Vane axial	125 Hz
Tube axial	63 Hz
Propeller	63 Hz

Note – Use for estimating purposes only. Use manufacturer's data when available.

Part C. Correction factor, C, for Off-peak Operation.

Static Efficiency % of Peak	Correction Factor dB
90 to 100	0
85 to 89	3
75 to 84	6
65 to 74	9
55 to 64	12
50 to 54	15

B-12.2 Noise Reduction from Fan Housing.

The fan housing and its nearby connected ductwork radiate fan noise into the fan room. The amount of noise is dependent on both internal and external dimensions of the housing and ductwork, the TL of the sheet metal, and the amount of sound absorption material inside the ductwork. Because of so many variables, there is no simple analysis procedure for estimating the PWL of the noise radiated by the housing and ductwork. However, Table B-14 offers a rough estimate of this type of noise. These are simply deductions, in dB, from the induct fan noise. At low frequency, the housing appears acoustically transparent to the fan noise, but as frequency increases, the TL of the sheet metal becomes increasingly effective.

Table B-14 Approximate Octave-Band Adjustments for Estimating the PWL of Noise Radiated by a Fan Housing and its Nearby Connected Duct Work.

Octave Frequency Band (Hz)	Value to be Subtracted From In-Duct Fan Noise (dB)
31	–
63	0
125	0
250	5
500	10
1000	15
2000	20
4000	22
8000	25

B-13 AIR COMPRESSORS.

Two types of air compressors are frequently found in buildings: one is a relatively small compressor (usually under 5 hp (3.73 kW)) used to provide a high-pressure air supply for operating the controls of the ventilation system, and the other is a medium-size compressor (possibly up to 100 hp (746 kW)) used to provide “shop air” to maintenance shops, machine shops, and laboratory spaces, or to provide ventilation system control pressure for large buildings. Larger compressors are used for special industrial processes or special facilities, but these are not considered within the scope of the document. The 3-foot (.914 m) SPLs are given in Figure B-5 and Table B-15.

Figure B-5 Sound Pressure Levels of Air Compressors at 3-ft (.914 m) Distance.
(Multiply hp values by 7.46 for metric equivalent of kW)

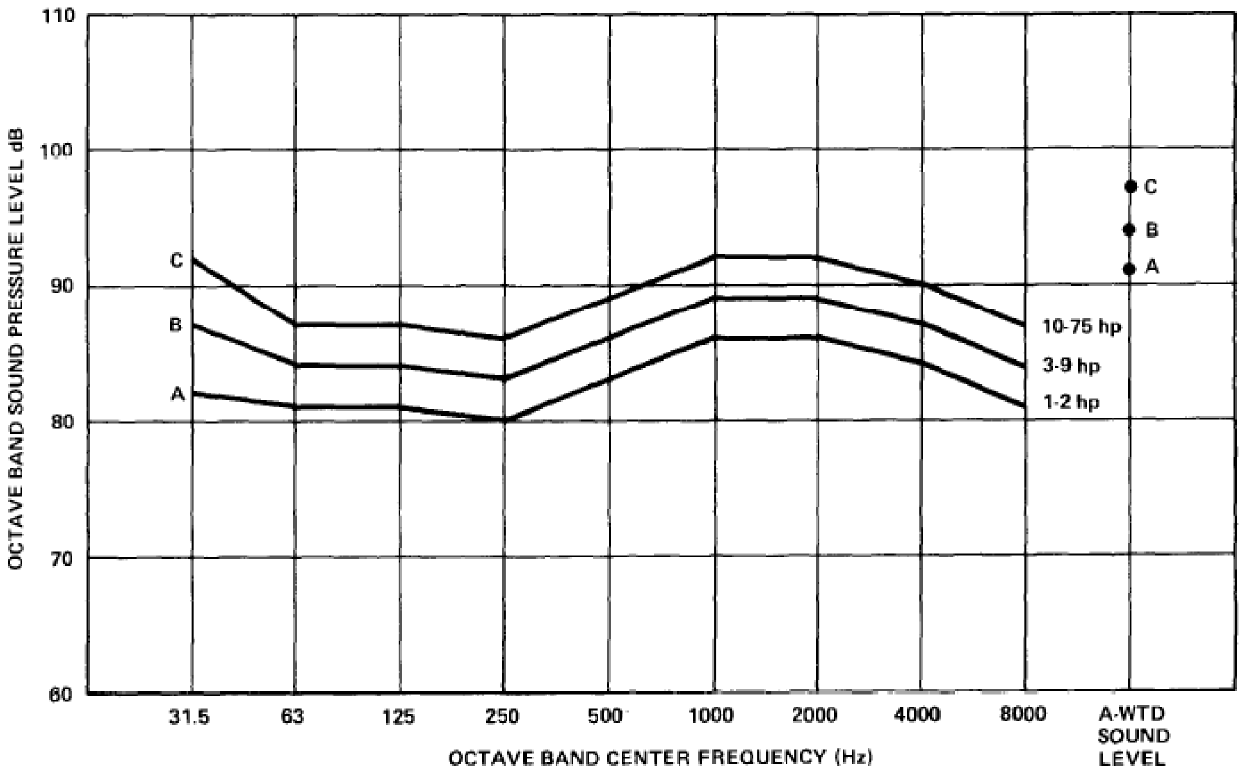


Table B-15 Sound Pressure Levels (dB at 3-ft (.914 m) Distance) for Air Compressors.

Octave Frequency Band (Hz)	Air Compressor Power Range		
	1-2 hp (dB)	3-9 hp (dB)	10-75 hp (bB)
31	82	87	92
63	81	84	87
125	81	84	87
250	80	83	86
500	83	86	89
1000	86	89	92
2000	86	89	92
4000	84	87	90
8000	81	84	87
A-weighted, dB(A)	91	94	97

B-14 RECIPROCATING ENGINES.

In a separate project for the Department of the Army, a comprehensive study has been made of the noise characteristics of reciprocating and turbine engines fueled by natural gas and liquid fuel. In the inactive UFC 3-450-02 Power Plant Acoustics, details are given for handling these data and for designing noise control treatments for small power plants at military bases. The noise levels of the engines as sound sources are summarized here because these engines may be used as power sources in buildings, and their noise must be considered. Typically, each engine type has three sound sources of interest: the engine casing, the air inlet into the engine, and the exhaust from the engine.

B-14.1 Engine Casing.

The PWL of the noise radiated by the casing of a natural-gas or diesel reciprocating engine is given by Equation B-6:

Equation B-6. Sound Power Level of Natural-Gas or Diesel Reciprocating Engine Casing

$$\mathbf{Lw} = \mathbf{93} + \mathbf{10}\,\mathbf{log}(\mathbf{rated\ hp}) + \mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D},$$

Where:
Lw = sound power level (dB)
rated hp = manufacturer’s engine horsepower rating
A, B, C, D = correction items from Table B-16 (in dB)

where Lw is the overall sound power level (in dB), “rated hp” is the engine manufacturer’s continuous full-load rating for the engine (in horsepower), and A, B, C, and D are correction terms (in dB), given in Table B-16. Octave band PWLs can be obtained by subtracting the Table B-17 values from the overall PWL given by Equation B-6. The octave band corrections are different for the different engine speed groups. For small engines (under about 450 hp), the air intake noise is usually radiated close to the engine casing, so it is not easy or necessary to separate these two sources; and the engine casing noise may be considered as including air intake noise (from both naturally aspirated and turbocharged engines).

Table B-16 Correction Terms (in dB) to be Applied to Equation B-6 for Estimating the Overall PWL of the Casing Noise of a Reciprocating Engine.

Speed correction term "A"	dB
Under 600 rpm	-5
600-1500 rpm	-2
Above 1500 rpm	0
Fuel correction term "B"	**dB**
Diesel fuel only	0
Diesel and/or natural gas	0
Natural gas only (May have small amount of "pilot oil")	-3
Cylinder arrangement term "C"	**dB**
In-line	0
V-type	-1
Radial	-1
Air intake correction term "D"	**dB**
Unducted air inlet to unmuffled Roots Blower	+3
Ducted air from outside the room or into muffled Roots Blower	0
All other inlets to engine (with or without turbochargers)	0

Table B-17 Frequency Adjustments (in dB) for Casing Noise of Reciprocating Engines.

Octave Frequency Band (Hz)	Value to be Subtracted from Overall PWL, in dB			
	Engine Speed Under 600 rpm	Engine Speed 600-1500 rpm		Engine Speed Over 1500 rpm
		Without Roots Blower	With Roots Blower	
31	12	14	22	22
63	12	9	16	14
125	6	7	18	7
250	5	8	14	7
500	7	7	3	8
1000	9	7	4	6
2000	12	9	10	7
4000	18	13	15	13
8000	28	19	26	20
A-weighted, dB(A)	4	3	1	2

B-14.2 Turbocharged Air Inlet.

Most large engines have turbochargers at their inlet to provide pressurized air into the engine for increased performance. The turbocharger is a turbine driven by the released exhaust gas of the engine. The turbine is a high-frequency sound source. Turbine configuration and noise output can vary appreciably, but an approximation of the PWL, of the turbocharger noise is given by Equation B-7:

Equation B-7. Sound Power Level of Turbocharger Air Inlet

$$\mathbf{Lw = 94 + 5\log(rated\ hp) - L/6}$$

Where:
Lw = sound power level (in dB)
rated hp = manufacturer's engine horsepower rating
L = length of ducted inlet to the turbocharger (ft) (m)

where Lw and "rated hp" are already defined and L is the length, in ft (cm m)., of a ducted inlet to the turbocharger. For many large engines, the air inlet may be ducted to the engine from a fresh air supply or a location outside the room or building. The term L/6, in dB, suggests that each 6 ft. (1.83 m) of inlet ductwork, whether lined with sound absorption material, will provide about 1 dB of reduction of the turbocharger noise radiated from the open end of the duct. This is not an accurate figure for ductwork in general; it merely represents a simple token value for this estimate. The octave band values given in Table B-18 are subtracted from the overall PWL of Equation B-7 to obtain the octave band PWLs of turbocharged inlet noise.

Table B-18 Frequency Adjustments fin dB) for Turbocharger Air Inlet Noise.

Octave Frequency Band (Hz)	Value to be Subtracted From Overall PWL (dB)
31	4
63	11
125	13
250	13
500	12
1000	9
2000	8
4000	9
8000	17
A-weighted, dB(A)	3

B-14.3 Engine Exhaust.

The PWL of the noise radiated from the unmuffled exhaust of an engine is given by Equation B-8:

Equation B-8. Sound Power Level of Unmuffled Natural-Gas or Diesel Reciprocating Engine Exhaust

$$\mathbf{Lw = 119 + 10\,log(rated\ hp) - T - L/4}$$

Where:
Lw = sound power level (in dB)
rated hp = manufacturer's engine horsepower rating
T = correction term (in dB)
L = length of exhaust pipe (ft)(m)

where T is the turbocharger correction term (T = 0 dB for an engine without a turbocharger and T = 6 dB for an engine with a turbocharger) and L is the length, in ft (cm m)., of the exhaust pipe. A turbocharger takes energy out of the discharge gases and results in an approximately 6-dB reduction in noise. The octave band PWLs of unmuffled exhaust noise are obtained by subtracting the values of Table B-19 from the overall PWL derived from Equation B-8. If the engine is equipped with an exhaust muffler, the final noise radiated from the end of the tailpipe is the PWL of the unmuffled exhaust minus the insertion loss, in octave bands, of the muffler.

Table B-19 Frequency Adjustments (in dB) for Unmuffled Engine Exhaust Noise.

Octave Frequency Band (Hz)	Value to be Subtracted From Overall PWL (dB)
31	5
63	9
125	3
250	7
500	15
1000	19
2000	25
4000	35
8000	43
A-weighted, dB (A)	12

B-15 GAS TURBINE ENGINES.

B-15.1 PWL of Three Sources.

As with reciprocating engines, the three principal sound sources of turbine engines are: the engine casing, the air inlet, and the exhaust. Most gas turbine manufactures will provide sound power estimates of these sources. However, when these are unavailable the overall PWLs of these three sources, with no noise reduction treatments, are given in the following equations:

for engine casing noise:

Equation B-9. Sound Power Level of Gas Turbine Engine Casing

$$\mathbf{Lw = 120 + 5\ \log(rated\ MW);}$$

Where:
Lw = sound power level (in dB)
rated MW = manufacturer's engine megawatts rating

for air inlet noise:

Equation B-10. Sound Power Level of Gas Turbine Engine Air Inlet

$$\mathbf{Lw = 127 + 15\ \log(rated\ MW);}$$

Where:
Lw = sound power level (dB)
rated MW = manufacturer's engine megawatts rating

for exhaust noise:

Equation B-11. Sound Power Level of Gas Turbine Engine Exhaust

$$\mathbf{Lw = 133 + 10\log(rated\ MW)};$$

Where:
Lw = sound power level (dB)
rated MW = manufacturer's engine megawatts rating

where "rated MW" is the maximum continuous full-load rating of the engine in megawatts. If the manufacturer lists the rating in "effective shaft horsepower" (EShp), the MW rating may be approximated by

Equation B-12. Megawatts Rating by Effective Shaft Horsepower

$$\mathrm{MW} = \mathrm{eshp}/1400.$$

Where:
MW = engine megawatts rating
EShp = effective shaft horsepower

Overall PWLs, obtained from Equations B-9 through B-11, are tabulated in Table B-20 for a useful range of MW ratings.

Table B-20 Overall PWLs of the Principal Noise Components of Gas Turbine Engines Having No Noise Control Treatments

Rated MW	Casing PWL dB	Inlet PWL dB	Exhaust PWL dB
0.10	115	112	123
0.13	116	114	124
0.16	116	115	125
0.20	117	117	126
0.25	117	118	127
0.32	118	120	128
0.40	118	121	129
0.50	118	122	130
0.63	119	124	131
0.80	120	126	132
1.0	120	127	133
1.3	121	129	134
1.6	121	130	135
2.0	122	132	136
2.5	122	133	137
3.2	123	135	138
4.0	123	136	139
5.0	123	137	140
6.3	124	139	141
8.0	125	141	142
10	125	142	143
13	126	144	144
16	126	145	145
20	127	147	146
25	127	148	147
32	128	150	148
40	128	151	149
50	128	152	150
63	129	154	151
80	130	156	152

B-15.1.1 Tonal Components.

For casing and inlet noise, particularly strong high-frequency sounds may occur at several of the upper octave bands. However which bands contain the tones will depend on the specific design of the turbine and, as such, will differ between models and manufacturers. Therefore, the octave band adjustments of Table B-21 allow for these peaks in several different bands, even though they probably will not occur in all bands. Because of this randomness of peak frequencies, the A-weighted levels may also vary from the values quoted.

Table B-21 Frequency Adjustments (dB) for Gas Turbine Engine Noise Sources

Octave Frequency Band (Hz)	Value To Be Subtracted From Overall PWL, in dB		
	Casing	Inlet	Exhaust
31	10	19	12
63	7	18	8
125	5	17	6
250	4	17	6
500	4	14	7
1000	4	8	9
2000	4	3	11
4000	4	3	15
8000	4	6	21
A-weighted, dB(A)	2	0	4

B-15.1.2 Engine covers.

The engine manufacturer sometimes provides the engine casing with a protective thermal wrapping or an enclosing cabinet, either of which can give some noise reduction. Table B-22 suggests the approximate noise reduction for casing noise that can be assigned to different types of engine enclosures. Refer to the notes of the table for a broad description of the enclosures. The values of Table B-22 may be subtracted from the octave band PWLs of casing noise to obtain the adjusted PWLs of the covered or enclosed casing. An enclosure specifically designed to control casing noise can give larger noise reduction values than those in the table. Note: the performance of enclosures that are supported on the same structure as the gas turbine, will be limited by structure borne sound. For this reason, care must be used in applying laboratory data of enclosure performance to the estimation of sound reduction of gas turbine enclosures.

Table B-22 Approximate Noise Reduction Gas Turbine Engine Casing Enclosures

Octave Frequency Band (Hz)	Noise Reduction, dB				
	Type 1	Type 2	Type 3	Type 4	Type 5
31	2	4	1	3	6
63	2	5	1	4	7
125	2	5	1	4	8
250	3	6	2	5	9
500	3	6	2	6	10
1000	3	7	2	7	11
2000	4	8	2	8	12
4000	5	9	3	8	13
8000	6	10	3	8	14

Notes:

- **Type 1.** Glass fiber or mineral wool thermal insulation with lightweight foil cover over the insulation.
- **Type 2.** Glass fiber or mineral wool thermal insulation with minimum
- 20 gage aluminum or 24 gage steel or 1/2-in. (1.27 cm) thick plaster cover over the insulation.
- **Type 3.** Enclosing metal cabinet for the entire packaged assembly, with open ventilation holes and with no acoustic absorption lining inside the cabinet.
- **Type 4.** Enclosing metal cabinet for the entire packaged assembly, with open ventilation holes and with acoustic absorption lining inside the cabinet.
- **Type 5.** Enclosing metal cabinet for the entire packaged assembly, with all ventilation holes into the cabinet muffled and with acoustic absorption lining inside the cabinet.

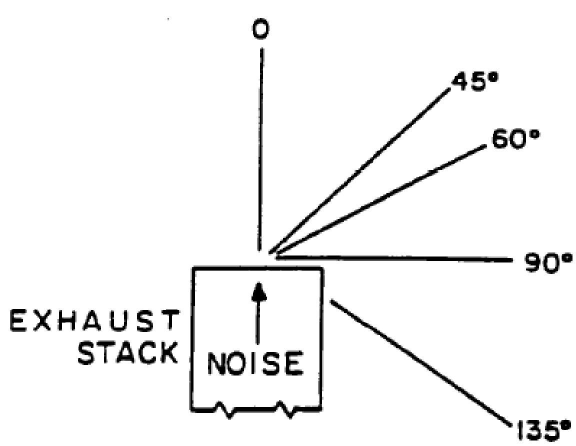
B-15.2 Exhaust and Intake Stack Directivity.

Frequently, the exhaust of a gas turbine engine is directed upward. The directivity of the stack provides a degree of noise control in the horizontal direction. Or, in some installations, it may be beneficial to point the intake or exhaust opening horizontally in a direction away from a sensitive receiver area. In either event, the directivity is a factor in noise radiation. Table B-23 gives the approximate directivity effect of a large exhaust opening. This can be used for either a horizontal or vertical stack exhausting hot gases. Table B-23 shows that from approximately 0 to 60 degrees from the axis of the stack, the stack will yield higher sound levels than if there was no stack and the sound were emitted by a nondirectional point source. From about 60 to 135 degrees from the axis, there is less sound level than if there were no stack. In other words, directly ahead of the opening there is an increase in noise, and off to the side of the opening there is a decrease in noise. The Table B-23 values also apply for a large-area intake opening into a gas turbine for the 0 to 60-degree range; for the 90 to 135 degree range, subtract an addition 3 dB from the already negative-valued quantities. For horizontal stacks, sound-reflecting obstacles out in front of the stack opening can alter the directivity pattern. Even irregularities on the ground surface can cause some backscattering of sound into the 90 to 180-degree regions, for horizontal stacks serving either as intake or exhaust openings. For small openings in a wall, such as for ducted connections to a fan intake or discharge, use approximately one-half the directivity effect of Table B-23 (as applied to intake openings) for the 0 to 90-degree region. For angles beyond 90 degrees, estimate the effect of the wall as a barrier.

Table B-23 Approximate Directivity Effect (in dB) of a Large Exhaust Stack Compared to a Nondirectional Source of the Same Power

Octave Frequency Band (Hz)	Relative Sound Level for Indicated Angle From Axis				
	0°	45°	60°	90°[a]	135° and larger[a]
31	8	5	2	-2	-3
63	8	5	2	-3	-4
125	8	5	2	-4	-6
250	8	6	2	-6	-8
500	9	6	2	-8	-10
1000	9	6	1	-10	-13
2000	10	7	0	-12	-16
4000	10	7	-1	-14	-18
8000	10	7	-2	-16	-20

[a] For air intake openings subtract 3 dB from the values in the 90º and 135° columns, in other words, -2 -3 = -5 dB for 31 cps at 90°.The diagram below represents the exhaust stack described in Table B-23.



B-16 ELECTRIC MOTORS.

Motors cover a range of 1 to 4000 hp (7.46 kW to 29.8 MW) and 450 to 3600 RPM. The data include both “drip-proof’ (DRPR) (splash-proof or weather-protected) and “totally enclosed fan-cooled” (TEFC) motors. Noise levels increase with power and speed.

Metric Conversion: Multiply motor hp by 7.46 for equivalent kW)

B-16.1 TEFC Motors.

The overall SPLs of TEFC motors, at the normalized 3-foot (.914 m) condition, follow approximately the relationships of Equations B-13 and B-14.

for power ratings under 50 hp,

Equation B-13. Sound Pressure Level of TEFC Motor Under 50 hp

$$\mathbf{Lp = 15 + 17\log hp + 15\ \log RPM}$$

Where:
Lp = sound pressure level (in dB)
hp = manufacturer’s horsepower rating
RPM = motor shaft speed in revolutions per minute

for power ratings above 50 hp,

Equation B-14. Sound Pressure Level of TEFC Motor Above 50 hp

$$\mathbf{Lp = 27 + 10\ \log hp + 15\ \log RPM}$$

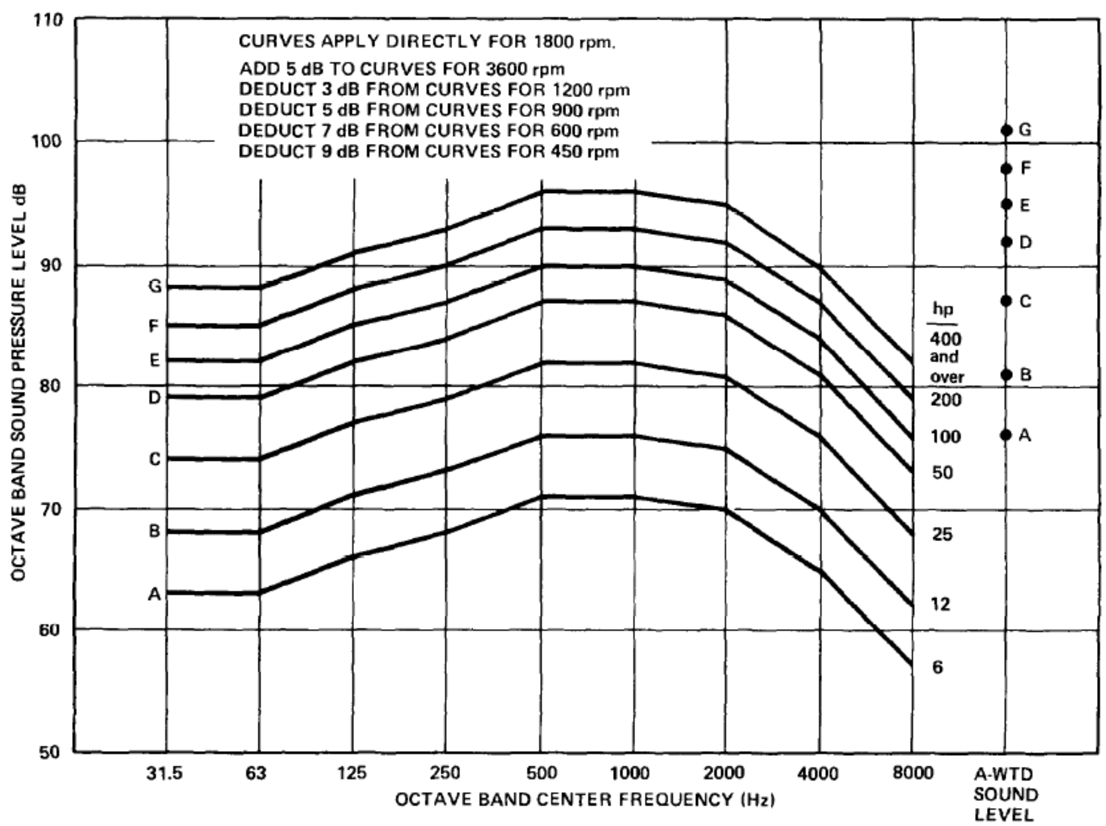
Where:
Lp = sound pressure level (in dB)
hp = manufacturer’s horsepower rating
RPM = motor shaft speed in revolutions per minute

where “hp” is the nameplate motor rating in horsepower and “RPM” is the motor shaft speed. For motors above 400 hp, use the calculated noise value for a 400-hp motor. These data are not applicable to large commercial motors in the power range of 1000 to 5000 hp. The octave band corrections for TEFC motors are given in Table B-24. The data of Equations B-12 and B-13 and Table B-24 are summarized in Figure B-6, which gives the SPLs at 3-foot (0.914 m) distance for TEFC motors for a working range of speeds and powers. Some motors produce strong tonal sounds in the 500, 1,000, or 2,000 Hz octave bands because of the cooling fan blade frequency. Table B-24 and Figure B-6 allow for a moderate amount of these tones, but a small percentage of motors may still exceed these calculated levels by as much as 5 to 8 dB. When specified, motors that are quieter than these calculated values by 5 to 10 dB can be purchased.

Table B-24 Frequency Adjustments (in dB) for TEFC Electric Motors

Octave Frequency Band (Hz)	Value to be Subtracted From Overall SPL (dB)
31	14
63	14
125	11
250	9
500	6
1000	6-
2000	7
4000	12
8000	20
A-weighted, dB(A)	1

Figure B-6 Sound pressure levels of TEFC motors at 3-ft (0.914 m). distance



B-16.2 DRPR Motors.

The overall SPLs of DRPR motors, at the normalized 3-foot condition, follow approximately the relationships of Equations B-15 and B-16.

for power ratings under 50 hp:

Equation B-15. Sound Pressure Level of DRPR Motor Under 50 hp

$$\mathbf{Lp = 10 + 17\ log\,hp + 15\ log\,RPM}$$

Where:
Lp = sound pressure level (in dB)
hp = manufacturer's horsepower rating
RPM = motor shaft speed in revolutions per minute

for power ratings above 50 hp:

Equation B-16. Sound Pressure Level of DRPR Motor Above 50 hp

$$\mathbf{Lp = 22 + 10\ log\,hp + 15\ log\,RPM}$$

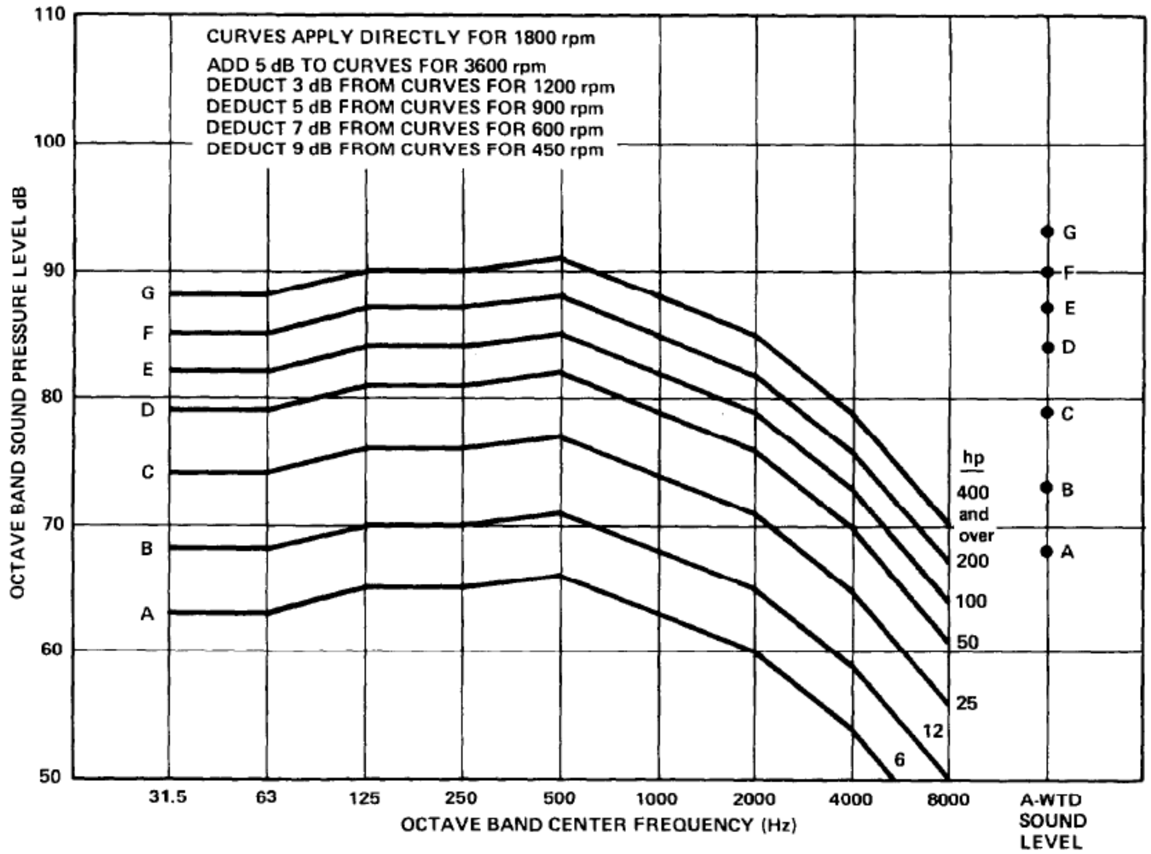
Where:
Lp = sound pressure level (in dB)
hp = manufacturer's horsepower rating
RPM = motor shaft speed in revolutions per minute

For motors above 400 hp, use the calculated noise value for a 400 hp motor. The octave band corrections for DRPR motors are given in Table B-25. The data of Equations B-15 and B-16 and Table B-25 are summarized in Figure B-7, which gives the SPLs at 3-foot distance for DRPR motors over a range of speeds and powers.

Table B-25 Frequency Adjustments (in dB) for DRPR Electric Motors

Octave Frequency Band (Hz)	Value to be Subtracted From Overall SPL (dB)
31	9
63	9
125	7
250	7
500	6
1000	9
2000	12
4000	18
8000	27
A-weighted, dB(A)	4

Figure B-7 Sound Pressure Levels of DRPR Motors at 3 ft (0.914 m). Distance



B-17 STEAM TURBINES.

Noise levels are found generally to increase with increasing power rating, but it has not been possible to attribute any specific noise characteristics with speed or turbine blade passage frequency (because these were not known on the units measured). The suggested normalized SPLs at 3-foot (0.914 m) distance are given in Figure B-8 and Table B-26.

Figure B-8 Sound Pressure Levels of Steam Turbines at 3 ft (0.914 m) Distance

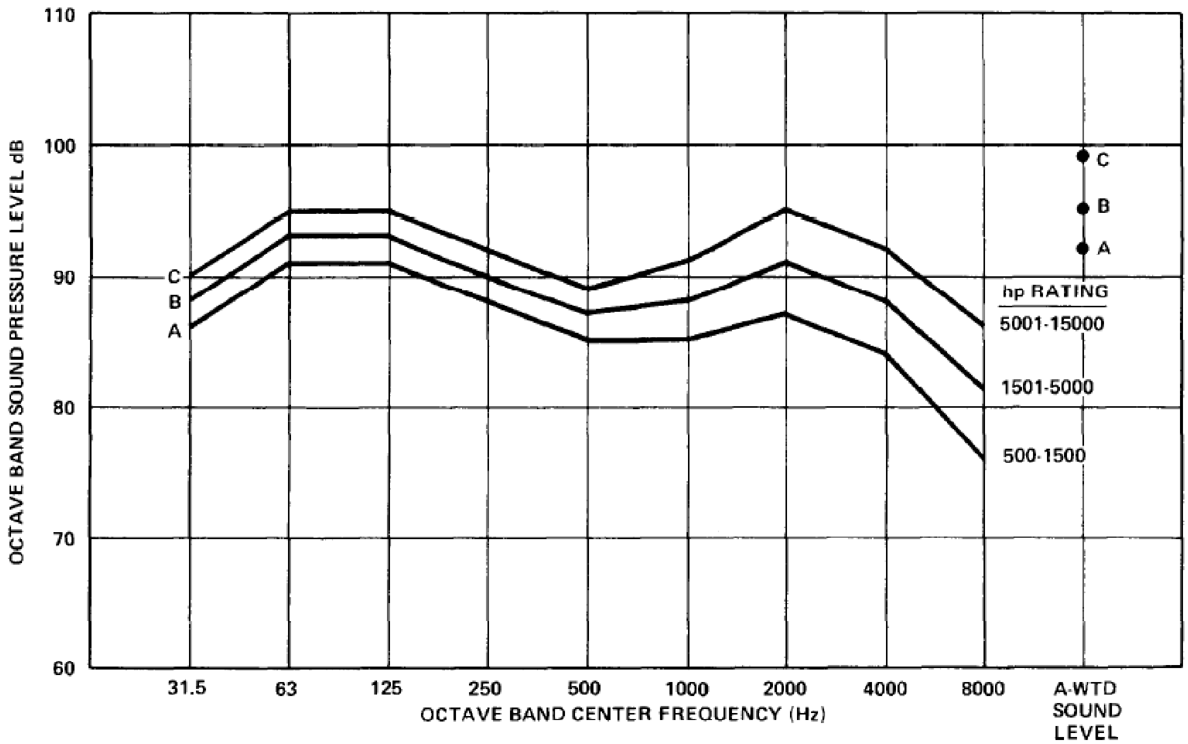


Table B-26 Sound Pressure Levels (dB at 3 feet (0.914 m) distance) for steam turbines

Octave Frequency Band (Hz)	Steam Turbine Power Ranger		
	500-1500 hp (dB)	1501-5000 hp (dB)	5001-15000 hp (dB)
31	86	88	90
63	91	93	95
125	91	93	95
250	88	90	92
500	85	87	89
1000	85	88	91
2000	87	91	95
4000	84	88	92
8000	76	81	86
A-weighted, dB(A)	92	95	99

Metric Conversion: Multiply motor hp by 7.46 for equivalent kW)

B-18 GEARS.

It is generally true that the noise output increases with increasing speed and power, but it is not possible to predict in which frequency band the gear tooth contact rate or the “ringing frequencies” will occur for any unknown gear. The possibility that these frequency components may occur in any of the upper octave bands is covered by, Equation B-17, which gives the octave band SPL estimate (at the 3 feet normalized condition) for all bands at and above 125 Hz:

Equation B-17. Sound Pressure Level of Gear Noise

$$\mathbf{Lp} = \mathbf{78} + \mathbf{3}\,\mathbf{log}(\mathbf{RPM}) + \mathbf{4}\,\mathbf{log}(\mathbf{hp})$$

Where:
Lp = sound pressure level (in dB)
RPM = speed of the slower gear shaft in revolutions per minute
hp = horsepower rating of the gear

where “RPM" is the speed of the slower gear shaft and “hp” is the horsepower rating of the gear or the power transmitted through the gear. For the 63 Hz band, 3 dB is deducted; and for the 31 Hz band, 6 dB is deducted from the Equation B-17 value. This estimate may not be highly accurate, but it will provide a reasonable engineering evaluation of the gear noise. Table B-27 gives the estimated SPL in the 125 through 8,000 Hz bands for a variety of speeds and powers, based on Equation B-17.

Table B-27 Approximate Sound Pressure Levels (dB at 3-ft (0.914 m). Distance) for Gears, in the 125-through 8000-Hz Octave Bands, from Equation B-17

Speed of Slower Gear Shaft (rpm)	Power Rating of Gear					
	50 hp (dB)	100 hp (dB)	200 hp (dB)	500 hp (dB)	1000 hp (dB)	2000 hp (dB)
600	93	94	95	97	98	99
1200	94	95	96	98	99	100
1800	95	96	97	99	100	101
2400	95	96	97	99	100	101
3600	95	97	98	100	101	102
4800	96	97	98	100	101	102

Metric Conversion: Multiply motor hp by 7.46 for equivalent kW)

B-19 GENERATORS.

The noise of generators, in general, can be quite variable, depending on speed, the presence or absence of air-cooling vanes, clearances of various rotor parts, and similar, but, most of all, on the driver mechanism. When driven by gas or diesel reciprocating engines, the generator is usually so much quieter than the engine that it can hardly be measured, much less heard. For gas turbine engines, the high-speed generator may be coupled to the engine through a large gear, and the gear and the generator may together produce somewhat indistinguishable noise in their compartment, which frequently is separated by a bulkhead from the engine compartment. Table B-28 gives an approximation of the overall PWL of several generators. It is not claimed that this is an accurate estimate, but it will give reasonable working values of PWL. It is to be noted that the PWL of the generator is usually less than that of the drive gear and less than that of the untreated engine casing. Octave band corrections to the overall PWL are given in Table B-29.

Table B-28 Approximate Overall PWL (in dB) of Generators, Excluding the Noise of the Driver Unit

Generator Speed, (rpm)	Electrical Power Rating of Generator							
	0.2 MW (dB)	0.5 MW (dB)	1 MW (dB)	2 MW (dB)	5 MW (dB)	10 MW (dB)	20 MW (dB)	50 MW (dB)
600	95	99	102	105	109	112	115	119
1200	97	101	104	107	111	114	117	121
1800	98	102	105	108	112	115	118	122
2400	99	103	106	109	113	116	119	123
3600	100	104	107	110	114	117	120	124
4800	101	105	108	111	115	118	121	125

Table B-29 Frequency Adjustments (in dB) for Generators, Without Drive Unit

Octave Frequency Band (Hz)	Value to be Subtracted From Overall SPL (dB)
31	11
63	8
125	7
250	7
500	7
1000	9
2000	11
4000	14
8000	19
A-weighted, dB(A)	4

B-20 TRANSFORMERS.

The National Electrical Manufacturers Association (NEMA) provides a means of rating the noise output of transformers. The NEMA "audible sound level," as it is called in the standard, is the average of several A-weighted sound levels measured at certain specified positions. The NEMA sound level for a transformer can be provided by the manufacturer. Based on field studies of many transformer installations, the PWL in octave bands has been related to the NEMA rating and the area of the four side walls of the unit. This relationship is expressed by Equation B-18:

Equation B-18. Sound Power Level of a Transformer

$$\mathbf{Lw = NEMA\ rating + 10\log A + C}$$

Where:
Lw = sound power level (in dBA)
NEMA rating = NEMA-compliant A-weighted transformer sound level
A = total surface area of transformer side walls (ft^2)
C = octave band correction (in dBA)

where “NEMA rating” is the A-weighted sound level of the transformer provided by the manufacturer, obtained in accordance with current NEMA Standards, A is the total surface area of the four side walls of the transformer in ft.^{2}, and C is an octave band correction that has different values for different uses, as shown in Table B-30. If the exact dimensions of the transformer are not known, an approximation will suffice. When in doubt, estimate the area on the high side. An error of 25 percent in area will produce a change of 1 dB in the PWL. Use the most nearly applicable C value from Table B-30. The Cl value assumes normal radiation of sound. Use the C_2 value in regular-shaped confined spaces where standing waves will very likely occur, which typically may produce 6 dB higher sound levels at the transformer harmonic frequencies of 120, 240, 360, 480, and 600 Hz (for 60-Hz line frequency; or other sound frequencies for other line frequencies). The sound power level of the transformer does not increase in this location, but the sound analysis procedure is more readily handled by presuming that the sound power is increased. The C_3 value approximates the noise of a transformer that has grown noisier (by about 10 dB) during its lifetime. This happens occasionally when the laminations or tie-bolts become loose, and the transformer begins to buzz or rattle. In a highly critical location, it would be wise to use this value. All the Table B-30 values assume that the transformer initially meets it quoted NEMA sound level rating. Field measurements have shown that transformers may have A-weighted sound levels that range from a few decibels (2 or 3 dB) above to as much as 5 or 6 dB below the quoted NEMA value. Quieted transformers that contain various forms of noise control treatments can be purchased at as much as 15 to 20 dB below normal NEMA ratings. When a quieter transformer is purchased and used, use the lowered sound level rating in place of the regular NEMA rating in Equation B-18, and the appropriate corrections from Table B-30 selected.

Table B-30 Octave-Band Corrections (in dB) to be Used in Equation B-18 for Obtaining PWL of Transformers in Different Installation Conditions

Octave Frequency Band (Hz)	Octave Band Corrections, in dB		
	C_1, see Note 1	C_2, see Note 2	C_3, see Note 3
31	-1	-1	-1
63	+5	+8	+8
125	+7	+13	+13
250	+2	+8	+12
500	+2	+8	+12
1000	-4	-1	+6
2000	-9	-9	+1
4000	-14	-14	-4
8000	-21	-21	-11

Notes:
Note 1. Use C1 for outdoor location or for indoor location in a large mechanical equipment room (over about 5000 $ft.^3$ or 141.58 m^3) containing many other pieces of mechanical equipment that serve as obstacles to diffuse sound and breakup standing waves.

Note 2. Use C2 for indoor locations in transformer vaults or small rooms (under about 5000 ft.3 or 141.58 m^3) with parallel walls and relatively few other large-size obstacles that can diffuse sound and breakup standing waves.

Note 3. Use C3 for any location where a serious noise problem would result when the transformer becomes noisy above its NEMA rating, following its installation and initial period of use.

B-21 OPENING IN A WALL.

An opening, such as a door, window, or louvered vent, in an exterior wall of a noisy room will allow noise to escape from that room and perhaps be disturbing to neighbors. The PWL of the sound that passes through the opening can be estimated from Equation B-19:

Equation B-19. Sound Power Level at Wall Opening

$$\mathbf{Lw = Lp + 10\ \log A - 10}$$

Where:
Lw = sound power level (in dB)
Lp = sound pressure level (in dB)
A = area of the opening (ft^2)(m^2)

where Lp is the SPL in the room at the location of the opening and A is the area, in $ft.^2$, of the opening. (Note, the factor of - 10 is due to the use of ft^2 for A, if m^2 had been used then this factor would be 0). For normal openings (windows or vents) without ducted connections to the noise source, it may be assumed that the sound radiates freely in all directions in front of the opening, but to the rear of the wall containing the opening, the barrier effect of the wall must be considered. For ducted connections from a sound source to an opening in the wall, the sound is somewhat “beamed” out of the opening and may be assumed to have a directivity effect of above one-half the amount given in Table B-23 for air intake openings of large stacks.

APPENDIX C INFORMATIVE REFERENCE

C-1 GENERAL.

This reference is not part of this UFC. It is intended to be informative and does not contain any requirements necessary for conformance to this document. Additional information can be found in a wide variety of other non-government technical publications related to noise and vibration control.

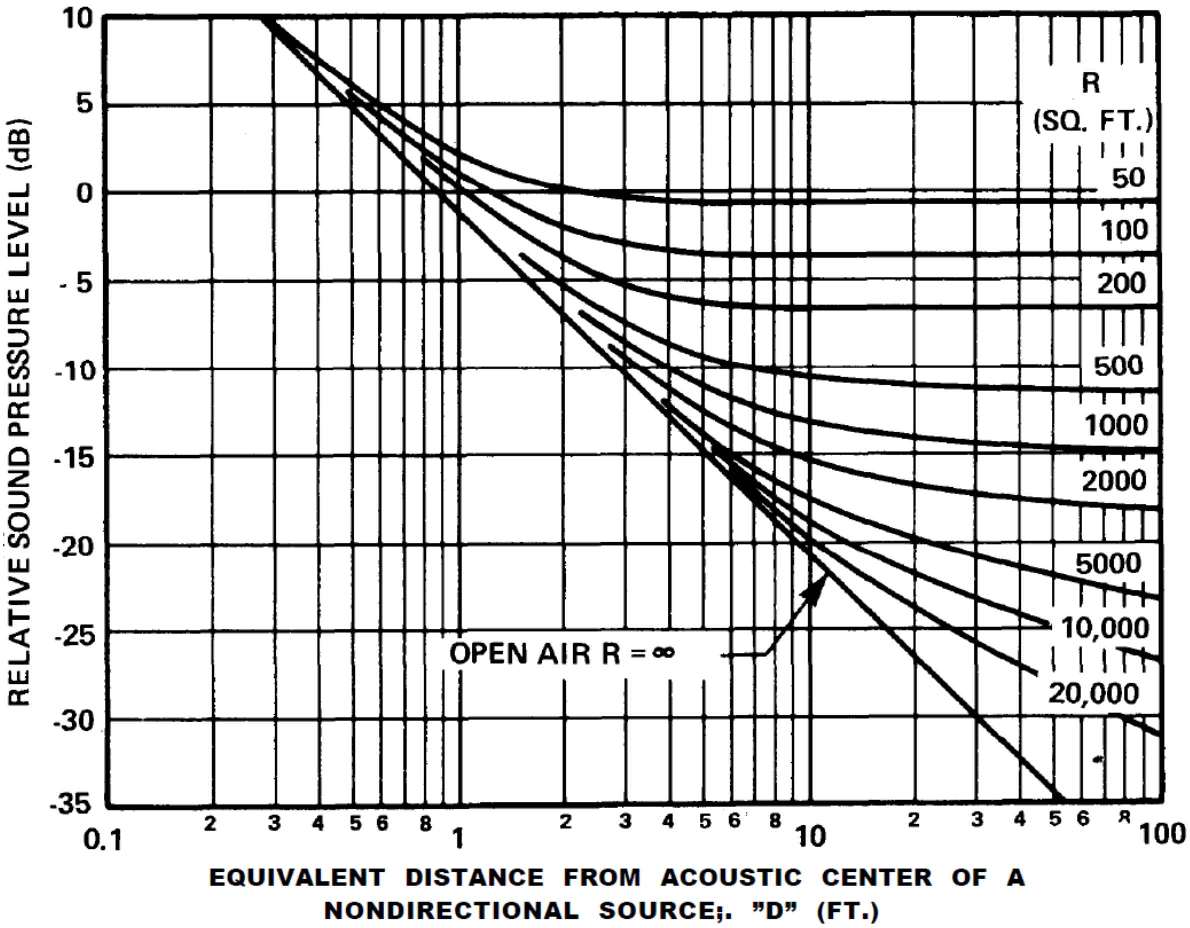
C-2 SOUND PRESSURE LEVEL IN A ROOM.

The sound pressure levels at a given distance or the sound power levels for individual equipment items can often be obtained from equipment suppliers. Appendix B also provides sound level and power level estimates for general classes of mechanical equipment. Once the characteristics of the sound source has been determined, then the sound level at any location within an enclosed space can be estimated. In an outdoor "free field" (no reflecting surfaces except the ground), the sound pressure level (SPL) decreases at a rate of 6 dB for each doubling of distance from the source. In an indoor situation, however, all the enclosing surfaces of a room confine the sound energy so that they cannot spread out indefinitely and become dissipated with distance. As sound waves bounce around within the room, there is a build-up of sound level because the sound energy is "trapped" inside the room and escapes slowly.

C-2.1 Effect of Distance and Absorption.

The reduction of sound pressure level indoors, as one moves across the room away from the sound source, is dependent on the surface areas of the room, the amount of sound absorption material on those areas, the distances to those areas, and the distance from the source. All of this is expressed quantitatively by the curves of Figure C-1. Figure C-1 offers a means of estimating the amount of SPL reduction for a piece of mechanical equipment (or any other type of sound source) in a room, as one moves away from some relatively close-in distance to any other distance in the room, provided the sound absorptive properties of the room (Room Constant) is known. Conversely Figure C-1 also provides a means of estimating the sound reduction in a room, from a given source, if the distance is constant and the amount of absorptive treatment is increased.

Figure C-1 Approximate Relationship Between "Relative Sound Pressure Level" (REL SPL) and Distance to a Sound Source for Various "Room Constant" Values



Note: This figure has been adjusted to consider large obstacles or large pieces of equipment distributed about the room. Therefore, the curves for large values of R do not agree with similar textbook curves that tend to ignore such obstacles. For metric where Ft is identified convert to m (meters)

C-2.2 General Application of Figure C-1.

Figure C-1 may be used for estimating SPL change from any given condition of Room Constant and distance to any other wanted condition of Room Constant and distance. This can be expressed by Equation C-1:

Equation C-1. Change in Room SPL between Room Constant and Distance Conditions

$$\mathbf{L_{pD2R2} = L_{pD1R1} - (REL\ SPL_{D1R1} - REL\ SPL_{\ D2R2})}$$

Where:
L_{pD2R2} = Change in SPL (in dBA) based on new conditions D2 (ft) and R2 (ft^2)
L_{pD1R1} = Known SPL (in dBA) based on measured conditions D1 (ft) and R1 (ft^2)
REL SPL_{D1R1} = Relative SPL based on new conditions (in dB)
REL SPL_{D2R2} = Relative SPL based on measured conditions (in dB)

where D1 and R1 are the distance (in feet or m) and Room Constant (in ft.^{2} or m^2) values for the measured or known sound pressure level L_{pD1Rl}; D_2 and R_2 are the distance and Room Constant values for the new set of conditions for which the new sound pressure level L_{pD2R2} is wanted; and REL SPL $_{D1R1}$ and REL SPL_{D2R2} (in dB) are read from the ordinate (vertical axis) of Figure C-1 for the specific combinations of D_1, R_1 and D_2, R_2. For estimating SPL change when only the Room Constant is changed and there is no change of distance (in other words, the equipment distance remains constant), the same distance value for D_1 and D_2 is used, and the equation is solved. For estimating SPL change when only the distance is changed and there is no change in Room Constant (in other words, the equipment remains in the same room, with no change in absorption), the same value of Room Constant for R_1 and R_2 is used, and the equation is solved. For a complete analysis, the calculations must be carried out for each octave frequency band.

C-2.3 Simplified Table for SPL Correction for Distance and Room Constant.

Table C-1 represents a simplification of Figure C-1 for a special condition of distance and room constant. Much of the collection of equipment sound data in Appendix B is given in terms of SPL at a normalized distance of 3 feet (0.914 m) and a normalized room constant of approximately 800 ft.^{2} (74.32 m^2). Table C-1 must not be used in converting sound power level (PWL) data to sound pressure level (see Equation C-2 and Table C-2). Table C-3 permits extrapolation from those normalized 3-foot (0.914 m) SPLs to some greater distance for a variety of different Room Constants.

Table C-1 Reduction of SPL in (dB) in Going from Normalized 3-foot (0.914 m) Distance and 800-ft.2 (74.32 m²) Room Constant to Any Other Distance and Room Constant

Room Constant "R" ($ft.^2$)	Distance "D" (in ft.) from Equipment								
	3	5	10	15	20	30	40	60	80
100	-5	-4	-4	-4	-4	-4	-4	-4	-4
200	-3	-2	-1	-1	-1	-1	-1	-1	-1
320	-2	0	0	0	0	0	0	0	0
500	-1	1	2	3	3	3	4	4	4
700	0	2	4	4	5	5	6	6	6
1000	1	3	5	6	7	7	8	0	0
2000	1	4	7	0	9	9	10	10	10
3200	2	5	0	9	10	11	12	12	12
5000	2	6	9	11	12	13	14	14	15
7000	2	6	10	12	13	14	15	15	16
10000	2	7	11	13	14	15	16	17	10
20000	2	7	12	14	16	18	19	21	22
Infinite	2	7	13	16	19	22	25	20	31

Note: Negative value of reduction means an Increase in sound level. **Convert feet to meter and ft² to m² as applicable**.

Table C-2 REL SPL Values for a Range of Distances "D" and Room Constants "R", for Use With PWL Data

Room Constant "R" ($ft.^2$)	Distance "D" (in ft.) from Equipment								
	3	5	10	15	20	30	40	60	80
100	-3	-4	-4	-4	-4	-4	-4	-4	-4
200	-5	-6	-7	-7	-7	-7	-7	-7	-7
320	-6	-7	-8	-8	-9	-9	-9	-9	-9
500	-7	-9	-10	-11	-11	-11	-11	-11	-11
700	-8	-10	-12	-12	-12	-13	-13	-13	-13
1000	-8	-11	-13	-13	-14	-14	-15	-15	-15
2000	-9	-12	-15	-16	-17	-17	-17	-18	-18
3200	-10	-13	-16	-17	-18	-19	-19	-20	-20
5000	-10	-14	-17	-18	-20	-21	-21	-22	-23
7000	-10	-14	-16	-19	-21	-22	-23	-24	-25
10000	-10	-14	-19	-21	-22	-23	-24	-25	-26
20000	-10	-15	-20	-22	-24	-26	-27	-30	-30
Infinite	-10	-15	-21	-24	-27	-30	-33	-36	-39

Table C-3 Low Frequency Multipliers For Room Constants.

Octave Frequency Band (Hz)	Percent of Area of Thin Surfaces to Total Surface Area of Room							
	0	10	20	30	40	60	80	100
31	1	1.3	1.6	1.9	2.2	2.8	3.4	4.0
63	1	1.3	1.6	1.9	2.2	2.8	3.4	4.0
125	1	1.3	1.6	1.9	2.2	2.8	3.4	4.0
250	1	1.2	1.3	1.4	1.6	1.9	2.1	2.4
500	1	1.1	1.1	1.2	1.2	1.3	1.5	1.6

Area in Table C-3 is shown as Ft², convert to M² as applicable.

C-2.4 SPL in a Room when PWL is Known.

The second major use of Figure C-1 is in determining the SPL in a room when the sound power level of the source is known. Equation C-2 provides this.

Equation C-2. Room SPL with Known PWL

$$\mathbf{L_{pD,R} = Lw + REL\ SPL_{D,R}}$$

Where:
$L_{pD,R}$ = sound pressure level (in dB) based on conditions D (ft) and R (ft^2)
Lw = known sound power level (in dB)
REL $SPL_{D,R}$ = relative sound pressure level (in dB)

where $L_{pD,R}$ is the SPL to be determined at distance D in the room of Room Constant R, Lw the sound power level of the source (in dB re 10^{12}W) and REL $SPL_{D,R}$ is read from the ordinate of Figure C-1 for the point of intersection of the D and R values specified. In most uses, the value of REL $SPL_{D,R}$ will be negative, so this amounts to a subtraction function. Hence, the signs must be followed carefully. The calculation is repeated for each octave band.

C-3 ROOM CONSTANT.

C-3.1 Calculation of a Room Constant.

The room constant is a measure of the amount of sound absorption that exists within a room. Most current acoustic textbooks give details of a conventional calculation of the Room Constant for any specific room, when the following facts are known: (1) all the room dimensions, (2) the wall, floor, and ceiling materials, (3) the amount and type of acoustic absorption materials, and (4) the sound absorption coefficients of the acoustic-materials at various specified frequencies. The calculation is summarized in Equation C-3:

Equation C-3. Room Constant Calculation

$$\mathbf{R} = \mathbf{S_1} \propto_1 + \mathbf{S_2} \propto_2 + \mathbf{S_3} \propto_3 + \ldots + \mathbf{S_n} \propto_n$$

Where:
R = room constant (ft²) (m²)
S_1 = surface area (each surface area in ft² (m²) notated by 1, 2,… n)
$\propto_1$ = sound absorption coefficient (each material coefficient notated by 1, 2,… n)

where R is the Room Constant (or "room absorption" as it is often called), S_1 is the total area of all the room surfaces having "sound absorption coefficients" $\propto_1$; S_2 is the total area of all the room surfaces having sound absorption coefficient $\propto_{12}$; and similar. The areas S_1…..S_n are expressed in ft² (m²), and the sound absorption coefficients ($\propto$'s) are dimensionless. The resulting Room Constant R is also expressed in ft² (m²). The term "Sabin" is used in the literature as a unit of room absorption or Room Constant, where one Sabin is the absorption provided by 1 ft² (0.093 m²) of material having perfect absorption, in other words, having a value of 1.0. In the manual, 1 ft² (0.093 m²) of absorption and 1 Sabin are used synonymously.

C-3.2 Sound Absorption Coefficients.

For most surfaces and materials, the sound absorption coefficients vary with frequency; hence the Room Constant must be calculated for all frequencies of interest. Even room surfaces that are not normally considered absorptive have small amounts of absorption. Table C-4 gives the published sound absorption coefficients of typical building materials. Usually, sound absorption coefficients are not measured in the 31, 63 and 8,000 Hz frequencies. Where the data at these frequencies are not available use 40% of the value of the 125 Hz for the 31 Hz band, 70% of the 125 Hz value for the 63 Hz band and 80% of the 4,000 values for the 8,000 Hz octave band. Values of sound absorption coefficients for specialized acoustical materials must be obtained from the manufacturer.

Table C-4 Sound Absorption Coefficients of General Building Materials and Furnishings (material in table is imperial, convert to metric as applicable)

Materials Part A	Coefficients					
	125 Hz	250 hz	500 hz	1000 hz	2000 hz	4000 hz
Brick, unglazed	.03	.03	.03	.04	.05	.07
Brick, unglazed, painted	.01	.01	.02	.02	.02	.03
Carpet, heavy, on concrete	.02	.06	.14	.37	.60	.65

Same, on 40 or hairfelt or foam rubber	.08	.24	.57	.69	.71	.73
Same, with impermeable latex backing on 40 or hairfelt or foam rubber	.08	.27	.39	.34	.48	.63
Concrete Block, light, porous	.36	.44	.31	.29	.39	.25
Concrete Block, dense, painted	.10	.05	.06	.07	.09	.08
Fabrics, light velour, 10 oz per sq. yard, hung straight, in contact with wall	.03	.04	.11	.17	.24	.35
Fabrics, medium velour, 14 oz per sq. yard, draped to half area	.07	.31	.49	.75	.70	.60
Fabrics, Heavy velour, 18 oz per sq. yd., draped to half area	.14	.35	.55	.72	.70	.65
Floors, Concrete or terrazzo	.01	.01	.015	.02	.02	.02
Floors, Linoleum, asphalt, rubber or cork tile on concrete	.02	.03	.03	.03	.03	.02
Floors, Wood	.15	.11	.10	.07	.06	.07
Floors, Wood parquet in asphalt on concrete	.04	.04	.07	.06	.06	.07
Glass, large panes of heavy plate glass	.18	.06	.04	.03	.02	.02
Glass, Ordinary window glass	.35	.25	.18	.12	.07	.04
Gypsum Board, ½-in. nailed to 2x4's 16-in. o.c.	.29	.10	.05	.04	.07	.09
Marble or Glazed Tile	.01	.01	.01	.01	.02	.02

Plaster, gypsum or lime, smooth finish on tile or brick	.013	.015	.02	.03	.04	.05
Plaster, gypsum or lime, rough finish on lath	.14	.10	.06	.05	.04	.03
Same, with smooth finish	.14	.10	.06	.04	.04	.03
Plywood paneling, 3/8-in. thick	.28	.22	.17	.09	.10	.11
Water Surface, as in a swimming pool	.008	.008	0.013	0.015	.020	.025
Air, Sabins per 1000 cubic feet	.09	.20	.49	1.2	2.9	7.4
Absorption of Seats and Audience Values given are in Sabins per square foot of seating area or per unit						
Part B	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Chairs, metal or wood seats, each, unoccupied	.15	.19	.22	.39	.38	.30
People in a room, per person (do not use for auditorium calculations)	2	3	4	5	5	4
Audience, seated in upholstered seats, per square feet floor area, for auditorium calculations	.60	.74	.88	.96	.93	.85

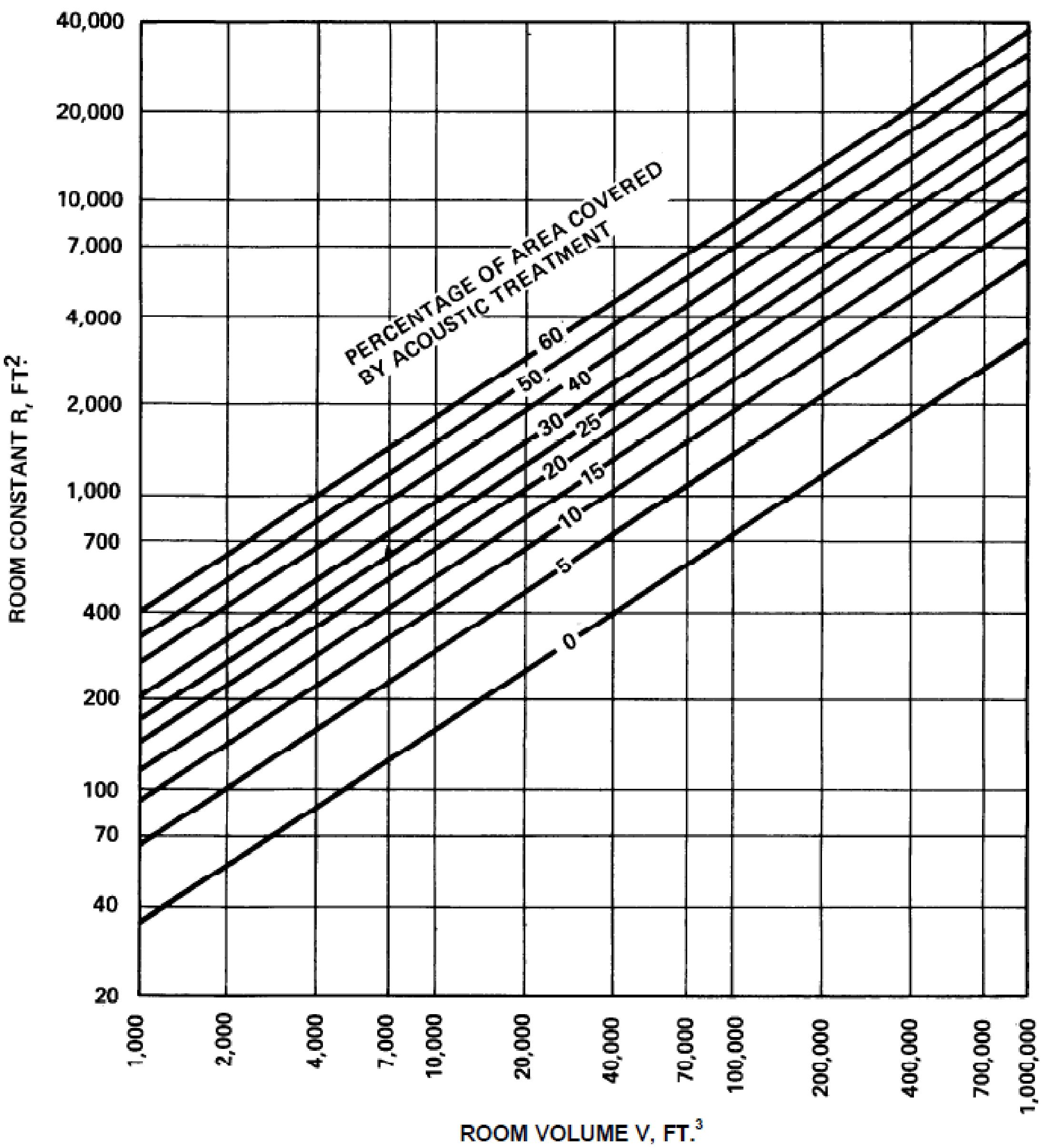
C-3.3 Estimation of Room Constant.

In the early stages of a design, some of the details of a room may not be finally determined, yet it may be necessary to proceed with certain portions of the design. An approximation of the Room Constant can be made using Table C-3 and Table C-4. The basic room dimensions are required but it is not necessary to have made all the decisions on side wall, floor, and ceiling materials. This simplification yields a less accurate estimate than does the more detailed procedure, but it permits rapid estimates of the Room Constant with gross, but nonspecific, changes in room materials and sound absorption applications. Then, when a favored condition is found, detailed calculations can be made with Equation C-1.

C-3.4 Use of Figure C-2.

Figure C-2 gives a broad relationship between the volume of a typically shaped room and the Room Constant as a function of the percentage of room area that is covered by sound absorption material. Room area means the total interior surface area of floor, ceiling, and all side walls. The Room Constant values obtained from this chart strictly apply at 1000 Hz, but in this simplified procedure are considered applicable for the 2000- through 8000-Hz bands as well.

Figure C-2 Room Constant Estimate



From Bolt Beranek and Newman Inc. Used with permission.
(Convert room constant (ft²) and room vol (ft³) to metric as applicable).

C-3.5 Use of Table C-4, part A.

Sound absorption materials are less effective at low frequency (at and below 500 Hz) than at high frequency (at and above 1000 Hz). Therefore, the high-frequency Room Constant obtained from Figure C-2 must be reduced to apply to the lower frequencies. Part A of Table C-4 gives a multiplier for doing this. This multiplier is a function of frequency, Noise Reduction Coefficient (NRC) range of any special sound absorption material, and the mounting type for installing the absorption material. The Noise Reduction Coefficient is the arithmetic average of the sound absorption coefficient at 250, 500, 1,000 and 2,000 Hz. Mounting type A consists of application sound absorptive material applied directly onto a hard backing such as a wall or ceiling. Mounting type B consists of sound absorptive material mechanically supported with a large air space behind the material, such as a typical suspended ceiling.

C-3.6 Use of Table C-4, part B.

Relatively thin wall materials (such as gypsum board, plaster, plywood, and glass), even though not normally considered as soft, porous, and absorptive, have relatively large values of sound absorption coefficient at low frequency. This is because these thin surfaces are lightweight and are easily driven by airborne sound waves. For this reason, they appear as effective sound absorbers at low frequency, and this characteristic must be considered in the calculation or estimation of Room Constant. Part B of Table C-4 gives a multiplier for doing this.

C-4 SAMPLE CALCULATIONS FOR INDOOR SOUND DISTRIBUTION.

Two sample calculations are provided, one in which the sound pressure level (SPL) for the equipment is provided and one where the sound power level (PWL) is provided.

C-4.1 Sound Pressure Level Provided.

To illustrate use of Equation C-2, a piece of equipment is measured by a manufacturer under one set of conditions and is to be used by the customer under an entirely different set of conditions. The data and calculations are summarized in Table C-5. The manufacturer's measurements, shown in column 2, are made at a 6-foot (1.83 m) distance from the equipment (here assumed nondirectional, that is, equal sound output in all directions) in a room whose Room Constants as a function of frequency are shown in column 3 of Table C-5. The customer is interested in the sound pressure levels at a 20-foot distance in a mechanical equipment room having the Room Constant values shown in column 5. In applying equation 3-2, D_1 = 6 ft (1.83 m)., D_2 = 20 ft (6.1 m)., R_1 is given by the column 3 data, R_2 is given in column 5, and the measured levels are listed in column 2. First, Figure C-1 is used to estimate the REL SPL_{D1R1} values for the 6-ft. distance and all the column 3 values of R1. These REL SPL values are given in column 4. Next, the REL SPLD2R2 values are estimated for the 20-foot (6.1 m) distance and all the column 5 values of R2. These REL SPL values are given in column 6. Column 7 shows the value of the difference (REL $SPLD_{1RI}$ - REL SPL_{D2R2}); it is necessary here to be extremely careful to preserve the correct signs. Finally, column 8 gives the value of SPL at D_2, R_2, which is equal to the column 2 value minus the column

7 value, again, being careful with the signs. To check the calculations, go back to Figure C-1 and follow one specific conversion, such as the 1000-Hz change of conditions. A pencil mark is placed at the junction of D_1 = 6 ft (1.83 m). and R_1 = 500 ft.^{2} (46.45 m^2), and it is noted that the measured SPL was 91 dB for that condition. Now, as one moves out to the junction of D_2 = 20 ft (6.1m). and R_2 = 1200 ft.^{2} (111.48 m^2), it is observed that there is a movement down the graph by 5 dB. This means there is a reduction of 5 dB from the initial condition of 91 dB. Therefore, the end condition is 91 - 5 = 86 dB, which is confirmed in the column 8 of Table C-5 for the 1000-Hz octave band. Hint: When the net movement is down on Figure C-1, there is a reduction from "starting SPL" to "ending SPL"; when the net movement is up on Figure C-1, there is an increase from "starting SPL to ending SPL." Note: this equation is to be used when SPL is given for one set of conditions and SPL is wanted for another set of conditions.

Table C-5 Summary of Data and Calculations Illustrating Use of Equation 3-1

Col. 1 Octave Band Center Frequency (Hz)	Col. 2 $L_{P_{D_1,R_1}}$ Measured at 6 ft. Distance (dB)	Col. 3 R_1 of Measurement Room (ft^2)	Col. 4 REL SPL_{D_1,R_1} from Fig. 5-1 (dB)	Col. 5 R_2 of Mechanical Equipment Room (ft^2)	Col. 6 REL SPL_{D_2,R_2} from Fig. 5-1 (dB)	Col. 7 Col. 4 minus Col. 6 (dB)	Col. 8 $L_{P_{D_2,R_2}}$ Col. 2 minus Col. 7 (dB)
31	81	350	-8	250	-7	-1	82
63	85	350	-8	250	-7	-1	86
125	87	400	-9	400	-10	+1	86
250	90	450	-9.5	750	-12.5	+3	87
500	96	480	-9.5	850	-13	+3.5	92
1000	91	500	-10	1200	-15	+5	86
2000	88	500	-10	1200	-15	+5	83
4000	83	500	-10	1200	-15	+5	78
8000	72	500	-10	1200	-15	+5	67

C-4.2 Sound Power Level Given.

Suppose a manufacturer submits the PWL data given in column 2 of Table C-6 for a particular centrifugal compressor. An engineer intends to install this compressor in a room having the R values shown in column 3 and needs to know the SPL at a 20-foot (6.1 m) distance. Column 4 shows the REL SPL values from Figure C-1 for the 20-foot (6.1 m) distances and the various Room Constants. Column 5 then gives the calculated SPL values.

Table C-6 Summary of Data and Calculations Illustrating Use of Equation 3-2

Col. 1 Octave Band Center Frequency (Hz)	Col. 2 PWL of Source (dB)	Col. 3 Room Constant ($ft.^2$)	Col. 4 REL SPL from Fig. 5-1 (dB)	Col. 5 SPL at Distance (dB)
31	95	400	-10	85
63	93	600	-12	81
125	94	800	-13	81
250	95	1200	-15	80
500	99	1600	-16	83
1000	102	2000	-17	85
2000	108	2000	-17	91
4000	105	2000	-17	88
8000	94	2000	-17	77

C-5 ADDITIONAL INFORMATION ON SOUND TRANSMISSION LOSS (TL), NOISE REDUCTION (NR) AND SOUND TRANSMISSION CLASS (STC).

(Convert room constant (ft^2) to metric as applicable)

C-5.1 Transmission Loss (TL) of Walls.

The TL of a wall is the ratio, expressed in decibels, of the sound intensity transmitted through the wall to the airborne sound intensity incident upon the wall. Thus, the TL of a wall is a performance characteristic that is entirely a function of the wall weight, material and construction, and its numerical value is not influenced by the acoustic environment on either side of the wall or the area of the wall. Procedures for determining transmission loss in the laboratory are given in ASTM E 90. This is the data usually given in most manufacturers' literature and in acoustic handbooks. Laboratory ratings are rarely achieved in field installations. Transmission loss values in the laboratory are usually greater, by 4 to 5 dB, than that which can be realized in the field even when good construction practices are observed. ASTM E336 is a corresponding standard method for determination of sound isolation in buildings (in situ). The approximate transmission loss or "TL" values, expressed in dB, of a number of typical wall construction materials are given in the tables of paragraph C-6. There are many other references that provide transmission loss performance for building materials. In addition, many manufactures also provide transmission loss for their products.

C-5.1.1 "Suggested" vs "Ideal" TL Values.

In several of the tables of paragraphs C-6 and C-7, two sets of TL data are given. The first is labeled "suggested design values," and the second is headed "ideal values." With good design and workmanship, the "suggested design values" can be expected. The "ideal values" are perhaps the highest values that can be achieved if every effort, in both design and execution, is made to assure a good installation, including control of all possible flanking paths of sound and vibration. The "suggested design values" are 1 to 3 dB low the "ideal values" in the low-frequency region and as much as 10 to 15 dB lower in the high-frequency region. When walls have ideal TL values as high as 60 to 70 dB, even the slightest leakage or flanking can seriously reduce the TL in the high-frequency region.

C-5.1.2 TL of Other Materials and Fabricated Partitions.

Because of the increasing need for good sound isolation in building design, many manufacturers are producing modular wall panels, movable partitions, folding curtains, and other forms of acoustic separators. When inquiring about these products, it is desirable to request their transmission loss data and to determine the testing facility where the product was evaluated (in example, laboratory vs field, and the standard employed).

C-5.1.3 Estimated TL of Untested Partitions.

For estimations of the TL of an untested partition, its average surface weight in (lb./ft.^{2}) (kg/m^2) and its basic structural form must be determined. Then, the range of approximate TL values for partitions of similar weight and structure can be obtained.

C-5.2 Noise Reduction (NR) of a Wall.

When sound is transmitted from one room (the "source room") to an adjoining room (the "receiving room"), it is the transmitted sound power that is of interest. The transmission loss of a wall is a performance characteristic of the wall structure, but the total sound power transmitted by the wall is also a function of its area (such as the larger the area, the more the transmitted sound power). The Room Constant of the receiving room also influences the SPL in the receiving room. A large Room Constant reduces the reverberant sound level in the room at an appropriate distance from the wall. Thus, three factors influence the SPL in a receiving room: the TL of the wall, the area S_W of the common wall between the source and receiving rooms, and the Room Constant R2 of the receiving room. These three factors are combined in Equation C-4:

Equation C-4. Sound Pressure Level of Receiving Room

$$\mathbf{L_{p2} = L_{p1} - TL + 10\log\left(\frac{1}{4} + \frac{S_W}{R_2}\right)}$$

Where:
L_{p2} = sound pressure level in the receiving room (in dB)
L_{p1} = sound pressure level in the source room (in dB)
TL = transmission loss of the wall (in dB)
S_w = common wall area (ft^2)(m^2)
R_2 = room constant of receiving room (ft^2)(m^2)

where L_{p1} is the SPL near the wall in the source room, and L_{p2} is the estimated SPL in the receiving room at a distance from the wall approximately equal to 75 percent of the smaller dimension (length or height) of the wall. The “noise reduction” (NR) of a wall is the difference between L_{p1} and L_{p2}; therefore,

Equation C-5. Transmission Loss with Wall Correction Term

$$\mathbf{NR + TL - 10\log\left(\frac{1}{4} + \frac{S_W}{R_2}\right) = T\,L + C}$$

Where:
NR = noise reduction (in dB)
TL = transmission loss (in dB)
S_w = common wall area (ft^2)(m^2)
R_2 = room constant of receiving room (ft^2)(m^2)
C = wall correction term (in dB)

And

Equation C-6. Wall Correction Term

$$\mathbf{C = -\,10\log\left(\frac{1}{4} + \frac{S_W}{R_2}\right)}$$

Where:
C = wall correction term (in dB)
S_w = common wall area (ft^2)(m^2)
R_2 = room constant of receiving room (ft^2)(m^2)

In the document, C is called the “wall correction term” and its value is given in Table C-7 for a range of values of the ratio S_W/R_2. Both S_W and R_2 are expressed in ft (m), so the ratio is dimensionless. When NR is known for the wall and room geometry, Equation C-7 becomes:

Equation C-7. Wall Correction Term with Known NR

$$\mathbf{L_{p2} + L_{p1} - NR}$$

Where:
C = wall correction
L_{p2} = sound pressure level in the receiving room (in dB)
L_{p1} = sound pressure level in the source room (in dB)
NR = noise reduction (in dB)

Table C-7 Wall or Floor Correction Term "C" for Use in the Equation NR = TL + "C"

Ratio S_W/R_2	"C" (dB)	Ratio S_W/R_2	"C" (dB)	Ratio S_W/R_2	"C" (dB)
0.00	+6	1.7	-3	15	-12
0.07	+5	2.2	-4	20	-13
0.15	+4	2.9	-5	25	-14
0.25	+3	3.7	-6	31	-15
0.38	+2	4.7	-7	40	-16
0.54	+1	6.1	-8	50	-17
0.75	0	7.7	-9	63	-18
1.0	-1	9.7	-10	80	-19
1.3	-2	12.0	-11	100	-29

(Select nearest integral value of C)

The SPL at any distance from the wall of the receiving room can be determined by using Figure C-1 and extrapolating from the "starting distance" (75 percent of the smaller dimension of the wall) to any other desired distance for the particular R2 value.

C-5.3 *TL_c* of Composite Structures.

When a wall is made up of two or more different constructions, each with its own set of TL values, the effective transmission loss of the composite wall (*TL_c*) can be calculated. The transmission coefficient "t", of each construction, is the ratio of the transmitted acoustic power to the incident acoustic power and is related to TL by Equations C-8.

Equation C-8. Transmission Coefficient

$$\mathbf{t} = \frac{\mathbf{1}}{\mathbf{10^{(0.1\,x\,TL)}}}$$

Where:
t = transmission coefficient
TL = transmission loss (in dB)

Once the transmission coefficient of each of the individual constructions has been determined then the composite transmission loss can be determined by Equation C-9.

Equation C-9. Composite Transmission Loss

$$\boldsymbol{TL_c} = \mathbf{10\,log}[(\boldsymbol{S_1} + \boldsymbol{S_2} + \boldsymbol{S_3} + \ldots)/(\boldsymbol{S_1}\,\boldsymbol{t_1} + \boldsymbol{S_2}\,\boldsymbol{t_2} + \boldsymbol{S_3}\,\boldsymbol{t_3}\ldots)]$$

Where:
TL_c = composite transmission loss (in dB)
S = surface area (in ft^2 (m^2)where each wall is notated by 1, 2,… n)
t = transmission coefficient (where each coefficient is notated by 1, 2,… n)

Where S_1 is the surface area of the basic wall having transmission loss TL_1, S_2 is the surface area of a second section (such as a door) having TL_2, S_3 is the surface area of a third section (such as a window) having TL3, and so on. Since the transmission loss is different depending on the frequency, this calculation must be repeated for each octave band of interest.

C-5.4 Sound Transmission Class (STC).

Current architectural acoustics literature refers to the term “Sound Transmission Class” (STC). This is a one-number weighting of transmission losses at many frequencies. The STC rating is used to rate partitions, doors, windows, and other acoustic dividers in terms of their relative ability to provide privacy against intrusion of speech or similar type sounds. This one-number rating system is heavily weighted in the 500- to 2000-Hz frequency region. Its use is not recommended for mechanical equipment noise, whose principal intruding frequencies are lower than the 500- to 2000 Hz region. However, manufacturers who quote STC ratings must have the 1/3 octave band TL data from which the STC values were derived, so it is possible to request the TL data when these types of partitions are being considered for isolation of mechanical equipment noise. The procedure for determining an STC rating is given in ASTM standard E 413.

C-5.5 TL of double walls.

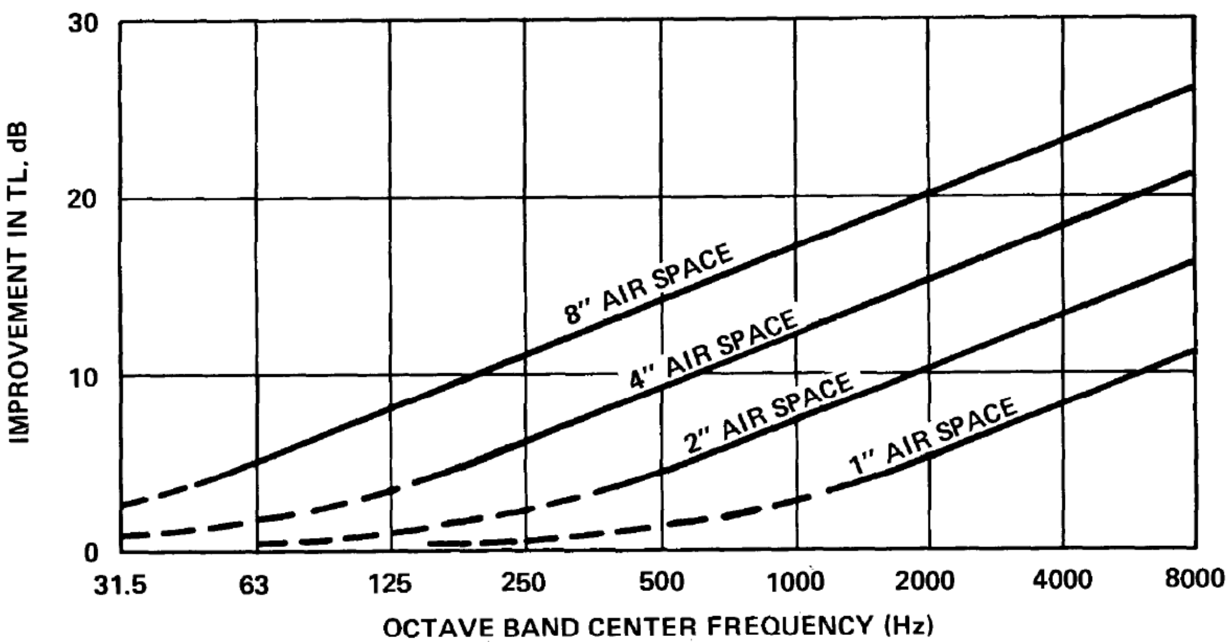
If mechanical equipment rooms are bordered by workspaces where a moderate amount of noise is acceptable, the equipment noise usually can be adequately contained by a single wall. Double walls of masonry, or two separate drywall systems, can be used to achieve even greater values of TL. Various intentional and unintentional structural connections between double walls have highly varying effects on the TL of double walls.

The improvement will be greatest at high frequency. The air space between the walls must be as large as reasonably possible to enhance the low-frequency improvement.

C-5.5.1 Influence of Air Space.

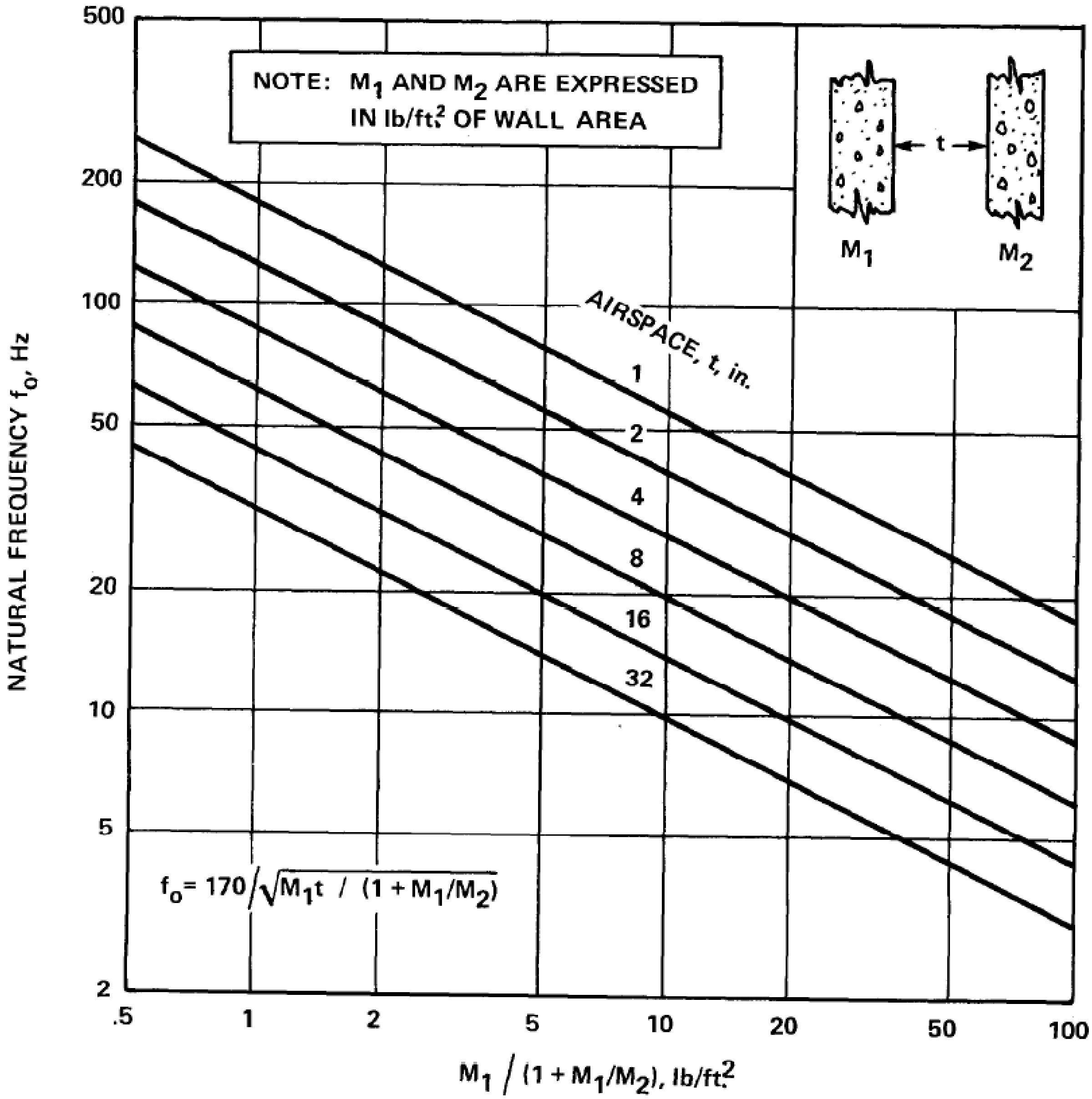
Figure C-3 shows the influence of the air space in double wall construction, assuming no structural connections between the two walls. Even though there may exist no structural connection between the walls, the walls are coupled by the intervening air space at low frequencies. The air space in a double-wall cavity acts somewhat as a spring (air is an "elastic medium"), and the mass of the walls and the air in the cavity have natural frequencies, as seen in Figure C-4. The total effect of a double wall, then, is to gain the improvement of Figure C-3 but to lose some of that gain in the vicinity of the natural frequency determined in Figure C-4. It is suggested that a loss of 5 dB be assigned to the octave band containing the natural frequency and a loss of 2 dB be assigned to the octave band on each side of the band containing the natural frequency.

Figure C-3 Improvement in Transmission Loss Caused by Air Space Between Double Walls Compared to Single Wall of Equal Total Weight, Assuming no Rigid Ties Between Walls



(for metric: air space in inches(") convert to centimeters (cm)

Figure C-4 Natural Frequency of a Double Wall With an Air Space

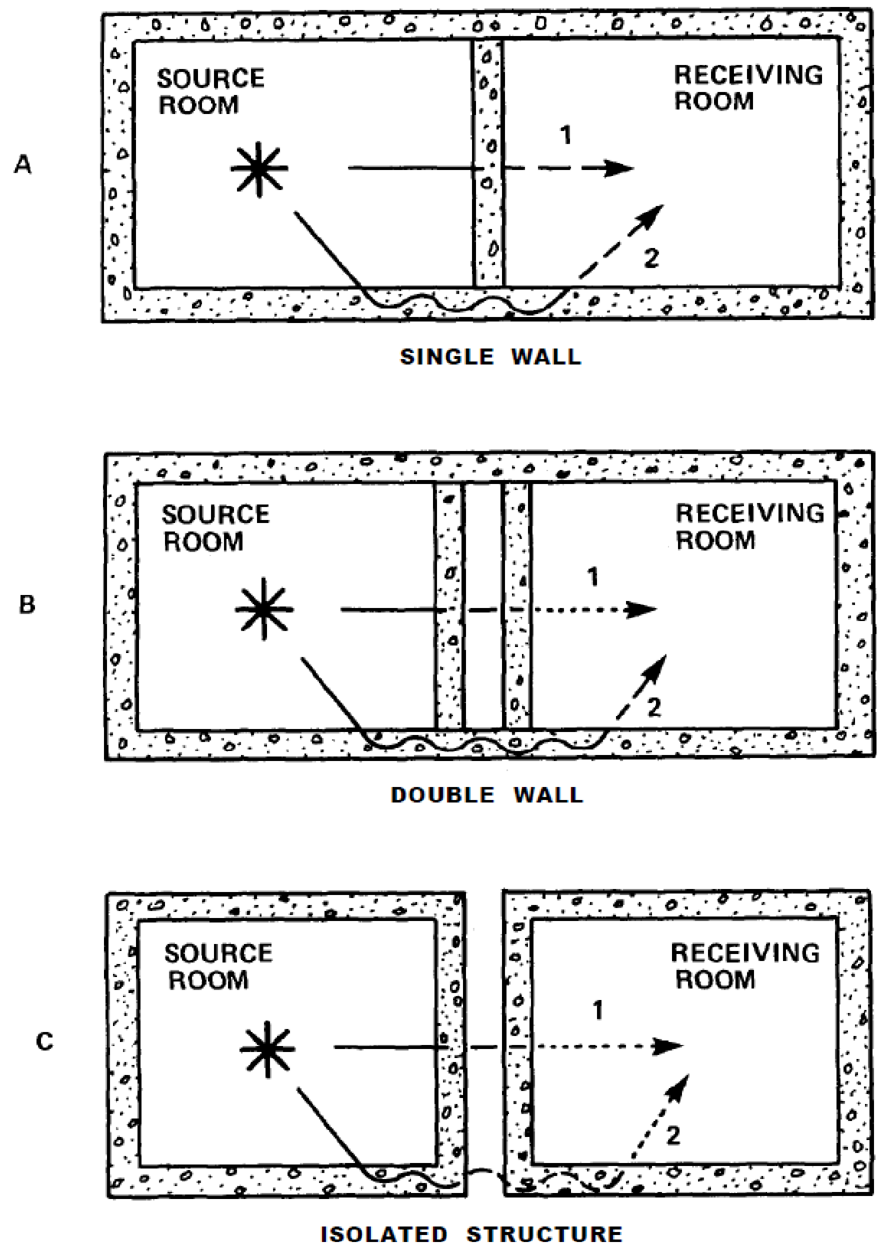


For metric: convert inches to centimeters and lb/ft^2 to kg/m^2)

C-5.5.2 Flanking Paths.

An obvious extension of the double wall concept is a wide corridor used to separate a noisy mechanical equipment room and rooms requiring NC 15 to NC 30 (Table 2-2). Although the airborne sound path through the double wall may appear to be under control, “flanking paths” may limit the actual achievable noise reduction into the quiet room. Figure C-5 illustrates flanking paths. When a structure, such as a wall or floor slab, is set into vibration by airborne sound excitation, that vibration is transmitted throughout all nearby connecting structures with very little decay as a function of distance. In a very quiet room, that vibration can radiate as audible sound. For most single walls between noisy and quiet spaces (part A of Figure C-5), the sound levels in the quiet room are limited by the TL of the single wall (path 1), and the sound by the flanking path (path 2) is too low to be of concern. However, the higher TL of the double wall (part B of Figure C-5) reduces the airborne sound (path 1) so much that the flanking path (path 2) becomes significant and limits the amount of noise reduction that can be achieved. Therefore, structural separation (part C of Figure C-5) is required in order to intercept the flanking path (path 2) and achieve the potential of the double wall.

Figure C-5 Schematic Illustration of Flanking Paths of Sound



C-5.5.3 Resilient Wall Mountings.

It is sometimes possible to enhance the TL of a simple concrete block wall or a study-type partition by resiliently attaching to that wall or partition additional layers of dry wall (gyp. bd.), possibly mounted on spring clips that are installed off 1-inch or 2-inch-thick furring strips, with the resulting air space tilled with sound absorption material. These constructions can provide an improvement in TL of 5 to 10 dB in the middle frequency region and 10 to 15 dB in the high frequency region, when properly executed.

C-6 TRANSMISSION LOSS - WALLS, DOORS, WINDOWS.

Generally, a partition will have better noise reduction with increasing frequency. It is therefore important to check the noise reduction at certain frequencies when dealing with low frequency, rumble type noise. Note that partitions can consist of a combination of walls, glass and doors. Walls can generally be classified as fixed walls of drywall or masonry, or as operable walls. These walls consist of drywall, studs and, sometimes, fibrous blankets within the stud cavity.

C-6.1 Framed Walls.

C-6.1.1 Drywall.

Drywall is a lightweight, low-cost material, and can provide a very high STC when used correctly. The use of Type X, or fire-rated drywall of the same nonrated drywall thickness, will have a negligible effect on acoustical ratings. Drywall is generally poor at low frequency noise reduction and is also very susceptible to poor installation. Drywall partitions must be thoroughly caulked with a nonhardening acoustical caulk at the edges. Tape and spackle is an acceptable seal at the ceiling and side walls. Electrical boxes, phone boxes, and other penetrations must not be back-to-back, but be staggered at least 2 feet (0.61 meters), covered with a fibrous blanket, and caulked. Multiple layers of drywall must be staggered. Wood stud construction has poor noise reduction characteristics because the wood stud conducts vibration from one side to the other. This can be easily remedied by using a metal resilient channel which is inserted between the wood stud and drywall on one side. Non-load bearing metal studs are sufficiently resilient and do not improve with a resilient channel. Load-bearing metal studs are stiff and can be improved with resilient channels installed on one side.

C-6.1.2 Fibrous Blankets.

Fibrous blankets in the stud cavity can substantially improve a wall's performance by as much as 10 dB in the mid and high frequency range where non-load bearing metal studs, or studs with resilient channels, are used. Use a minimum 2-inch-thick (5.1 cm), 3/4 lb/ft^3 (12.2 kg/m^3) fibrous blanket. Blankets up to 6 inches (15.24 cm) thick provide a modest additional improvement.

C-6.1.3 Double or Staggered Stud Walls.

When a high degree of noise reduction is needed, such as between a conference room and mechanical room, use double or staggered stud wall construction with two rows of metal or wood studs without bracing them together, two layers of drywall on both sides, and a 6 inch (15.24 cm) thick fibrous blanket.

C-6.2 Masonry Walls.

Masonry construction is heavy, durable, and can provide particularly good low frequency noise reduction. Concrete masonry units (CMU) made of shale or cinder have good noise reduction properties when they are approximately 50 percent hollow and not less than medium weight aggregate. Parging or furring with drywall on at least one side substantially improves the noise reduction at higher frequencies. The thicker the block, the better the noise reduction. An 8-inch-thick (20.32 cm), semi-hollow medium aggregate block wall with furring and drywall on one side is excellent around machine rooms, trash chutes, and elevator shafts.

C-6.3 Doors.

The sound transmission loss of both hollow and solid core doors will substantially increase when properly gasketed. Regular thermal type tape-on gaskets may not seal well because of door warpage and can also cause difficulty in closing the door. Tube type seals fitted into an aluminum extrusion can be installed on the door stop and fitted to the door shape. Screw type adjustable tube seals are available for critical installations. Sills with a half-moon seal at the bottom of the door are recommended in place of drop seals, which generally do not seal well. Two gasketed doors with a vestibule are recommended for high noise isolation. Special acoustical doors with their own jambs and door seals are available when a vestibule is not practical or very high noise isolation is required.

C-6.4 Windows.

Fixed windows will be close to their laboratory TL rating. Operable sash windows can be 10 dB less than the lab rating due to sound leaks at the window frame. Gaskets are necessary for a proper seal. Some window units will have unit TL ratings which would be a rating of both the gasketing and glass type. Double-glazed units are no better than single-glazed if the air space is 1/2 inch (1.3 cm) or thinner. A 2-inch (5.1 cm) airspace between glass panes will provide better noise reduction. Laminated glass has superior noise reduction capabilities. Installing glass in a neoprene “U” channel and installing sound absorbing material on the jamb between the panes will also improve noise reduction. Special acoustical window units are available for critical installations.

C-6.5 Transmission loss values for building partitions.

Tables C-8 through C-17 provide octave band transmission losses for various constructions, comments or details on each structure are given in the footnotes of the tables. STC ratings are useful for cursory analysis when speech transmission is of concern. Use the octave band transmission losses for a more thorough analysis, particularly when the concern is for mechanical equipment.

Table Construction Material No.

- Dense poured concrete or solid-core concrete block or masonry.
- Hollow-core dense concrete block.
- “Cinder block” or other lightweight porous block with sealed skin.
- Dense plaster.
- Stud-type partitions.
- Plywood, lumber and simple wood doors.
- Glass walls or windows.
- Double-glass windows.
- Filled metal panel partition and acoustic doors.
- Sheet aluminum, steel, lead, and lead-vinyl curtain.

Table C-8 Transmission Loss (in dB) of Dense Poured Concrete or Solid-Core Concrete Block or Masonry[a]

Octave Frequency Band (Hz)	Suggested Design Values						“Ideal Values”		
	Thickness of Concrete or Masonry (in.)						Thickness (in.)		
	4	6	8	10	12	16	4	8	16
	Approximate Surface Weight (lb/ft.^{2})						Surface Wt. (lb/ft.^{2})		
	48	72	96	120	144	192	48	96	192
31	29	32	34	36	36	36	30	36	38
63	35	36	36	36	36	37	36	38	38
125	36	36	37	37	38	41	38	38	44
250	36	38	41	43	44	46	38	44	52
500	41	44	45	47	48	49	43	52	58
1000	45	48	49	50	51	53	51	58	64
2000	50	52	53	54	55	57	57	64	70
4000	54	56	57	58	59	61	63	70	76
8000	58	60	61	62	63	65	69	76	82
STC	45	48	49	51	52	53	49	55	62

Notes:

a. Apply appropriate conversion in table when calculations are metric.
b. "Dense" concrete and masonry assumes 140-150 lb/ft^2 density.
c. For lower values of density, estimate the actual surface weight (in lb/ft^2 of wall area) and use the TL from the column in the table that is closest to that surface weight.
d. If desired, install hollow-core block and fill voids completely (a course at a time) with concrete or mortar of the required density.

Table C-9 Transmission Loss (in dB) of Hollow-Core Dense Concrete Block or Masonry[a]

Octave Frequency Band (Hz)	Suggested Design Values						"Ideal Values"		
	Thickness of Concrete or Masonry (in.)						Thickness (in.)		
	4	6	8	10	12	16	4	8	16
	Approximate Surface Weight (lb/ft.^{2})						Surface Wt. (lb/ft.^{2})		
	28	36	44	52	60	76	28	44	76
31	26	28	29	31	32	33	26	30	34
63	31	33	35	36	36	36	32	36	38
125	35	36	36	36	36	36	37	38	38
250	36	36	36	37	37	38	38	38	39
500	37	38	41	42	43	44	38	42	48
1000	42	44	45	46	47	48	45	50	54
2000	46	48	49	50	51	52	53	56	60
4000	50	52	53	54	55	56	59	62	66
8000	54	56	57	58	59	60	65	68	72
STC	42	43	45	46	47	48	45	48	52

Notes:

a. Apply appropriate conversion in table when calculations are metric.
b. "Dense" concrete and masonry assumes 140-150 lb/ft^3 density, if solid.
c. For lower density concrete, estimate the actual surface weight and use the TL for that value.

Table C-10 Transmission Loss (in DB) of "Cinder Block" or Other Lightweight Porous Block Material with Impervious Skin on Both Sides to Seal Pores[a]

Octave Frequency Band (Hz)	Suggested Design Values				"Ideal Values"	
	Thickness of Cinder Block (in.)				Thickness (in.)	
	4	6	8	10	4	10
	Approximate Surface Weight (lb/ft.^{2})				Surface Wt. (lb/ft.^{2})	
	24	36	48	60	24	60
31	22	26	27	28	24	30
63	27	28	28	28	29	30
125	28	28	28	28	30	30
250	28	29	30	33	30	35
500	30	34	36	37	32	42
1000	36	38	40	41	41	48
2000	40	42	43	44	47	54
4000	43	45	46	47	53	60
8000	46	48	49	50	59	66
STC	36	38	39	41	39	46

Notes:
a. Apply appropriate conversion in table when calculations are metric.
b. Lightweight block material assumes 65-75 lb/ft.^{3} density.
c. If hollow-core block or block of other density is used, select TL value for equivalent surface weight; interpolate or extrapolate if necessary.
d. Both sides of wall surfaces must be sealed with a plaster skim coat or two coats of heavy paint to achieve these values.

Table C-11 Transmission Loss (in dB) of Dense Plaster[a]

Octave Frequency Band (Hz)	Suggested Design Values					"Ideal Values"	
	Thickness of Plaster (in.)					Thickness (in.)	
	1/2	3/4	1	1-1/2	2	1/2	2
	Approximate Surface Weight (lb/ft.^{2})					Surface Wt. (lb/ft.^{2})	
	4-1/2	7	9	13	18	4-1/2	18
31	8	12	14	17	20	10	22
63	14	18	20	24	26	16	28
125	20	24	26	27	28	22	30
250	26	28	28	28	28	28	30
500	28	28	28	28	29	30	30
1000	28	28	29	32	34	30	38
2000	29	32	34	36	38	30	44
4000	35	37	38	40	41	38	50
8000	38	41	42	43	44	44	56
STC	29	30	31	33	34	31	37

Notes:

a. Apply appropriate conversion in table when calculations are in metric.
b. “Dense” plaster assumes approximately 9 lb/ft^2 surface weight per 1 in. thickness.
c. If lightweight nonporous plaster is used, these TL values may be used for equivalent surface weight. These data must not be used for porous or "Acoustic plaster."
d. If plaster is to be used on typical stud wall construction, estimate the surface weight of the-plaster and use the TL values given here for that amount, but increase the TL values where appropriate.

Table C-12 Transmission Loss (in dB) of Stud-Type Partitions

Octave Frequency Band (Hz)	Type 1	Type 2	Type 3	Improvements A	Improvements B
31	4	9	6	2	2
63	10	16	12	2	2
125	17	24	20	3	2
250	26	34	30	3	3
500	34	42	39	4	4
1000	40	48	46	4	4
2000	46	46	52	3	5
4000	44	48	50	3	6
8000	48	52	54	3	5
STC	37	44	41	3	3

Notes:

Type 1: One layer 1/2-in (1.27 cm). thick gypsum wallboard on each side of 2x4-in (5.1x10.2 cm). wood studs on 16-in (40.1 cm). centers. Fill and tape joints and edges, finish as desired. For equal width metal studs, add 2 dB in all bands and to STC.

Type 2: Two layers 5/8-in (1.6 cm). thick gypsum wallboard on each side of 2x4-in. (5.1x10.2 cm) wood studs on 16-in. (40.1 cm) centers. Fill and tape Joints and edges, finish as desired. For equal width metal studs, add 3 dB in all bands and to STC.

Type 3: One layer 5/8-in (1.6 cm). thick gypsum wallboard on outer edges of staggered studs, alternate studs supporting separate walls.2x4 in. (5.1x10.2 cm) wood studs on 16-in. (40.1 cm) centers for each wall. Fill and tape joints and edges, finish as desired. For equal width metal studs, add 1 dB in all bands and to STC.

Improvement A.
1. These values may be added to TL of Type 1 or Type 3 partition if l/2-in (1.27 cm) thick fibrous "sound-deadening board" is installed between studs and each layer of gypsum board.
2. These values may be added to TL of each type of partition if resilient spring clips or resilient metal channels are used to support one layer of gypsum board on one side of the set of studs. (For Type 2, delete the second layer of gypsum board on this side; keep two layers on opposite side.) No significant additional benefit will result from combining resilient supports and sound-deadening board under the same layer of gypsum board.

Improvement B.
1. If full area 3-in (7.62 cm). thick glass fiber or mineral wool is loosely supported inside the air cavity between walls, add these values to TL of Type 1 or Type 2 partition. Acoustic absorption material must not contact both interior surfaces of gypsum board (in other words, must not serve as partial "sound bridge" between walls).
2. If minimum 1-1/2-in. (3.8 cm) thick glass fiber or mineral wool is loosely supported inside the air cavity, add these values to TL of Type 3 partition or add one half these values to TL of Type 1 or 2 partition. Follow precautions of Step B.1 above.

Notes (continued)
Regarding both Improvements A and B.
The combined TL benefits of one type A improvement and one type B improvement can be applied to each of the partition types shown. More than two of these improvements to one partition will result in no significant additional TL benefit.

Table C-13 Transmission Loss (in dB) of Plywood, Lumber, and Simple Wood Doors.

Octave Frequency Band (Bz)	Thickness of Plywood or Lumber (In.)				
	1/4	1/2	1	2	4
	Approximate Surface Weight (lb/ft²)				
	1	2	4	8	16
31	0	2	7	12	17
63	2	7	12	17	18
125	7	12	17	18	19
250	12	17	18	19	22
500	17	18	19	22	30
1000	18	19	22	30	35
2000	19	22	30	35	39
4000	22	30	35	39	43
8000	30	35	39	43	47
STC	18	21	24	28	33

1. Apply metric conversion to material dimension when calculations are metric.
2. Surface weight based on 48 lb/ft^3 density, or 4 lb/ft^2 per in. thickness.
3. Lumber construction requires tongue-and-groove Joints, overlapping joints or sealing of joints against air leakage. For intermediate thicknesses, interpolate between thicknesses given in table.
4. For ungasketed hollow-core flush-mounted wood doors, use TL for 1/2-in. thick plywood.
5. For solid-core wood doors or approximately 2-in. thickness, well gasketed all around, use TL for 2-in. thick plywood.
6. For small-area doors or boxes, framing around Cage of panel adds effective mass and stiffness and will probably give higher TL values than shown.

Table C-14 Transmission LOSS (in dB) of Glass Walls or Windows

Octave Frequency Band (Hz)	Thickness of Glass (in.) 1/8	1/4	1/2	3/4
	Approximate Surface Weight (lb/ft^2) 1-1/2	3	6-1/2	10
31	2	7	13	17
63	8	14	19	22
125	13	20	24	26
250	19	25	27	28
500	23	27	29	29
1000	27	28	29	30
2000	27	28	31	32
4000	27	31	36	38
8000	31	34	40	43
STC	26	28	30	31

Notes:

1. Apply metric conversion to material dimensions when calculations are metric.
2. Variations in surface area and edge-clamping conditions can alter the TL values considerably.
3. There is not much consistency among published data.
4. TL tests usually are not carried out at 31-63 Hz; values given are estimates only.
5. In typical operable windows, poor seals can reduce these values.
6. Special laminated safety glass containing one or more viscoelastic layers sandwiched between glass panels will yield 5-10 dB higher values than given here for single thicknesses of glass; available in approximately 1/4- to 3/4-in. (0.64- to 1.9-cm) thicknesses.

Table C-15 Transmission Loss (in dB) of Typical Double-Glass Windows, Using 1/4-in (0.64 cm).-Thick Glass Panels with Different Air Space Widths

Octave Frequency Band (Hz)	Width of Air Space (in.)		
	1/4	1-1/2	6
31	13	14	15
63	18	19	22
125	23	26	30
250	26	30	35
500	29	34	40
1000	34	38	43
2000	31	37	44
4000	34	41	50
8000	38	46	54
STC	31	37	43

Notes:

1. Apply metric conversion to material dimensions when calculations are metric.

2. For maximum acoustic performance, mount each sheet of glass in soft sealing gaskets to minimize rigid, structural connections between the sheets.

Table C-16 Transmission Loss (in dB) of a Filled Metal Panel Partition and Several Commercially Available Acoustic Doors

Octave Frequency Band (Hz)	Filled Metal Panel Partition[a]	Acoustic Doors, Nominal Thicknesses				
		2-in. Thick[b]	4-in. Thick[c]	6-in. ThicK[d]	10-in. Thick[e]	Two Sets 4-in. Doors in Double Walls 32-in. Air Space[f]
31	19	--	27	34	--	42
63	22	--	29	37	--	48
125	26	31	34	41	47	54
250	31	34	36	47	53	60
500	36	37	40	52	61	67
1000	43	39	45	55	66	75
2000	48	43	49	59	65	84
4000	50	47	51	62	69	90
8000	52	--	--	60	--	95
STC	41	40	45	58	64	71

Notes:

a. Apply metric conversion to material dimensions when calculations are metric.
b. Constructed of two 18 ga. steel panels filled with 3 in. of 6-8 lb/ft^3 glass fiber or mineral wool; Joints and edges sealed airtight.
c. Average of 4 doors, 1-3/4-in. to 2-5/8-in. thick, gasketed.
d. Average of 2 doors, all 4-in. thick, gasketed around all edges, range of weight 12-23 lb/ft.
e. Average of 4 doors, 6-in to 7-in. thick, gasketed, installed by manufacturer, range of weight 23-70 lb/ft^2.
f. Average of 2 doors, each 10-in. thick, gasketed, installed by manufacturer, range of weight 35-38 lb/ft^2.
g. Estimated performance, in isolated 12-in. thick concrete walls, no leakage, no flanking paths.

Table C-17 Approximate Transmission Loss (in dB) of Aluminum, Steel and Lead

	Aluminum			**Steel**				**Lead**			
	Thickness (in.)			Thickness (in.)				Thickness (in.)			
Octave Frequency Band (Hz)	1/16	1/8	1/4	1/16	1/8	1/4	1/2	1/32	1/16	1/8	Lead/Vinyl Curtain
	Surface Weight (lb/ ft²)			Surface Weight (lb/ ft²)				Surface Weight (lb/ ft²)			Surface Weight (lb/ ft²)
	1	2	3 ½	2 ½	5	10	20	2	4	7 ½	1
31	0	3	9	5	11	17	23	2	6	14	--
63	3	9	15	11	17	23	29	8	14	20	--
125	9	15	21	17	23	29	35	14	20	26	13
250	15	21	27	23	29	35	40	20	26	32	17
500	21	27	29	29	35	40	40	26	32	38	20
1000	21	29	29	35	40	40	40	32	38	44	28
2000	29	29	29	40	40	40	41	38	44	50	34
4000	29	29	30	40	40	41	48	44	50	56	38
8000	29	30	40	40	41	48	54	50	56	56	–
STC	25	28	29	33	38	40	41	30	36	42	26

Notes:

a. Apply metric conversion to material dimensions when calculations are metric.
b. Surface weight of aluminum based on 170 lb/ft^3 density or 14 lb/ft^2 per in. thickness.
c. Surface weight of steel based on 480 lb/ft^3 density or 40 lb/ft^3 per-in. thickness.
d. Surface weight of lead based on 700 lb/ft^3 density or 59 lb/ft^3 per In. thickness.
e. Variations in surface area and edge clamping conditions can alter the TL values or aluminum and steel. Lead assumed "limp." Application of vibration damping material to one surface of steel or aluminum will reduce resonances and help increase TL values in resonance regions.
f. TL tests usually are not conducted at 31-63 Hz; values given are estimates only.

C-7 TRANSMISSION LOSS OF FLOOR-CEILING COMBINATIONS.

Many mechanical equipment areas are located immediately above or below occupied floors of buildings. Airborne noise and structure borne vibration radiated as noise may intrude into these occupied floors if adequate controls are not included in the building design. The approximate octave band “TL” and “NR” are given here for five floor-ceiling combinations frequently used to control airborne machinery noise to spaces above and below the mechanical equipment room. To achieve high airborne sound isolation and provide a massive base for the equipment, one must specify heavy concrete floors. All floor slabs are assumed to be of dense concrete (140 to 150 lb/ft.^{3} density). For low density concrete, the thickness must be increased to have the equivalent surface weight for the desired TL. The weight of a housekeeping pad under the equipment must not be counted in the floor weight, although it does aid in the support of heavy equipment. The five suggested floor-ceiling combinations are based on flat concrete slab construction, but comments are given later for the use of other forms and shapes of concrete floors. **Many of the following tables and figures will need conversion of material dimensions when calculations are performed in metric units.**

C-7.1 Type 1 Floor-ceiling.

This is the simplest type and consists only of a flat concrete floor slab. The TL is given in Table C-18 for several thicknesses. Acoustic tiles or panels mounted directly to the underside of the slab add nothing to the TL, but they contribute to the Room Constant in the room in which they are located and therefore aid in reducing reverberant levels of noise. The TL table starts with a 4-inch-thick (10.2 cm) slab, but this thickness is not recommended for large heavy rotary equipment at shaft speeds under about 1200 rpm or for any reciprocating equipment over about 25 hp. It is essential that there be no open holes through the floors to weaken the TL values.

Table C-18 Transmission Loss (in dB) of Type 1 Floor-Ceiling Combinations

Octave Frequency Band (Hz)	Thickness of Dense Concrete Slab (In.) 4	6	8	10	12
	Approximate Surface Weight ($lb/ft.^2$) 48	72	96	120	144
31	29	32	34	36	36
63	35	36	36	36	37
125	36	36	37	37	38
250	36	38	41	43	44
500	41	44	45	47	48
1000	45	48	49	50	51
2000	50	52	53	54	55
4000	54	56	57	58	59
8000	58	60	61	62	63
STC	45	48	49	51	52

C-7.2 Type 2 Floor-ceiling.

This floor-ceiling combination consists of a concrete floor slab below which is suspended a typical low-density acoustic tile ceiling in a mechanical support system. To qualify for the Type 2 combination, the acoustic tile must not be less than 3/4 in. (1.9 cm) thick, and it must have a noise reduction coefficient (NRC) of at least 0.65 when mounted. The air space between the suspended ceiling and the concrete slab above must be at least 12 inches (30.5 cm), but the TL improves when the space is larger. The estimate TL of a Type 2 floor-ceiling is given in Table C-19 for a few typical dimensions of concrete floor slab thickness and air space. Interpolate or extrapolate for dimensions not given in the table. Increased mass is most beneficial at low frequency and increased air space is helpful across all frequency bands.

Table C-19 Transmission Loss (in dB) of Type 2 Floor-Ceiling Combinations

Octave Frequency Band (Hz)	Thickness of Dense Concrete Slab (in.) 4	6	8	10	12
	Air Space Between Slab and Suspended Acoustic Ceiling (in.) 12	15	18	24	24
31	29	33	35	37	38
63	35	37	38	39	40
125	37	38	40	41	42
250	38	41	44	46	48
500	43	47	49	51	53
1000	48	53	54	56	57
2000	53	57	59	61	62
4000	57	61	63	64	65
8000	61	64	67	68	69
STC	48	51	52	55	57

C-7.3 Type 3 Floor-ceiling.

This floor-ceiling combination is very similar to the Type 2 combination except that the acoustic tile material is of the “high TL” variety. This means that the material is of high density and usually has a foil backing to decrease the porosity of the back surface of the material. Most acoustical ceiling materials manufacturers produce “high TL” products within their lines. An alternate version of the Type 3 combination includes a suspended ceiling system of light-weight metal panel sandwich construction, consisting of a perforated panel on the lower surface and a solid panel on the upper surface, with acoustic absorption material between. The minimum NRC for the Type 3 acoustical material must be 0.65. The estimated TL of a Type 3 floor-ceiling is given in Table C-20 for a few typical dimensions of concrete floor slab thickness and air space.

Table C-20 Transmission Loss (in dB) of Type 3 Floor-Ceiling Combinations

Octave Frequency Band (Hz)	Thickness of Dense Concrete Slab (in.)				
	4	6	8	10	12
	Air Space Between Slab and Suspended "High TL" Acoustic Ceiling (in.)				
	12	15	18	24	24
31	31	35	38	40	42
63	37	39	41	42	44
125	39	41	43	44	46
250	41	44	48	50	52
500	46	50	53	55	58
1000	52	57	59	61	63
2000	57	62	64	66	68
4000	62	67	69	70	71
8000	66	71	74	75	76
STC	51	55	58	60	62

C-7.4 Type 4 Floor-ceiling.

This floor-ceiling combination consists of a concrete floor slab, an air space, and a resiliently supported plaster or gyp. bd. ceiling. This combination is for use in critical situations where a high TL is required. The ceiling must have a minimum 12 lb/ft.^{2} (703.1 kg/m^2) surface weight and the plenum space must be at least 18 inches (4.6 cm) high. The estimated TL of the Type 4 floor-ceiling combination is given in Table C-21 for a few typical dimensions of floor slab, air space, and ceiling thicknesses.

Table C-21 Transmission Loss (in dB) of Type 4 Floor-Ceiling Combinations

Octave Frequency Band (Hz)	Thickness of Dense Concrete Slab (in.)				
	4	6	8	10	12
	Air Space Between Slab and Resiliently Suspended Plaster Ceiling (in.)				
	15	18	24	30	30
	Thickness of Dense Plaster Ceiling (in.)				
	1	1	1	14	2
31	33	38	41	44	16
63	39	42	44	46	48
125	41	43	46	48	51
250	44	48	51	54	58
500	50	54	57	60	64
1000	56	61	64	66	69
2000	61	66	70	72	74
4000	67	72	75	76	77
8000	70	75	78	81	83
STC	55	59	61	64	68

C-7.4.1 Resiliently Supported Ceiling.

The ceiling must be supported on resilient ceiling hangers that provide at least 1/10 inch (0.25 cm) static deflection under load. Neoprene-in-shear or compressed glass fiber hangers can be used, or steel springs can be used if they include a pad or disc of neoprene or glass fiber in the mount. A thick felt pad hanger arrangement can be used if it meets the static deflection requirement. The hanger system must not have metal-to-metal short-circuit paths around the isolation material of the hanger. Where the ceiling meets the vertical wall surface, the perimeter edge of the ceiling must not make rigid contact with the wall member. Provide a 1/4-inch (0.64 cm) open joint at this edge, which is tilled with a nonhardening caulking or mastic or fibrous packing after the ceiling plaster is set.

C-7.4.2 Critical Locations.

Critical locations require special care, Caution: This combination must be used only in critical situations, and special care must be exercised to achieve the desired TL values: full vague floor weight and thickness, no holes through the floor, and completely resiliently supported nonporous dense ceiling. When the plaster of gyp. bd. ceiling is not supported resiliently, the TL value will fall about midway between the Type 3 and Type 4 values for the corresponding dimensions and floor slab weights.

C-7.5 Type 5 floor-ceiling.

The "floating concrete floor," as shown on Figure C-6, is a variation that can be added to any one of the Type 1 through 4 combinations. This becomes necessary when all other floor systems clearly fail to meet the required TL values. The values given in Table C-22 are improvements in TL that can be added to the values of Tables C-18 through C-21 if a well-designed and well-constructed floating floor is used. Careful designs have included prevention of flanking paths of sound or vibration, the Table C-22 values have been achieved and even exceeded. However, if flanking paths are not prevented by intentional design considerations, only one-half of these improvements may be reached.

Figure C-6 Typical Floating Floor Construction

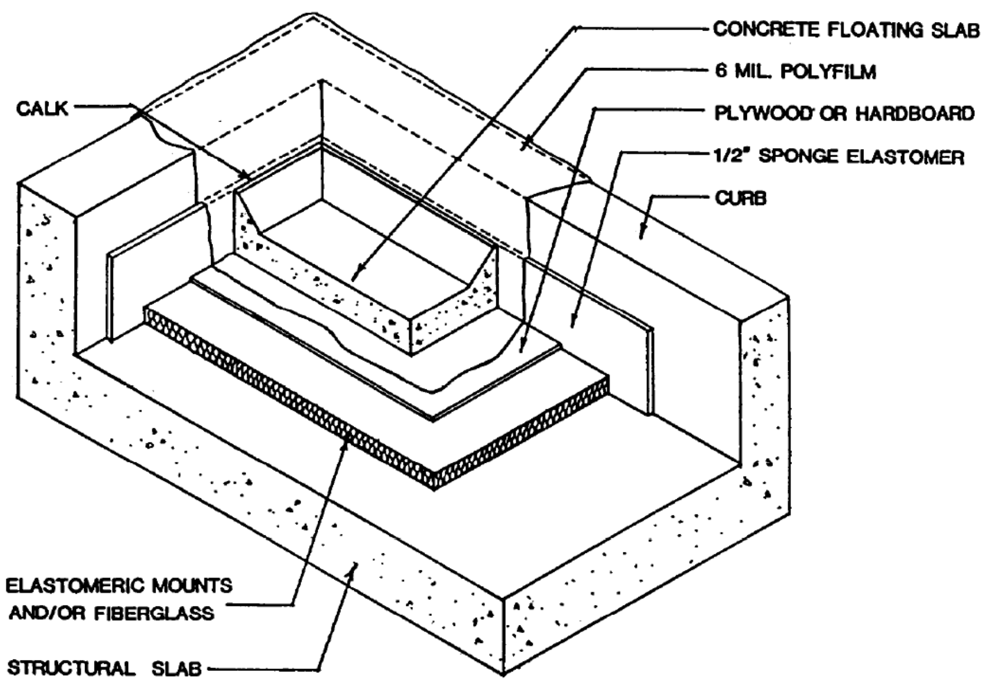


Table C-22 Approximate Improvement in Transmission Loss (in dB) When Type 5 Floating Floor is Added to Types 1 through 4 Floor-Ceiling Combinations

Octave Frequency Band (Hz)	Thickness of Floating Floor Slab (tn.)		
	3	4	5
	Air Space Between Structural Slab and Floating Slab (in.)		
	2	2	2
	Add Following Values (in dB) to Type 1-Type 4 TL Values		
31	5	7	9
63	7	9	11
125	8	10	12
250	9	11	13
500	10	12	14
1000	11	13	15
2000	12	14	16
4000	12	11	16
8000	12	14	16
STC	10	12	14

Note:

1. To achieve these values in practice, flanking paths of noise and vibration must be eliminated. Use only one half of the values if flanking paths are not clearly reduced by intentional design measures.

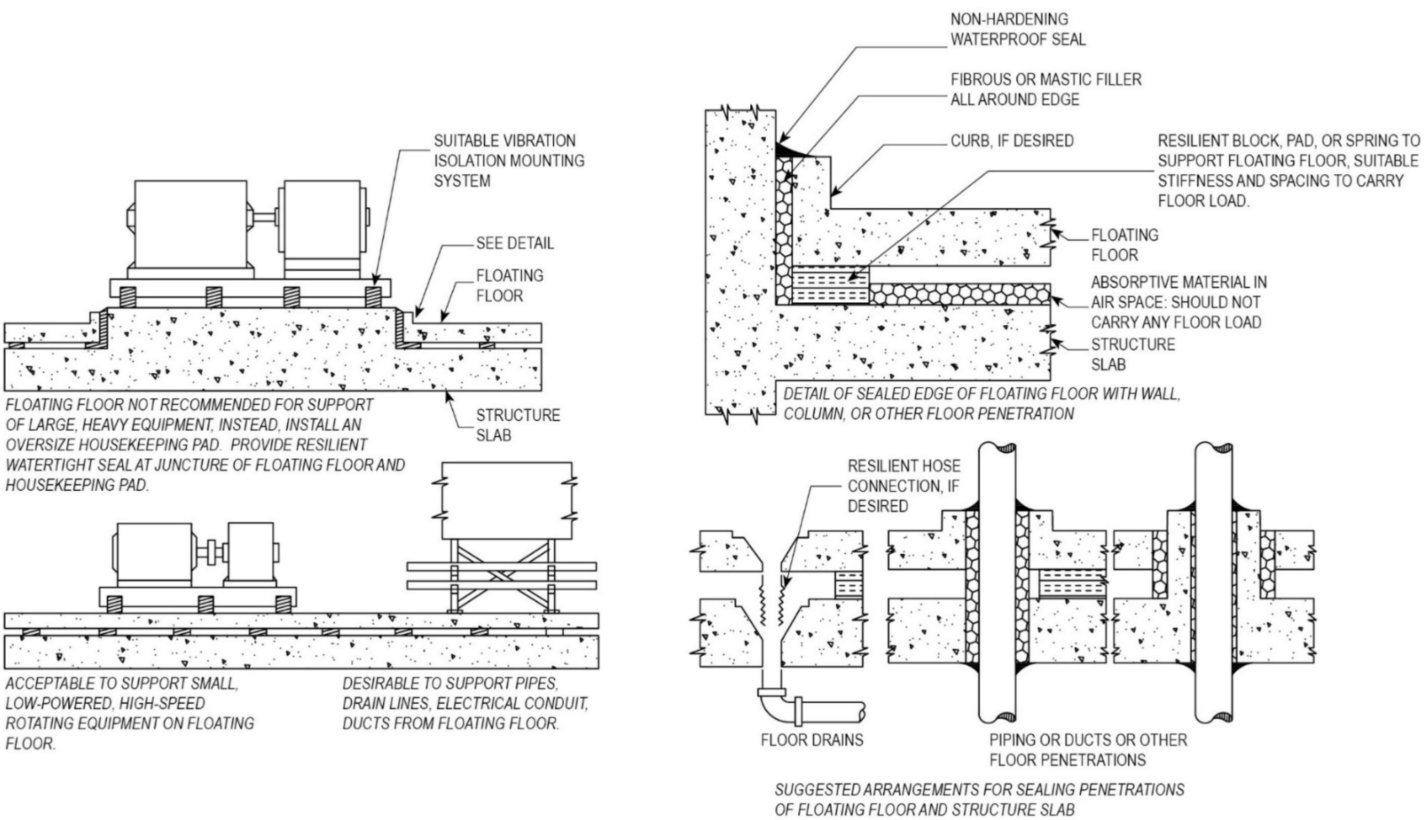
C-7.5.1 Support of Floating Floor.

The floating concrete floor must be supported off the structure floor at a height of at least 2 inches (5.1 cm) with properly spaced blocks of compressed glass fiber or multiple layers of ribbed or waffle-pattern neoprene pads or steel springs in series with two layers of ribbed or waffle-pattern neoprene pads. The density and loading of the compressed glass fiber or neoprene pads must follow the manufacturers' recommendations. When steel springs are used, their static deflection must not be less than 1/4 inch (0.64 cm). In some systems the 2-inch (5.1 cm) space between the floating slab and the structure slab is partially filled with a 1-inch (2.54 cm) thickness of low-cost glass fiber or mineral wool blanket of 3- to 4-lb/ft^3 density. Around all the perimeter edges of the floating floor (at the walls and around all concrete inertia bases within the floating floor area), there must be l-inch gaps and packed with mastic or fibrous filling and then sealed with a waterproof nonhardening caulking or sealing material. A curb must be provided around the perimeter of the floated slab to prevent water leakage into the sealed perimeter joints, and several floor drains must be set in the structure slab under the floating slab to provide run-off of any water leakage into this cavity space.

C-7.5.2 Area of Floating Slab.

The floating slab must extend over the full area that needs the added protection between the noisy and the quiet spaces. The floating floor must not support any large, heavy operating equipment. Instead, such equipment must be based on extra-height house-keeping pads that protrude above the floating floor. The floating floor is beneficial, however, in reducing transmitted noise from lightweight equipment and pipe and duct supports. Figure C-7 offers suggestions on applications and details of floating floors.

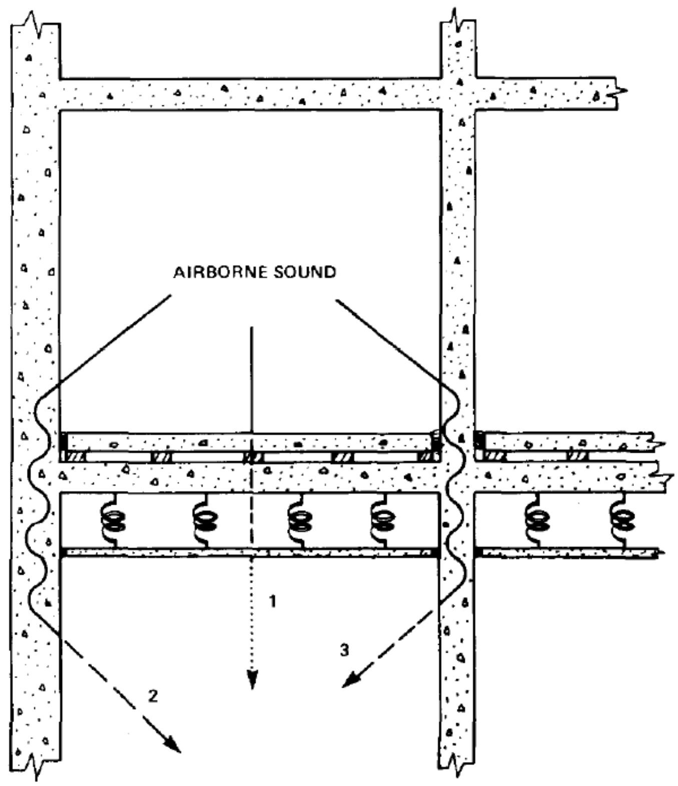
Figure C-7 Suggested Applications and Details of Floating Floors for Improvement of Airborne Sound Transmission Loss



C-7.5.3 Prevention of Flanking Paths.

Figure C-8 illustrates possible flanking paths (paths 2 and 3) of noise and vibration caused by airborne excitation of walls and columns in the mechanical equipment room. These paths make it impossible to achieve the low noise levels that the floating floor and resilient ceiling would permit (via path 1). Airborne excitation of structural surfaces in the mechanical equipment room must be prevented by protecting all walls and columns with isolated second walls or encasements. As an alternative, the radiating walls and columns in the quiet receiving room can be covered with isolated second walls or encasements.

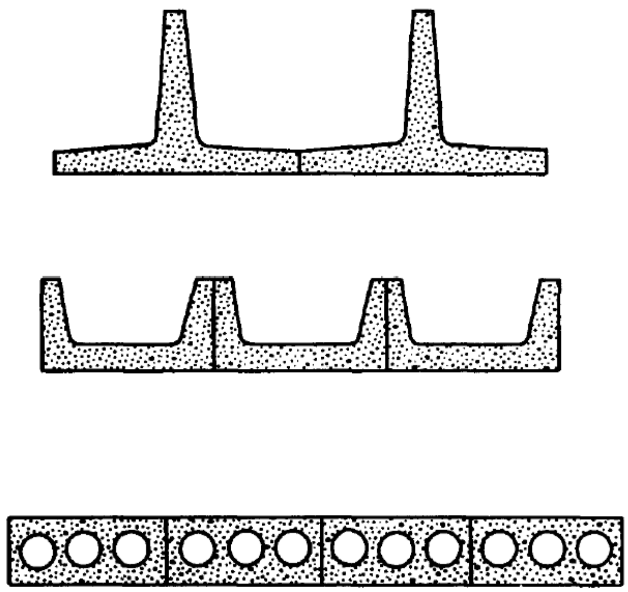
Figure C-8 Structure-borne Flanking Paths of Noise (Paths 2 and 3) Limit the Low Sound Levels Otherwise Achievable with High-TL Floating Floor Construction (Path 1)



C-7.6 Non-flat Floor Slabs.

The above five types of floors are assumed to be of flat slab construction. Other popular forms are of a beam-slab type that provides stiffening beams combined with thin sections of concrete, such as prestressed cored slabs, T-shaped beams, and coffered pan construction (Figure C-9). Since the thin section usually accounts for about 60 to 80 percent of the total floor area, the TL is largely influenced by the thickness and area of the thinnest section. The thick web of the beam component gives mass and stiffness, and this may improve the low-frequency TL. There is no collection of measured data on these types of floors, so only a rough estimating procedure is suggested. First, it is necessary to estimate the surface weight in (lb/ft^2 or kg/m^2) of the thinnest section of concrete and to estimate the average surface weight of the total floor. Second, the arithmetic average of these two surface weights is obtained, and this average is used to enter Tables C-18 through C-21 for the TL of the equivalent weight of a flat concrete slab. If the resulting average corresponds to a surface weight of less than 6-inch (15.24 cm)- thick solid concrete, the floor is not recommended for the support of large mechanical equipment directly above spaces requiring NC 20 to NC 35 (Table 3-1). All floor slab recommendations are based on acoustical considerations and must not be construed as referring to the structural adequacy of the slabs.

Figure C-9 Non-flat Concrete Floors



C-7.7 Noise Reduction (NR) of Floor-ceilings.

The procedure for determining the noise reduction of floor-ceiling construction is identical to that given in Section C-5.2 for walls. The area SW now becomes the floor area common to the source and receiving rooms, and the correction term C is now called the “floor correction term,” but it is still obtained from Table C-1.

C-8 OUTDOOR NOISE.

Mechanical equipment such as cooling towers, rooftop units and exhaust fans are commonly located outdoors. In addition, there is an increasing trend to placing additional mechanical equipment outdoors. Unacceptable noise from electrical or mechanical equipment, whether located indoors or outdoors, may be strong enough to be transmitted to neighbor locations. The sound transmission paths are influenced by three broad types of natural effects: distance effects, atmospheric effects, and terrain and vegetation effects. In addition, structures such as barriers and buildings influence the transmission of sound to the neighbor positions. The quantitative values of these natural effects and structural interferences in outdoor sound propagation are given in this section.

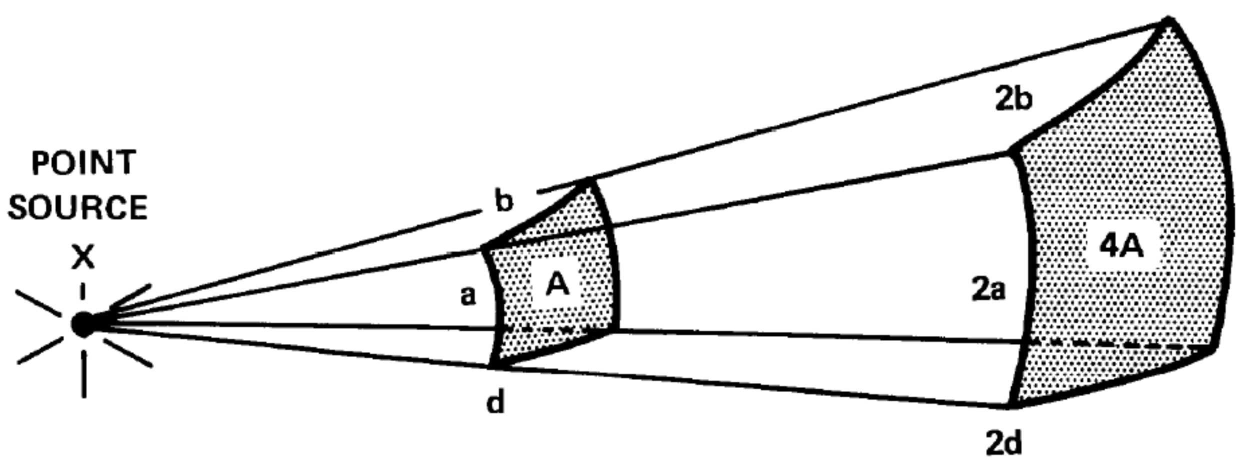
C-8.1 Distance Effects.

Acoustical energy from a source spread out as it travels away from the source, and the sound pressure level drops off with distance according to the “inverse square law.” This effect is common to all types of energy propagation originating from an essentially point source and free of any special focusing. In addition, the air absorbs a certain amount of sound energy by “molecular absorption,” and small amounts of ever-present air movement and inhomogeneities give rise to “anomalous excess attenuation.” These three distance effects are summarized in the following paragraphs.

C-8.1.1 Effect of Distance.

Figure C-10 illustrates the “inverse square law” for drop-off of SPL with distance. A point source of sound is shown at point “X”, and the rays show the path of an element of sound energy traveling away from the source. At the distance “d” from the source, the sound energy is assumed uniformly spread over the small area “A” (which is the product of the two lengths “a” and “b”). At twice the distance, 2d, the lengths a and b are expanded to 2a and 2b, and the resulting area over which the sound is now spread has become 4A, 4 times the area back at distance d. Sound pressure level is related to the “energy per unit area” in the sound wave; so, in traveling twice the original distance from the source, the energy per unit area has decreased by a factor of 4 which corresponds to a reduction of 6 dB in the sound pressure level. Simply illustrated, this is the “inverse square law”; that is, the SPL decreases at the rate of 6 dB for each doubling of distance from the source. An equation and a table incorporating this effect are given in paragraph C-8.1.4.

Figure C-10 Inverse Square Law of Sound Propagation



C-8.1.2 Molecular Absorption.

In addition to the reduction due to the inverse square law, air absorbs sound energy, and that the amount of absorption is dependent on the temperature and humidity of the air and the frequency of the sound. Table C-23 gives the molecular absorption coefficients in dB per 1000-foot (305 meter) distance of sound travel for a useful range of temperature and relative humidity of the octave frequency bands. A “standard day” is frequently defined as having a temperature of 59 deg. F (15 deg. C) and a relative humidity of 70 percent. For long-time average sound propagation conditions, use the molecular absorption coefficients for standard day conditions. For any specific application of measured or estimated SPL for known temperature and humidity conditions, use the Table C-23 values.

Table C-23 Molecular Absorption Coefficients, dB per 1000 ft (305 m), as a Function of Temperature and Relative Humidity

Temperature °F	Temperature °C	Relative Humidity $	Octave Band Center Frequency, Hz[b] 63	125	250	500	1000	2000	4000	8000
14	-10	10	0.3	0.5	0.6	0.9	1.2	1.8	2.8	4.0
		50	0.1	0.2	0.6	1.6	4.4	8.6	13.9	17.0
		90	0.1	0.1	0.3	0.9	2.6	7.2	18.3	26.6
32	0	10	0.2	0.6	1.3	2.4	3.5	4.8	6.9	8.9
		50	0.1	0.1	0.3	0.9	2.6	7.5	20.3	32.9
		90	0.1	0.1	0.3	0.6	1.4	4.1	12.1	21.9
50	10	10	0.1	0.3	1.0	2.7	6.5	11.9	17.5	21.1
		50	0.1	0.2	0.3	0.7	1.6	4.4	13.3	24.0
		90	0.1	0.2	0.3	0.7	1.3	2.8	7.3	13.3
59	15	10	0.1	0.3	0.8	2.3	6.1	14.4	25.9	32.6
		30	0.1	0.2	0.4	0.8	2.0	6.1	17.7	31.6
		50	0.1	0.2	0.4	0.7	1.5	3.6	10.5	19.3
("Std Day")		70	0.1	0.2	0.4	0.7	1.5	3.0	7.6	13.7
		90	0.1	0.2	0.4	0.7	1.5	3.0	6.6	11.2
68	20	10	0.1	0.2	0.6	1.8	5.3	14.2	31.9	44.9
		30	0.1	0.2	0.4	0.8	1.8	4.8	14.4	26.2
		50	0.1	0.2	0.4	0.8	1.6	3.4	8.6	15.6
		70	0.1	0.2	0.4	0.8	1.6	3.3	7.1	11.9
		90	0.1	0.2	0.4	0.8	1.6	3.3	7.0	10.8
77	25	10	0.1	0.2	0.5	1.5	4.4	12.4	33.5	52.6
		30	0.1	0.2	0.4	0.9	1.8	4.1	11.6	21.7
		50	0.1	0.2	0.4	0.9	1.8	3.6	8.0	13.4
		70	0.1	0.2	0.4	0.9	1.8	3.6	7.6	11.7
		90	0.1	0.2	0.4	0.9	1.8	3.6	7.6	11.7
86	30	10	0.1	0.2	0.5	1.2	3.6	10.4	29.3	50.7
		50	0.1	0.2	0.5	1.0	2.0	4.0	8.3	12.9
		90	0.1	0.2	0.5	1.0	2.0	4.0	8.3	12.8
100	38	10	0.1	0.3	0.6	1.1	2.7	7.7	23.0	41.3
		50	0.1	0.3	0.6	1.1	2.3	4.6	9.6	14.6
		90	0.1	0.3	0.6	1.1	2.3	4.6	9.6	14.6

Taken from "Standard Values of Atmospheric Absorption as a function of Temperature and Humidity," SAE ARP 866A, 15 March 1975, Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Penn.15096.
[b] Use 0 dB/1000 ft (305 m) for 31 Hz octave band.
Used with permission from Society of Automotive Engineers, Inc

C-8.1.3 Anomalous Excess Attenuation.

Large-scale effects of wind speed, wind direction, and thermal gradients in the air can cause large differences in sound transmission over large distances. These are discussed briefly under "atmospheric effects" in section C-8.2. Almost all the time, however, there are small-scale influences of these atmospheric factors. Even under stable conditions for sound propagation through the air, small amounts of diffraction, refraction (bending), and sound interference occur over large distances because of small wind, temperature, and humidity differences in the air. These are combined into "anomalous excess attenuation" which is applied to long-term sound level estimates for average-to-good sound propagation conditions. Table C-24 gives the values of anomalous excess attenuation, in dB per 1000-foot (305 meter) distance. These are conservative average values; higher values than these have been measured in long-time studies of sound travel over a variety of field conditions. Anomalous excess attenuation helps explain the fact that measure SPLs at large distances are frequently lower than estimated SPLs even when sound propagation conditions seem quite good.

Table C-24 Values of Anomalous Excess Attenuation per 1000 ft (305 m)

Frequency Band, HZ	Anomalous Excess Attenuation, dB/1000 ft.
31	0.3
63	0.4
125	0.6
250	0.8
500	1.1
1000	1.5
2000	2.2
4000	3.0
8000	4.0

C-8.1.4 Estimating Outdoor Sound Levels.

The sound level, at a distance, can most readily be calculated if the sound power level (Lw) is known. In some cases, the sound power is not known, however the sound pressure level (Lp) at a given distance is known. In this case the sound pressure level at different distance can be derived from the known sound pressure level. Consideration for each of these cases is given below.

C-8.1.4.1 SPL from Known Lw.

Equation C-10 combines the effects of distance, atmospheric attenuation, and anomalous attenuation for the calculation of sound pressure level when the sound power level of the source is known.

Equation C-10. SPL Using Known Outdoor Conditions

$$\mathbf{Lp = Lw - 10\log(2\pi d^2)1 + d(\propto_m + \propto_a)/1000\ -\ 10}$$

Where:
Lp = sound pressure level (in dB)
Lw = sound power level (in dB)
d = distance from source (ft)(m)
$\propto_{\mathbf{m}}$ = *molecular absorption coefficient*
$\propto_{\mathbf{a}}$ = *anomalous excess attenuation*

Where Lp is the SPL at distance d (in ft.) from a sound source whose PWL is Lw, is the molecular absorption coefficient (in dB/1000 ft (305 m).) from Table C-23 and is the anomalous excess attenuation (in dB/1000 ft (305 m).) from Table C-24. Equation C-10 is simplified to Equation C-11:

Equation C-11. SPL Using Known Distance Term

$$\mathbf{Lp = Lw - DT}$$

Where:
Lp = sound pressure level (in dB)
Lw = sound power level (in dB)
DT = distance term (in dB)

where DT, in decibels, is called the “distance term” and is defined by equation C-12:

Equation C-12. Distance Term

$$\mathbf{DT = 10(\log 2\pi d^2) + d(\propto_m + \propto_a)/1000 - 10}$$

Where:
DT = distance term (in dB)
d = distance from source (ft)(m)
$\propto_{\mathbf{m}}$ = *molecular absorption coefficient*
$\propto_{\mathbf{a}}$ = *anomalous excess attenuation*

Table C-25 gives tabulated data for the distance term out to a distance of 80 feet (25.4 meters). For such short distances, the molecular absorption and anomalous excess attenuation are usually negligible and are ignored in this simplifying table. The Table C-25 values can be applied to all octave bands for most close-in situations. However, at larger distances the absorption and attenuation effects become significant, and Table C-26 gives the distance terms as a function of the octave bands for distances from 80 feet (25.4 meters) out to 8000 feet (2439 meters).

Table C-25 Distance Term (DT), in dB, to a Distance of 80 ft (25.4 m)

Distance D ft.	Distance Term, DT dB	Distance ft.	Distance Term, DT dB
1.3	0	18	23
1.8	3	20	24
2.5	6	22.5	25
3.2	8	25	26
4	10	28	27
5	12	31.5	28
6.3	14	35.5	29
8	16	40	30
9	17	45	31
10	18	50	32
11	19	56	33
12.5	20	63	34
14	21	71	35
16	22	80	36

Table C-26 Distance Term (DT), in dB, at Distances of 80 ft. to 8000 ft. (25.4 – 2439 m)

Distance D ft.	Octave Band Center Frequency, HZ Distance Term (DT), D8								
	31	63	125	250	500	1000	2000	4000	8000
80	36	36	36	36	36	36	36	37	37
89	37	37	37	37	37	37	37	38	39
100	38	38	38	38	38	38	39	39	40
112	39	39	39	39	39	39	40	40	41
125	40	40	40	40	40	40	41	41	42
140	41	41	41	41	41	41	42	42	43
160	42	42	42	42	42	42	43	44	45
180	43	43	43	43	43	44	44	45	46
200	44	44	44	44	44	45	45	45	48
225	45	45	45	45	45	46	46	47	49
250	46	46	46	46	46	47	47	49	50
280	47	47	47	47	48	48	48	50	52
315	48	48	48	48	49	49	50	51	54
355	49	49	49	49	50	50	51	53	55
400	50	50	50	50	51	51	52	54	57
450	51	51	51	52	52	52	53	56	59
500	52	52	52	53	53	53	55	57	61
560	53	53	53	54	54	55	56	59	63
630	54	54	55	55	55	56	57	61	65
710	55	55	56	56	56	56	57	59	63
800	56	56	57	57	57	58	60	64	70
890	57	57	58	58	59	60	62	66	73
1000	58	58	59	59	60	61	63	69	76
1200	60	60	61	61	62	63	66	72	81
1400	61	62	62	63	64	65	68	76	86
1600	62	63	63	64	65	67	70	79	90
1800	64	64	64	65	66	69	73	82	95
2000	65	65	66	66	68	70	74	85	99
2250	66	66	67	68	69	72	77	89	105
2500	67	67	68	69	71	74	79	93	110
2800	68	68	69	70	72	75	82	97	117
3150	69	70	71	72	74	77	84	101	124
3500	70	71	72	73	75	79	87	106	131
4000	71	72	73	75	77	82	91	112	141
4500	72	73	75	76	79	85	94	119	151
5000	73	75	76	78	81	87	98	125	161
5500	74	76	77	79	83	89	101	131	170
6000	75	77	79	81	84	92	105	137	180
6500	76	77	79	82	86	94	108	143	189
7000	77	78	81	83	88	95	111	149	199
7500	78	79	82	85	89	98	115	155	208
8000	76	80	82	85	90	100	118	161	218

C-8.1.4.2 SPL at Another Distance from Known SPL.

Equation C-13 can be used to calculate the sound pressure level at any distance if the sound pressure level at one distance is given.

Equation C-13. Calculated Sound Pressure Level Using Known SPL and DT

$$\mathbf{L_{p2} = L_{p1} - DT_2 + DT_1}$$

Where:
L_{p2} = calculated sound pressure level (in dB)
L_{p1} = known sound pressure level (in dB)
DT_2 = known distance term for calculated SPL (in dB)
DT_1 = known distance term for known SPL (in dB)

where Lp1 is the known SPL at distance d, and L_{p2} is the wanted SPL distance d_2. The distance terms DT_1 and DT_2 are evaluated in Equation C-12 or obtained from Tables C-25 and C-26. This equation applies when d_1 is greater than the physical dimension of the sound source.

C-8.2 Atmospheric Effects.

Wind and temperature variations can cause bending of sound waves and can influence changes in sound levels at large distances. These are normally short-term effects and do not provide reliable noise control. However, they help explain the variations that occur in outdoor sound propagation and measurements.

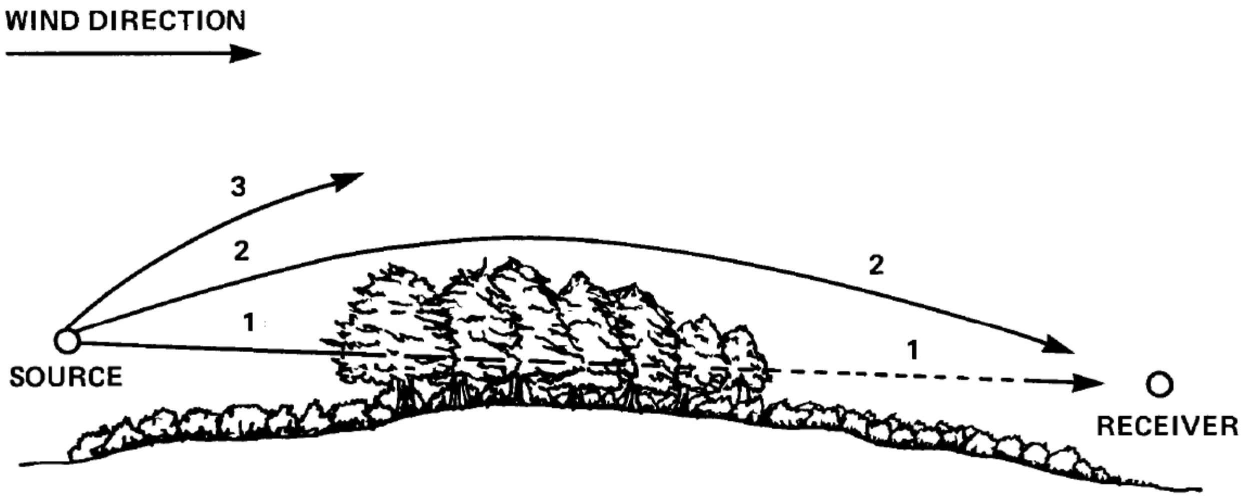
C-8.2.1 Wind Effect.

A steady, smooth flow of wind, equal at all altitudes, would have no noticeable effect on sound transmission. In practice, however, wind speeds are slightly higher above the ground than at the ground, and the resulting wind speed gradients tend to “bend” sound waves over large distances. Sound traveling with the wind is bent down to earth, while sound traveling against the wind is bent upwards above the ground. The downwind and upwind effects are summarized in the next two paragraphs. Irregular, turbulent, or gusty wind provides fluctuations in sound transmission over large distances (possibly because of partial wavelength interference of various paths taken by various sound rays of the total beam). The net effect of these fluctuations may be an average reduction of a few decibels per 100 yards (91.44 meters) for gusty wind with speeds of 15 to 30 mph (24.1 to 48.3 km/hr). However, gusty wind or wind direction cannot be counted on for noise control over the lifetime of an installation.

C-8.2.2 Downwind Effect.

Figure C-11 illustrates the principal influence of downwind on sound propagation. When there is no wind, the principal sound arrives at the receiver by path 1. Along this path, the ground, vegetation, and trees can absorb some of the sound. During downwind conditions, however, the path 2 sound (that normally travels upward into the sky and does not return to earth) is bent down and returns to the earth, sometimes passing above the attenuating ground surfaces and the vegetation, thus yielding higher sound levels to the receiver. This can occur only for relatively large distances between source and receiver (say, 1000 feet (305 m) or more). In summary, downwind can reduce or eliminate some of the attenuating effects of terrain and vegetation or of solid barriers that otherwise intercept sound paths.

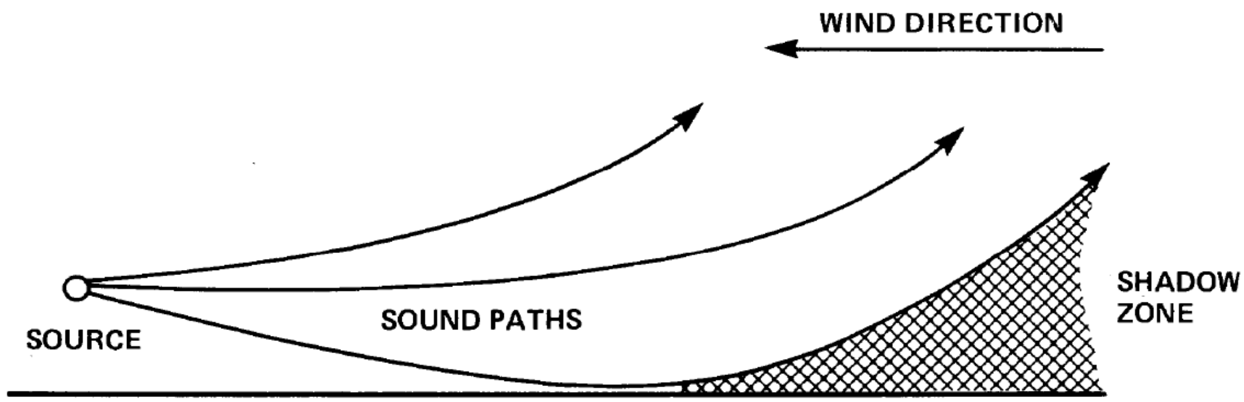
Figure C-11 Downwind Sound Diffraction.



C-8.2.3 Upwind effect.

A strong persistent upwind condition can cast a shadow zone, as shown schematically in Figure C-12. When wind speed profiles are known, the distance to the shadow zone can be estimated, but this is an impractical field evaluation. It is sufficient to realize that the shadow zone can account for up to about 25-dB sound level reduction and that this can occur at distances greater than about 1000 feet (305 meters) for wind speeds above about 10 to 15 mph (24.1 to 48.3 km/hr).

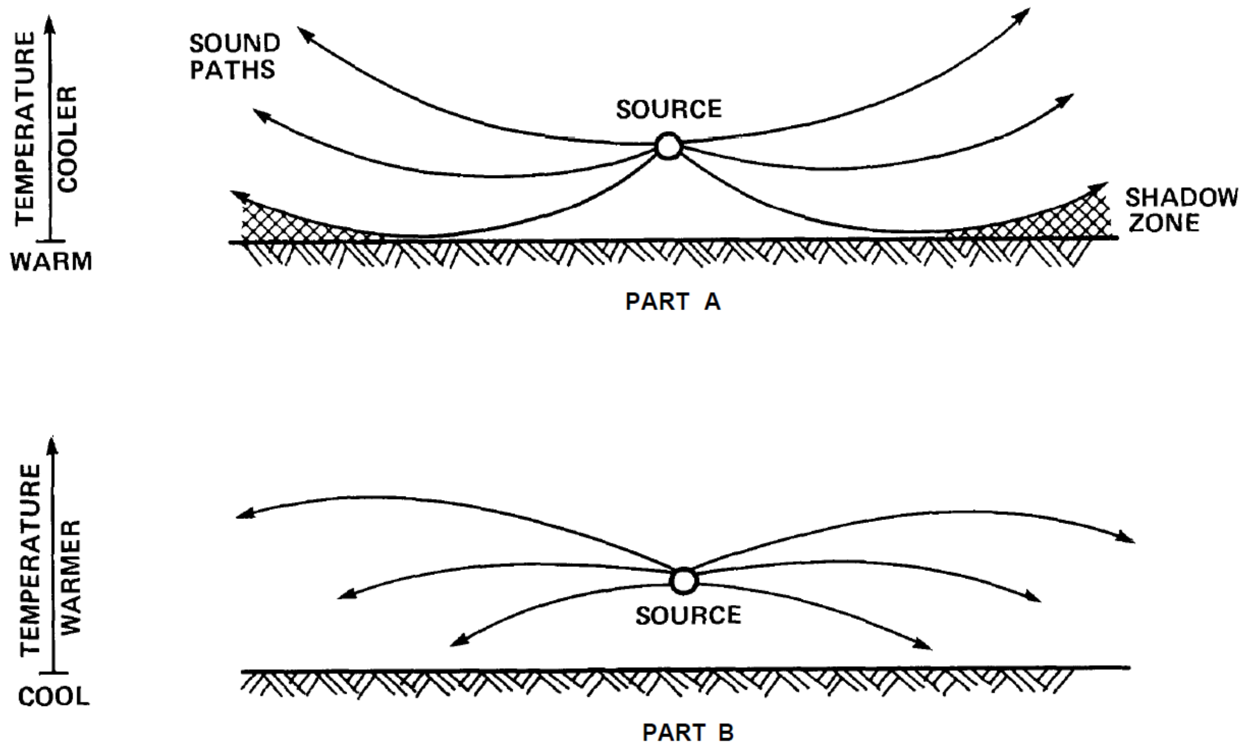
Figure C-12 Upwind Sound Diffraction



C-8.2.4 Temperature effect.

Constant temperature with altitude produces no effect on sound transmission, but temperature gradients can produce bending in much the same way as wind gradients do. Air temperature above the ground is normally cooler than at the ground, and the denser air above tends to bend sound waves upward, as in part A of Figure C-13. With “temperature inversions,” the warm air above the surface bends the sound waves down to earth. These effects are negligible at short distances, but they may amount to several dB at very large distances (say, over a half mile). Again, little or no increase is caused by thermal gradients (compared to homogeneous air), but there may be a decrease in sound levels.

Figure C-13 Effects of Temperature Gradients on Sound Propagation



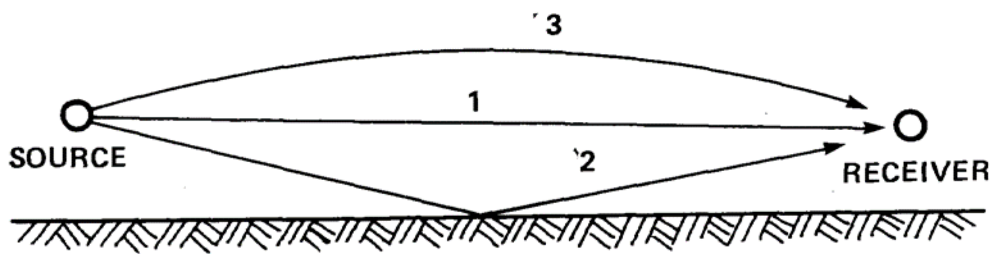
C-8.2.5 Precipitation.

Rain, mist, fog, hail, sleet, and snow are the various forms of precipitation to consider. These have not been studied extensively in their natural state, so there are no representative values of excess attenuation to be assigned to them. Rain, hail, and sleet may change the background noise levels, and a thick blanket of snow provides an absorbent ground cover for sound traveling near the ground. Precipitation or a blanket of snow are intermittent, temporary, and of relatively short total duration, and they must not be counted on for steady-state sound control, even though they offer noticeable attenuation.

C-8.3 Terrain and vegetation.

Sound transmission near the earth's surface involves essentially three components of sound paths, shown schematically by Figure C-14. The ground-reflected sound (path 2) may arrive at the receiver either in phase or out of phase with the direct sound (path 1) and can either increase or decrease the received sound level. The ground surface may be hard or soft (reflective or absorbent), and this also affects the phase and magnitude of the reflected path. Paths 1 and 2 usually determine the sound levels at the receiver, but a solid barrier or dense woods can practically eliminate these paths. In such situations, path 3 may become significant. Path 3 is made up of relatively low-level sound that is refracted (bent) or scattered back to earth by numerous small patches of inhomogeneous air of varying temperature, speed, direction, density, and similar. Field studies show that when paths 1 and 2 are virtually eliminated, there remain sound levels that are about 20 to 25 dB below the path 1 and 2 sound levels. These are the sound levels arriving by way of the numerous paths that together make up path 3, as visualized in Figure C-14.

Figure C-14 Outdoor Sound Propagation Near the Ground



C-8.3.1 Attenuation of Woods and Vegetation.

Table C-27 presents the approximate insertion loss of a 100-foot-deep growth of medium-dense woods made up of a mixture of deciduous and coniferous trees having a height in the range of 20 to 40 feet (6.1 to 12.2 m). For this density, the visibility penetration is about 70 to 100 feet (21 to 30 m).

Table C-27 Insertion Loss for Sound Transmission Through a Growth of Medium-Dense Woods

Octave Frequency Band, HZ	Insertion Loss, dB per 100 ft. of Woods
31	0
63	1/2
125	1
250	1 1/2
500	2
1000	3
2000	4
4000	4 1/2
8000	5

C-8.4 Barriers.

A barrier is a solid structure that intercepts the direct sound path from a source to a receiver. It provides a reduction in sound pressure level within its “shadow zone.” A wall, a building, a large mound of earth, an earth berm, a hill, or some other form of solid structure can serve as a barrier. The approximate insertion loss of an outdoor barrier can be estimated.

C-8.4.1 Barrier Parameters.

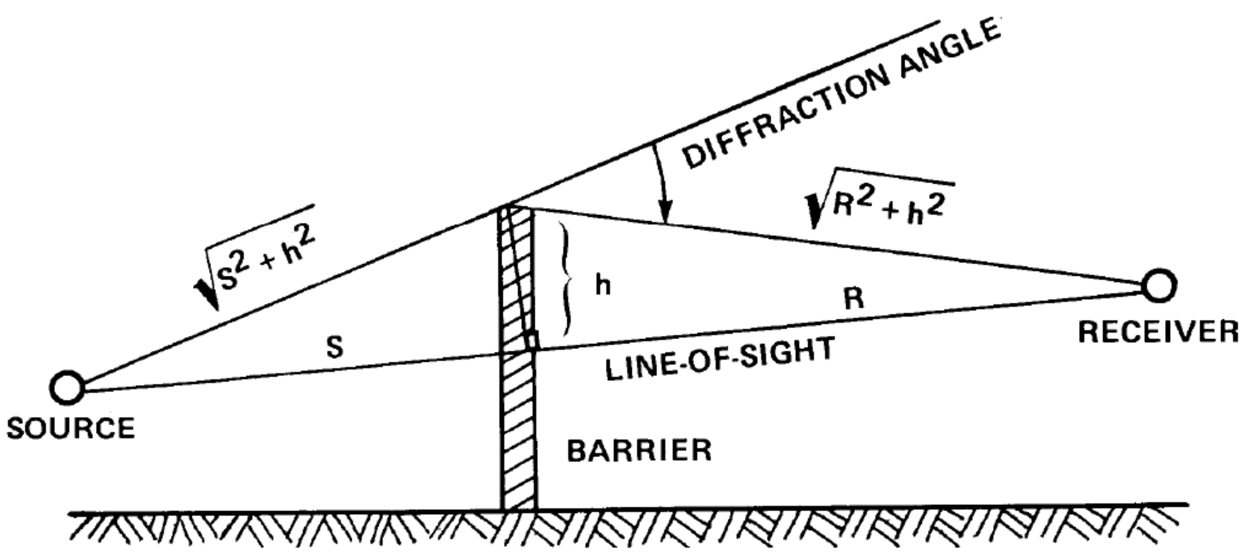
Figure C-15 illustrates the geometrical aspects of an outdoor barrier where no extraneous surfaces reflect sound into the protected area. The insertion loss provided by the barrier to the receiver position is a function of the path length difference between the actual path traveled and the line-of-sight direct path. Large values of barrier height “h” above the line-of-sight path produce large values of the diffraction angle and large values of path length difference, which in turn provide strong shadow zones and large values of insertion loss. The direct line-of-sight path length is S+R, and the actual distance traveled is $\left(\sqrt{\{S^2 + h^2\}} + \sqrt{\{R^2 + h^2\}}\right)$. Then the path length difference is given in Equation C-14.

Equation C-14. Path Length Difference

$$\boldsymbol{\delta = \sqrt{\{S^2 + h^2\}} - S + (\sqrt{\{R^2 + h^2\}} - R}$$

Where:
δ = path length difference
S = distance from source to barrier along line-of-sight to the receiver (ft)(m)
h = barrier height (ft)(m)
R = distance from receiver to barrier along line-of-sight to the source (ft)(m)

Figure C-15 Parameters and Geometry of Outdoor Sound Barrier



C-8.4.1.1 Insertion Loss Values.

Table C-28 gives the insertion loss of an outdoor barrier wall as a function of the path length difference and the octave band frequency. The following restrictions apply.

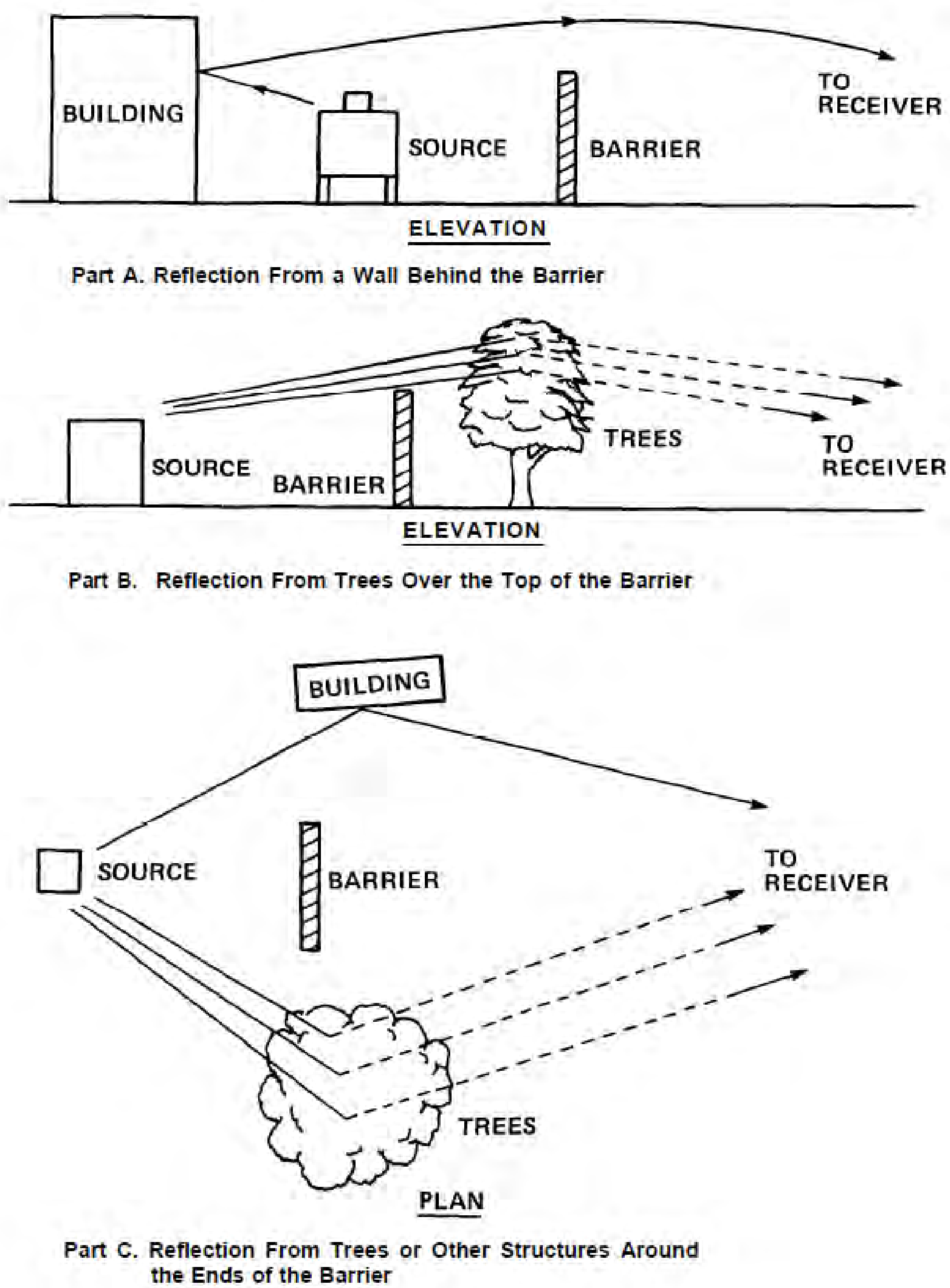
Table C-28 Insertion Loss of an Ideal Solid Outdoor Barrier

Path-Length Difference, ft.	Insertion Loss, dB Octave Band Center Frequency, Hz								
	31	63	125	250	500	1000	2000	4000	8000
.01	5	5	5	5	5	6	7	8	9
.02	5	5	5	5	5	6	8	9	10
.05	5	5	5	5	6	7	9	10	12
.1	5	5	5	6	7	9	11	13	16
.2	5	5	6	8	9	11	13	16	19
.5	6	7	9	10	12	15	18	20	22
1	7	8	10	12	14	17	20	22	23
2	8	10	12	14	17	20	22	23	24
5	10	12	14	17	20	22	23	24	24
10	12	15	17	20	22	23	24	24	24
20	15	18	20	22	23	24	24	24	24
50	18	20	23	24	24	24	24	24	24

C-8.4.1.2 Other Reflecting Surfaces.

There must be no other surfaces that can reflect sound around the ends or over the top of the barrier into the protected region (the shadow zone). Figure C-16 shows examples of reflecting surfaces that can reduce the effectiveness of a barrier wall. These situations must be avoided.

Figure C-16 Examples of Surfaces That Can Reflect Sound Around or Over a Barrier Wall



C-8.4.1.3 TL of Barrier.

The barrier wall or structure must be solid (no penetrating holes) and must be constructed of a material having sound transmission loss (TL) that is at least 10 dB greater than the calculated insertion loss of the barrier in all octave bands.

C-8.4.1.4 Width of Barrier.

Each end of the barrier must extend horizontally beyond the line of sight from the outer edge of the source to the outer edge of the receiver building by a distance that is at least 3 times the value of h used in the calculation.

C-8.4.1.5 Large Distances.

For large distances, sound scattered and bent over the barrier (the path 3 concept in Figure C-14) reduces its effectiveness. It is suggested that the calculated insertion loss be reduced by about 10 percent for each 1000-foot (305 meter) distance between source and receiver.

C-8.4.1.6 Atmospheric Effects.

For wind speeds above about 10 to 15 mph (24.1 to 48.3 km/hr).along the direction of the sound path from source to receiver and for distances over about 1000 feet (305 meters) between source and receiver, the wind bends the sound waves down over the top of the barrier. Under these conditions, the barrier will appear to be very ineffective.

C-8.4.1.7 Terrain-vegetation Effects.

When both a barrier and the terrain-vegetation effects of paragraph C-8.3 occur simultaneously, only the larger values of attenuation calculated for these two effects must be used. The sum of both effects should not be used.

C-8.4.1.8 Another building as a Barrier.

If the barrier is another building, there must be no large openings entirely through the building that would destroy its effectiveness as a barrier. A few small open windows in the near and far walls would probably be acceptable, provided the interior rooms are large. The building may qualify as a compound barrier.

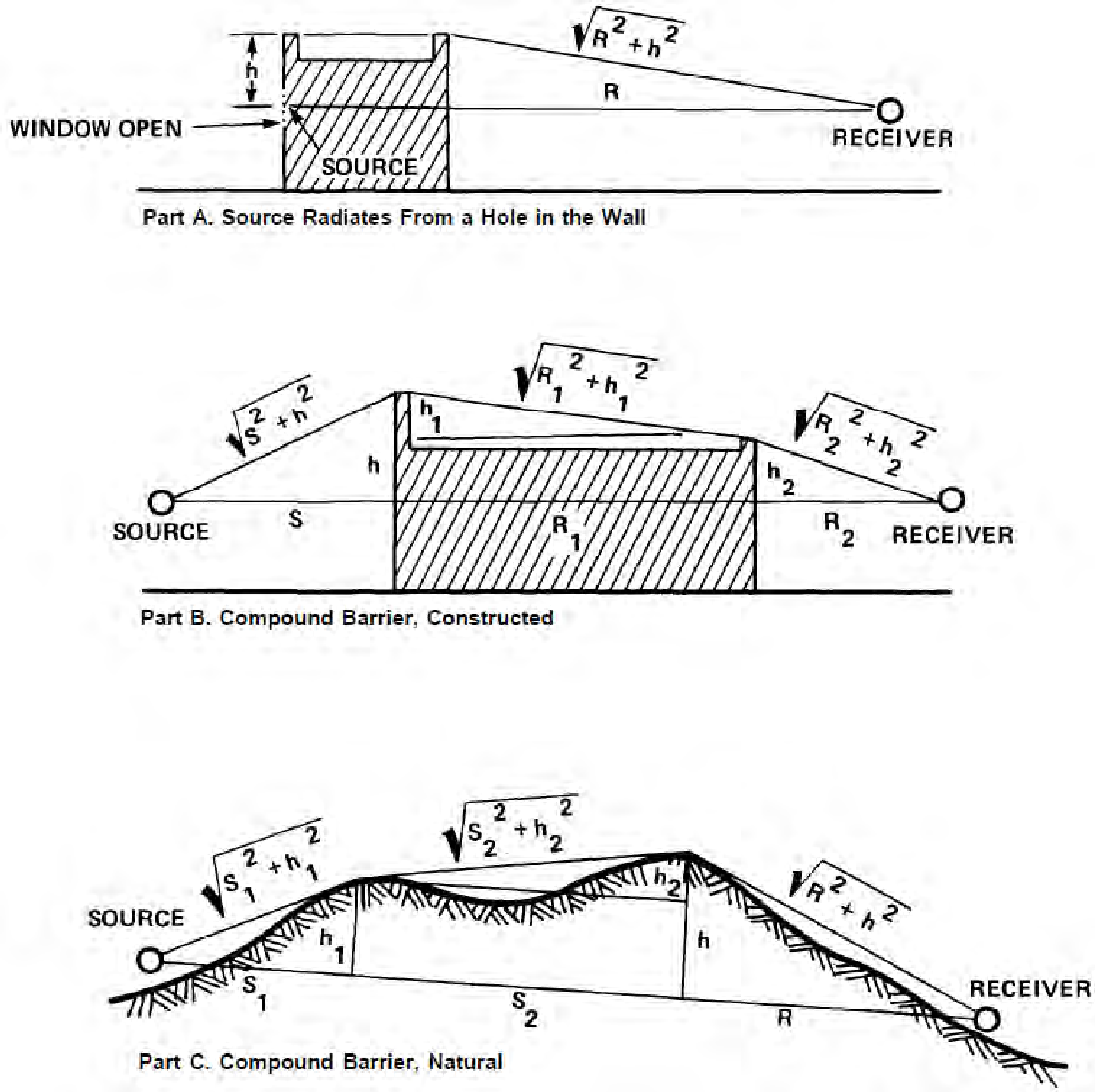
C-8.4.1.9 Caution.

A large flat reflecting surface, such as the barrier wall, may reflect more sound in the opposite direction than there would have been with no wall at all present. If there is no special focusing effect, the wall may produce at most only about 2 or 3 dB higher levels in the direction of the reflected sound.

C-8.4.2 Unusual Barrier Geometries.

Figure C-17 illustrates three common situations that do not fall into the simple geometry of Figure C-15. The procedure suggested here is to estimate the path length difference and use Table C-28 to obtain the insertion loss, even though this simplified approach has not been proven in field or model studies.

Figure C-17 Compound Barriers



C-8.4.3 In-wall Sound Source.

In part A of Figure C-17, the source could be a wall-mounted exhaust fan, an inlet to a ventilating fan, or a louvered opening permitting air into (and noise out of) a mechanical equipment room. The conventional source distance S is zero and the slant distance becomes h. Thus, the total path length difference is $\left(h + \sqrt{\{R^2 + h^2\}} - R\right)$.

C-8.4.4 Compound Barrier.

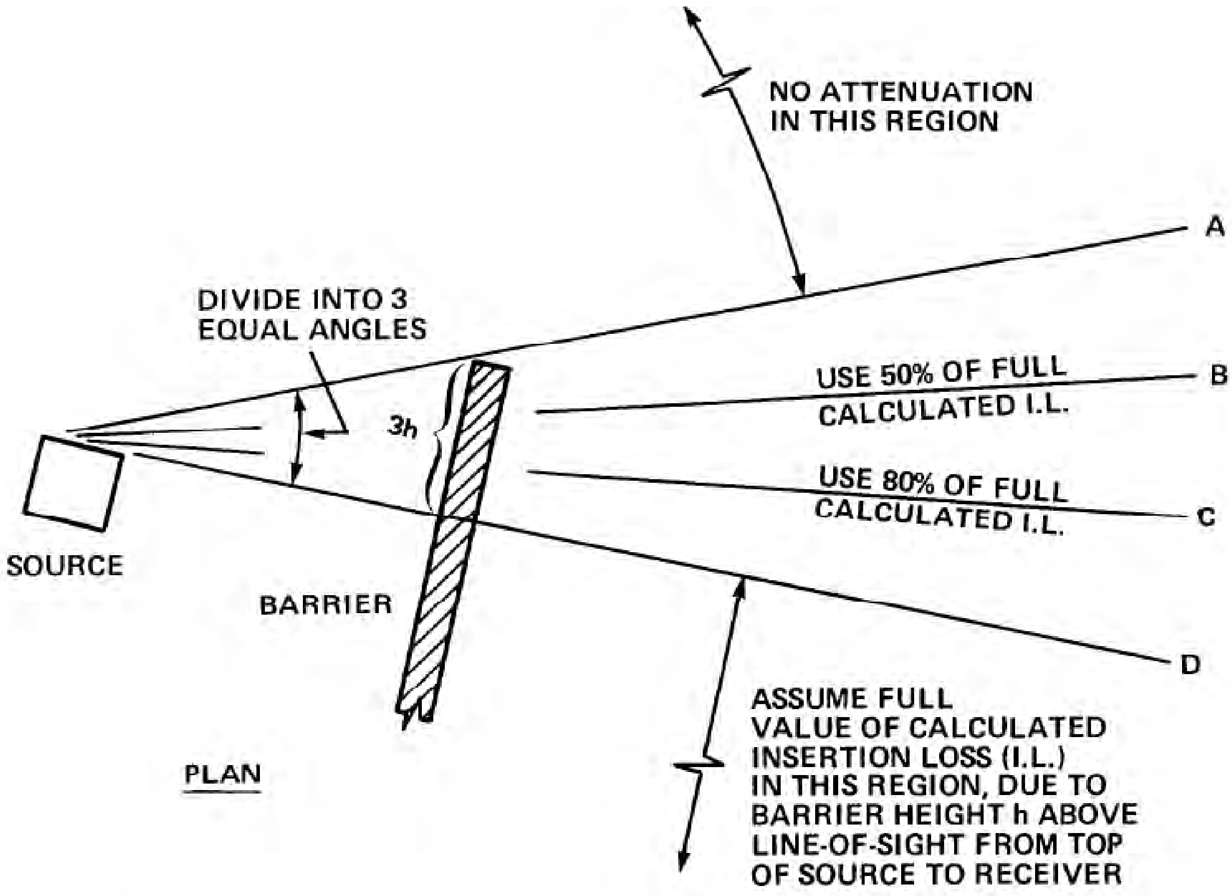
In part B of Figure C-17, the path length difference is calculated from three triangles, as follows: $\delta = \left[\left(\sqrt{\{S^2 + h^2\}} - S\right) + \left(\sqrt{\{{R_1}^2 + {h_1}^2\}} - R1\right) + \left(\sqrt{\{{R_2}^2 + {h_2}^2\}} - R2\right)\right]$

Part C of Figure C-17 is another form of compound barrier and also requires the three-triangle calculation.

C-8.4.5 Edge Effect of Barriers.

Figure C-18 represents a plan view of a source and one end of a barrier wall. Near the end of the wall, the barrier effectiveness is reduced because some sound is refracted over the top of the wall, some sound is refracted around the end of the wall, and some sound is reflected and scattered from various non-flat surfaces along the ground near the end of the barrier. For critical problems, this degradation of the barrier near its end must be considered. Figure C-18 suggests a simplified procedure that gives approximately the insertion loss (IL.) near the end of the barrier.

Figure C-18 Edge Effects at End of Barrier



PROCEDURE

GIVEN: h IS HEIGHT OF BARRIER USED IN CALCULATION OF I.L.

STEPS:
1. MARK OFF HORIZONTAL DISTANCE 3h FROM EACH END OF BARRIER (ONLY ONE END SHOWN IN ABOVE SKETCH)
2. DRAW LINES A AND D
3. DIVIDE ANGLE INTO 3 EQUAL PARTS
4. DRAW LINES B AND C
5. ASSIGN I.L. VALUES AS SHOWN; INTERPOLATE BETWEEN

C-8.5 Reception of Outdoor Noise Indoors.

An intruding noise coming from an outdoor noise source or by an outdoor noise path may be heard by neighbors who are indoors.

C-8.5.1 Noise Reduction (NR) of Exterior Constructions.

When outdoor noise enters a building, it is reduced, even if the building has open windows. The actual amount of noise reduction depends on many factors: building construction, orientation, wall area, window area, open window area, and interior acoustic absorption. For practical purposes, however, the approximate noise reduction values provided by a few typical building constructions are given in Table C-29. For convenience and identification, the listed wall constructions are labeled with letters A through G and are described in the notes under the table. If the exact wall construction of a building is known, a more accurate estimate of the noise reduction can use the procedures of paragraph C-5.

Table C-29 Approximate Noise Reduction of Typical Exterior Wall Constructions

Octave Frequency Band (Hz)	Wall Type						
	A	B	C	D	E	F	G
31	0	8	12	17	10	22	28
63	0	9	13	19	14	24	32
125	0	10	14	20	20	25	34
250	0	11	15	22	26	27	36
500	0	12	16	24	28	30	38
1000	0	13	17	26	29	33	42
2000	0	14	18	28	30	38	48
4000	0	15	19	30	31	43	53
8000	0	16	20	30	33	48	58

Notes:

A. No wall; outside conditions.

B. Any exterior wall construction, with open windows covering about 5% of exterior wall area.

C. Any typical wall construction, with small open-air vents of about 1% of exterior wall area; all windows closed.

D. Any typical wall construction, with closed but operable windows covering about 10-20% of exterior wall area.

E. Sealed glass wall construction, 1/4 in. glass thickness over approximately 50% of exterior wall area.

F. Approximately 20 lb/ft.^{2} solid wall construction with no windows and no cracks or openings.

G. Approximately 50 lb/ft.^{2} solid wall construction with no windows and no cracks or openings.

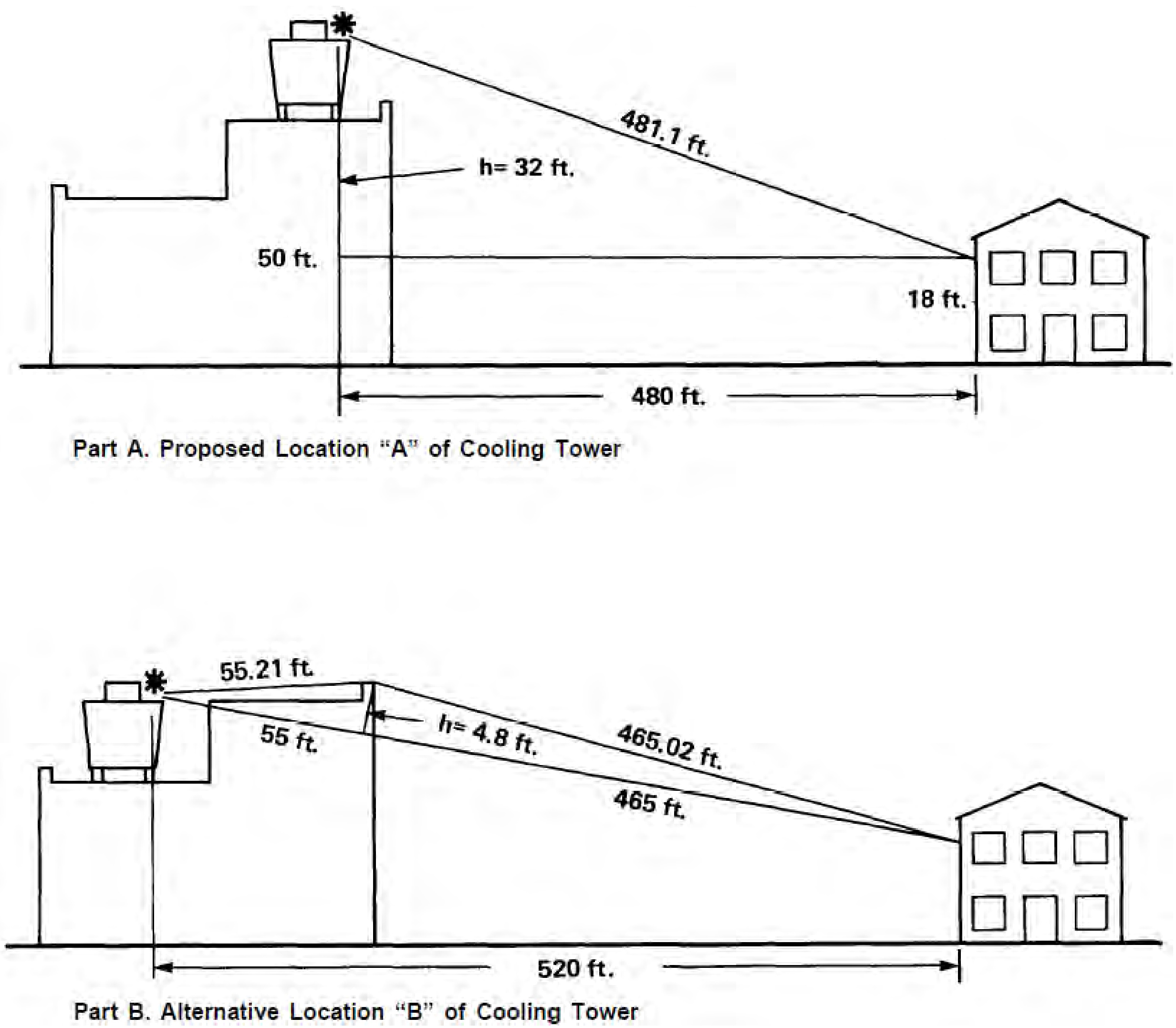
C-8.5.2 Indoor Sound Pressure Levels.

Indoor octave band SPLs are calculated by subtracting the Table C-29 NR values from the outdoor SPLs measured or estimated at the outdoor receiver position.

C-8.6 Combined Effects, Sample Calculation.

A sample calculation shows the steps for combining the material of this chapter. The calculations are completed in all octave bands and illustrate some portion of each item covered. Figure C-19 shows an elevation view of a refrigerated warehouse and a nearby residence. Part A of the figure shows the proposed location of a cooling tower on top of a penthouse mechanical equipment room that has a direct line-of-sight path to the second-floor windows of the dwelling. The sound power level of the cooling tower is known. The residence is of brick construction with open windows covering about 5 percent of the exterior wall area. It is desired to calculate the SPL for the cooling tower noise received inside the upper floor of the residence. Assume the entire PWL radiates from the position near the top of the cooling tower.

Figure C-19 Elevation Profile of Cooling Tower Used in Example.



C-8.6.1 Location "A."

Table C-30 summarizes the data for this part of the analysis. Column 2 of the table gives the sound power level of the cooling tower; Column 3 gives the distance term for the 480-foot distance (from Table C-26) and Column 4 gives the calculated average SPL outside the upper windows of the residence (Col 4 = Col 2 - Col 3). Column 5 gives the noise reduction for the type E wall (from Table C-29), Column 6 gives the indoor SPL, and Column 7 shows the indoor SPL values that correspond to an NC-25 curve, suggested here for sleeping. Comparison of the estimated SPL values with the NC-25 values shows excess noise of 8 to 12 dB in the 250- to 2000-Hz bands (Co1 8).

Table C-30 Location "A" Cooling Tower Problem

Col. 1 Octave Band Center Frequency (Hz)	Col. 2 Sound Power Level of Source (dB)	Col. 3 Distance Term for 480 ft Distance (dB)	Col. 4 Average Outdoor SPL at Residence (dB)	Col. 5 NR Wall Type B (dB)	Col. 6 Indoor SPL (dB)	Col. 7 SPL of NC-25 Curve (dB)	Col. 8 Noise Excess (dB)
31	108	52	56	8	48	--	--
63	109	52	57	9	48	54	--
125	112	52	60	10	50	44	6
250	110	53	57	11	46	37	9
500	108	53	55	12	43	31	12
1000	105	53	52	13	39	27	12
2000	100	54	46	14	32	24	8
4000	95	57	38	15	23	22	1
8000	91	60	31	16	15	21	--

C-8.6.2 Location "B."

Table C-31 summarizes the data for this alternate location of the cooling tower where it receives the benefit of the barrier effect of the penthouse mechanical room. The geometry for this barrier produces a path length difference of 0.23 feet. The insertion loss for the barrier is given in column 4 of Table C-31. Column 5 gives the average outdoor SPL at the residence because of the barrier and the slightly increased distance to the new location (Col 5 = Col 2 - Col 3 - Col 4). Column 7 gives the new indoor SPLs which are compared with the column 8 values of the NC-25 curve. A noise excess of only 3 dB occurs in one octave band. This would be considered a more nearly acceptable solution to the cooling tower noise problem.

Table C-31 Location "B" Cooling Tower Problem

Col. 1 Octave Band Center Frequency (Hz)	Col. 2 Sound Power Level of Source (dB)	Col. 3 Distance Term for 520 ft. Distance (dB)	Col. 4 Barrier Insertion Loss for δ = .23 ft. (dB)	Col. 5 Average Outdoor SPL at Residence (dB)	Col. 6 NR Wall Type B (dB)	Col. 7 Indoor SPL (dB)	Col. 8 SPL of NC-25 Curve (dB)	Col. 9 Noise Excess (dB)
31	108	52	5	51	8	43		—
63	109	52	5	52	9	43	54	—
125	112	52	6	54	10	44	44	0
250	110	53	8	49	11	38	37	1
500	108	53	9	46	12	34	31	3
1000	105	54	11	40	13	27	27	0
2000	100	55	13	32	14	18	24	—
4000	95	58	16	21	15	6	22	—
8000	91	62	19	10	16	--	21	—

C-8.7 Source Directivity.

The analysis procedures of this chapter assume that the sound source radiates sound equally in all directions. In some cases, this is not the case, that is more sound energy will be transmitted in one direction when compared to other directions. This is referred to as the "Directivity" of the sound source, which can be an inherent result of the design or the result of the equipment installation very close to reflecting surfaces. In the example given above the cooling tower directivity was not considered. In Location A, the SPLs at the residence would have been a few dB higher if the louvered surface of the cooling tower faced the residence or a few dB lower of the end surface of the cooling tower faced the residence. In Location B, the orientation of the cooling tower would have been less critical, because the barrier and other reflecting surfaces on the roof would tend to average out the cooling tower directivity characteristics. Typically, source directivity is difficult to obtain. Source directivity for certain sources is included under Appendix B. If source directivity information is unavailable assume that the sound source radiates uniformly in all directions.

C-9 AIRBORNE SOUND.

C-9.1 Quality of Analysis Procedure.

C-9.1.1 Variations and Uncertainties in the Individual Data.

It is necessary to realize that small errors or discrepancies or uncertainties exist with each bit of quoted data, and it is not realistic to rely on the analysis method to the nearest one or two decibels. It is largely for that reason that labels such as "preferred", "acceptable" and "marginal" are used. These labels offer some gradations in degree of reliability of the final values. It is even possible that, if the noise levels of certain specific pieces of mechanical equipment are much lower than the design estimates used in the manual, a design calculated to be "unacceptable" could actually turn out to be "acceptable." This result must not be counted on, however, as a means of avoiding a difficult problem. Of course, there is also the possibility that in a particular installation many of the statistical factors will work together to produce a "marginal" condition where the analysis showed "preferred" or "acceptable" condition.

C-9.1.2 System Reliability.

In most cases, the procedure will produce a workable design. The methods and techniques described here are based on many experiences with noise control problems, and these methods have helped produce many satisfactory or improved installations. (Sometimes the economics of a situation may not justify an entirely satisfactory solution for all concerned, but proper use of the analysis can bring a desired and predictable improvement.) The manual will have served a sufficiently useful purpose if it reveals only that a problem is so serious that the manual alone cannot solve the problem and that special assistance or special designs may be required.

C-9.1.3 Aids in Decision-making.

A certain amount of judgment may enter some design decisions. A suggestion is offered here for helping guide the decision for three types of situations.

1. When a particular design involves a crucial area, a conservative approach must be followed. The design must not be weakened to try "to get by" with something simpler.
2. When a particular design involves a distinct threat to someone's safety or well-being, a conservative approach must be used. Examples could be an employee who might suffer hearing loss in an MER because a separate control room was not provided, or a tenant who would not pay rent because of noise coming from an overhead MER, or a neighbor who might go to court because of disturbing noise. On the other hand, noise in a corridor or a lobby is of much less concern to someone's well-being.
3. If a particular design involves a permanent structural member that is not easily modified or corrected later (in the event it may prove unsatisfactory), a conservative approach must be used. A poured concrete floor slab is not easily replaced by a new and heavier floor slab. On the other hand, a lightweight movable partition can be changed later if necessary. An attenuator can be added later or enlarged later if necessary. Compromises may be justified if the compromised member can be corrected later at relatively small extra cost. Compromises must not be made when the later corrective measure is impossible or inordinately expensive.

C-9.2 Noise Control Treatments.

C-9.2.1 General Applications.

A primary advantage of the manual and of the various noise-analysis procedures offered in this document is that it elevates the awareness of the architect and engineer to problems of noise and vibration. This is an important first step to noise control. Without awareness, the noise problem is ignored in the design, and later problems in remedial steps are compounded. In most building situations, noise control is provided by application of the basic contents of the manual:

- Adequate wall and floor-ceiling constructions must be designed to contain the noise and limit its transmission into adjoining areas.
- Acoustic absorption material must be used in either or both the sound transmitting room and the sound receiving room to absorb some of the sound energy that “bounces” around the room. Quantitative data and procedures for incorporating sound absorption materials are included in the tables and data forms.
- Transmission loss data must be used to select various types of construction materials for the design of noise enclosures.
- Building layouts must be modified to redistribute noise sources in a more favorable arrangement, bring together noisy areas in one part of a building and quiet areas in a different part of the building (to minimize their reaction on one another), and use less critical “buffer zones” to separate noisy and quiet areas.
- Vibration isolation mounts must be used for the support of mechanical or vibrating equipment. Details of such mounts are given in chapter 9.
- Attenuators must be used to control noise transmission through air passageways.
- Duct lining treatments (when allowed) may be used to control noise transmission through ducted connections.
- Specifications must be used to limit the noise output of purchased equipment for use in the building.
- The basic elements of acoustics must be understood and used in order to work intelligently with SPL and PWL data for many types of electrical and mechanical noise sources, know the effects of distance (both indoors and outdoors), appreciate the significance of noise criteria, and be able to manipulate acoustic data in a meaningful and rational way. A few of these items are discussed below.

C-9.2.2 Absorbers.

Acoustical ceiling and wall panels are the most common sound absorbers. Absorbers are rated by the ratio of noise absorbed to noise impacted on the absorber’s surface. A coefficient of 1.0 indicates 100 percent absorption; a coefficient of zero indicates 0 percent absorption. Noise Reduction Coefficient (NRC) is the average coefficient of sound absorption measured at 250 Hz, 500 Hz, 1 kHz, and 2 kHz. Sound absorption must be designed to absorb the frequencies of the sound striking it. For example, a transformer enclosure must have an absorption coefficient of at least .75 in the 125 Hz band (the sound of electrical hum is twice the 60-cycle powerline frequency). Auditoriums must have even absorption over a wide frequency range for a balanced reverberant sound.

C-9.2.3 Test Methods.

There are three basic mountings for sound absorption tests used by ASTM (ASTM E 795-83): 1) Type A.-hard against a concrete surface (formally designated as No. 1), 2) Type D.-with a 3/4-inch (1.9 cm) airspace behind the test material, such as a wood furring strip (formally designated as No. 2), and 3) Type E.-with a 16-inch (40.1 cm) airspace behind the test material, such as an acoustical ceiling (formally designated as No. 7). See Table C-3 for absorption coefficients of some typical building materials.

C-9.2.4 Core Material.

Absorbers consist of a core material, usually fibrous or porous, with a facing as a cover. Fibrous cores are typically 1 inch (2.54 cm) thick for general noise control, and 2 inches (5.1 cm) thick for auditoriums, music, or low frequency absorption. If a minimum 2-inch (5.1 cm) airspace is provided behind a 1-inch (2.54 cm) core, the effect is approximately equivalent to a 2-inch (5.1 cm) thick core. 1-inch (2.54 cm) thick fibrous cores have an NRC of .75, and 2 inch (5.1 cm) thick fibrous cores have a NRC of .95 with a Type D mounting.

C-9.2.5 Facings.

Facings over the acoustical core material serve as both a visual and a protective screen. They are typically cloth, perforated vinyl, wood screens, or expanded metal. Expanded metal, such as plasterer's metal lath, is relatively vandal-proof. Expanded or perforated metal facings must be at least 23 percent open; 33 percent is preferable.

C-9.2.6 Ceilings.

Acoustical ceilings are of two basic types: mineral fiber and fiberglass. Mineral ceiling tiles with a fissured pattern have an NRC of .55 to .65 with a Type E (or No. 7) mounting. Fiberglass ceiling tiles have an NRC of .95 and are normally used in open office design. Fiberglass ceiling tiles, however, have no resistance to sound traveling through them, whereas 5/8-inch standard mineral tiles have a 35 to 40 STC rating for sound transmission from one office to another where the dividing wall stops just above the dropped ceiling line. Lab ratings for such walls can be achieved by installing a baffle over the wall in the ceiling plenum, or by extending the walls up to the underside of the next floor.

C-9.2.7 Enclosures.

From the material given in the manual, it is possible to estimate the noise levels inside a solid-wall enclosure that contains a piece of noisy equipment and to estimate the noise levels that will be transmitted from that enclosure into the surrounding spaces.

- In acoustic terms, an enclosure is an almost air-tight chamber containing the noise source. Small cracks around doors are known noise leaks and cannot be tolerated if a high degree of sound isolation is required. The walls of the enclosure must be solid and well-sealed. If air can escape through the enclosure, sound can escape through the enclosure. A favorite analogy in acoustics is that the same amount of sound power can pass through a 1-in.^{2} (0.093 m^2) hole as through a 100-ft.^{2} (9.3 m^2), 6-inch, 15 cm) thick solid concrete wall. A seemingly negligible crack around a door or at the ceiling joint of a wall can have much more than 1 in.^{2} (6.5 cm^2) of area.
- Where openings in an enclosure are required, they must be given adequate acoustic treatment in order not to weaken seriously the effectiveness of the enclosure. Ventilation ducts may be muffled, clearance holes around pipes, ducts, and conduit must be sealed off airtight, and passageways for material flow must be protected with “sound traps” (attenuators).

C-9.2.8 Barriers, Partial-height Partitions.

Many offices, shops, and tool rooms contain barriers or partial-height partitions that serve to separate areas or people or functions. When used with nearby acoustically absorbent ceilings, these partitions can provide a small amount of acoustic separation-possibly 3 to 5 dB of noise reduction in the low-frequency region and 5 to 10 dB in the high-frequency region, depending on the geometry and the absorption in the area. Where noise reduction values of 20 to 30 dB are desired, partial-height partitions would be useless. A caution is offered here against use of partial-height partitions as control room separators or as small office enclosures out in the middle of an engine room or as a telephone booth enclosure during MER noise.

C-9.2.9 Damping Materials.

Damping is the resistive force to vibratory motion. Sheet metal has low damping properties and will ring when impacted. Loaded vinyl and lead both have high mass and high damping and will thud when impacted. Loaded vinyl has replaced lead in general usage because of lower cost, and because loaded vinyl is available in sheets with an adhesive backing. The loaded vinyl may be cut with scissors and directly applied to noisy ducts or sheet metal at a low cost, usually with good results.

C-9.2.10 Combination.

Combination foam absorbers and loaded vinyl barriers in sandwich type construction are available with adhesive backs and are often used to reduce noise in vehicle cabs or on vibrating equipment covers. Lagging is the process of applying a fibrous or porous material, such as 3-pound density fiberglass, over a noisy duct or pipe, and then covering the fiberglass with sheet metal or loaded vinyl. This method is useful on steam piping, valves, ducting, and fans. Lagging may not be used where it could cause excessive heat buildup, such as on compressors. Enclosures, made of plywood or sheet metal with fiberglass used as an absorber on the inside, can be effective in reducing machinery noise. Enclosures of clear plastic panels can be used where visibility is required. Ventilation may be provided on compressors or computer enclosures by installing foam or fiberglass lined duct (when allowed) at the bottom for cool inlet air, and at the top for hot exhaust air. Enclosures must be carefully fitted together with no gaps which could leak noise. Convenient access panels must be designed into all noise control enclosures.

C-9.2.11 Attenuators.

Attenuators are characterized as either “reactive attenuator” or “dissipative attenuators.” Reactive attenuators usually consist of large-volume chambers containing an internal labyrinth-like arrangement of baffles, compartments, and perforated tubes. Reactive attenuators smooth out the flow of impulsive-type exhaust discharge and, by the arrangement of the internal components, attempt to reflect sound energy back toward the source. There is usually no acoustic absorption material inside a reactive attenuator. Dissipative attenuators are almost entirely made up of various arrangements of acoustic absorption material that dissipates or absorbs the acoustic energy.

C-9.2.12 Reactive Attenuators.

Reactive attenuators are used almost entirely for gas and diesel reciprocating engine exhausts. Somewhat more detailed information on the performance and use of reactive attenuators is included in the **Inactive** UFC 3-450-02 Power Plant Acoustics.

C-9.2.13 Dissipative Attenuators.

As the name implies, these attenuators are made up of various arrangements of acoustically absorbent material that absorbs sound energy out of the moving air or exhaust stream. The most popular configuration is an array of “parallel baffles” placed in the air stream. The baffles may range from 2 inches to 16 inches (5.1 cm to 40.1 cm) thick and are filled with glass fiber or mineral wool. Under severe uses, the attenuator material must be able to withstand the operating temperature of the air or gas flow, and it must have adequate internal construction and surface protection to resist the destruction and erosion of high-speed turbulent flow. These attenuators must be obtained from an experienced, reputable manufacturer to ensure proper quality of materials, design, workmanship, and ultimately, long life and durability of the installation.

C-9.2.14 Packaged Duct Attenuator.

For ducted air handling or air-conditioning systems, packaged duct attenuators can be purchased directly from reputable acoustical products suppliers. Their catalogs show the available dimensions and insertion losses provided in their standard rectangular and circular cross-section attenuators. These packaged duct attenuators are sold by most manufacturers in 3-foot (0.91 meters), 5-foot (1.52 meters), and 7-foot (2.13 meters) lengths. They are also usually available in two or three "classes," depending on attenuation. The mufflers of the higher attenuation class typically have only about 25 to 35 percent open area, with the remainder of the area tilled with absorption material. The lower attenuation classes have about 50 percent open area. The attenuators with the larger open area have less pressure drop and are known as "low pressure-drop units." The attenuators with the smaller open area are known as "high pressure-drop units." In critical situations, attenuator "self-noise" may also be a problem with these duct attenuators. If high-speed air is required, the manufacturer can usually provide self-noise data. When ordering special-purpose attenuators, specify the flow speed and the temperature of the air or gas flow, as these may require special surface protection and special acoustic filler materials.

C-9.2.15 Duct Lining.

Internal duct lining is prohibited. Prior to any design or construction, any consideration for its use must first be approved by exemption.

Only when approved for use: Duct lining is used to absorb duct-transmitted noise. Typically, duct lining is 1 inch (2.54 cm) thick. Long lengths of duct lining can be very effective in absorbing high-frequency sound, but the thin thickness is not very effective for low frequency absorption. The ASHRAE Guide can be used to estimate the attenuation of duct lining. Lined 90-degree turns are very effective in reducing high-frequency noise. For other than acoustical purposes (in example thermal), review other criteria for the use of duct lining and the potential of its prohibition.

C-10 AIR DISTRIBUTION FOR HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS.

In this section, consideration is given to the sound levels resulting from the operation of Heating, Ventilation and Air Conditioning (HVAC) systems in buildings. Information is provided on the most common HVAC equipment found in many commercial office buildings, how sound is propagated within ducted ventilation systems and the procedure for calculating sound levels in rooms from ventilation systems.

C-10.1 General Spectrum Characteristics of Noise Sources.

The most frequently encountered noise sources in a ducted air distribution system designed to deliver a constant volume of air are fans, control dampers, and air outlets such as diffusers, grilles, and registers (return air grilles with dampers). In a variable volume system terminal unit, such as variable air valves (VAVs), fan powered air valves, and mixing boxes, are an additional frequently encountered noise source. Operation of any of these identified noise sources can result in noise generated over most of the audio frequency spectrum. Typically, however, centrifugal fans generate their highest noise levels in the low frequency range in or below the octave centered at 250 Hz. Diffusers, and grilles, however, typically generate the highest noise levels in the octaves centered at 1000 Hz, or above. In between these low and high frequency sources, terminal units produce their highest noise levels in the mid-frequency range in the octaves centered at 250, 500, and 1000 Hz bands. In addition to these frequency characteristics, the normal sound propagation path between the various system sources and an occupant of the space served influences the typically observed spectra. Thus, the fans in a system are typically somewhat remote to an observer, and the fan sound is attenuated by the properties of the path including noise control measures. However, this path attenuation is greatest in the mid-, and high frequency range, and thus the noise reaching the receiver will primarily be in the low frequency range because of both the source and path characteristics. With diffusers and grilles, however, there is little or no opportunity to provide attenuation between the source and the receiver, and thus the high frequency noise of the source alone determines the spectrum content. With air terminal units the most direct path is often sound radiating from the case of the unit and traveling through a ceiling, usually acoustical, direct to the observer in the space being served. The attenuation of a typical ceiling increases slightly with frequency, and thus the typical noise of an air terminal unit in an occupied space will tend to shift downward by an octave to have its highest sound pressure levels in the octaves with center frequencies at 125, 250, and 500 Hz. Thus, in summary, when a system is designed to achieve good acoustical balance among the various sources, fan noise will control the noise level in the low frequency range, air terminal units will control in the mid-frequency range, and air outlets will control in the high frequency range.

C-10.2 Specific Characteristics of Noise Sources.

C-10.2.1 Fans.

To determine the requirements for noise control for a ducted air distribution system one of the primary requirements is to determine the octave band sound power level of the fan noise at the discharge and intake duct connections to a fan. These sound power levels can be determined by a methodology described in Appendix B or obtained from a fan manufacturer for the specific application and this is generally the preferable method. Note: the method given in Appendix B yields the sound power level for a fan selected to operate at its maximum efficiency, however the ASHRAE method suggests a correction factor, “C” on Table B-13, for off-peak operation at various fan efficiencies. With a system designed to deliver a constant volume to a space it is usually possible to operate a properly selected fan at or near its maximum efficiency. However, for a variable volume system, with a fan operating at a constant speed, the static efficiency will generally be significantly below its maximum static efficiency. Thus, for variable volume systems the adjustment to the power level for operating efficiency is very important. Variable speed drives allow the fan to operate at or near the peak efficiency for different air quantities and static pressures. In this instance the fan efficiency can be maintained near its maximum, and the sound power levels are reduced as the air quantity delivered and the static pressure are reduced in accordance with Equation B-5.

In order to use Equation B-5 and Table B-13 it is necessary to determine the static efficiency of the fan, and to compare it with the maximum static efficiency of the type of fan being utilized. The operating static efficiency of a fan may be obtained from the following:

Equation C-15. Static Efficiency

$$\textbf{Static Efficiency} = (\mathbf{Q} * \mathbf{P})/(\mathbf{6356} * \mathbf{BHP})$$

Where :
Q = air quantity (cfm)(m³/s)
P = static pressure (in)(cm)
BHP = brake horsepower

This calculated static efficiency is then compared with the maximum efficiency for the fan, which may be taken as 80% for a centrifugal fan with airfoil blades; 75% for centrifugal fans with backwardly inclined, single thickness blades; 70% for a vane axial fan; and 65% for a centrifugal forward curved fan. The ratio of the calculated static efficiency to the maximum static efficiency is then used to determine the correction for off-peak efficiency as shown on part C of Table B-13. For example, if the calculated static efficiency for a forward curved fan is 62%, then the ratio of the calculated static efficiency to the maximum static efficiency is 62% divided by 80%, or approximately 82%. In other words, the actual static efficiency is approximately 82% of the maximum static efficiency and the off-peak correction from part C of Table B-13 is 6 dB.

C-10.2.2 Air Terminal Units.

Air terminal units are components used in ducted air distribution systems to maintain the desired temperature in a space served by varying the volume of air. Basically, these units consist of a sheet metal box containing a damper, controls, and a sensor, and they are usually connected to a supply header via a flexible circular duct. They usually discharge air to one or more diffusers via rectangular sheet metal ducts. In their simplest form these units are designated as variable air valves (VAVs). However, units are also available with an auxiliary fan in the box to supplement the air delivered by mixing induced air from the ceiling plenum with the primary air from the supply header. Units with these auxiliary fans are termed fan powered terminals (FPTs), and they are available in two forms. In one form the fan only operates when it is necessary to mix warm air from the ceiling plenum with the primary air, and this type of unit is designated as a “parallel” FPT. The intermittent operation of the fan in this type of unit leads to some increased awareness of the noise generated. In a second form the fan operates continuously and handles both the primary air and the return air from the ceiling plenum. Both the primary air and return is mixed in varying quantities to maintain a constant volume delivered to the space served. This type of unit is designated as a “series” FPT. The noise of any air terminal unit can propagate to the space served via a number of paths, but the two prominent paths are (1) via the unit’s discharge ductwork to the connected outlet(s), or (2) by direct sound radiated from the casing of the unit into a ceiling plenum and then through a ceiling (usually acoustical) into the space served. Manufacturers publish data giving the octave band sound power level for the unit discharge sound, and the casing sound. These data are usually measured in accordance with Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 880-2008. With a VAV terminal unit the measurements for the casing sound measure only the casing sound. For a fan powered box (FPT) the casing sound data includes both the sound radiated by the casing, and the fan sound radiated from the air intake opening to the unit casing.

C-10.2.3 Noise Level Prediction.

C-10.2.3.1 Sound Level.

To predict the sound level in an occupied space produced by a terminal unit serving a space, procedures suggested in AHRI Standard 885-2008 may be used. For the duct borne sound, radiated by the air outlets, the estimation procedure involves two steps:

1. Reducing the sound power of the discharge, by the insertion loss (IL) of the duct system between the unit outlet and the space outlets, to obtain the unit sound power emitted into the room from the air outlets.
2. Applying the octave band “Rel SPLs” to obtain the octave band sound pressure levels in the room.

C-10.2.3.2 Radiated Sound.

For the casing radiated sound again two steps are required to estimate the sound pressure levels in a room with a unit located in the ceiling plenum, these are:

1. a plenum/ceiling transfer factor which combines the insertion loss (IL) of the ceiling and the absorption of the plenum is subtracted from the published power level for each octave band, and
2. the room factor for the space is subtracted from the power levels transmitted through the ceiling.

C-10.2.3.3 Transfer Values.

Values for the Plenum/Ceiling Transfer for typical acoustical ceilings are given in Table C-32. These values are applicable to typical ceiling construction, with some openings for lights and return air. These values do not apply when the terminal unit is located directly above a return air opening.

Table C-32 Plenum/Ceiling Transfer Factor.

	Octave Band Center Frequency (Hz)						
	63	125	250	500	1000	2000	4000
Type 1 Fiberglass Tile 1/2" - 6 lb/cu.ft	4	8	8	8	10	10	14
Type 2 Mineral Fiber Tile 5/8" - 35 lb/cu.ft	5	9	10	12	14	15	15
Type 3 Sheet Rock 5/8" - 22 lb/sq.ft	10	15	21	25	27	26	27

Note: Values for ceilings with typical penetrations and light fixtures.

C-10.2.4 Noise Control.

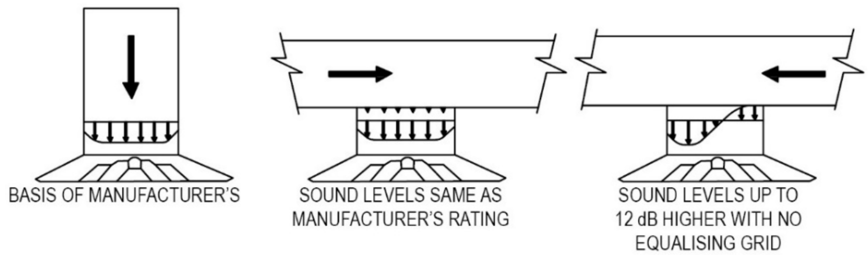
Typical noise control measures for air terminals, including VAVs, fan powered units, and mixing boxes are:

- Locating units above spaces such as corridors, work rooms, or open plan office areas. Do not locate VAV units over spaces where the noise exceeds an NC or RC 35. Do not locate fan powered terminal units (FPT), which are sized for 1,500 CFM, over spaces where the noise exceeds an NC or RC 40.
- Locating the units at least 5 ft. (1.52 meters) away from an open return air grille located in the ceiling,
- Installing sound attenuators, provided as options by some manufacturers, or acoustically lined sheet metal elbows, at the induced (return) air openings in the casings of fan powered units, or
- Installing acoustically lined elbows above ceiling return air openings when they must be near, or directly below a terminal unit.

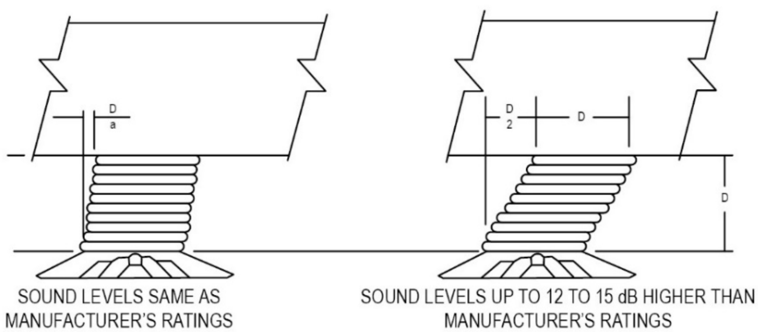
C-10.2.4.1 Diffusers, Grilles, and Control Dampers.

Diffusers and grilles are devices used to deliver to, or return air from, a building space. They are available in rectangular and circular forms, and in a linear or strip form. Generally, these devices include vanes, bars, tins, and perforated plates to control the distribution of air into the space. All these elements which make up a diffuser or grille act as spoilers in the air stream. When the air flows across the spoilers, noise is generated that, for a particular diffuser or grille design, varies by the 5th to the 6th power of the velocity. Because of the wide variety in diffuser design, and the sizes available, manufacturers publish sound level data in their catalogs. Most manufacturers only provide the NC level that the diffuser noise will reach with different quantities of air flow in a room where the “Rel SPL” is 10 dB. Thus, for a room with different acoustical properties an adjustment must be made to the quoted NC value. Some manufactures also publish the sound power level of the diffusers or grilles in octave bands. As this form of information is more useful for design than the NC values, request octave band data for any facility where sound level is considered critical. In using the manufacturer’s data care must be taken to note the data usually applies only to diffusers in an ideal installation. For example, placing a damper, even in an open position, behind a diffuser or grill may increase the noise generated by up to 15 dB. In general, where sound level is critical dampers must not be placed directly behind diffusers but preferably be located where the diffuser duct branches off the header, or main duct. In this location any damper generated sound can be attenuated by acoustic lining in the diffuser drop, and any resulting non-uniformity in the air flow delivered to the diffuser will be much less than if a damper is placed directly behind the diffuser. Also, the position of deflection bars in grilles, and vanes in diffuser can change the level of the noise generated. Thus, these factors need to be noted when using the data to predict diffuser sound levels in a space. Finally, regarding published data, Note: that the data is taken with uniform air delivery to or from the device. In application, this condition may not be met as shown in Figure C-20 showing that with non-uniform flow caused by short duct connections to a header duct, or by badly misaligned flexible duct the sound levels may be quickly increased by 5, 10, or 15 dB.

Figure C-20 Good and Poor Air Delivery Conditions to Air Outlets



A. Proper and Improper Airflow Conditions to an Outlet



B. Effect of Proper and Improper Alignment of Flexible Duct Connector

C-10.2.4.2 Control of Fan Noise in a Duct Distribution System.

Fan noise propagating along a duct system may be reduced by (1) propagation along the duct, (2) by duct branching, (3) by elbows, and (4) by end reflection.

C-10.2.4.3 Propagation in the Duct Distribution System.

Noise attenuation with propagation in a duct system result from; 1) natural energy losses as sound is transmitted through sheet metal duct walls to the space through which the duct passes; and 2) by absorption of energy in the internal glass fiber lining of the sheet metal duct.

C-10.2.4.4 Unlined Duct.

Table C-33 lists the natural attenuation, in dB/ft (m) for unlined rectangular sheet metal ducts without external thermal insulation. This attenuation, attributed to sound transmission through the duct walls, can be significant, in the low frequency range, for long lengths of duct. The attenuation values are given as a function of the ratio of the duct perimeter P and the duct cross sectional area A. This data is applicable only to normal sheet metal rectangular ducts typically used in the air conditioning industry. This data must not be used for ducts using metal heavier than 16 ga.; for circular ducts (which is relatively stiff) or for ducts made of glass fiber board.

Table C-33 Approximate Natural Attenuation in Unlined Sheet-Metal Ducts

P/A ratio in/sq. in.	Octave Band Center Frequency (Hz)		
	63	125	250 and over
Over 0.31	0	0.3	0.1
0.31 to 0.13	0.3	0.1	0.1
Under 0.13	0.1	0.1	0.1
Note: Double these values for Sheetmetal duct with external glass fiber insulation			

C-10.2.4.5 Duct Lining Attenuation.

Internal duct lining is prohibited. Prior to any design or construction, any consideration for its use must first be approved by exemption.

Only when approved for use: The octave band attenuation, in dB/ft (m), that is expected due to absorption of sound by 1 inch thick internally duct lining, is given in Table C-34. As noted on the table, the data can be used for any length of duct in the unshaded portion, but in the shaded portion the attenuation must not be applied for more than 10 ft. in any straight duct run between elbows or turns. Note, these attenuation factors are for the effects of the internal lining only and do not include the effects of natural attenuation as given on Table C-33.

Table C-34 Attenuation in Lined Ducts

Internal Cross-Sectional Dimensions (Inches)			Perimeter / Area Ratio (in/in^2)	Octave Band Center Frequency (Hz)						
				63	125	250	500	1000	2000	4000
4	x	4		0.16	0.44	1.21	3.32	9.10	10.08	3.50
4	x	6		0.13	0.37	1.01	2.77	7.58	8.26	3.13
4	x	8		0.12	0.33	0.91	2.49	8.82	6.45	2.57
4	x	10		0.11	0.31	0.85	2.32	6.37	5.02	2.07
6	x	6		0.12	0.34	0.93	2.56	7.01	7.50	3.17
6	x	10		0.10	0.27	0.75	2.04	5.61	5.67	2.67
6	x	12		0.09	0.26	0.70	1.92	5.26	4.80	2.33
6	x	18		0.08	0.23	0.62	1.70	4.67	2.95	1.51
8	x	8		0.10	0.28	0.77	2.12	5.82	6.08	2.94
8	x	12		0.09	0.24	0.65	1.77	4.85	4.98	2.64

Internal Cross-Sectional Dimensions (Inches)			Perimeter / Area Ratio (in/in²)	Octave Band Center Frequency (Hz)						
				63	125	250	500	1000	2000	4000
8	x	16		0.08	0.21	0.58	1.59	4.37	1.83	2.17
8	x	24		0.07	0.19	0.52	1.42	3.88	2.33	1.41
10	x	10		0.09	0.24	0.67	1.84	5.04	5.17	2.79
10	x	16		0.07	0.20	0.55	1.49	4.10	4.04	2.41
10	x	20		0.07	0.18	0.50	1.38	3.78	3.30	2.05
10	x	30		0.06	0.16	0.45	1.23	3.36	2.03	1.34
12	x	12		0.08	0.22	0.60	1.64	4.48	4.52	2.67
12	x	18		0.07	0.18	0.50	1.36	3.74	3.71	2.99
12	x	24		0.06	0.16	0.45	1.23	3.38	2.89	1.97
12	x	36		0.05	0.15	0.40	1.09	2.99	1.78	1.28
15	x	15		0.07	0.19	0.52	1.42	3.88	3.84	2.53
15	x	22		0.06	0.16	0.43	1.19	3.27	3.2	2.29
15	x	30		0.05	0.14	0.39	1.06	2.91	2.48	1.86
15	x	45		0.05	0.13	0.34	0.94	2.17	1.51	1.21
18	x	18	0.22	0.06	0.17	0.46	1.26	3.45	3.37	2.42
18	x	28	0.18	0.05	0.14	0.38	1.03	2.84	2.69	2.13
18	x	36	0.17	0.05	0.13	0.34	0.94	2.59	2.15	1.78
18	x	54	0.15	0.04	0.11	0.31	0.84	1.65	1.32	1.16
24	x	24	0.17	0.05	0.14	0.38	1.05	2.87	2.73	2.26
24	x	36	0.14	0.04	0.12	0.32	0.87	2.39	2.24	2.02
24	x	48	0.13	0.04	0.10	0.29	0.78	1.90	1.75	1.66
24	x	72	0.11	0.03	0.09	0.25	0.70	1.06	1.07	1.08
30	x	30	0.13	0.04	0.12	0.33	0.91	2.49	2.32	2.14
30	x	45	0.11	0.04	0.10	0.28	0.76	1.88	1.90	1.91
30	x	60	0.10	0.03	0.09	0.25	0.68	1.35	1.48	1.57
30	x	90	0.09	0.03	0.08	0.22	0.60	0.76	0.91	1.02
36	x	36	0.11	0.04	0.11	0.29	0.81	2.01	2.00	2.04

36	x	54	0.09	0.03	0.09	0.25	0.67	1.42	1.66	1.83
36	x	72	0.08	0.03	0.08	0.22	0.60	1.02	1.30	1.5
36	x	108	0.07	0.03	0.07	0.20	0.54	0.57	0.8	0.98
42	x	42	0.10	0.04	0.10	0.27	0.73	1.59	1.81	1.97
42	x	64	0.08	0.03	0.08	0.22	0.60	1.11	1.47	1.75
42	x	84	0.07	0.03	0.07	0.20	0.55	0.84	1.16	1.45
42	x	126	0.06	0.02	0.06	0.18	0.49	0.45	0.71	0.94
48	x	48	0.08	0.03	0.09	0.24	0.67	1.3	1.65	1.90
48	x	72	0.07	0.03	0.07	0.20	0.58	0.92	1.35	1.7
48	x	96	0.06	0.02	0.07	0.18	0.5	0.66	1.05	1.4
48	x	144	0.06	0.02	0.06	0.16	0.45	0.37	0.65	0.91

Notes:
a) Apply appropriate conversion when calculations are performed in metric units.
b) Based on measurements of surface-coated duct liners of 1.5 lb./cu feet density representative for all liners with density of 1.5 to 3.0lb./cu ft.
c) dark line represents division between high and low frequency high frequency attenuation are applicable to a maximum of 10-ft.
d) attenuations apply to, airflow less than 2,000 1pm.
e) for attenuation due to sheet metal only SN Table 12 - 5
f) for critical applications, reduce attenuations by 10% to account for differences between manufacturers.

For the bands centered at 63, and 125 Hz the total attenuation for a lined duct is a sum of the natural (Table C-33) and lined duct (Table C-34) attenuations. For example, in a 24 x 24-inch (61 x 61 cm) (duct the attenuation in the 63 Hz octave is 0.05 dB/ft due to internal lining (Table C-34), plus 0.3 dB for the loss associated with sound transmission through the duct wall (Table C-33 with a P/A ration of 0.17). Review other criteria for prohibition of duct lining.

C-10.2.5 Sound Transmission Loss at Duct Branches.

When one duct branches off from a main, or header, duct the sound power propagating in the main duct up to the branch point is assumed to divide into the branch ducts in accordance with the ratio of the cross-sectional area of each branch, to the total cross-sectional area of all the ducts leaving the branch point. Thus, following any branch point the energy transmitted into any one duct is less than the initial sound power in the main duct before the branch point, and this loss, in dB, for each branch duct is given as:

Equation C-16. Duct Branch Sound Transmission Loss

Duct Branch Division Loss in $\mathbf{dB = 10\,log(B/T)}$

Where:
B = use Table 35 for branch area ratios
T = use Table 35 for branch area ratios

Table C-35 Lists the energy loss in dB for a range of branch area ratios. This power division is applied equally to each octave band.

Table C-35 Power Level Loss at Branches

B/T	Division (dB)	B/T	Division (dB)
1.00	0	0.10	10
0.00	1	0.08	11
0.63	2	0.063	12
0.50	3	0.05	13
0.40	4	0.04	14
0.32	5	0.032	15
0.25	6	0.025	16
0.20	7	0.02	17
0.16	8	0.016	18
0.12	9	0.012	19

C-10.2.6 End Reflection.

When a duct, in which sound is propagating, opens abruptly into a large space, or room, sound reflection occurs at the end or opening of the duct. The reflected sound is transmitted back into the duct and is attenuated. The loss in dB associated with this reflection is significant at low frequencies and is given in Table C-36 for a range of duct diameters. These values apply to a duct outlet flush mounted in a structure, but may also be applied, conservatively, to duct outlets flush mounted in a suspended acoustical ceiling. This data must not be applied when the duct branch dropping from a header duct to a diffuser or grill is less than 3 to 5 duct diameters, or where flexible ducts are used to connect a diffuser to a main branch. When the duct distribution system connects to a strip or linear diffuser, the end reflection must be taken as one-half the loss in dB given in Table C-36 for the diameter of the duct serving the linear diffuser section.

Table C-36 End Reflection Loss

A. Terminated at Acoustic Tile Ceiling or in Free Space.

Circular Duct Mean Duct Width (Inches)	Octave-Band Center Frequency (Hz) 63	125	250	500	1K
6	20	14	9	5	2
8	18	12	7	3	1
10	16	10	6	2	1
12	14	9	5	2	1
16	12	7	3	1	0
20	10	6	2	1	0
24	9	5	2	1	0
28	8	4	1	0	0
32	7	3	1	0	0
36	6	3	1	0	0
48	5	2	1	0	0
72	3	1	0	0	0

B. Terminated Flush with Hard Ceiling, Wall, or Floor.

Circular Duct Mean Duct Width (inches)	Octave Band Center Frequency (Hz) 63	125	250	500	1K
6	18	13	8	4	1
8	16	10	6	2	1
10	14	9	3	2	1
12	13	8	4	1	0
16	10	6	2	1	0
20	9	5	2	1	0
24	8	4	1	0	0
28	7	3	1	0	0
32	6	2	1	0	0
36	5	2	1	0	0
48	4	1	0	0	0
72	2	1	0	0	0

C-10.2.7 Losses at Elbows.

Sound is reflected or attenuated at 90-degree elbows occurring in duct systems. Table C-37 lists representative losses in dB for unlined rectangular elbows with turning vanes, or circular elbows for any size, and for a range of sizes for elbows with one-inch-thick lining in the elbow and associated upstream and downstream ductwork.

Table C-37 Losses Caused by Duct Elbows

	Duct Diameter (inches)	Octave Band Frequency (Hz) 63	125	250	500	1000	2000	4000	8000
Lined elbows	5 to 10	0	0	1	2	3	4	6	8
	11 to 20	0	1	2	3	4	6	8	10
	21 to 40	1	2	3	4	5	6	8	10
	41 to 80	2	3	4	5	6	8	10	12
Unlined elbows	All sizes	1	2	3	3	3	3	3	3

C-10.2.8 Sound Attenuators (Prepackaged Attenuators).

Sound attenuators, sometimes termed duct silencers, or mufflers are manufactured specifically for ventilation, and air conditioning systems by several manufacturers. These are used in air distribution systems as a means of providing increased sound attenuation where normal duct attenuation is insufficient. Attenuators are available in modular form to fit a range of cross-sections for rectangular ducts, and are usually readily available in lengths of 3, 5, 7, and 10 ft. (0.91, 1.52, 2.13, and 3.01 meters). They are also available for circular ducts in a range of diameters, and the length is a function of diameter, being 2 to 3 times the diameter. For the various lengths, and for both rectangular and circular ducts the attenuators are available with low, medium, or high pressure drop for a given velocity, usually expressed in terms of the air velocity in the duct at the attenuator entrance (in other words, “face velocity”). For example, low pressure drop attenuators will have a pressure drop of less than 0.1 in. of water with a face velocity of 1000 ft/min (5.08 m/s), but high pressure drop units will have a drop of close to 0.5 inch (1.27 cm) of water at the same velocity. Attenuators with a higher-pressure drop will most often provide greater sound attenuation. The actual installed pressure drop will also be a function of both the unit location in an air distribution system, and the uniformity and turbulence of the entering air flow. Manufacturers provide guidelines for estimating the installed operating pressure drop for different conditions. The manufacturers of duct attenuators also publish information on the sound power generated by flow in the air passages of the attenuator. However, this flow noise, or self-noise, is seldom a problem unless the flow velocities in the duct are high (in example greater than 3,000 FPM, (4560 mps), or the sound level criteria for the space served calls for very low levels, such as for a concert hall). Typical dynamic sound insertion loss values for normal rectangular sound attenuators, with glass fiber packed linings, for both low and high pressure drop attenuators are tabulated in Table C-38. These values are applicable when the flow and the sound are in the same direction and the flow velocity is moderate (approximately 1,000 FPM, 4560 mps). Manufactures provide dynamic sound insertion losses for various flow velocities when the air flow and sound are in the same direction (supply) and when the air flow and sound are in opposite directions (return).

Table C-38 Representative IL Values for Sound Attenuators

Type	Length in Ft.	Octave Band Center Frequency (Hz) 63	125	250	500	1000	2000	4000	8000
Low Pressure Drop	3	2	4	8	14	21	22	14	11
	5	3	5	11	23	31	34	19	13
	7	5	9	16	32	41	43	24	16
	10	6	15	22	37	52	53	35	23
Standard Pressure Drop	3	3	6	13	23	33	33	23	14
	5	4	11	20	37	44	44	36	22
	7	6	13	28	42	47	47	45	30
	10	8	15	35	50	56	57	57	40

The manufacturers of these attenuators can also provide polymer sheeting to enclose the sound absorptive glass fiber packing for cleanliness and resistance to certain chemicals. Certain manufactures also make attenuators without any sound absorptive packing (in other words, “pack-less”) for systems serving spaces that must maintain very clean environments. The insertion losses for these units are typically somewhat less than for the normal attenuators, and the manufacturers must be consulted regarding their specific acoustic performance.

C-10.2.9 Attenuators Using Active Cancellation.

Active sound attenuation as a means of noise control has in recent years moved from the laboratory to a growing number of applications including the control of fan noise in ducted systems. Active sound attenuation involves the use of an auxiliary sound source to generate a sound wave that interferes and cancels an unwanted sound wave. This system of cancellation is limited to plane wave conditions, which means that the wavelength of the sound to be cancelled must generally be greater than the largest dimension of the duct. While this is not a problem for most air distribution systems, it does generally limit the frequency range for application to below about 500 Hz. Recently, with the development of adaptive, digital signal processing, the application of this method has been extended to cancelling broad band noise and thus is not now limited to cancelling only tonal sounds. Finally, in some applications it has been proposed to combine in one attenuator both active cancellation and passive dissipative elements to attenuate the low and high frequencies respectively. Thus, active cancellation may find application in the future in the HVAC industry, but its cost and operation will probably limit its application to situations where the space for the use of conventional dissipative lining or attenuators is not available.

C-11 PROCEDURE FOR CALCULATING NOISE CONTROL REQUIREMENTS FOR AN AIR DISTRIBUTION SYSTEM.

C-11.1 Procedure for Calculating Noise Control Requirements for an Air Distribution System.

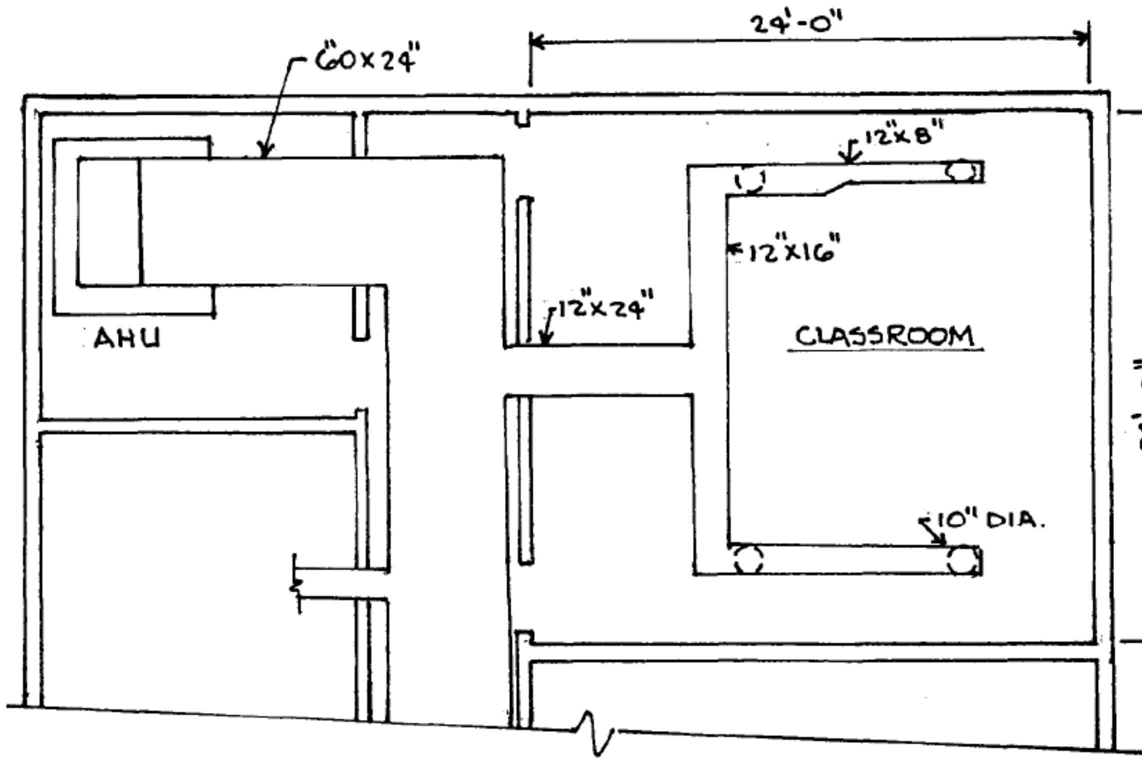
1. The procedure for calculating the noise control requirements for an air distribution system involves six steps:
   a. Selection of noise criteria or goal for the space(s) served.
   b. Estimating sound power level of sources.
   c. Estimating the insertion loss of the duct distribution system applicable to each source to arrive at the sound power at the air outlet(s) in the space(s) served.
   d. Determine the total sound power within the room from all the sources.
   e. Determining the “Rel SPL” for the space served and subtracting that from the sound power levels, from previous step, to obtain the sound pressure levels in the space.
   f. Compare calculated sound pressure levels in each octave band with the criteria to determine noise control requirements in dB.
2. To carry out step (a) it is necessary to know the function of the space served, and for that function such as a conference room select the appropriate RC or NC criteria, to serve as the noise control. To carry out step (b) for a constant volume system essentially means determining the sound power level, in each octave band, for the fan, and for a diffuser, or grille. These data can normally be obtained from a manufacturer, but if the equipment is not selected the fan power levels can be determined from the method given in Appendix B. The diffuser or grille sound power levels can be determined approximately from a manufacturer’s catalog for an identical or similar type of outlet. Similarly, with a variable volume system the sound power level for the air discharge of an air terminal unit, such as a VAV, or FPT, can be obtained from a manufacturer’s catalog for a given operating condition. For step (c) the attenuation provided by unlined and lined ducts, by sound attenuators, elbows, branches, and end reflection are added together to find the total insertion loss (IL) applicable to the control of the fan sound power as it propagates along the duct path between the fan and the air outlet. Similarly, for the prediction of the noise level in the space served caused by duct transmitted air discharge noise from an air terminal unit it is necessary to determine the insertion loss of the duct distribution system between the terminal unit and the room air outlet. This IL will consist of the attenuation of any unlined or lined ductwork, elbows, duct branches, or splits, and end reflection although this latter will not be significant for air terminal unit noise. In step (d) the sound power level of all sources contributing to the sound power at the air outlet are determined and combined to find the total sound power level, in

octave bands, at the air outlet. For step (e) it is necessary to determine the Room Factors and the “Rel SPLs” (see Chapter 3) for the space served and apply the “Rel SPL” to the sound power levels at the air outlet for each source to obtain the sound pressure level produced by that outlet at any location in the space served. For step (f) the resulting sound pressure levels are compared to the selected criteria to determine if additional sound attenuation is necessary.

C-11.2 Calculation Example.

In this example the noise control requirements for an air distribution system serving a classroom as shown in Figure C-21 are calculated. A fan with forward curved blades delivers 20,000 cubic feet per minute (cfm) to several classrooms and offices against a static pressure of 2.5 in. of water with 12 brake horsepower. The main supply duct has dimensions of 60 x 24 inches resulting in an air velocity of 2000 ft/min. The closest classroom, which has dimensions of 24 x 24 x 10 ft, is supplied by a duct branching off from the main header duct. The classroom air is delivered from four diffusers, 10 inch in diameter each, mounted in the ceiling, each delivering 500 cfm. Thus, the total air supplied by the branch duct is 2000 cfm, with an air velocity of 1000 ft/min. in the 12 x 24 in. duct. The only acoustical material applied to the room surfaces is a suspended acoustical ceiling representing approximately 25% of the room surfaces. In this example it is assumed that the entire duct system is internally lined with one-inch-thick sound absorptive insulation, and the duct cross-sectional flow area is given by the dimensions stated in the schematic figure.

Figure C-21 Plan View of Supply Duct for Example



The tabulated results for this example are as follows:

C-11.2.1 Step (1).

In this step an NC 30 is selected as the sound pressure level design criteria.

C-11.2.2 Step (2).

In this step the sound power level (Lw), in dB re 10-12 watts of the supply fan and the diffusers are determined.

C-11.2.2.1 Fan Lw.

From Equation B-5 and Table B-13 Octave Band Center Frequencies

Octave Band Center Frequencies

	63	*125*	*250*	*500*	*1k*	*2k*	*4k*
Fan Kw	47	43	39	36	34	32	28
10log(cfm)	43	43	43	43	43	43	43
BFI.				2			
20log(p)	8	8	8	8	8	8	8
Eff. Corr.	6	6	6	6	6	6	6
Total Lw of Fan	104	100	96	95	91	89	85

C-11.2.2.2 Diffuser Lw, w/o Damper.

From suppliers' catalog.

Octave Band Center Frequencies

	63	125	250	500	1k	2k	4k
Lw of One Diffuser	N/A	43	37	35	40	40	23

C-11.2.3 Step (3).

In this step, the total attenuation for fan noise provided by the duct system (including the lined ductwork If applicable), the duct branches, the elbows, and the end reflection loss are determined. This consists of determining the insertion loss (IL) for each element and then summing all the insertion losses.

C-11.2.3.1 (1) Lined Ductwork (where applicable) IL in dB.

The insertion losses from each rectangular duct element are determined from Tables C-33 and C-34. The result of each element is summed by octave bands to provide the total duct attenuation in dB in each octave band.

Octave Band Center Frequencies

	63	125	250	500	lk	2k	4k
20' of 24x60	3	4	7	18	32	30	30
9' of 12x24	3	2	5	12	31	27	19
10' of 12x16	4	3	7	16	41	41	28
3' of 10"	0	1	2	5	6	6	5
Total	10	10	21	>50	>50	>50	>50

Note: Table C-34 does not contain entries for the 24x60 and 12x16 ducts. The attenuation values for these ducts are obtained by interpolation. For example, the attenuation for the 24x60 duct is the average value of the 24x48 and 24x72 ducts. For the 24x60 duct the full 20 feet of length is used since the elbow breaks the length into two lengths less than 10 feet each. Note: that the total attenuation is the sum of the attenuation due to the internal lining (Table C-34) and the natural attenuation (Table C-33). The attenuation for the 10" round duct was obtained from a supplier's catalog. The total attenuation for all the duct elements is limited to approximately 50 dB because this is usually the maximum that can be obtained in a connected system due to structural flanking down the duct wall.

C-11.2.3.2 (2) Branches (to one diffuser).

The branch attenuation is determined by Equation C-16 or Table C-35. With a branch area of 2 sq. ft. (for example: 24x24) and the area after the branch of 10 sq. ft. (for example: 24x60) the area ratio of the branch is 2/(10+2) or 0.167. The sound power loss at the take-off in the corridor is approximately 8 dB in accordance with Equation C-16. The power division in the "T" and diffuser take-off are determined in a similar fashion and are approximately 3 dB each (in other words, 50% each way). Therefore, the total attenuation due to all the branching is approximately 14 dB in all the octave bands.

Octave Band Center frequencies

	63	125	250	500	1k	2k	4k
Branch att. in corridor	8	8	8	8	8	8	
"T" in room	3	3	3	3	3	3	3
Diffuser Take-off	3	3	3	3	3	3	3
Total (dB)	14	14	14	14	14	14	14

C-11.2.3.3 (3) Four elbows.

There are four elbows between the fan and the classroom. The attenuation of each of these can be found from Table C-37. The first elbow is the 24x60 inch elbow that goes from the vertical to the horizontal at the fan outlet. For this elbow the duct diameter used is 24 inches since this is the dimension in the plane of the turn. The second elbow is a 60x24, for this elbow the dimension is 60 inches. The third elbow is the "T" from 12x24 to 12x16 over the classroom. In (2) above a power division was taken for this "T" fitting, however since some energy is also reflected from the "T" it also acts like an elbow. For the "T" the characteristic dimension is 24". And the final elbow is the 12x16 over the classroom. For this elbow the characteristic dimension is 16". The attenuations for each elbow and the total attenuations for all of the elbows is given below.

Octave Band Center Frequencies

	63	125	250	500	1k	2k	4k
24x60	1	2	3	4	5	6	8
60x24	2	3	4	5	6	8	10
24x12	1	2	3	4	5	6	8
16x12	0	1	2	3	4	6	8
Total IL	4	8	12	16	20	26	34

C-11.2.3.4 (4) End loss.

The end reflection loss is taken from Table C-36 part A, where the diameter is 10 inches. Part A was used since the diffuser was mounted in an acoustical tile ceiling. If the ceiling was hard (gyp. bd., plaster, concrete, and the rest.) then part B would have been used.

Octave Band Center Frequencies

	63	125	250	500	1k	2k	4k
End Reflection	16	10	6	2	1	0	0

C-11.2.3.5 Total IL.

The total insertion loss of the ducted air supply system is the arithmetical sum, in each octave band, of the insertion losses of (1) through (4) above.

Octave Band Center Frequencies

	63	125	250	500	1k	2k	4k
Total line ducts	10	10	21	>50	>50	>50	>50
Total branches	14	14	14	14	14	14	14
Total elbows	4	8	12	16	20	26	34
End Reflection	16	10	6	2	1	0	0
Total IL (all duct elements)	44	42	53	>50	>50	>50	>50

Note again, the insertion loss is limited to approximately 50 dB. This is because flanking sound traveling within the duct walls can become a significant source of sound when the sound levels within the air stream have been attenuated a great deal. If attenuations greater than 50 dB are required, additional vibration breaks within the duct would have to be evaluated.

C-11.2.4 Step (4).

In this step the total sound power at each of the two diffusers closest to the fan is determined. First the sound power transmitted to the room from the fan via the supply duct, is determined by subtracting the total attenuations (c. (5) above) from the total sound power of the fan (b. (1) above) by octave bands. These steps are shown below.

	Octave Band Center Frequencies						
	63	125	250	500	1k	2k	4k
Total Fan Lw (b.(1) above)	104	100	96	95	91	89	85
Total Duct IL (c.(5) above)	44	42	53	>50	>50	>50	>50
Resulting Fan Lw in Classroom	60	58	43				

Then the sound power of the diffuser is added, logarithmically, to the sound power transmitted by the fan, as shown below.

	Octave Band Center Frequencies						
	63	125	250	500	1k	2k	4k
Fan Lw in Classroom	60	58	43				
Diffuser Lw		43	37	35	40	40	23
Total	60	58	44	35	40	40	23

This analysis provides the total sound power into the room from the operation of one diffuser. It also indicates the frequency range of the significant sources of sound. For example, the 63, 125 and 250 Hz octave bands are dominated by the sound of the fan, whereas the level of the other octave bands are determined by the operation of the ceiling diffuser. This distinction is important since sound control for each of these two items are different, as discussed in the section below.

C-11.2.5 Step (5).

In this step the Room Factor is determined to obtain the “Rel SPL” as described in paragraph C-2. The sound pressure levels in octave bands (Lp) in the room, from one diffuser, is then the total sound power from the diffuser plus the “Rel Spl” as given in equation C-13. The room volume is 5760 cu. ft., and the acoustic ceiling is 25% of the room surface area. Thin wall surfaces are used on 30% of the room surface area. The term “REL SPL” is determined for a distance of 8 ft. from one diffuser.

	Octave Band Center Frequencies						
	63	125	250	500	1k	2k	4k
Room Factor (sq/ft.)	450	600	450	500	600	600	600
"Rel SPL"	-9	-11	-9	-10	-11	-11	-11
Total Lw (d. above)	60	58	44	35	40	40	23
Lp-Octave band Sound level	51	47	35	25	29	29	12

C-11.2.6 Step (6).

In this step the Lp from e. above is compared with the NC 30 criteria.

	Octave Band Center Frequencies						
	63	125	250	500	1k	2k	4k
Lp (one diffuser)	51	47	35	25	29	29	12
NC 30 criteria	57	48	41	35	31	29	28
Required Reduction	0	0	0	0	0	0	0

This analysis shows that the sound due to the operation of the fan just meets the selected goal in the 125 Hz octave band. In addition, the diffuser sound, from one diffuser, would just meet the criteria in the octave band centered at 2000 Hz. However, for this classroom, consider the total sound from all four diffusers. As the two diffusers closest to the fan are at identical duct distances from the fan the sound of each diffuser can be assumed to be identical. Also, the added duct length to the next two diffusers is not sufficient to lower the fan noise significantly. Therefore, the diffuser noise must be equal for all four outlets. Thus, in the center of the room it is found that the required IL must be increased by the factor of 10 log (4), or 6 dB. In this case the sound pressure level in the room for all four diffusers would be:

	Octave Band Center Frequencies						
	63	125	250	500	1k	2k	4k
Lp (4 diffusers)	57	53	41	31	35	35	18
NC 30 criteria	57	48	41	35	31	29	28
Required Reduction (Considering Four Outlets)	0	5	0	0	4	6	0

To provide the additional IL required for the fan noise in the 125 Hz octave band a 5 ft. long standard pressure drop attenuator could be installed in the 60x24 duct in the fan room, or in the 12x24 duct leading to the classroom. The location of choice would depend on the need for sound attenuation in other portions of the duct system. The sound in the 1,000 and 2,000 Hz octave bands are due to the diffusers. Attenuators in the duct will not attenuate this sound. For the diffuser noise one solution would be to increase the diffuser size, and this would require changing the diameter of the diffuser drop from a 10 in. to 12 in. diameter yielding lower sound power levels by the order of 8 to 10 dB.

C-12 VIBRATION CONTROL INFORMATION.

This section provides the details of vibration isolation mountings so that the desired vibration conditions discussed in Chapter 4 can be met for most electrical and mechanical equipment. In addition, typical forms of vibration isolators are given, five general types of mounting systems are described, and summary tables offer suggested applications of five mounting systems for the mechanical equipment commonly found in buildings. A discussion of the general consideration for effective vibration isolation is presented in Appendix A.

C-12.1 Vibration Isolation Elements.

Table C-39 lists the principal types of vibration isolators and their general range of applications. This table may be used as a general guide for comparing isolators and their range of static deflections and natural frequencies as applied to two equipment categories (rotary and reciprocating) and two equipment locations (noncritical and critical). Additional details are required for actual selections of mounts. Vibration isolator types are discussed in this paragraph, and equipment installations are discussed in the remaining paragraphs of this chapter.

Table C-39 General Types and Applications of Vibration Isolators

Isolator Type	Typical Range of Static Deflection (in.)	Corresponding Approximate Range of Natural Frequency (Hz)	Vibration Isolation Applications – Non-specific			
			Noncritical Locations[c]		Critical Locations[c]	
			Rotary Equipment	Reciprocating Equipment	Rotary Equipment	Reciprocating Equipment
Steel Spring[a]	.25 to 10	6 to 1	Yes	Yes	Yes	Special[d]
Neoprene-in-shear, double deflection	.25 to .5	6 to 4	Yes	Yes	Yes	No[e]
Neoprene-in-shear, single deflection	.1 to .25	10 to 6	Yes	Yes	Yes	No[e]
Compressed block of glass fiber, 2-in thick[b]	.02 to .15	20 to 8	Yes	No	Yes	No
Neoprene pad, ribbed or waffle-pattern, 1 to 4 layers[b]	.02 to .25	20 to 6	Yes	No	Yes	No
Felt or cork pads or strips	.01 to .1	30 to 10	See text for application and limitations			
Air Spring	---	10 to 1	See text for application and limitations			

Note:
a. Apply appropriate conversion to material dimension when using metric calculations.
b. Always use pad-type isolator in series with spring to control high-frequency structure borne noise in critical locations.
c. May be used alone for relatively high-speed rotary equipment or in series with steel springs in critical locations for reduction of high-frequency structure borne noise. Not normally used alone for vibration isolation of reciprocating equipment.
d. Refer to paragraph 4-2d for definition of noncritical and critical locations.
e. Special design required for reciprocating equipment at critical locations, especially for low speeds.
f. Not normally recommended for this application but can be adapted as special design.

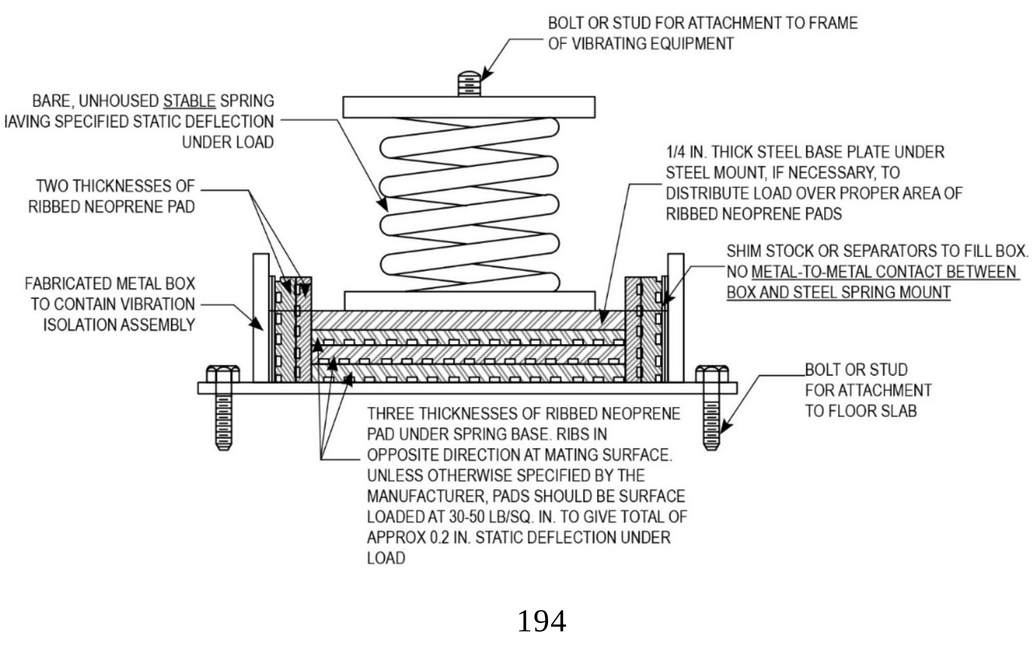
C-12.1.1 Steel Spring Isolators.

Steel springs are used to support heavy equipment and to provide isolation for the typical low-frequency range of about 3 to 60 Hz (180- to 3600-rpm shaft speed). Steel springs have natural frequencies that fall in the range of about 1 Hz (for approximately 10-inch static deflection) to about 6 Hz (for approximately 1/4-inch or 0.64-cm) static deflection). Springs transmit high-frequency structure borne noise, so they must be supplemented with a high-frequency pad-type isolator when used to support equipment directly over critical locations in a building. Unhoused "stable" steel springs are preferred over housed unstable or stable springs. Unstable springs tend to tilt over when they are loaded and to become short-circuited when they bind against the inside walls of the spring housing. Stable steel springs have a diameter that is about 0.8 to 1.2 times their compressed height. They have a horizontal stiffness that is approximately equal to their vertical stiffness; therefore, they do not tend to tilt sideways when a vertical load is applied. The free-standing unhoused spring can easily be inspected to determine if the spring is compressed correctly, is not overloaded to the point that adjacent coils are solid against one another, and is not binding against its mounting bracket, and to ensure that all springs of a total installation are uniformly compressed, and that the equipment is not tilting on its base. For reasons of safety, steel springs are always used in compression, not in tension.

C-12.1.2 Neoprene-In-shear Isolators.

Neoprene is a long-lasting material which, when properly shaped, can provide good vibration isolation for the conditions shown in Figure C-22. Typically, neoprene-in-shear mounts have the appearance of a truncated cone of neoprene bonded to bottom and top metal plates for bolting to the floor and to the supported equipment. The mount usually has an interior hollow space that is conically shaped. The total effect of the shaping is that for almost any direction of applied load, there is a shearing action on the cross section of neoprene. In this shearing configuration, neoprene serves as a vibration isolator; hence, the term "neoprene-in-shear." A solid block of neoprene in compression is not as effective as an isolator. Manufacturers' catalogs will show the upper limit of load-handling capability of large neoprene-in-shear mounts. Two neoprene-in-shear mounts are sometimes constructed in series in the same supporting bracket to provide additional static deflection. This gives the double deflection mount referred to in Table C-39.

Figure C-22 Suggested Arrangement of Ribbed Neoprene Pads for Providing Resilient Lateral Restraint to a Spring Mount



C-12.1.3 Compressed Glass Fiber.

Blocks of compressed glass fiber serve as vibration isolators when properly loaded. The manufacturers have several different densities available for a range of loading conditions. Typically, a block is about 2-inches (0.051 meters) thick and has an area of about 10 to 20 in.^{2} (65 to 129 cm^2). but other dimensions are available. These blocks are frequently used in series with steel springs to remove high-frequency structure borne noise, and they are often used alone, at various spacings, to support floating concrete floor slabs. The manufacturer's data must be used to determine the density and area of a block required to achieve the desired static deflection. Unless otherwise indicated, a static deflection of about 5 to 10 percent of the uncompressed height is normal. With long-time use, the material might compress an additional 5 to 10 percent of its height. This gradual change in height must be kept in mind during the designing of floating floors to meet floor lines of structural slabs.

C-12.1.4 Ribbed Neoprene Pads.

Neoprene pads with ribbed or waffle-pattern surfaces are effective as high frequency isolators in series with steel springs. In stacks of 2 to 4 inch (0.051 to 0.1 meters) thicknesses, they are also used for vibration isolation of flow power rotary equipment. The pads are usually about 1/4 to 3/8 inches (0.64 to 0.95 cm) thick, and they compress by about 20 percent of their height when loaded at about 30 to 50 lb/in^2 (2.11 to 3.52 kg/cm^2). Higher durometer pads may be loaded up to about 100 lb/in^2 (7.04 kg/cm^2). The pads are effective as isolators because the ribs provide some shearing action, and the spaces between the ribs allow lateral expansion as an axial load is applied. The manufacturer's literature must be used for proper selection of the material (load-deflection curves, durometer, surface area, height, and similar).

C-12.1.5 Felt Pads.

Felt strips or pads are effective for reducing structure borne sound transmission in the mounting of piping and vibrating conduit. One or more layers of 1/8 or 1/4-inch (0.32 or 0.64 cm) thick strips must be wrapped around the pipe under the pipe clamps that attach the piping to building structures. Felt pads will compress under long time and high load application and must not be used alone to vibration isolate heavy equipment.

C-12.1.6 Cork Pads.

Cork pads, strips, or blocks may be used to isolate high frequency structure borne noise, but they are not recommended for high load bearing applications because cork gradually compresses under load and loses its resilience. High density construction cork is sometimes used to support one wall of a double wall. In this application, the cork will compress slightly with time, and it will continue to serve as a high frequency isolator (say, for structure borne noise above about 100 to 200 Hz), but it will not provide good low frequency isolation at equipment driving frequencies of about 10 to 60 Hz. Years ago, before other resilient materials came into widespread use, cork was often misused under heavy vibrating equipment mounts: full area cork pads were frequently loaded at rates of 1 to 5 lb/in^2 (0.071 to 0.352 kg/cm^2). This is such a low loading rate that the cork appears stiff and does not provide the desired resilience. If cork is to be used for vibration isolation, a load deflection curve must be obtained from the supplier, and the cork must be used in the central linear region of the curve (possibly loaded at about 10 to 20 lb/in^2 or 0.7 to 14.1 kg/cm^2). With this loading, the compressed material will have an initial deflection of about 5% and will continue to compress gradually with age.

C-12.1.7 Air Springs.

Air springs are the only practical vibration isolators for very low frequencies, down to about 1 Hz or even lower for special problems. An air mount consists of pressurized air enclosed in a resilient reinforced neoprene chamber. The air is pumped up to the necessary pressure to carry its load. Since the chamber is subject to very slow leakage, a system of air mounts usually includes a pressure sensing monitor and an air supply (either a pump or a pressurized air tank). A group of air mounts can be arranged to maintain very precise leveling of a base by automatic adjustment of the pressure in the various mounts. If air mounts are used in a design, an active air supply is required. Operational data must be obtained from the manufacturer.

C-12.2 Mounting Assembly Types.

In this paragraph, five basic mounting systems are described for the vibration isolation of equipment. Certain general conditions relating to all the systems are first mentioned.

C-12.2.1 General Conditions.

C-12.2.1.1 Building Uses.

Isolation recommendations are given for three general equipment locations: on grade slabs, on upper floors above noncritical areas, and on upper floors above critical areas. It is assumed that the building under consideration is an occupied building involving many spaces that would require or deserve the low noise and vibration environments of such buildings as hotels, hospitals, office buildings, and the like. Hence, the recommendations are aimed at providing low vibration levels throughout the building. If a building is intended to serve entirely such uses lobbies, kitchens, and machinery spaces, the recommendations given here are too severe and can be simplified at the user’s discretion. An on-grade slab usually represents a more rigid base than is provided by a framed upper floor, so the vibration isolation recommendations can be relaxed for on-grade installations. Of course, vibration isolation treatments must be the very best when a high-quality occupied area is located immediately under the MER, as compared with the case where a “buffer zone” or noncritical area is located between the MER and the critical area.

C-12.2.1.2 Structural Ties, Rigid Connections.

Each piece of isolated equipment must be free of any structural ties or rigid connections that can short-circuit the isolation joint.

- Flexible electrical conduit whip must be long and "floppy" so that it does not offer any resistance or constraint to the free movement of the equipment. Piping must be resiliently supported. Limit stops, shipping bolts, and leveling bolts on spring isolators must be set and inspected to ensure that they are not inadvertently short-circuiting the spring mounts.
- All building trash must be removed from under the isolated base of the equipment. Loose pieces of grout, 2x4s, nuts, bolts, soft drink bottles, beer cans, welding rods, pipes, and pipe couplings left under an equipment base can short-circuit the isolation mounts. It is recommended that 2-inch (5.1 cm) to 4-inch (10.2 cm) clearances be provided under all isolated equipment in order to facilitate inspection and removal of trash from under the base.
- For many equipment installations, there is no need to bolt down the isolation mounts to the floor because the smooth operation of the machine and the weight of the complete assembly keep the system from moving. For some systems, however, it may be necessary to restrain the equipment from "creeping" across the floor. In these situations, it is imperative that the hold-down bolts not short circuit the pads. A suggested restraining arrangement is illustrated in Figure C-22. Simpler versions can be devised.
- For buildings located in earthquake-prone areas, the isolation mounts must contain snubbers or motion-limiting devices that restrain the equipment against unusual amounts of movement. These snubbers must be set to provide adequate free movement for normal equipment operation. These devices are available from most suppliers of isolator equipment.

C-12.2.2 Type I Mounting Assembly.

The specified equipment must be mounted rigidly on a large integral concrete inertia block. (Unless specified otherwise, all concrete referred to in this manual must have a density of at least 140 to 150 lb/ft.^{3} or 2270 to 2432 kg/m^3)

- The length and the width of the inertia block must be at least 30 percent greater than the length and width of the supported equipment.
- Mounting brackets for stable steel springs must be located off the sides of the inertia block at or near the height of the vertical center-of-gravity of the combined completely assembled equipment and concrete block. If necessary, curbs or pedestals must be used under the base of the steel springs in order to bring the top of the loaded springs up to the center-of-gravity position. As an alternative, the lower portion of the concrete inertia block can be lowered into a pit or cavity in the floor so that the steel springs will not have to be mounted on curbs or pedestals. In any event, the clearance between the floor (or all the surfaces of the pit) and the concrete inertia block must be at least 4 inches, and provision must be allowed to check this clearance at all points under the block.

- Floor slab thickness. It is assumed that MER upper floor slabs will be constructed of dense concrete of 140-150 lb/ft3 (2270 to 2432 kg/m^{3}) density, or, if lighter concrete is used, the thickness will be increased to provide the equivalent total mass of the specified floor. For large MERs containing arrays of large and heavy equipment, it is assumed that the floor slab thickness will be in the range of 8 to 12 inches (20 to 31 cm), with the greater thicknesses required by the greater floor loads. For smaller MERs containing smaller collections of lighter weight but typical equipment, floor slab thicknesses of 6 to 10 inches (15 to 25 cm) are assumed. For occasional locations of one or a very few pieces of small high-speed equipment (say 1800 rpm or higher) having no reciprocating action, floor slabs of 4 to 6 inches (10 to 15 cm) may be used with reasonable expectation of satisfactory results. However, for reciprocating-action machines operating at the lower speeds (say, under 1200 rpm), any floor slab thicknesses reduced from those listed above begin to invite problems. There is no clear crossover from “acceptable” to “unacceptable” in terms of floor slab thickness, but each reduction in thickness increases the probability of later difficulties due to vibration. The thicknesses mentioned here are based on experience with the “acoustics” of equipment installations. These statements on thicknesses are in no way intended to represent structural specifications for a building. “House-keeping pads” under the equipment are assumed, but the height of these pads is not to be used in calculating the thickness of the floor slab.
- The ratio of the weight of the concrete block to the total weight of all the supported equipment (including the weight of any attached filled piping up to the point of the first pipe hanger) must be in accordance with the recommendations given in the paragraph and table for the equipment requiring this mounting assembly. The inertia block adds stability to the system and reduces motion of the system in the vicinity of the driving frequency. For reciprocating machines or for units involving large starting torques, the inertia block provides much-needed stability.
- The static deflection of the free-standing stable steel springs must be in accordance with the recommendations given in the paragraph and table for the equipment. There must be adequate clearance all around the springs to assure no contact between any spring and any part of the mounted assembly for any possible alignment or position of the installed inertia block.

C-12.2.3 Type II Mounting Assembly.

This mount is the same as the Type I mount in all respects except that the mounting brackets and the top of the steel springs must be located as high as practical on the concrete inertia block but not necessarily as high as the vertical center-of-gravity position of the assembly, and the clearance between the floor and the concrete block must be at least 2 inches (5.1 cm).

- If necessary, the steel springs can be recessed into pockets in the concrete block, but clearances around the springs must be large enough to assure no contact between any spring and any part of the mounted assembly for any possible alignment or position of the installed inertia block. Provision must be made to allow positive visual inspection of the spring clearance in its recessed mounting.
- When this type of mounting is used for a pump, the concrete inertia block can be given a T-shape plan, and the pipes to and from the pump can be supported rigidly with the pump onto the wings of the T. In this way, the pipe elbows will not be placed under undue stress.
- The weight of the inertia block and the static deflection of the mounts must be in accordance with the recommendations given in the table for the equipment.

C-12.2.4 Type III Mounting Assembly.

The equipment or the assembly of equipment must be mounted on a steel frame that is stiff enough to allow the entire assembly to be supported on flexible point supports without fear of distortion of the frame or misalignment of the equipment. Mount the frame on resilient mounts-steel springs or neoprene-in-shear mounts or isolation pads, as the static deflection would require. If the equipment frame itself already has adequate stiffness, no additional framing is required, and the isolation mounts may be applied directly to the base of the equipment.

- The vibration-isolation assembly must have enough clearance under and all around the equipment to prohibit contact with any structural part of the building during operation.
- If the equipment has large starting and stopping torques and the isolation mounts have large static deflections, give consideration to providing limit stops on the mounts. Limit stops might also be desired for large deflection isolators if the filled and unfilled weights of the equipment are very different.

C-12.2.5 Type IV Mounting Assembly.

The equipment must be mounted on an array of “pad mounts”. The pads may be of compressed glass fiber or of multiple layers of ribbed neoprene or waffle-pattern neoprene of sufficient height and of proper stiffness to support the load while meeting the static deflection recommended in the applicable accompanying tables. Cork, cork-neoprene, or felt pad materials may be used if their stiffness characteristics are known and if they can be replaced periodically whenever they have become so compacted that they no longer provide adequate isolation.

- The floor must be grouted or shimmed to assure a level base for the equipment and therefore a predictable uniform loading on the isolation pads.

- The pads must be loaded in accordance with the loading rates recommended by the pad manufacturer for the densities or durometers involved. In general, most of these pads are intended for load rates of 30 to 60 psi (2.1 to 4.2 kg/cm^2), and if they are underloaded (for example, at less than about 10 psi (0.7 kg.cm^2)), they will not be performing at their maximum effectiveness.

C-12.2.6 Type V Mounting Assembly (for Propeller-type Cooling Towers).

Large, low-speed propeller-type cooling towers located on roof decks of large buildings may produce serious vibration in their buildings if adequate vibration isolation is not provided. In extreme cases, the vibration may be evident two or three floors below the cooling towers.

- It is recommended that the motor, drive shaft, gear reducer, and propeller be mounted as rigidly as possible on a “unitized” structural support and that this entire assembly be isolated from the remainder of the tower with stable steel springs in accordance with paragraph C-12.3. Adequate clearance between the propeller tips and the cooling tower shroud must be provided to allow for starting and stopping vibrations of the propeller assembly. Several of the cooling tower manufacturers provide isolated assemblies as described here. This type of mounting arrangement is shown schematically in Figure C-23.
- In addition, where the cooling tower is located on a roof deck directly over an acoustically critical area, the structure-borne waterfall noise may be objectionable; it can be reduced by locating three layers of ribbed or waffle-pattern neoprene between the base of the cooling tower and the supporting structure of the building. This treatment is usually not necessary if there is a noncritical area immediately under the cooling tower.
- A single-treatment alternate to the combined two treatments of (1) and (2) above is the isolation of the entire cooling tower assembly on stable steel springs, also in accordance with paragraph C-12.3. The springs must be in series with at least two layers of ribbed or waffle-pattern neoprene if there is an acoustically critical area immediately below the cooling tower (or within about 25 feet (7.6 m) horizontally on the floor immediately under the tower). It is necessary to provide limit stops on these springs to limit movement of the tower when it is emptied and to provide limited movement under wind load.
- Pad materials, when used, must not be short-circuited by bolts or rigid connections. A schematic of an acceptable clamping arrangement for pad mounts is shown in Figure C-24. Cooling tower piping must be vibration-isolated in accordance with suggestions given for piping.

Figure C-23 Schematic of Vibration Isolation Mounting for Fan and Drive-Assembly of Propeller-Type Cooling Tower

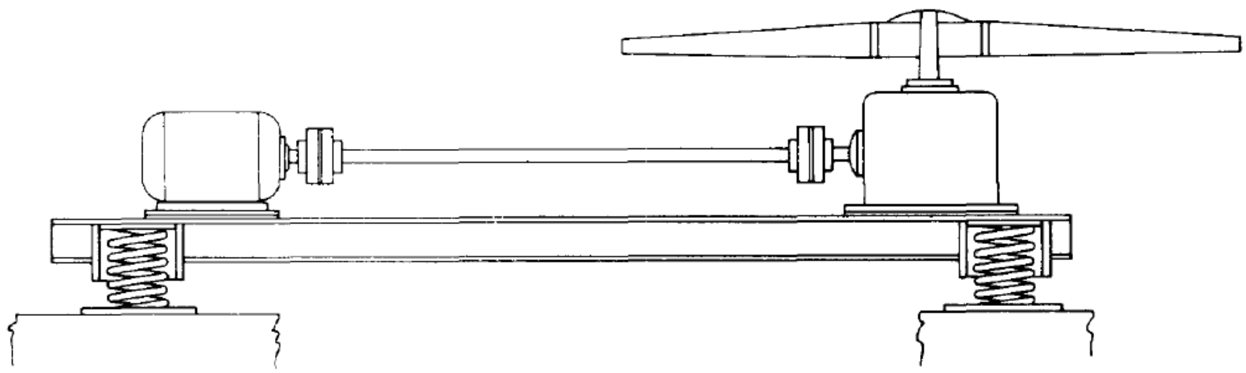
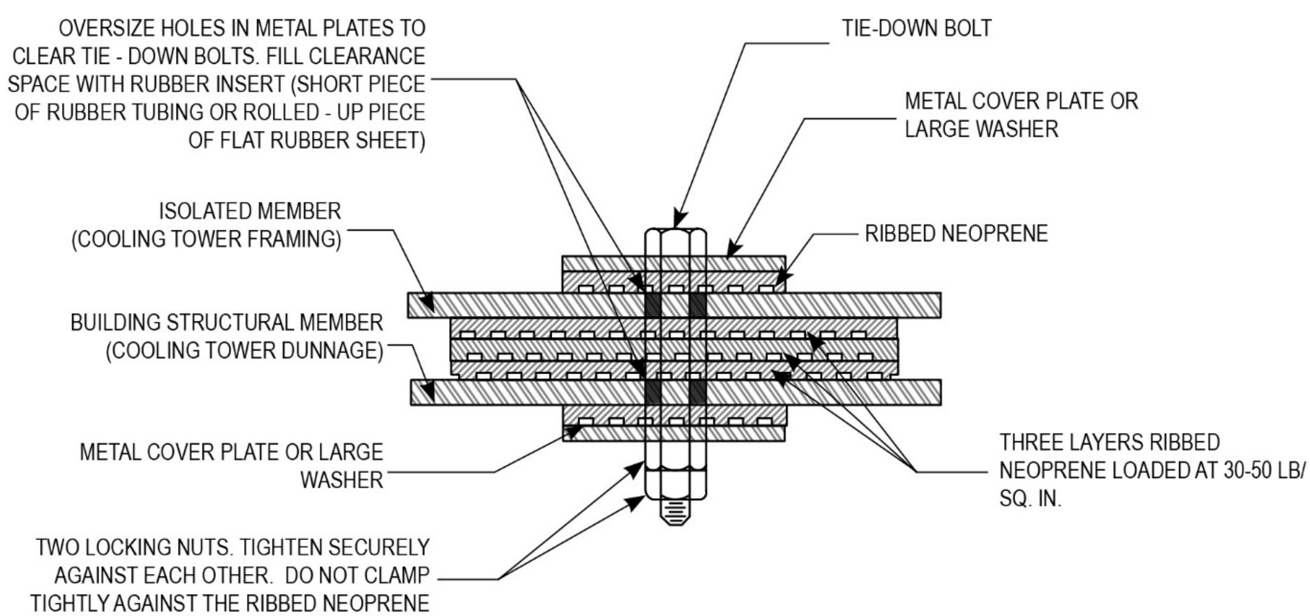


Figure C-24 Schematic of a Resilient Clamping Arrangement With Ribbed Neoprene Pads



C-12.3 Tables of Recommended Vibration Isolation Details.

C-12.3.1 Table Format.

A common format is used for all the tables that summarize the recommended vibration isolation details for the various types of equipment. A brief description of the format is given here.

C-12.3.1.1 Equipment Conditions.

The three columns on the left of the table define the equipment conditions covered by the recommendations: location, rating, and speed of the equipment. The rating is given by a power range for some equipment, cooling capacity for some, and heating capacity for some. The rating and speed ranges generally cover the range of equipment that might be encountered in a typical building. Subdivisions in rating and speed are made to accommodate variations in the isolation. If vibrating equipment is supported or hung from an overhead floor slab, immediately beneath an acoustically critical area, the same degree of vibration isolation must be provided as is recommended for the location designated as "on upper floor above critical area". Similarly, if the vibrating equipment is hung from an overhead floor slab beneath a noncritical area, the same vibration isolation should be provided as is recommended for the location designated as "on upper floor above noncritical area."

C-12.3.1.2 Mounting Recommendations.

In the following tables, the three columns on the right of the table summarize three basic groups of recommendations: Column 1, the type of mounting; Column 2, the suggested minimum ratio of the weight of the inertia block (when required) to the total weight of all the equipment mounted on the inertia block; and Column 3, the suggested minimum static deflection of the isolator to be used.

- When the weight of the inertia block is being considered, the larger weight of the range given must be applied where the nearby critical area is very critical, or where the speed of the equipment is near the lower limit of the speed range given or the rating of the equipment is near the upper limit of the rating range. Conversely, the lower end of the weight range may be applied where the nearby critical area is less critical, or where the speed is near the upper limit of the speed range, or the rating is near the lower limit of the rating range.
- When the static deflection of the isolators is being considered, these minimum values are keyed to the approximate span of the floor beams; that is, as the floor span increases, the floor deflection increases, and therefore the isolator deflection must increase. The specific minimum deflection in effect specifies the type of isolator that can be used; refer to Table C-39 for the normal range of static deflection for most isolators. Specific selections must be made from manufacturers' catalog data.
- The recommendations given here assume that a moderate amount of large equipment (say, more than five or six pieces, totaling more than about 300 to 600 hp) is located on the MER floor. For a smaller array of equipment or for a single piece of equipment remote from other equipment, the recommendations can be relaxed, either by decreasing the static deflection of the mount or by decreasing the weight of the inertia block or even by eliminating the inertia block where a critical area is not involved.
- Resilient support of all piping connected to vibrating equipment must be in accordance with paragraph C-12.4.1. This recommendation applies to the mounting of each piece of vibrating equipment, even though it is not repeated below for each piece of equipment.

C-12.3.2 Centrifugal and Axial-flow Fans.

The recommended vibration isolation mounting for fans are given in Table C-40. Ducts must contain flexible connections at both the inlet and discharge of the fans, and all connections to the fan assembly must be clearly flexible. The entire assembly can bounce with little restraint when one jumps up and down on the unit. Where supply fan assemblies are located over critical areas, it is desirable to install the entire inlet casing and all auxiliary equipment (coil decks and filter sections) on floated concrete slabs. The floated slab may also serve to reduce airborne noise from the fan inlet area into the floor area below. Large ducts (cross-section area over 15 sq feet) that are located within about 30 feet of the inlet or discharge of a large fan (over 20 hp) must be supported from the floor or ceiling with resilient mounts having a static deflection of at least 1/4 inch (0.64 cm).

Table C-40 Vibration Isolation Mounting for Centrifugal and Axial-flow Fans

Equipment Conditions			Mounting recommendations				
Equipment Location	Power Range (HP)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	Under 3	Under 600 600-1200 Over 1200		No Isolation Required			
	3-25	Under 600 600-1200 Over 1200	III	–	1 in. ½ ½		
	26-200	Under 600 600-1200 Over 1200	III	–	1 ½ in. 1 ½		
On Upper Floor Above Non-Critical Area	Under 3	Under 600 600-1200 Over 1200	III III III	– – –	1 in. ½ ½	1 ½ in. ¾ ½	2 in. 1 ¾
	3-25	Under 600 600-1200 Over 1200	II III III	2 in. – –	1 in. 1 ½ 1	1 ½ in. 2 1 ½	2 in. 3 2
	26-200	Under 600 600-1200 Over 1200	II II II	2 in. 2 2	2 in. 1 ½ 1	3 in. 2 1 ½	4 in. 3 2
On Upper Floor Above Critical Area	Under 3	Under 600 600-1200 Over 1200	II III III	2 in. – –	1 ½ in. 1 ½ 1	2 in. 2 1 ½	3 in. 3 2
	3-25	Under 600 600-1200 Over 1200	II II II	3 in. 2 2	2 in. 1 ½ 1	3 in. 2 1 ½	4 in. 3 2
	26-200	Under 600 600-1200 Over 1200	II II II	3 in. 2 2	3 in. 2 1	4 in. 2 ½ 1 ½	5 in. 3 2

Apply conversion to material dimensions and distances when metric calculations are performed.

Col. 1: Mounting type (see text).
Col. 2: Minimum ratio of weight of inertia block to total weight of supported load.
Col 3: Minimum static deflection of stable steel springs in inches for indicated floor span in feet.

C-12.3.3 Reciprocating Compressor Refrigeration Equipment.

The recommended vibration isolation for this equipment is given in Table C-41. These recommendations apply also to the drive unit used with the reciprocating compressor. Pipe connections from this assembly to other equipment must contain flexible connections.

Table C-41 Vibration Isolation Mounting for Reciprocating Compressor Refrigeration Equipment Assembly

<table>
<tr><th colspan="3">Equipment Conditions</th><th colspan="5">Mounting recommendations</th></tr>
<tr><td rowspan="2">Equipment Location</td><td rowspan="2">Cooling Capacity (Tons)</td><td rowspan="2">Speed Range (rpm)</td><td rowspan="2">Column 1</td><td rowspan="2">Column 2</td><td colspan="3">Column 3</td></tr>
<tr><td>30 ft.</td><td>40 ft.</td><td>50 ft.</td></tr>
<tr><td rowspan="6">On Grade Slab</td><td rowspan="3">10-50</td><td>600-900</td><td>III</td><td></td><td colspan="3">2 in.</td></tr>
<tr><td>901-1200</td><td>III</td><td></td><td colspan="3">1 ½</td></tr>
<tr><td>1201-2400</td><td>III</td><td></td><td colspan="3">1</td></tr>
<tr><td rowspan="3">51-175</td><td>600-900</td><td>II</td><td>2-3 in.</td><td colspan="3">2 in.</td></tr>
<tr><td>901-1200</td><td>III</td><td></td><td colspan="3">2</td></tr>
<tr><td>1201-2400</td><td>III</td><td></td><td colspan="3">½</td></tr>
<tr><td rowspan="6">On Upper Floor Above Non-Critical Area</td><td rowspan="3">10-50</td><td>600-900</td><td>II</td><td>2-3 in.</td><td>2 in.</td><td>3 in.</td><td>4 in.</td></tr>
<tr><td>901-1200</td><td>II</td><td>2-3</td><td>1 ½</td><td>2</td><td>3</td></tr>
<tr><td>1201-2400</td><td>II</td><td>2-3</td><td>1 ½</td><td>1 ½</td><td>2</td></tr>
<tr><td rowspan="3">51-175</td><td>600-900</td><td>II</td><td>3-4 in.</td><td>3 in.</td><td>4 in.</td><td>5 in.</td></tr>
<tr><td>901-1200</td><td>II</td><td>3-4</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>1201-2400</td><td>II</td><td>2-3</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td rowspan="6">On Upper Floor Above Critical Area</td><td rowspan="3">10-50</td><td>600-900</td><td>II</td><td>3-4 in.</td><td>3 in.</td><td>4 in.</td><td>5 in.</td></tr>
<tr><td>901-1200</td><td>II</td><td>3-4</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>1201-2400</td><td>II</td><td>2-3</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td rowspan="3">51-175</td><td>600-900</td><td>I</td><td>4-6 in.</td><td>3 in.</td><td>4 in.</td><td>5 in.</td></tr>
<tr><td>901-1200</td><td>II</td><td>3-5</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>1201-2400</td><td>II</td><td>3-4</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td colspan="8">Apply conversion to material dimensions and distances when metric calculations are performed.
Col 1: Mounting type (see text)
Col 2: Minimum ratio of weight of inertia block to total weight of supported load
Col 3: Minimum static deflection of stable steel springs in inches for indicated floor span in feet.</td></tr>
</table>

C-12.3.4 Rotary-screw-Compressor Refrigeration Equipment.

The recommended vibration isolation for this equipment is given in Table C-42.

Table C-42 Vibration Isolation Mounting for Rotary Screw Compressor Refrigeration Equipment Assembly

Equipment Conditions			Mounting recommendations				
Equipment Location	Cooling Capacity (Tons)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	100-500	2400-4800	III		1 in.		
On Upper Floor Above Non-Critical Area	100-500	2400-4800	III		1 in.	1½ in.	2 in.
On Upper Floor Above Critical Area	100-500	2400-4800	II	2-3 in.	1 in.	1½ in.	2 in.

Apply conversion to material dimensions and distances when metric calculations are performed.

Col. 1: Mounting type (see text).
Col. 2: Minimum ratio of weight of inertia block to total weight of supported load.
Col. 3: Minimum static deflection of stable steel springs in inches for indicated floor span in feet.

C-12.3.5 Centrifugal Compressor Refrigeration Equipment.

The recommended vibration isolation for this equipment, including the drive unit and the condenser and chiller tanks, are given in Table C-43.

Table C-43 Vibration Isolation Mounting for Centrifugal Compressor Refrigeration Equipment Assembly.

Equipment Conditions			Mounting recommendations				
Equipment Location	Cooling Capacity (Tons)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	100-500	OVER 3000	III		¾ in.		
	501-4000	OVER 3000	III		1 in.		
On Upper Floor Above Non-Critical Area	100-500	OVER 3000	III		1 in.	1½ in.	2 in.
	501-4000	OVER 3000	III	1 ½ in.	1 ½	2	3
On Upper Floor Above Critical Area	100-500	OVER 3000	II	2-3	1 ½	2	3
	501-4000	OVER 3000	II	3-5	1 ½	2	3

Apply conversion to material dimensions and distances when metric calculations are performed.

Col. l: Mounting type (see text).
Col. 2: Minimum ratio of weight of inertia block to total weight or supported load.
Col. 3: Minimum static deflection of stable steel springs in inches tor indicated floor span in feet.

C-12.3.6 Absorption-type Refrigeration Equipment.

The recommended vibration isolation for this equipment is given in Table C-44.

Table C-44 Vibration Isolation Mounting for Absorption-Type Refrigeration Equipment Assembly

Equipment Conditions			Mounting recommendations				
Equipment Location	Cooling Capacity (Tons)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	ALL SIZES		IV		½ in.		
On Upper Floor Above Non-Critical Area	ALL SIZES		III		½ in.	¾ in.	1 in.
On Upper Floor Above Critical Area	ALL SIZES		III		1 in.	1 ½ in.	2 in.

Apply conversion to material dimensions and distances when metric calculations are performed.

Col. 1: Mounting type (see text).
Col. 2: Minimum ratio of weight of inertia block to total weight of supported load.
Col. 3: Minimum static deflection or isolators in inches for indicated floor span in feet.

C-12.3.7 Boilers.

The recommended vibration isolation for boilers is given in Table C-45. These apply for boilers with integrally attached blowers. Follow Table C-40 for the support of blowers that are not directly mounted on the boiler. A flexible connection or a thermal expansion joint must be installed in the exhaust breaching between the boiler and the exhaust stack.

Table C-45 Vibration Isolation Mounting for Boilers

Mounting recommendations						
Equipment Location	Heating Capacity (bhp)	Column 1	Column 2	Column 3		
				30 ft.	40 ft.	50 ft.
On Grade Slab	Under 200 200 - 1000 Over 1000	–		Not required		
On Upper Floor Above Non-Critical Area	Under 200	III		1/8 in.	½ in.	½ in.
	200-1000	III		½	½	1
	Over 1000	III		½	½	1
On Upper Floor Above Critical Area	Under 200	III		½	1	1 ½
	200-1000	III		1	1 ½	2
	Over 1000	III		1	1 ½	2

C-12.3.8 Steam Valves.

Steam valves are usually supported entirely on their pipes; paragraph C-12.4.1 must be applied to the resilient support of steam piping, including steam valves.

C-12.3.9 Cooling Towers.

The recommended vibration isolation for propeller-type cooling towers is given in Table C-46. Additional for the installation are given in paragraph C-12.2.6, which describes the Type V mounting assembly. The recommended vibration isolation for centrifugal-fan cooling towers is given in Table C-47.

Table C-46 Vibration Isolation Mounting for Propeller-Type Cooling Towers

Equipment Conditions			Mounting recommendations			
Equipment Location	Power Range (hp)	Speed Range (rpm)	Column 1	Column 2	Column 3	
On Grade Slab	Vibration isolation usually not required					
On Upper Floor Above Non-Critical Area	Under 25	150-300 301-600 Over 600	V	Install On	5 in. 3 3	SPRINGS MAY BE LOCATED
	25-150	150-300 301-600 Over 600	V	Dunnage Attached To	6 in. 4 3	UNDER DRIVE ASSEMBLY
	Over 150	150-300 301-600 Over 600	V	Building Columns Only	6 in. 5 4	OR UNDER TOWER BASE
On Upper Floor Above Critical Area	Same as for location above noncritical area, except install ribbed or waffle pattern neoprene between tower and building.					
Apply conversion to material dimensions and distances when metric calculations are performed. Col. l: Mounting type (see text). Col. 2: Minimum ratio of weight of inertia block to total weight or supported load (not applicable here). Col. 3: Minimum static deflection of stable steel springs in inches.						

Table C-47 Vibration Isolation Mounting for Centrifugal-Type Cooling Towers

Equipment Conditions			Mounting recommendations				
Equipment Location	Power Range (HP)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	Vibration isolation usually not required						
On Upper Floor Above Non-Critical Area	Under 25	450-900 901-1800 Over 1800	III		1 in. ¾ ¾	1 ½ in. 1 1	2 in. 1 ½ 1 ½
	25-150	450-900 901-1800 Over 1800	III		1 ½ in. 1 ¾	2 in. 1 ½ 1	3 in. 2 1 ½
	Over 150	450-900 901-1800 Over 1800	III		2 in. 1 ½ 1	3 in. 2 1 ½	4 in. 3 2
On Upper Floor Above Critical Area	Under 25	450-900 901-1800 Over 1800	III	Include ribbed or waffle-pattern neoprene between tower and building.	1 ½ in. 1 ¾	2 in. 1 ½ 1	3 2 1 ½
	25-150	450-900 901-1800 Over 1800	III		2 in. 1 ½ 1	3 in. 2 1 ½	4 in. 3 2
	Over 150	450-900 901-1800 Over 1800	III		3 in. 1 ½ 1	4 in. 2 1 ½	6 in. 3 2

Apply conversion to material dimensions and distances when metric calculations are performed.

Col. I: Mounting type (see text).
Col. 2: Minimum ratio or weight or inertia block to total weight of supported load.
Col. 3: Minimum static deflection of stable steel springs in inches for indicated floor span in feet.

C-12.3.10 Motor- Pump Assemblies.

Recommended vibration isolation for motor-pump units is given in Table C-48. Make electrical connections to the motors with long “floppy” lengths of flexible armored cable, and piping must be resiliently supported. For most situations, a good isolation mounting of the piping will overcome the need for flexible connections in the pipe. An important function of the concrete inertia block (Type II mounting) is its stabilizing effect against undue bouncing of the pump assembly at the instant of starting. This gives better long-time protection to the associated piping. These same recommendations may be applied to other motor-driven rotary devices such as centrifugal-type air compressors and motor-generator sets in the power range up to a few hundred horsepower.

Table C-48 Vibration Isolation Mounting for Motor-Pump Assemblies

Equipment Conditions			Mounting Recommendations				
Equipment Location	Power Range (hp)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	Under 20	450-900 901-1800 1801-3600	Vibration isolation usually not required for acoustic purposes.				
	20-100	450-900 901-1800 1801-3600	II II II	2-3 in. 1 ½ - 2 ½ 1 ½ - 2 ½	1 ½ in. 1 3/4		
	Over 100	450-900 901-1800 1801-3600	II II II	2-3 in. 2-3 1 ½ 2 ½	2 in. 1 ½ 1		
On Upper Floor Above Non-Critical Area	Under 20	450-900 901-1800 1801-3600	II II II	2-3 in. 1 ½ - 2 ½ 1 ½ - 2 ½	1 ½ in. 1 3/4	2 in. 1 ½ 1	3 in. 2 1 1/2
	20-100	450-900 901-1800 1801-3600	II II II	2-3 in. 2-3 1 ½ - 2 ½	1 ½ in. 1 1	2 in. 1 ½ 1 ½	3 in. 2 2
	Over 100	450-900 901-1800 1801-3600	II II II	3-4 in. 2-3 2-3	2 in. 1 ½ 1	3 in. 2 1 ½	4 in. 3 2
On Upper Floor Above Critical Area	Under 20	450-900 901-1800 1801-3600	II II II	3-4 in. 2-3 2-3	1 ½ in. 1 ¾	2 in. 1 ½ 1	3 in. 2 1 ½
	20-100	450-900 901-1800 1801-3600	II II II	3-4 in. 2-3 2-3	2 in. 1 ½ 1	3 in. 2 1 ½	4 in. 3 2
	Over 100	450-900 901-1800 1801-3600	II II II	3-4 in. 2-3 2-3	3 in. 2 1 ½	4 in. 3 2	5 in. 4 3

Apply conversion to material dimensions and distances when metric calculations are performed.

Col. I: Mounting type (see text).
Col. 2: Minimum ratio or weight or inertia block to total weight or supported load.
Col. 3: Minimum static deflection or stable steel springs in inches for indicated floor span in feet.

C-12.3.11 Steam Turbines.

Table C-49 provides a set of general isolation recommendations for steam-turbine-driven rotary equipment, such as gears, generators, or centrifugal-type gas compressors. The material given in Table C-43 applies when a steam turbine is used to drive centrifugal-compressor refrigeration equipment. The recommendations given in Table C-41 apply when a steam turbine is used to drive reciprocating-compressor refrigeration equipment or reciprocating-type gas compressors.

Table C-49 Vibration Isolation Mounting for Steam-Turbine Driven Rotary Equipment

Equipment Conditions			Mounting recommendations				
Equipment Location	Power Range (hp)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	500-1500	Over 3000	III		½ in.		
	1501-5000	Over 3000	III		¾		
	5001-150000	Over 3000	III		1		
On Upper Floor Above Non-Critical Area	500-1500	Over 3000	III		1 in.	1 ½ in.	2 in.
	1501-5000	Over 3000	III		1 ½	2	3
	5001-150000	Over 3000	III		2	3	4
On Upper Floor Above Critical Area	500-1500	Over 3000	II	2-3 in.	1 ½	1 ½	2
	1501-5000	Over 3000	II	2-3	1 ½	2	3
	5001-150000	Over 3000	II	2-3	2	3	4
Apply conversion to material dimensions and distances when metric calculations are performed							
Col. 1: Mounting type (see text). Col. 2: Minimum ratio of weight of inertia block to total weight of supported load. Col. 3: Minimum static deflection of stable steel springs in inches for indicated floor span in feet.							

C-12.3.12 Gears.

When a gear is involved in a drive system, vibration isolation must be provided in accordance with recommendations given for either the main power drive unit or the driven unit, whichever imposes the more stringent isolation conditions.

C-12.3.13 Transformers.

Recommended vibration isolation for indoor transformers is given in Table C-50. In addition, power leads to and from the transformers must be as flexible as possible. In outdoor locations, earth-borne vibration to nearby neighbors is usually not a problem, so no vibration isolation is suggested. When vibration becomes a problem, the transformer could be installed on neoprene or compressed glass fiber pads having 1/4-inch (.64cm) static deflection.

Table C-50 Vibration Isolation Mounting for Transformers

Equipment Conditions			Mounting recommendations				
Equipment Location	Power Range (kva)	Speed Range (rpm)	Column 1	Column 2	Column 3		
					30 ft.	40 ft.	50 ft.
On Grade Slab	Under 10		IV		1/8 in.		
	10-100		IV		1/8 in.		
	Over 100		IV		½ in.		
On Upper Floor Above Non-Critical Area	Under 10		IV		1/8 in.	½ in.	½ in.
	10-100		III		½	½	½ i
	Over 100		III		½	½	1
On Upper Floor Above Critical Area	Under 10		III		½	½	¾
	10-100		III		½	¾	1
	Over 100		III		½	1	1 ½
Apply conversion to material dimensions and distances when metric calculations are performed.							

Col. 1: Mounting type (see text).
Col. 2: Minimum ratio of weight of inertia block to total weight of supported load.
Col. 3: Minimum static deflection of isolators in inches for indicated floor span in feet.

C-12.3.14 Air Compressors.

Recommended mounting for centrifugal type air compressors of less than 10 hp are the same as those given for motor-pump units in Table C-48. The same recommendations would apply for small (under 10 hp) reciprocating type air compressors. For reciprocating type air compressors (with more than two cylinders) in the 10 to 50 hp range, the recommendations given in Table C-41 apply for the conditions. For 10 to 100 hp, one-or two-cylinder, reciprocating type air compressors, the recommendations of Table C-51 apply. This equipment is a potential serious source of low frequency vibration in a building when it is not isolated. In fact, the compressor must not be in certain parts of the building, even if it is vibration isolated. The locations to avoid are indicated in Table C-51. When these compressors are used, all piping should contain flexible connections (paragraph C-14.4.2), and the electrical connections must be made with flexible armored cable.

Table C-51 Vibration Isolation Mounting for One or Two-Cylinder Reciprocating-Type Air Compressors in the 10-to l00-hp Size Range

Equipment Conditions			Mounting Recommendations				
Equipment Location	Power Range (kva)	Speed Range (rpm)	Column 1	Column 2	Column 3 30 ft.	Column 3 40 ft.	Column 3 50 ft.
On Grade Slab	Under 20	300-600	I	4-8 in.	4 in.		
		601-1200	I	2-4	2		
		1201-2400	I	1-2	1		
	20-100	300-2400	I	6-10 in.	5 in.		
			I	3-6	3		
			I	2-3	1 ½		
On Upper Floor Above Non-Critical Area	Under 20	300-600	Not recommended				
		601-1200	I	3-6 in.	4 in.	NO[a]	NO[a]
		1201-2400	I	2-3	2	4	NO[a]
	20-100	300-600	Not recommended				
		601-1200	Not recommended				
		1201-2400	I	3-6 in.	3 in.	6 in.	NO[a]
On Upper Floor Above Critical Area	Under 20	300-600	Not recommended				
		601-1200	Not recommended				
		1201-2400	I	3-6 in.	4 in.	NO[a]	NO[a]
	20-100	300-2400	Not recommended				

Apply conversion to material dimensions and distances when metric calculations are performed.
Col. l: Mounting type (see text).
Col. 2: Minimum ratio of weight of inertia block to total weight of supported load.
Col. 3: Minimum static deflection of stable steel springs in inches for indicated floor span in feet.
a. 'NO" indicates "NOT RECOMMENDED" for this combination of conditions.

C-12.3.15 Natural-gas and Liquid-fuel Engines, Reciprocating and Turbine.

Vibration isolation of these engines is discussed in detail in the **Inactive** UFC 3-450-02 Power Plant Acoustics.

C-12.4 Vibration isolation - Miscellaneous.

C-12.4.1 Resilient Pipe Supports.

All piping in the MER that is connected to vibrating equipment must be supported from resilient ceiling hangers or from floor-mounted resilient supports.

- As a rule, the first three pipe supports nearest the vibrating equipment must have a static deflection of at least one-half the static deflection of the mounting system used with that equipment. Beyond the third pipe support, the static deflection can be reduced to 1/4 inch (0.64 cm) or 1/2 inch (1.3 cm) for the remainder of the pipe run in the MER.
- When a pipe passes through the MER wall, a minimum 1-inch (2.54 cm) clearance must be provided between the pipe and the hole in the wall. The pipe must be supported on either side of the hole, so that the pipe does not rest on the wall. The clearance space must then be stuffed with fibrous filler material and sealed with a nonhardening caulking compound at both wall surfaces.
- Vertical pipe chases through a building must not be located beside acoustically critical areas. When they are located beside critical areas, pipes must be resiliently mounted from the walls of the pipe chase for a distance of at least 10 feet (3.05 meters) beyond each such area, using both low-frequency and high-frequency isolation materials.
- Pipes to and from the cooling tower must be resiliently supported for their full length between the cooling tower and the associated MER. Steam pipes must be resiliently supported for their entire length of run inside the building. Resilient mounts must have a static deflection of at least 1/2 inch (1.3 cm).
- In highly critical areas, domestic water pipes and waste lines can be isolated with the use of 1/4-inch (0.64 cm) to 1/2-inch (1.3 cm) thick wrappings of felt pads under the pipe strap or pipe clamp.
- Whenever a steel spring isolator is used, it must be in series with a neoprene isolator. For ceiling hangers, a neoprene washer or grommet must always be included; and if the pipe hangers are near very critical areas, the hanger must be a combination hanger that contains both a steel spring and a neoprene-in-shear mount.
- During inspection, the hanger rods must be checked to ensure they are not touching the sides of the isolator housing and thereby shorting-out the spring.

C-12.4.2 Flexible pipe connections.

To be effective, a flexible pipe connection must have a length that is approximately 6 to 10 times its diameter. Tie rods must not be used to bolt the two end flanges of a flexible connection together. Flexible connections are either of the bellows type or are made up of wire-reinforced neoprene piping, sometimes fitted with an exterior braided jacket to confine the neoprene. These connections are useful when the equipment is subject to high-amplitude vibration, such as for reciprocating-type compressors. Flexible connections generally are not necessary when the piping and its equipment are given thorough and compatible vibration isolation. For serious pipe vibration problems, two flexible connections can be used, mounted 90 degrees to each other. Inertial masses may be attached to the piping to add stability and help maintain pipe alignment.

C-12.4.3 Non-vibrating Equipment.

When an MER is located directly over or near a critical area, it is usually desirable to isolate most of the nonvibrating equipment with a simple mount made up of one or two pads of neoprene or a 1-inch (2.54 cm) or 2 inch (5.1cm) layer of compressed glass fiber. Heat exchangers, hot water heaters, water storage tanks, large ducts, and some large pipe stands may not themselves be noise sources, yet their pipes or their connections to vibrating sources transmit small amounts of vibrational energy that they then may transmit into the floor. A simple minimum isolation pad will usually prevent this noise transfer.

C-12.4.4 Summary.

In this section, complete vibration isolation mounting is laid out for most of the equipment included in an MER. Most of these have been developed and proven over many years of use. Although all the entries of the accompanying tables have not been tested in actual equipment installations, the schedules are self-consistent in terms of various locations and degrees of required isolation. Hence, the mounting is considered realistic and reliable. They are not extravagant when considered in the light of the extremely low vibration levels required to achieve near inaudibility. The noise and vibration control methods given here are designed to be simple to follow and to put into use. If these methods and recommendations are carried out, with appropriate attention to detail, most equipment installations will be tailored to the specific needs of the building and will give very satisfactory results acoustically.

C-13 SOUND LEVELS FOR EQUIPMENT.

Due to the variety of equipment installed in buildings and the multiplicity of uses for each equipment item, there are several standards for measurement of sound from mechanical equipment. There are many ANSI standards that describe general procedures for the measurement of sound power levels and sound levels of equipment, both in the laboratory and in field. AHRI has produced several standards for the measurement of air-conditioning equipment. The noise level estimates given in this manual will probably equal or exceed the actual noise levels of approximately 80 to 90 percent of all those types of machinery that will be encountered in typical building use. In many cases, actual noise levels may fall 3 to 6 dB below the estimates, and for some types of equipment some noise levels may fall as much as 10 to 15 dB below the estimates. Thus, there appears to be no shortage of available equipment that will fall at or below the estimated noise levels given in the manual, and it would not be discriminatory or unreasonable to specify that any purchased equipment for a particular building be required not to exceed the estimated values given here for that equipment. This is especially true if the actual acoustic design of a wall or floor or room treatment is dependent upon one or two particularly noisy pieces of equipment. A noise specification would not be necessary for relatively quiet equipment that does not dictate noise control design for the MER or the building.

C-13.1 Exemptions and Waiver.

If a noise level specification is required to be met for a particular piece of equipment, and this becomes a “hardship” on the manufacturer or the owner in terms of cost or availability, depending on the response of all the bidders, utilize the exemption and waiver process and the noise specification may possibly be exempted or waived. If some bidders agree to meet the specification while others do not, this could be a valid basis for selecting the quieter equipment.

If no bidders can meet the specification, it may be necessary to reevaluate the noise control requirements of the MER. If the equipment is so noisy that it is responsible for the noise design in the first place the specification can be exempted or waived via the exemption and waiver process. It is the primary purpose of this UFC to prevent such situations. Too many waivers would negate the value of the noise evaluation as a part of the design phase of the building. When the equipment measured for this study represents a fair sampling, it is likely that most of the equipment would meet a noise specification.

C-13.2 Sample Specifications.

The sample noise level specifications given below offer a broad set of procedures and suggestions for specifying noise data (SPL or PWL) on any desired piece of equipment. This is not offered as a “standard” for noise measurements, however. Any acceptable and applicable measurement and specification procedure recommended by an appropriate standards group (such as ANSI, ISO, ASTM, IEEE, ASHRAE, or others) may be used as a basis for setting up an equipment noise specification.

C-13.2.1 Sample SPL Specifications.

Table C-52 is an example form of a SPL specification. The type of equipment and the desired maximum sound pressure levels are inserted in the appropriate blanks. The 3-foot (0.914 m) distance is taken from the nearest surface rather than from the acoustic center since the exact location of the acoustic center is not easily defined. A minimum room volume of 4000 ft^3 (113 m^3) is offered, but this could be modified to accept somewhat smaller rooms. Small rooms are more subject to standing wave fluctuations. Even at the 3-foot (0.914 m) distance, SPL values for the same source may vary as much as 5 to 7 dB from an outdoor to an indoor site (or from a large room to a small room). Since it is impractical to specify Room Constant limits for the measurement room, it then becomes necessary to judge or compare various sound level submittals in terms of their ability to meet the design need. A sound source measured in a large-volume room, in a highly absorbent room, or outdoors will produce lower sound levels than when measured in a small or reverberant room. This difference is an important aspect of comparing competitive equipment.

Table C-52 Sample Sound Pressure Level Specification

Octave Band (Hz)	Sound Pressure Level (dB re 20 miropascals)
31	____________
63	____________
125	____________
250	____________
500	____________
1000	____________
2000	____________
4000	____________
8000	____________

(Insert desired values in blanks)

C-13.2.2 Sample PWL Specification.

Table C-53 is an example form of a PWL specification.

1. The maximum sound pressure levels measured at a distance of 3 ft. from the (equipment in question) must not exceed the following decibel values in the nine octave frequency bands:

Table C-53 Sample Sound Power Level Specification

Octave Band (Hz)	Sound Power Level (dB re 10^{-12} watt)
31	______
63	______
125	______
250	______
500	______
1000	______
2000	______
4000	______
8000	______

(Insert desired values in blanks)

2. At least four sets of sound pressure level readings must be submitted with the bid, where each set is taken at a 3-ft (0.914 m). distance from each of the four principal orthogonal surfaces of the equipment. Each octave band reading of each set of readings must be no greater than the specified value of Item 1 above.
3. The test room in which the noise measurements are conducted must have a volume of not less than 4000 ft^3 (113 m^3)and all principal surface areas of the room must be described in sufficient acoustic detail to permit an estimation of the approximate Room Constant or Room Absorption for the space.
4. During the tests, the equipment must be in normal operation at not less than 50% full rated load (or at a specified mutually acceptable load' condition). The tests must be carried out by the equipment manufacturer or by an approved testing agency, having proven capability in noise measurements and using approved measurement equipment and acceptable measurement procedures. Approved "standards" of measurements must apply.
5. In lieu of the tests under Item 4 above, final testing for conformance with the Item 1 noise levels may be made following complete installation of the equipment in the customer's building, provided the equipment manufacturer will remove and replace the equipment at his own expense if it fails to meet the noise tests. To be acceptable, the replacement equipment must meet the noise tests. For the on-site tests, the equipment must be in normal operation at not less than 50% hill rated load (or at a specified mutually acceptable load condition), and the tests must be in accordance with the procedures given in Item 4 above.
6. For all noise tests, the ambient sound levels of the test area must be at least 10 dB below the specified levels of Item 1 above, and the octave

band sound measurement equipment must meet the applicable ANSI standards for that type of equipment.

During the tests, the equipment must be in normal operation at not less than 50% full rated load (or at a specified mutually acceptable load condition). The tests must be carried out by the equipment manufacturer or by an approved testing agency, having proven capability in noise measurements and using approved measurement equipment and acceptable measurement procedures. Approved "standards" of measurements must apply. In lieu of the tests under Item 2 above, final testing for conformance with the Item 1 noise levels may be made following complete installation of the equipment in the customer's building, provided the equipment manufacturer will remove and replace the equipment at his own expense if it fails to meet the noise tests. To be acceptable, the replacement equipment must meet the noise tests. For the on-site tests, the equipment must be in normal operation at not less than 50% full rated load (or at a specified mutually acceptable load condition), and the tests must be in accordance with the procedures given in Item 2 above. For all noise tests, the ambient sound levels of the test area must be at least 10 dB below the equipment sound levels, and the octave band sound measurement equipment must meet the applicable ANSI standards for that type of equipment. Sound pressure level readings (in decibels re 20 microPascals) and all other data (including test room size and acoustic characteristics) used in the determination of the sound power levels must be submitted with the bid.

C-14 SAMPLE RC MARK II RATING.

C-14.1 RC Mark II Rating Method.

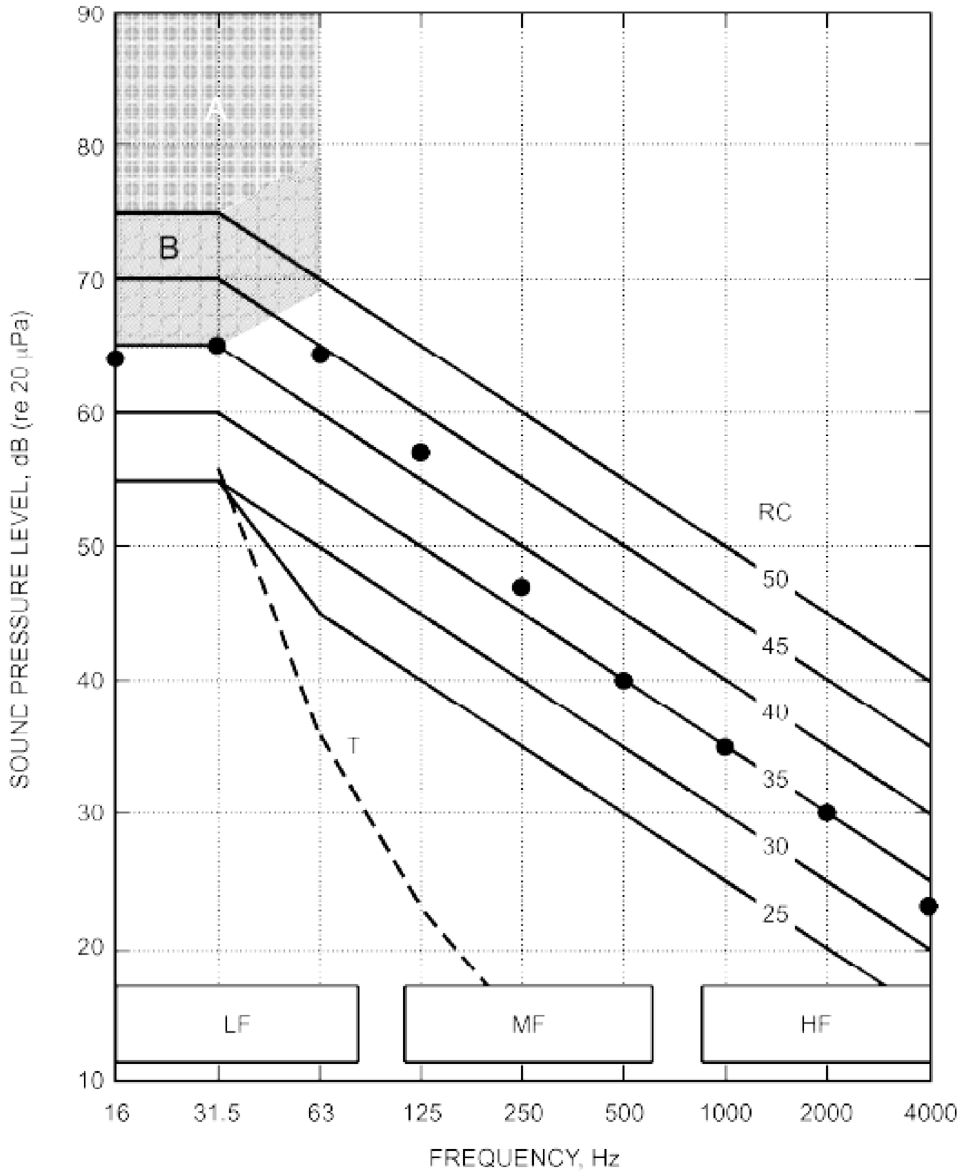
The following shows a sample plot and calculation for RC Mark II rating of known HVAC system noise levels. For additional information on procedures and applications of the RC Mark II method, see 2019 ASHRAE Handbook, Chapter 49 “Noise and Vibration Control. “Quality assessment index (QAI).

The quality assessment index (QAI) is a measurement of the deviation of the noise spectrum under evaluation from the shape of the RC reference curve. The QAI estimates the probable reaction of an occupant when system design does not produce optimum sound quality. The basis for estimating occupant satisfaction is that changes in sound level of less than 5 dB do not cause subjects to change their ranking of sounds of similar spectral content. However, level changes greater than 5 dB do significantly affect subjective judgments. Additional information on QAI is described in the 2019 ASHRAE Handbook, Chapter 49 “Noise and Vibration Control.”

C-14.2 Sample RC Mark II Rating.

Figure C-25 is an example of an RC Mark II rating plotted against RC curves. Table C-54 is a sample calculation of the RC Mark II Rating method using the data from Figure C-25.

Figure C-25 Example Plot of RC Mark II Rating



Note:

- Noise levels for lightweight wall and ceiling constructions:
  - In shaded region B are likely to generate vibration that may be perceptible. There is a slight possibility of rattles in light fixtures, doors, windows, etc.
  - In shaded region A have a high probability of generating easily perceptible noise-induced vibration. Audible rattling in light fixtures, doors, windows, etc. may be anticipated.
- Regions LF, MF, and HF are explained in the text.
- Solid dots are sound pressure levels for the example discussed in the text.

Table C-54 Example Calculation of RC Mark II Rating

	Frequency, Hz								
	16	**31**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Spectrum Levels	64	65	64	57	47	40	35	30	23
Average of 500 to 2000 Hz levels							35		
RC contour	60	60	55	50	45	40	35	30	25
Levels: RC contour	4	5	9	7	2	0	0	0	-2
		LF			MF			HF	
Special deviations		6.6			4.0			-0.6	
QAI					7.2				
RC Mark II rating					**RC 35 (LF)**				

1000, and 2000 Hz octave bands is 35 dB, so the RC 35 curve is selected as the reference for spectrum quality evaluation.

The spectral deviation factors in the LF, MF, and HF regions are 6.6, 4.0, and -0.6 respectively, giving a QAI of 7.2 The maximum positive deviation factor occurs in the LF region and QAI exceeds 5; therefore, the rating of the spectrum is RC 35 (LF). An average room occupant likely will perceive this spectrum as rumbly in character.

APPENDIX D GLOSSARY

D-1 ACRONYMS.

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
DRPR	Drip Proof
FGI	Facilities Guidelines Institute
IL	Insertion Loss
LEED	Leadership in Energy and Environmental Design
MER	Mechanical Equipment Room
NC	Noise Criterion
NIC	Noise Isolation Class
OSHA	Occupational Safety and Health Administration
PWL	Sound Power Level
RC	Room Constant
SD	Static Deflection
SPL	Sound Pressure Level
STC	Sound Transmission Class
STCc	Composite Sound Transmission Class
TEFC	Totally Enclose Fan-cooled
TL	Transmission Loss
TLc	Composite Transmission Class
UFC	Unified Facilities Criteria
U.S.	United States

D-2 DEFINITION OF TERMS.

Absorption: Conversion of acoustic energy to heat energy or another form of energy within the medium of sound-absorbing materials.

Absorption Coefficient: The ratio of sound energy absorbed by the acoustical material to that absorbed by a perfect absorptive material. It is expressed as a decimal fraction.

Average Sound Level and Average SPL: The arithmetic average of several related sound levels (or SPL in a specified frequency band) measured at different positions or different times, or both.

A-Weighting (dBA): A frequency response characteristic incorporated in sound-level meters and similar instrumentation. The A-weighted scale response de-emphasizes the lower frequencies and is therefore like the human hearing.

Background Noise: The total noise produced by all other sources associated with a given environment in the vicinity of a specific sound source of interest and includes any Residual Noise.

Decibel (dB): A unit for expressing the relative power level difference between acoustical or electrical signals. It is ten times the common logarithm of the ratio of two related quantities that are proportional to power.

Field Sound Transmission Class (FSTC): A single-number rating derived from measured values of field sound transmission loss in accordance with ASTM E-413, “Rating Sound Insulation”, and ASTM E-336, “Measurement of Airborne Sound Insulation in Buildings”. It provides an estimate of the performance of actual partitions in place and considers acoustical room effects.

Field Sound Transmission (FSTL): The sound loss through a partition installed in a building, in a Loss specified frequency band. It is the ratio of the airborne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side, expressed in decibels.

Frequency (Hz): The number of cycles occurring per second. (Hertz is a unit of frequency, defined as one cycle per second).

Noise: Any unwanted sound that can produce undesirable effects or reactions in humans.

Noise Criteria (NC): Octave band curves used to define acceptable levels of mechanical equipment noise in occupied spaces. Superseded by the Room Criteria (RC).

Noise Isolation Class (NIC): A single-number rating derived from measured values of noise reduction, as though they were values of transmission loss, in accordance with E-413. It provides an estimate of the sound isolation between two enclosed spaces that are acoustically connected by one or more paths.

Octave Band: A range of frequencies whose upper band limit frequency is nominally twice the lower band limit frequency.

Octave-Band Sound Level: The integrated sound pressure level of only those sin-wave Pressure components in a specified octave band, for a noise or sound having a wide spectrum.

Residual Noise: The measured sound level which represents the summation of the sound from all the discrete sources affecting a given site at a given time, exclusive of the Background Noise or the sound from a Specific Sound Source of interest. In acoustics, residual noise often is defined as the sound level exceeding 90% of a noise monitoring period.

Room Criteria (RC): Octave band criteria used to evaluate acceptable levels of mechanical equipment noise in occupied spaces.

Sound Power level (Lw or PWL): Ten times the common logarithm of the ratio of the total acoustic power radiated by a sound source to a reference power. A reference power of a picowatt or 10^{-12} watt is conventionally used.

Sound Pressure Level (Lp or SPL): Ten times the common logarithm to the base 10 of the ratio of the mean square sound pressure to the square of a reference pressure. Therefore, the sound pressure level is equal to 20 times the common logarithm of the ratio of the sound pressure to a reference pressure (20 microPascals or 0.0002 microbar).

Sound Transmission Class (STC): A single-number rating derived from measured values of transmission loss in accordance with ASTM E-413, “Classification for Rating Sound Insulation” and ASTM E-90, “Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions”. It is designed to give an estimate of the sound insulation properties of a partition or a rank ordering of   a series of partitions.

Sound Transmission Loss (TL): A measure of sound insulation provided by a structural configuration. Expressed in decibels, it is ten times the common logarithm of the sound energy transmitted through a partition, to the total energy incident upon the opposite surface.

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APPENDIX E REFERENCES

E-1 GOVERNMENT PUBLICATIONS.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.95

29 CFR 1910.95, *Occupational noise exposure*

UNIFIED FACILITIES CRITERIA (UFC)

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 3-101-01, *Architecture*

UFC 3-450-02 (Inactive), *Power Plant Acoustics*

E-2 INDUSTRY STANDARDS.

AIR CONDITIONING, HEATING, AND REFRIGERATION INSTITUTE (AHRI)

https://www.ahrinet.org/

AHRI Standard 575, *Method of Measuring Sound Within an Equipment Space*

AHRI Standard 885, *Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets*

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

https://ansi.org/

S1.4-1983/S1.4a-1985, *American National Standard Specification for Sound Level Meters*

S1.11-1966 (R 1976), *American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets*

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

https://www.ashrae.org/

2019 ASHRAE Handbook, Chapter 49, *Noise and Vibration Control*

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

https://www.astm.org/

ASTM C423, *Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method*

ASTM E90, *Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements*

ASTM E336, *Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings*

ASTM E413, *Classification for Rating Sound Insulation*

ASTM E477, *Standard Test Method for Laboratory Measurements of Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers*

ASTM E497, *Standard Practice for Installing Sound-Isolating Lightweight Partitions* (Withdrawn 2008)

ASTM E596, *Standard Test Method for Laboratory Measurement of Noise Reduction of Sound-Isolating Enclosures*

ASTM E756, *Standard Test Method for Measuring Vibration-Damping Properties of Materials*

ASTM E795, *Standard Practices for Mounting Test Specimens During Sound Absorption Tests*

ASTM E966, *Standard Guide for Field Measurements of Airborne Sound Attenuation of Building Facades and Facade Elements*

ASTM E1014, *Standard Guide for Measurement of Outdoor A-Weighted Sound Levels*

ASTM E1574, *Standard Test Method` for Measurement of Sound in Residential Spaces*

E-3 INDUSTRY PUBLICATIONS.

Engineering Noise Control, David A. Bies & C.H. Hansen, Unwin Hyman, Boston, MA 1988.

Noise Control in Buildings, Cyril M. Harris, McGraw-Hill, New York, NY 1994.

Noise Control in Building Services, Alan Fry, Pergamon Press, New York, NY 1988.

Noise & Vibration Control, Leo L. Beranek, The Institute of Noise Control Engineering, Washington, DC, 1988.

Noise and Vibration Control Engineering, Leo L. Beranek, & Istvan L. Ver, John Wiley & Sons, New York, NY 1992.

Noise & Vibration Control in Buildings, Robert S. Jones, McGraw-Hill, New York, NY 1984.

Shock & Vibration Handbook, 3rd Edition, Cyril M. Harris, McGraw-Hill, New York, NY 1988.

UFC 3-460-01
16 July 2019
Change 3, 08 June 2023

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: PETROLEUM FUEL FACILITIES

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: PETROLEUM FUEL FACILITIES

U.S. ARMY CORPS OF ENGINEERS

\2 NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity) **/2/**

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	1 May 2020	Chapters 2, 3, 4, 5, 7, 8, 10, 12, Appendix D. Main changes include removing AFFF use and clarified the criteria for Canopies.
2	12 January 2022	Chapters 2, 4, 5, 8, 9, 11, 15, and 16. Main change is adding Chapter 16 Austere Fuel Facilities. Other changes include providing distances between tanks and photovoltaic arrays, allowing non-metallic material for external stairways, and allowing the use of positive displacement pumps for product recovery return. Other changes includes updating reference documents.
3	08 Jun 2023	Chapters 2, 4, 6, 8, 9, 10, 12, Appendix E, Restored paragraphs which were inadvertently deleted during Change 2 publication. Other changes includes updating reference documents.

This UFC supersedes UFC 3-460-01, dated 16 July 2019.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

Refer to UFC 1-200-01, *General Building Requirements*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)

REVISION SUMMARY SHEET

Document: UFC 3-460-01, Design: Petroleum Fuel Facilities

Superseding: UFC 3-460-01, dated 16 July 2019, Change 2, dated 12 January 2022

Description: Unified Facilities Criteria (UFC) 3-460-01 contains general criteria and standard procedures for the design and construction of military land-based facilities which receive, store, distribute, or dispense liquid petroleum fuels. It is also applicable to liquefied petroleum gases (LPG) and compressed natural gas (CNG) facilities. These criteria are applicable to all branches of the Department of Defense (DoD) and the Defense Logistics Agency (DLA).

Reasons for Document: This update to UFC 3-460-01 incorporates changes to the design requirements for fuel facilities. These changes are based on lessons learned from the previous guidelines, new technologies, updated requirements by the services for fuel handling and quality, new regulations, coordinate with unified facilities guide specifications (UFGS), and other reference documents. Incorporation of these changes will decrease the life-cycle costs by ensuring the integrity of the fueling systems during operations and decreasing maintenance requirements.

Impact: The changes to this UFC will impact the design and cost of fuel facilities. However, the following benefits should be realized.

- Ensure that the fuel quality issued to the DoD aircraft, trucks, ships, and vehicles is such that no damage is realized to DoD assets.
- By ensuring that all fuel facilities will be standardized throughout the tri-services.
- Decrease the amount of maintenance and repair required on the fuel facility system.
- Exceptions for austere locations can be approved by Service Headquarters SME to avoid non-beneficial costs.

Unification Issues:

There are a few items that are either Navy, Air Force or Army specific. The list below summarizes these items, along with the justification for it to be Service Specific:

- The Navy requires the use of a fusible link butterfly valve at the inlet to truck fillstand and on supply and return risers at aircraft direct fueling stations. The Navy's position for fusible link valves is primarily because JP-5, which is primarily used by the Navy, does not have the static dissipater additive (SDA), so it is more likely to spark during transport thru pipelines and equipment than any other fuel. (Refer to paragraph 2-

3.14.3). The fusible link will shut if there is a fire or other high-temperature event. Also, the Navy's aircraft direct fueling stations are designed to hot refuel aircraft, so the fusible link will also protect the aircraft if there is a high-temperature event between the tank and the fusible link.

- The Air Force allows the use of internally coated filter-separators and piping from the filter-separators to the skin of the aircraft. Since it is Air Force policy to always filter the fuel at the skin of the aircraft, any paint and carbon particles in the fuel will be filtered before entering the aircraft. The Navy does not filter at the skin of the aircraft, therefore the filter-separator must be either aluminum or stainless steel, and the piping from the filter-separator to the aircraft is to be stainless steel. In addition, for Navy systems, the return line is also to be stainless steel if there is any possibility for recirculating the fuel without going thru two filtrations.
- This UFC references Service-Specific documents, which the tri-service fuel community does not oversee. Also, each service has its own requirements for fuel quality and operations.

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TABLE OF CONTENTS

TABLES

CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria, UFC 3-460-01, contains general criteria and standard procedures for the design and construction of military land-based facilities which receive, store, distribute, or dispense liquid fuels. It is also applicable to the handling of liquefied petroleum gases (LPG) and compressed natural gas (CNG). It provides guidance on the rehabilitation, deactivation, or closure of fueling facilities. Support facilities are also included. Facility Plate 001 provides assistance in identifying UFC chapter numbers for specific fueling components.

These criteria, except Chapters 12, 13, and 14 of this UFC, are intended for new construction only and do not apply retroactively to facilities existing at the time this UFC was issued. However, these criteria, including Chapters 12, 13, and 14, are applicable when modernizing or expanding existing facilities if the improvements can be justified in terms of obsolescence, expanded operational requirements, safety, environmental compliance, or excessive maintenance costs.

1-2 APPLICABILITY.

The guidance contained in this UFC is intended for use by facility planners, engineers, and architects for individual project planning and for preparing engineering and construction documentation for all real property facilities used for storing, distributing, and dispensing fuels for reciprocating and jet engine aircraft, automotive fuels, lubricating oils, and alternate fuels. In addition, it is intended for use by operations and maintenance personnel as a guidance document for facility design, modifications, and improvements.

1-3 DEPARTMENT OF DEFENSE (DOD) FUELS DISCIPLINE WORKING GROUP (FDWG).

This UFC was updated by the DoD Fuels Discipline Working Group (FDWG). The DoD FDWG consists of recognized POL experts, primarily from the engineering community, to establish the criteria for the DoD community on ways to provide safe, operationally effective, and economic DoD fuel facilities systems to meet the mission requirements. The FDWG will examine, develop, recommend, and provide design features for the standardization of facilities, system components, and equipment, and procedures used in fuel handling systems for storage, distribution, maintenance and dispensing of aircraft, marine, and ground fuels. The FDWG will evaluate facility component parts on DoD installations and will serve as a pool of expertise to assist in resolving systemic fuel handling facility problems. FDWG meetings will also serve as a forum to update members on new system components, and equipment, DoD or service-specific programs, and changes affecting the fuels maintenance, repair and construction community. Refer to Appendix B, Charter for DoD Fuels Discipline Working Group for more information.

1-4 SERVICE HEADQUARTERS SUBJECT MATTER EXPERTS (SME).

It is recognized that the policies, obligations, and responsibilities of the military branches may vary on some minor points. Therefore, consult the Subject Matter Expert at the appropriate Service Headquarters for interpretation. For the purposes of interpretation of this UFC, the Subject Matter Expert at the appropriate Service Headquarters is defined as follows:

a. Army – Headquarters, U.S. Army Corps of Engineers, POL Facilities Proponent (CECW-EC)

b. Air Force – The Air Force Fuels Facilities Subject Matter Expert (AFCEC/COSM) or officially designated alternate

c. Navy/Marine Corps – NAVFAC POL Facility Subject Matter Expert (NAVFAC EXWC, SH25)

1-4.1 Service Provider Subject Matter Expert (SME).

DLA Installation Support for Energy (DLA DS-FEI) is the Executive Agent as defined in DOD 4140.25M.

1-4.2 Service Control Point (SCP).

For the purposes of interpretation of this UFC, the Service Control Point is defined as follows:

a. Army – Army Petroleum Center

b. Air Force – Air Force Petroleum Office

c. Navy/Marine Corps – Naval Supply Systems Command - Energy

1-5 WAIVERS AND EXEMPTIONS.

For specific interpretations, waivers or exemption, contact the appropriate Service Headquarters Subject Matter Experts (SME) and refer to MIL-STD-3007 for the waiver process.

Recommended UFC language generated from recurring waivers and exemptions will be considered by the DoD Fuel Facilities Engineering Panel with supporting rationale for inclusion on FDWG voting agendas. Recommended changes to this UFC are then reviewed/approved by the voting members of the DoD Fuels Facilities Discipline Working Group, preferably in a normal recurring meeting.

1-6 POLICY.

Design petroleum fuel facilities to meet the operational and management requirements of the Command in which the facility is located, as well as to meet all applicable federal, state, and local regulations concerning environmental, health, safety, and fire protection issues.

1-7 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, DoD Building Code (General Building Requirements). UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFC and government criteria referenced therein.

1-8 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-9 REFERENCED STANDARDS.

The execution agency issuing a contract for design and/or construction services will direct the use of standard designs, guide specifications, and/or definitive drawings. In other situations, where these standards are not readily available, contact appropriate Service Headquarters for assistance in obtaining these documents.

1-10 GLOSSARY.

Appendix D contains acronyms, abbreviations, and definition of terms.

1-11 REFERENCES.

Appendix E contains a list of other criteria and references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

1-12 PROJECTS OUTSIDE OF THE UNITED STATES AND ITS TERRITORIES.

1-12.1 NATO Standards.

For fueling projects located outside of the United States and its territories, and in a NATO (North Atlantic Treaty Organization) country, review and comply with all appropriate host-nation regulations, NATO documents such as STANAG 3784, and this UFC.

1-12.2 Non-NATO Projects.

For fueling projects located outside of the United States and its territories, and not in a NATO country, use host-nation standards (if more stringent), this UFC, and applicable Service policy.

1-13 DOCUMENT HIERARCHY.

For the design of all DoD fueling projects, modify the UFGS and standard design drawings to meet the specific needs of the project. The document hierarchy in order of decreasing precedence is as follows:

a. Unified Facility Criteria (UFC)

b. Unified Facilities Guide Specification (UFGS)

c. DoD Standards

The UFCs, UFGSs, and DoD Standards must be site-adapted for each specific fueling facility.

CHAPTER 2 GENERAL DESIGN REQUIRMENTS

2-1 OPERATIONAL CAPABILITIES.

Design fuel facilities for continued operation using emergency or temporary expedients despite the loss of one or more components of the fuel receiving and/or dispensing system by enemy action or other factors. For tactical or mission-related fuel facilities, provide an alternative source of fuel supply to the fuel facility to ensure emergency operation under the most adverse conditions, including back up power (emergency generators). Maintain consistency with prescribed criteria in appropriate directives, instructions, and standard designs (including NATO Standards).

2-2 FUEL SPECIFICATIONS.

The following specifications apply to the various petroleum fuels that may be addressed:

a. MIL-DTL-5624, Turbine Fuel, Aviation, Grades JP-4 and JP-5.

b. MIL-DTL-38219, Turbine Fuel, Low Volatility, JP-7.

c. MIL-DTL-83133, Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34 and NATO F-35).

d. AFLP-3747 Guide Specifications (Minimum Quality Standards) for Aviation Turbine Fuels (F-24, F-27, F-34, F-35, F-37, F-40 and F-44).

e. MIL-DTL-25524, Turbine Fuel, Aviation, Thermally Stable (JPTS).

f. ASTM D1655, Standard Specification for Aviation Turbine Fuels.

g. CID A-A-52557, Fuel Oil, Diesel; for Posts, Camps and Stations.

h. CID A-A-59693, Diesel Fuel, Biodiesel Blend (B20).

i. MIL-DTL-16884, Fuel, Naval Distillate.

j. ASTM D3699, Standard Specification for Kerosene.

k. ASTM D4814, Standard Specification for Automotive Spark-Ignition Engine Fuel.

l. ASTM D910, Standard Specification for Aviation Gasoline (Avgas).

m. ASTM D975, Standard Specification for Diesel Fuel Oils.

n. MIL-DTL-87107, Propellant, High Density Synthetic Hydrocarbon Type, Grade JP-10.

o. ASTM D5798, Standard Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines.

p. ASTM D6751, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.

q. ASTM D7467, Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20).

r. ASTM D396, Standard Specification for Fuel Oils.

s. MIL-PRF-26536 Propellant, Hydrazine.

t. MIL-PRF-9000 Lubricating Oil, Shipboard Internal Combustion Engine, High-Output Diesel.

u. MIL-PRF-17331 Lubricating Oil, Steam Turbine & Gear, Moderate Service.

v. ASTM D1835, Standard Specification for Liquefied Petroleum (LP) Gases.

w. SAE J1616, Standard for Natural Gas Vehicle Fuel.

2-3 FUEL PROPERTIES AND ADDITIVES.

In addition to the fuel specifications, refer to Coordinating Research Council, Inc., CRC Report No. 635, Handbook of Aviation Fuel Properties, for additional fuel properties. The following paragraphs list typical physical properties of various grades of fuel and additives which would affect the design of a petroleum fuel facility. The NATO designation is shown in brackets.

2-3.1 Motor Gasoline (Mogas) [F-46] [ASTM D4814].

2-3.1.1 Physical Properties of Mogas.

a. Specific Gravity 0.70 to 0.78

b. Reid Vapor Pressure 0.58 to 15 psia (at 100 degrees F (38 degrees C))

c. Flash Point -31 degrees F (-35 degrees C) to -45 degrees F (-43 degrees C)

d. Viscosity <1 cSt (at 104 degrees F (40 degrees C))

2-3.1.2 Special Precautions for Mogas.

Because of its high volatility, gasoline produces large amounts of vapor at ordinary temperatures. When confined in a tank or container at liquid temperatures above 20 degrees F (-7 degrees C), the vapor space is normally too rich to be explosive. At temperatures 20 degrees F (-7 degrees C) or less, vapor spaces above gasoline may be in the explosive range. One gallon (3.785 L) of liquid gasoline when vaporized will occupy about 25 cubic feet (700 L) of space, and if permitted to escape and become diluted with air, it is highly flammable. Provide a design that precludes disposing of mogas into storm or sanitary sewers.

2-3.2 Aviation Gasoline (Avgas) [F-18] [ASTM D910].

2-3.2.1 Descriptions of Aviation Gasoline.

Aviation gasoline is a high-octane aviation fuel used for piston or Wankel engine powered aircraft. It is distinguished from motor gasoline, which is the everyday gasoline used in ground vehicles. In military service, avgas is seldom used in manned aircraft but is commonly used in Unmanned Aerial Vehicles (UAVs).

The Air Force has a standard design for small avgas fuel systems. Contact the Air Force Fuels Service Headquarters Subject Matter Expert (SME) for more information.

2-3.2.2 Avgas Grades.

100LL, spoken as "100 low lead", is the most common grade used in military applications. It is dyed blue and contains a maximum of 2 grams of lead per US gallon (0.56 grams/liter) and is the most commonly available and used aviation gasoline. Other grades that are theoretically available include Grade 80, Grade 91, Grade 100, and Grade 82UL. The differences between all 80, 91, 100, and 100LL are lead content and color. Grade 82UL is unleaded.

2-3.2.3 Physical Properties of Avgas (100 LL).

a. Specific Gravity 0.68 to 0.74

b. Reid Vapor Pressure 5.5 to 7.0 psia (at 100 degrees F (38 degrees C))

c. Flash Point < -35 degrees F (-37 degrees C)

d. Melting/Freezing Point < -72 degrees F (-58 degrees C)

2-3.2.4 Special Precautions for Avgas.

Using the wrong grade of gasoline will cause engine problems. Virtually all grades of avgas available contain tetra-ethyl lead (TEL) as a lead based anti-knock compound. See mogas for flammability issues.

2-3.3 Aviation Turbine Fuels.

2-3.3.1 Physical Properties of Aviation Turbine Fuels.

Table 2-1. Properties of Aviation Fuels

	Property					
Grade Number [NATO Code]	Relative Density	Specific Gravity	Reid Vapor Pressure at 100°F(38°C) psia (kPa)	Minimum Flash Point, °F (°C)	Average (kin.) Viscosity at 100°F (38°C), $ft^2/s \times 10^{-5}$ (cSt)	Freezing Point, °F (°C)
JP-4 [F-40]	57° to 45° API	0.751 to 0.802	2 to 3 (13.8 to 20.7)	-20 (-29)	0.9×10^{-5} (0.8)	-72 (-58)
JP-5 [F-44]	48° to 36° API	0.788 to 0.845	0.04 (0.3)	140 (60)	1.6×10^{-5} (1.5)	-61 (-52)
JP-8 [F-34]	51° to 37° API	0.775 to 0.840	0.05 (0.3)	100 (38)	1.9×10^{-5} (1.8)	-53 (-47)

	Property					
Grade Number [NATO Code]	Relative Density	Specific Gravity	Reid Vapor Pressure at 100°F(38°C) psia (kPa)	Minimum Flash Point, °F (°C)	Average (kin.) Viscosity at 100°F (38°C), $ft^2/s \times 10^{-5}$ (cSt)	Freezing Point, °F (°C)
JP-10	20° to 18.5° API	0.935 to 0.943	0.11 (0.8)	67 (19)	3.4×10^{-5} (3.2)	-110 (-79)
JPTS	53° to 46° API	0.767 to 0.797	0.11 (0.8)	110 (43)	1.3×10^{-5} (1.2)	-64 (-53)
Jet A	51° to 37° API	0.775 to 0.840	0.029 (0.2)	100 (38)	1.6×10^{-5} (1.5)	-40 (-40)
Additized Jet A [F-24]	51° to 37° API	0.775 to 0.840	0.029 (0.2)	100 (38)	1.6×10^{-5} (1.5)	-40 (-40)
Jet A-1 [F-35]	51° to 37° API	0.775 to 0.840	0.05 (0.3)	100 (38)	1.6×10^{-5} (1.5)	-53 (-47)
TS-1	51° API	0.708 to 0.838	3.11 (21.44)	82 (28)	$0.6 \text{ X } 10^{-5}$ (0.56)	-58 (-50)
Hydrazine	9° API	1.007	NA	126 (52)	NA	NA

2-3.3.2 Special Precautions for Aviation Turbine Fuels.

Because of the serious consequences of a turbine engine failure and the nature of the fuel systems in turbine engines, provide designs which include means to prevent contamination of aviation turbine fuels by dirt, water, or other types of fuels. Solid contaminants are generally those which are insoluble in fuel. Most common are iron rust, scale, sand, and dirt. Iron rust contaminates aviation turbine fuel. Special filtration is required for receiving aviation turbine fuel into bulk storage and operating storage to remove contaminants before the fuel is delivered to aircraft. To preserve fuel quality, limit materials in contact with the fuel to stainless steel, non-ferrous, or coated carbon steel for aircraft fueling systems. Do not use zinc, copper, and zinc- or copper-bearing alloys in contact with aviation turbine fuels, including pipe, valves, system components, and accessories. The maximum allowable aircraft servicing use limits of solids and free water are provided in MIL-STD-3004. Provide a design that precludes disposing of aviation turbine fuels into storm or sanitary sewers.

2-3.4 Kerosene [ASTM D3699].

2-3.4.1 Physical Properties of Kerosene.

a. Relative density

b. API Gravity 51 degrees to 37 degrees API

c. Specific Gravity 0.775 to 0.840

d. Reid Vapor Pressure 0.5 psia (3.5 kPa) (maximum at 100 degrees F (38 degrees C))

e. Flash Point (minimum) 100 degrees F (38 degrees C)

f. Viscosity at 104 degrees F (40 degrees C) 1 to 2 x 10-5 ft2/s (0.9 to 1.9 cSt.)

g. Freezing Point -22 degrees F (-30 degrees C) (maximum)

2-3.4.2 Special Precautions for Kerosene.

Design separate systems for kerosene to avoid discoloration caused by contamination. Provide a design that precludes disposing of kerosene into storm or sanitary sewers.

2-3.5 Diesel Fuels.

2-3.5.1 Sulfur Content of Diesel Fuels.

Diesel fuel that is available for motive fuel in the United States is Low Sulfur Diesel (LSD) which has a maximum sulfur content of 500 ppm and Ultra Low Sulfur Diesel (ULSD) which has a maximum sulfur content of 15 ppm, both meeting ASTM D975. Since ULSD has a sulfur content much less than LSD, very small concentrations of LSD will contaminate ULSD and mandate downgrading it to LSD. Take precautions when designing systems to ensure that cross contamination is prevented.

2-3.5.2 Physical Properties of Diesel Fuels.

Table 2-2. Physical Properties of Diesel Fuels

	Automotive DF-2 [F-54]	Diesel Fuel Marine [F-76]	Ultra Low Sulfur Diesel [ASTM D975]
(a) Relative Density API Gravity, °API (Specific Gravity)	40 to 34 (0.825 to 0.855)	39 to 33 (0.830 to 0.860)	30 (0.876)
(b) Reid Vapor Pressure at 100 °F (38 °C), psia (kPa)	0 (0)	0 (0)	0 (0)
(c) Flash Point, °F (°C)	131 (55)	140 (60)	150 (66)
(d) Viscosity at 104°F (40°C) ft^2/s (cSt)	2.0 to 4.4 x 10-5 (1.9 to 4.1)	1.8 to 4.6 x 10-5 (1.7 to 4.3)	2.7 x 10-5 (2.5)
(e) Pour Point, °F (°C)	10 (-12)	20 (-7)	0 (-18)

Notes: (1) JP-8 is currently used as arctic grade diesel fuel (DFA) in the Arctic and Antarctic for heating fuel. The gross heating value of JP-8 is 18,400 Btu/lb (42 800 kJ/kg).

(2) DF-1, winter grade diesel fuel, has a flash point of 100 degrees F (38 degrees C) and a viscosity of 1.4 to 2.6 x 10^{-5} ft^2/s (1.3 to 2.4 cSt) at 104 degrees F (40 degrees C).

2-3.5.3 Special Precautions for Low Sulfur Diesel Fuels.

While not as critical as with aviation turbine fuels, diesel fuel systems are subject to damage by dirt and water in the fuel. Avoid contamination by dirt and water or dilution by lighter fuels. In cold climates, provide designs that will prevent "gelling." Provide a design that precludes disposing of diesel fuels into storm or sanitary sewers.

2-3.5.4 Special Precautions for Ultra Low Sulfur Diesel.

With the reduction in sulfur content comes a reduction in overall lubricity and conductivity of the fuel. A lower lubricity level can cause premature wear and damage to metal parts in typical compression ignition engines. Lubricity additives are added in accordance with ASTM D975 . Lower conductivity can cause a potential for an increased risk in fire or explosion caused by static electricity. Even though a conductivity additive is added it is recommended that flow rates are limited and bonding and grounding of system components be utilized to minimize static electricity during loading operations.

2-3.6 Burner Fuel Oils.

2-3.6.1 Physical Properties of Burner Fuel Oils.

Table 2-3. Physical Properties of Burner Fuel Oils

	Grade Number					
	1	2	4	5 Light	5 Heavy	6
Relative Density °API	48 to 36	40 to 28	30 to 15	22 to 14	23 to 8	22 to 7
Specific Gravity	0.786 to 0.843	0.825 to 0.877	0.876 to 0.966	0.922 to 0.972	0.913 to 1.017	0.922 to 1.022
Reid Vapor Pressure at 100°F (38°C), psia (kPa)	< 0.1 (< 0.7)	< 0.1 (< 0.7)	< 0.1 (< 0.7)	< 0.1 (< 0.7)	< 0.1 (< 0.7)	< 0.1 (< 0.7)
Minimum Flash Point, °F (°C)	100 (38)	100 (38)	130 (54)	130 (54)	130 (54)	150 (66)
Average viscosity at 100°F (38°C), $ft^2/s \times 10^{-5}$(cSt)	1.5 to 2.4 (1.4 to 2.2)	2 to 3.3 (1.9 to 3.1)	11.3 to 70 (10.5 to 65)	70 to 215 (65 to 200)	323 to 969 (300 to 900)	208 to 807 (193 to 750)
Pour Point, °F (°C)	-10 (-23)	-5 (-21)	21 (-6)	20 to 30 (-7 to -1)	20 to 30 (-7 to -1)	30 to 70 (-1 to 21)
Gross Heat Value, Btu/lb (kJ/kg)	19,765 (45 973)	19,460 (45 264)	18,840 (43 820)	18,560 (43 171)	18,825 (43 787)	18,200 (42 333)

2-3.6.2 Special Precautions for Burner Fuel Oils.

When the ambient temperature of the burner fuel oil is less than 20 degrees F (11 degrees C) above the pour point temperature, the burner fuel oil needs to be heated. At the burner fuel oil's pour point temperature, the fuel oil has reached a gel-like state and would be difficult to pump. In nearly all cases, No. 6 fuel oil requires heating to be pumped. In some cases, No. 4 and No. 5 burner fuel oils will require heating. Provide a design that precludes disposing of burner fuel oils into storm or sanitary sewers.

2-3.7 Alternative Fuel (E85) [[ASTM D5798].

2-3.7.1 Physical Properties of E85.

a. Specific Gravity 0.760 to 0.780

b. Reid Vapor Pressure 6-12 psia (42 to 83 kPa)

c. Flash Point (minimum) -20 degrees F (-30 degrees C)

d. Viscosity is 6.1x10-6 to 3.4x10-5 ft2/s (0.57 to 3.19 cSt)

e. Pour Point -212 degrees F (-100 degrees C)

2-3.7.2 Special Precautions for E85.

Due to the corrosiveness of E85, many common materials used with gasoline systems are not compatible with the handling and storage of alcohols (E85, or ethanol, is 85 percent ethyl alcohol). Zinc, brass, lead, aluminum, and lead based solder are several metals that become degraded by ethanol exposure. Other metals, including unplated carbon steel, stainless steel, black iron and bronze seem to have acceptable resistance to ethanol corrosion. Certain nonmetallic materials that have been successfully used with ethanol include: Buna-N, Neoprene rubber, polyethylene, nylon, polypropylene, nitrile, Viton, and Teflon. Common nonmetallic materials degraded by ethanol are natural rubber, polyurethane, cork gasket material, leather, polyester-bonded fiberglass laminate, polyvinyl chloride (PVC), polyamides, and methyl-methacrylate plastics. Proper cleaning of existing tanks that are being converted for E85 storage is required, because E85's solvent properties loosen tank deposits. In ethanol dispensing a one-micron in-line filter is recommended for impurity/particle removal. The shelf life of E85 is approximately 60-90 days in some cases. At normal temperatures E85 is less explosive than gasoline, but E85 is more explosive at lower temperatures. Ethanol vapors have similar behavior to gasoline, but a lower vapor pressure. E85 is an electrical conductor and is potentially carcinogenic. Provide a design that precludes disposing of E85 into storm or sanitary sewers.

2-3.8 Alternative Fuel Bio-Diesel (B20).

2-3.8.1 Physical Properties of Bio-Diesel.

Biodiesel fuel B20 is a blend of petroleum diesel fuel meeting ASTM D975 and 100 percent (neat) biodiesel fuel meeting either ASTM D6751 or EN 14214, where the biodiesel content of the blended fuel is no more than 20 percent biodiesel by volume (B20). Biodiesel has physical properties very similar to conventional diesel.

a. Specific Gravity 0.870 to 0.890

b. Reid Vapor Pressure 0.0 psia (0.0 kPa) (maximum at 100 degrees F (38 degrees C))

c. Flash Point (minimum) 100 degrees F (38 degrees C) for D1, 126 degrees F (52 degrees C)

d. Viscosity at 104 degrees F (40 degrees C) 1.2 to 4.4 x 10-5 ft2/s (1.3 to 4.1 cSt.)

e. Pour Point 10 degrees F (-12 degrees C)

2-3.8.2 Special Precautions for Bio-Diesel.

In dispensing Bio-Diesel, it is recommended that a 30-micron and a 10-micron in-line filter be used, in succession, as a primary and secondary means for impurity/particle removal. Bio-Diesel (B100) has good solvent qualities and will remove deposits from fuel systems. As a result, it may require more filter changes initially. One of the most commonly used blends of Bio-Diesel is B20. B20 has not been approved for use in combat or tactical vehicles or equipment. The usage of bio-diesel in other engines/vehicles has been reviewed by vehicle manufacturers and copies can be obtained at http://www.biodiesel.org/. B20 should be used within six months of manufacturer, because of the fuels shelf life. Users should be aware that a B20 blend will have increased viscosity requirements. Provide a design that precludes disposing of bio-diesel fuels into storm or sanitary sewers.

2-3.9 Liquefied Petroleum Gas (LPG).

2-3.9.1 Physical Properties of LPG.

LPG is composed predominantly of propane and propylene with minor amounts of butane, isobutane, and butylene. It is odorless, colorless, and non-toxic. To reduce the danger of an explosion from undetected leaks, commercial LPG usually contains an odorizing agent which gives it a distinctive pungent odor. LPG is a vapor at atmospheric conditions. It is normally stored as a liquid at a storage pressure of 200 psia (1400 kPa). LPG has the following properties:

a. Freezing Point, degrees F (degrees C) -305 (-187)

b. Relative Density (Specific Gravity) 147 degrees API (0.588)

c. Vapor Pressure at 100 degrees F (38 degrees C), 175.8 (1212) psi (kPa)

d. Heat Content, Btu/lb (kJ/kg) 21,591 (50 221)

2-3.9.2 Special Precautions for LPG.

a. Store LPG under pressure in appropriate pressure-rated tanks.

b. The potential for fire and explosion presents extreme hazards to life and property. Provide adequate relief venting and additional fire protection in accordance with NFPA 58.

c. Provide tank spacing in accordance with the requirements of Chapter 10 of this UFC.

2-3.10 Compressed Natural Gas (CNG).

2-3.10.1 Physical Properties of CNG.

Appendix A to NFPA 52, Compressed Natural Gas (CNG) Vehicular Fuel Systems, defines certain CNG properties. Natural gas is a flammable gas. It is colorless, tasteless, and non-toxic. It is a light gas, weighing about two thirds as much as air. It tends to rise and diffuse rapidly in air when it escapes from the system. Natural gas burns in air with a luminous flame. At atmospheric pressure, the ignition temperature of natural gas mixtures has been reported to be as low as 900 degrees F (482 degrees C). The flammable limits of natural gas-air mixtures at atmospheric pressure are about 5 percent to 15 percent by volume of natural gas. While natural gas consists principally of methane, it also contains ethane, small amounts of propane, butane, and higher Hydrocarbons and may contain small amounts of nitrogen, carbon dioxide, hydrogen sulfide, and helium which will vary from zero to a few percent depending upon the source and seasonal effects. As distributed in the United States and Canada, natural gas also contains water vapor. This “pipeline quality” gas can contain 7 pounds or more of water per million cubic feet of gas (112 kg/106 m^3). Some constituents of natural gas, especially carbon dioxide and hydrogen sulfide in the presence of liquid water, can be corrosive to carbon steel, and the corrosive effect is increased by pressure. The pressures used in CNG systems covered by NFPA 52 are substantial and well above those used in transmission and distribution piping and in other natural gas consuming equipment. As excessive corrosion can lead to sudden explosive rupture of a container, this hazard must be controlled. Pressures in CNG fueling stations are typically less than 5,000 psi (35 000 kPa).

2-3.10.2 Special Precautions for CNG.

a. Provide venting for safety relief in areas where CNG is to be stored.

   1. CNG is a highly flammable substance. Therefore, in design of facilities, use the following precautions to prevent fires from becoming uncontrollable:
   2. Do not directly extinguish fires with water.
   3. Do not extinguish large fires.
   4. Allow large fires to burn while cooling adjacent equipment with water spray.
   5. Shut-off CNG source, if possible.
   6. Extinguish small fires with dry chemicals.

b. CNG is non-toxic but can cause anoxia (asphyxiation) when it displaces the normal 21 percent oxygen in a confined area without adequate ventilation.

c. Because of corrosion problems, water in Department of Transportation (DOT) certified tanks is limited to 0.5 pounds per million cubic feet (8 kg/10 6 m3).

2-3.11 OTTO Fuels.

Information on OTTO fuels is contained in NAVSEA S6340-AA-MMA-010, Technical Manual for OTTO Fuel II Safety, Storage, and Handling Instructions, published by direction of Commander, Naval Sea Systems Command. Distribution of this document is restricted and Naval Sea Systems Command handles requests for information.

2-3.12 Lubricating Oils.

2-3.12.1 Steam Turbine Oils [0-250] [MIL-PRF-17331].

a. For use in main turbines and gears, auxiliary turbine installations, certain hydraulic equipment, general mechanical lubrication, and air compressors.

b. Physical Properties:

1. Flash Point: 400 degrees F (204 degrees C) minimum.
2. Pour Point: 20 degrees F (-6 degrees C) maximum.
3. Viscosity at 104 degrees F (40 degrees C), 80 to 104 x 10-5 ft2/s (74 to 97 x 10-6 m2/s).

2-3.12.2 Lubricating Oils [0-278], [MIL-PRF-9000].

For use in advanced design high-output shipboard main propulsion and auxiliary diesel engines using fuel conforming to MIL-DTL-16884.

2-3.12.3 Special Precautions for Lubricating Oils.

To pump the oil when the ambient temperature of the lubricating oil is less than 20 degrees F (11 degrees C) above the pour point temperature, heat the lubricating oil. At the pour point temperature, the oil becomes gel-like and is difficult to pump. Ensure the design does not allow the discharge of lubricating oil into storm or sanitary sewers.

2-3.13 Hydrazine - Water (H-70) [MIL-PRF-26536].

2-3.13.1 Physical Properties of H-70.

This fuel is a mixture of 70 percent hydrazine and 30 percent water. It is a clear, oily, water-like liquid with a fishy, ammonia-like odor. It is stable under extremes of heat and cold; however, it will react with carbon dioxide and oxygen in the air. It may ignite spontaneously when in contact with metallic oxides such as rust.

2-3.13.2 Special Precautions for H-70.

Keep working and storage areas clean and free of materials that may react with hydrazine. Provide only stainless steel in areas where extended contact is possible. Areas where incidental contact is possible should be kept free of rust. Ensure the design does not allow the discharge of H-70 into storm or sanitary sewers.

2-3.14 Fuel Additives.

Contact Service Control Point for fuel additization requirements.

2-3.14.1 Fuel System Icing Inhibitor (FSII), High Flash, [MIL-DTL-85470] (diethylene glycol monomethyl ether (DIEGME)).

a. Used in aviation turbine fuels to prevent the formation of ice crystals from entrapped water in the fuel at freezing temperatures. In addition, it has good biocidal properties, preventing growth of microorganisms in the fuel.

b. Avoid water entry/bottoms in storage tanks because the additive will dissolve in the water, reducing the concentration of additives left in the fuel.

c. Refer to fuel specification for more information.

d. Consult federal, state, and local regulations for appropriate disposal methods.

2-3.14.2 Corrosion Inhibitor/Lubricity Improver (CI), [MIL-PRF-25017].

A combination lubricity improver and corrosion inhibitor additive, procured under MIL-PRF-25017, is injected in all military aviation turbine fuels at the refinery in order to improve the lubricating characteristics of the fuel.

2-3.14.3 Static Dissipater Additive.

Static dissipater additive (SDA) enhances safety during handling and flight by reducing static discharge potential in the vapor space above the fuel. SDA increases the conductivity of the fuel, thus decreasing the electrostatic charge relaxation time (the rate of which a charge dissipates or travels through the fuel) which decreases the potential for ignition from static charges. The actual proportion is in accordance with the specific fuel military specification. For fuel system design purposes, assume a lower limit of 50 picosiemens per meter in the determination of relaxation requirements. SDA is added to all JP-8 (F-34; F-35). SDA is not added to JP-5 and F-76 or to Jet A/A-1 that is stored at military installations

2-4 PRODUCT SEGREGATION.

2-4.1 Product Grades.

Except as otherwise approved by Service Headquarters, provide separate receiving, storage, and distribution systems for each product. Except as otherwise approved by Service Headquarters, prevent misfueling (transferring a type of fuel other than the type intended) by using different size piping, valves, adaptors, nozzles, etc. The products to be segregated include:

a. Mogas.

b. Avgas.

c. Diesel fuel, including low sulfur diesel and ultra-low sulfur diesel and distillate type burner fuels (No. 1, No. 2, and kerosene).

d. Aviation turbine fuel, separate systems for each grade.

e. Residual type burner fuels (No. 4, No. 5, and No. 6).

f. Lubricating oils.

g. LPG.

h. CNG.

i. OTTO fuels.

j. E85.

k. Bio-diesel.

l. Hydrazine.

2-4.2 Exceptions.

Designs for different products using the same piping may be approved for long receiving lines such as from a tanker or barge pier or a cross-country pipeline to a storage facility. Where such common use occurs, make provisions for receiving and segregating the interface between two products. Consider the use of pigs or break-out tanks to separate batches. Exceptions will not be approved for common systems to carry both clean and residual type fuels.

2-5 TRANSFER FLOW RATES.

Table 2-4 shows the recommended range of design flow rates. In some cases, greater rates may be needed to meet the operational requirements of a particular facility.

Table 2-4. Design Flow Rates

Service[1]	Aviation Turbine Fuel	Diesel Fuel	Burner Fuel Oils	Mogas
Between storage tanks, gpm (m^3/hr)	600 to 1,200 (136 to 272)	600 to 1,200 (136 to 272)	600 to 1,200 (136 to 272)	600 to 1,200 (136 to 272)
Tank car unloading to storage (per car), gpm (m^3/hr)	300 to 600 (68 to 136)	300 to 600 (68 to 136)	300 to 600 (68 to 136)	300 (68)
Tank truck unloading to storage (per truck), gpm (m^3/hr)	300 to 600 (68 to 136)	300 to 600 (68 to 136)	300 to 600 (68 to 136)	300 to 600 (68 to 136)
Gravity receipt tank to storage gpm (m^3/hr)	600 (136)	600 (136)	600 (136)	600 (136)
Storage to tank truck/refueler loading (per truck), gpm (m^3/hr)[2]	300 or 600 (68 or 136)	300 or 600 (68 or 136)	300 or 600 (68 or 136)	300 or 600 (68 or 136)
Delivery from direct fueling stations to aircraft, gpm (m^3/hr)	Varies[3]	N/A	N/A	N/A
Delivery from direct fueling stations to helicopters, gpm (m^3/hr)	Varies[3]	N/A	N/A	N/A
Between super tanker and storage, gpm (m^3/hr)	16,800 (3815)	16,800 (3815)	16,800 (3815)	16,800 (3815)
Between regular tanker and storage, gpm (m^3/hr)	7,000 (1590)	7,000 (1590)	7,000 (1590)	7,000 (1590)
Between barge and storage, gpm (m^3/hr)	2,800 (636)	2,800 (636)	2,800 (636)	2,800 (636)
To fleet oilers, gpm (m^3/hr)	3,500 (795)	3,500 (795)	N/A	N/A
To AOEs, gpm (m^3/hr)	7,000 (1590)	7,000 (1590)	N/A	N/A
To carriers, gpm (m^3/hr)	2,450 (556)	2,450 (556)	N/A	N/A
To average cruisers, gpm (m^3/hr)	700 (159)	1,400 (318)	N/A	N/A
To average destroyers, gpm (m^3/hr)	700 (159)	1,400 (318)	N/A	N/A
Storage to tank car loading (per car), gpm (m^3/hr)	300 or 600 (68 or 136)	300 or 600 (68 or 136)	300 or 600 (68 or 136)	300 or 600 (68 or 136)

Notes: (1) At dockside, deliveries from tankers should be assumed to be at a pressure of 80 to 100 psig (600 to 700 kPa), and deliveries to tankers to be at 60 psig (400 kPa). Rates to other ships are maximums based on fueling at sea capacities. Lesser rates for fueling at piers can be used if more practical. Loading rates are based on 40 psig (300 kPa) maximum per hose at ship connections.
(2) For truck fillstands, system must be designed to deliver a refueling nozzle pressure of 35 psig with a flow range of 50 to 560 gpm.
(3) Refer to Chapter 4 of this UFC for guidance on fueling rates for aircraft. Contact appropriate Service Headquarters for actual fueling rates for aircraft for which design applies.

2-6 PHYSICAL SECURITY.

Plan and design fuel facilities with the goal of protecting the fuels, storage, and transfer capability from enemy attack, terrorists, sabotage, fire, seismic activity, and other damaging influences. In high threat areas, more extensive protection may be required. Consult appropriate Service Headquarters for guidance. NATO projects have their own specific criteria which govern protection level requirements.

2-6.1 Antiterrorism and Physical Security.

2-6.1.1 Physical Security Program.

Per DoD 5200.08-R, *Physical Security Program*, at a minimum, fuel support points, pipeline, pumping stations, and piers must be designated and posted as Controlled Areas. Areas containing critical assets may be designated as a restricted area. Coordinate with installation or activity Security and Antiterrorism Officer (ATO) to determine area designation (controlled or restricted), threat environment, Design Basis Threat (DBT), level of protection and access control requirements.

Controlled and restricted areas are defined areas in which there are special restrictive measures employed to prevent unauthorized entry. Restricted areas may be of different types depending on the nature and varying degree of importance of the protected asset. Restricted areas must be authorized by the installation Commander, properly posted, and must employ physical security measures.

2-6.1.2 DoD Security Engineering Facilities Planning Manual.

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*, supports the planning of DoD facilities that include requirements for security and antiterrorism. Use in conjunction with UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, to establish the security and antiterrorism design criteria that will be the basis for DoD facility designs.

2-6.2 Security Fencing.

Unless otherwise directed by Service Headquarters, provide security fencing around all petroleum facilities to ensure safety and inhibit sabotage, theft, vandalism, or entry by unauthorized persons. Install a 7-foot (2.1 m) fabric height fence of chain-link type with three-strand barbed wire outriggers on top or its equivalent. Ensure fencing, gates, and associated clearance requirements are in accordance with UFC 4-022-03. Contact the Installation Security Organization for additional requirements.

2-7 MAINTAINABILITY CAPABILITIES.

Provide adequate maintenance space around all system components including:

a. Filter-separator and other filtration device maintenance access, particularly element removal. For vertical filtration devices provide stair and platform access to at least one side of each unit.

b. Manual valves, especially replacement of slips in double block and bleed tapered lift plug valves.

c. Adequate room and locations for the use of an intelligent pig launcher/receiver in all section of piping.

d. Meter reading and maintenance.

e. Control valves.

f. Pumps, including removal.

g. Instruments, especially those mounted on tank shells.

2-8 VOICE COMMUNICATIONS.

Provide voice communications (direct line for Air Force projects only) between separated areas such as receiving, dispensing, pump stations, and fuel storage areas to coordinate operations involved in fuel transfer. Refer to UFC 3-501-01 and UFC 3-550-01.

2-9 OTHER COMMUNICATIONS.

2-9.1 Data Communications.

Data communications systems must be designed and accredited by designated accrediting authority or authorizing official in accordance with the applicable Telecommunications Industry Association (TIA) and Electronic Industries Association (EIA) documents. Coordinate with local Base Communications squadron where applicable. For Army, Navy, and Air Force communication systems design criteria see UFC 3-580-01.

2-9.2 Fire Alarm Communication.

Fire alarm communications systems must be coordinated with the Base Fire Department. For fire alarm communication system requirements see the relevant UFGS.

2-10 WORKER SAFETY.

Design facilities to comply with the most stringent of the Occupational Safety and Health Administration (OSHA) or the host nation standards. Also, ensure that design complies with service-specific occupational safety and health criteria. For Navy, OPNAVINST 5100.23 Series applies. For Air Force,**\2** AFMAN 91-203 ***/2/*** applies. Incorporate design standards to ensure proper storage for all hazardous chemicals in accordance with 29 CFR 1910.1200, Hazard Communication.

2-10.1 Emergency Showers and Eyewash Stations.

Fixed emergency showers and eyewash stations are required in workshops, **\2\ /2/** hydrazine storage facilities, hydrazine servicing facilities, additive injection facilities, pumphouses, fuel piers and other similar facilities. Fixed emergency showers and eyewash stations, or portable eyewash units, must be installed at other locations where fuel is transferred to/from **\1\ /1/** aircraft. Table 2-5 below provides minimum requirements for fixed emergency shower and eyewash stations and portable eyewash stations for DoD installations. **\2** Refer to UFC 4-310-03 for requirements for Emergency Showers and Eyewash Stations for fuel laboratories. **/2/** Refer to Appendix D of UFC 3-420-01 for additional requirements associated with Emergency Shower and Eyewash Stations.

Table 2-5. Emergency Shower and Eyewash Station Locations[1]

Facility	ES & EW[2]	EW[3]
\2\ /2/	**\2\ /2/**	
Hydrazine Storage and Hydrazine Servicing Facilities	✓	
Additive Injection Facilities	✓	
Fuel Maintenance Workshops	✓	
Fuel Piers	✓	
Filtration Buildings**\1**[4]**/1/**	✓	
Pumphouses/Pump Pads/Pump Shelters (with Filtration)**\1**[4]**/1/**	✓	
Pumphouses/Pump Pads/Pump Shelters (without Filtration)**\1\/1/**		✓
Truck or Tank Car Off-loading Facilities**\1\/1/**		✓
Truck or Tank Car Loading Facilities**\1\/1/**		✓
Ground Product Dispensing Facilities**\1**[5]**/1/**		✓

Notes: (1) Contact Service Specific Fuels Subject Matter Expert (SME) for approval to install emergency showers and eyewashes in other locations not specifically mentioned in Table 2-5.
(2) ES & EW – Emergency Shower and Eyewash Station, Fixed Units.
(3) EW – Eyewash Station Only, **\1** Fixed or **/1/**Portable Units.
(4) Designer to review availability of existing utilities.**\1**If there are insufficient utilities, use of portable eyewash units only is sufficient.
(5) Fixed or Portable Eyewash Unit is optional.**/1/**

2-11 ELECTRICAL DESIGN.

2-11.1 Area Classifications.

Classify all fuel facilities, except as modified by this UFC, in accordance with API RP 500, NFPA 30, NFPA 70, and IEEE C2. These practices may be modified where unusual conditions occur, where locations contain hazardous atmospheres classified other than Group D (as defined by NFPA 70), or where a system component malfunction may cause hazardous situations. Use sound judgment in applying these requirements. Specify a higher classification wherever necessary to maintain safety and continuity of service. Treat combustible liquids under pressure as flammable liquids. All piping and system components including those connected to an atmospheric storage tank must be considered pressurized. Ensure design is in accordance with the requirements designated in NFPA 70 for the specific division and class. Ensure temperature class or operating temperature of the system components are in accordance with NFPA 70. Ensure that project drawings include hazardous area plans indicating extent and classification of areas. Drawings should provide dimensions indicating extent of classified areas and should include sections/elevations when required to fully convey the extent of the areas.

2-11.1.1 Class I, Division 1.

Class I, Division 1 locations include:

a. Outdoor locations and those indoor locations having positive mechanical ventilation that is within 3 feet (0.9 m) of the fill openings or vents on individual containers to which flammable liquids are being transferred. Provide alarm devices on all ventilation systems.

b. Outdoor locations within 5 feet (1.5 m) of open end of vents and openings on liquid fuel storage tanks extending in all directions.

c. Entire pit, sump, open trench, or other depression, any part of which is within a Division 1 or 2 location and is without mechanical ventilation.

d. Locations within and on exterior walls of open top spill containment structures including oil/water separators and spill containment boxes.

e. Locations at fuel dispensers.

f. Locations within 3 feet (0.9 m) of vent, extending in all directions, when loading a truck through the bottom connection.

g. All pump/filter houses handling liquid fuels.

h. Any area containing electrical system components that are or may be exposed to atomized fuel and where the ambient temperature can at any time be above the flash point of the fuel.

2-11.1.2 Class I, Division 2.

Class I, Division 2 locations include:

a. Outdoor locations between 5 feet (1.5 m) and 10 feet (3 m) of the Division 1 zones at vents and openings, on liquid fuel storage tanks extending in all directions.

b. Entire pit, sump, open trench, or other depression, any part of which is within a Division 1 or 2 location and is provided with mechanical ventilation.

c. Outdoor locations within 3 feet (0.9 m) of the exterior surface of pumps, air relief valves, withdrawal fittings, meters, and similar devices that are located in pipelines handling liquid fuels under pressure. Class I, Division 2 locations extend upward 18 inches (450 mm) above grade level and within 10 feet (3 m) horizontally from any surface of the device.

d. Locations within and extending upward to the top of the dikes that surround aboveground tanks containing liquid fuels and within 10 feet (3 m), extending in all directions of the tank shell, ends, or roof.

e. Locations extending upward 18 inches (450 mm) above grade level within 15 feet (4.6 m) horizontally from any surface of open top spill containment structures including oil/water separators and spill containment boxes, whether installed indoors or outdoors.

f. Locations 25 feet (7.6 m) horizontally in all directions on pier side from portion of hull containing cargo and from water level to 25 feet (7.6 m) above cargo tank at highest point.

g. Area between 3 feet (0.9 m) and 10 feet (3 m) extending in all directions from vent when loading a truck. Also upward 18 inches (450 mm) above grade and within 10 feet (3 m) horizontally from the truck load connection

2-11.1.3 Non-Classified Locations.

Non-classified locations include:

a. Outdoor locations having closed piping systems handling flammable or combustible liquids that have no pumps, air relief valves, withdrawal fittings, valves, screwed fittings, flanges, meters, or similar devices which create joints in piping.

b. Office buildings, boiler rooms, control rooms, and similar locations that are outside the limits of hazardous locations, as defined above, and are not used for transferring flammable or combustible liquids or containers for such liquids.

c. Areas in which flammable and combustible liquids are stored in accordance with NFPA 30, outside the limits of a classified location, and the liquids are not transferred.

2-11.2 Illumination.

Illuminate all working areas for night operations to the minimum intensity recommended in Table 4 of API RP 540 and Petroleum, Chemical and Petrochemical Plants in Table 30.2 of IESNA Lighting Handbook 10th Edition. Lighting design should also provide for road access on tall light posts to allow for lamp replacement. For facilities within the jurisdiction of the U.S. Coast Guard under 33 CFR Part 154, illuminate to the minimum intensity required by that regulation. Provide security lighting in accordance with UFC 3-530-01. If local or state regulations exist, follow the most stringent requirements.

2-11.3 Grounding and Bonding***.

The following references apply to grounding and bonding systems:

a. IEEE 142

b. NFPA 70

c. NFPA 77

d. NFPA 780

e. API RP 540

f. API RP 2003

g. IEEE 1100

h. NFPA 407

i. UFC 3-575-01

2-11.3.1 Grounding Requirements.

Ground the following items in accordance with Article 250 of NFPA 70:

a. Motor, generator, and transformer frames.

b. Non-current-carrying metallic parts of electrical system components and installations, such as enclosures for IESNA boards, switchgear, and motor control centers.

c. Metallic messengers of self-supporting cables.

d. Exposed conductive materials enclosing electrical conductors, such as metallic conduit, metallic tubing, metallic armoring, sheaths and shields, cable troughs, trays and racks, wireways, and busways.

e. Filter-separators and other filtration system components.

2-11.3.2 Current and Lighting Protection.

Provide lightning protection in accordance with **\2** UFC 3-575-01 and NFPA 780 ***/2/*** and local installation requirements. For fault current protection and lightning protection, ground the following items through ground rods or beds or bond to a grounded network. Provide ground for these items as required by the above references.

a. **\2\ /2/**

b. Lightning arrestors and lightning shield conductors.

c. Operating mechanisms of overhead airbreak switches.

d. Canopies.

e. Aboveground storage tanks.

2-11.3.3 Static Electricity Prevention.

To prevent the buildup static electricity, ground the following items directly through ground rods or beds or bond to a grounded network. Do not exceed 10,000 ohms of resistance to ground, unless otherwise stated. Do not bond dissimilar metals together.

a. Aboveground tanks, vessels, stacks, heat exchangers, and similar system components not directly supported or bolted to a grounded supporting network.

b. Pipe and pipe support columns in accordance with the more stringent of NFPA 77 or below.

   1. Provide (minimum) 1 ground rod on pipe runs 100 feet (30 m) long or less unless the pipe is connected to a grounded source within the 100 feet (30 m).

   2. Provide (minimum) 2 ground rods on runs of pipe that exceed 100 feet (30 m), but are less than 300 feet (90 m) in length.

   3. Provide (minimum) 1 ground rod at intervals not exceeding 300 feet (90 m) on runs of pipe that are greater than 300 feet (90 m) in length.

   4. Parallel pipes may be bonded and common ground rods used, spaced in accordance with (1) through (3) above.

c. Aircraft direct fueling stations.

d. Hydrant pits.

e. Internal floating pans bonded to the storage tank shell.

f. Aboveground portions of electrically isolated piping at truck, rail, and marine loading and unloading stations.

2-11.3.4 Installation.

Isolate grounding systems for instrumentation, instrument control boards, and electronic system components from all other ground systems. Additional grounding is not required for overhead electrical system components bolted directly to grounded metallic structures. Where feasible, separate the conductor connecting a lightning rod to the grounding electrode from other grounding conductors. Route with a minimum of sharp bends and in the most direct manner to the grounding electrode. Do not use this electrode in lieu of grounding electrodes which may be required for other systems. This provision does not prohibit the required bonding together for grounding electrodes of different systems.

2-12 CATHODIC PROTECTION.

Obtain the services of a National Association of Corrosion Engineers (NACE)-certified Corrosion Specialist or Cathodic Protection Specialist or a registered professional

Corrosion Engineer to perform all cathodic protection design and testing. **\2** All designs will comply with UFC 3-570-01. ***/2/***

2-12.1 Tanks.

For all underground steel tanks and tank bottoms of aboveground vertical tanks, provide cathodic protection in accordance with UFC 3-570-01, API RP 651, 40 CFR Part 280, UL 1746, and UFC 3-460-03. For additional information on cathodic protection, refer to UFC 3-460-03 and **\2\ for Air Force follow** AFI32-1001 ***/2/***. Current tank design configuration electrically isolates the tank bottom from surrounding earth. Therefore, install cathodic protection between the liner and the tank bottom.

2-12.2 Piping.

For all carbon steel and stainless steel underground and underwater piping, provide cathodic protection in accordance with UFC 3-570-01 and 40 CFR Part 280. For additional information on cathodic protection, refer to UFC 3-460-03, NACE SP0169, and 49 CFR Part 195. Buried stainless steel corrodes and, therefore, must be cathodically protected.

2-12.2.1 Over-Voltage Protection (OVP) Devices.

Provide OVP devices across all aboveground flanges with insulating flange kits connected to underground and underwater cathodically protected piping. Require OVP devices to be designed for use with insulating flange kits and for use in Class I, Division 1 areas. Provide covers over flanges to preclude dirt from degrading insulating flange gaskets; refer to DoD Standard Design AW 078-24-28.

2-12.3 Structures.

Obtain the services of a (NACE)-certified Corrosion Specialist or Cathodic Protection Specialist or a registered professional Corrosion Engineer to evaluate the need for cathodic protection on carbon steel portions of fueling support facilities. Comply with UFC 3-570-01.

2-12.4 Test Stations.

Installation of cathodic protection test stations within Class I, Division 1 locations is prohibited and within Class I, Division 2 locations must be avoided, if practical. If the installation of cathodic protection test stations within Class I, Division 2 locations is unavoidable, these test stations must be considered nonincendive and therefore will not require explosion proof enclosures.

2-13 ENVIRONMENTAL PROTECTION.

2-13.1 General Policy.

It is the firm policy of the Department of Defense to design and construct fueling facilities in a manner that will prevent damage to the environment by accidental discharge of fuels, their vapors or residues. Designs must comply with foreign government, national, state, and local environmental protection regulations that are in effect at a particular facility.

2-13.2 Regulations and Guidelines.

2-13.2.1 Within U.S.A.

Within the jurisdiction of the United States, adhere to the following environmental protection guidelines:

a. National Environmental Policy Act (NEPA), 42 USC 4321.

b. Facilities Transferring Oil or Hazardous Material in Bulk, U.S. Coast Guard Regulations, 33 CFR Part 154.

c. Standards of Performance for New Stationary Sources, Environmental Protection Agency Regulations, 40 CFR Part 60.

d. National Emission Standards for Hazardous Air Pollutants for Source Categories, Environmental Protection Agency Regulations, 40 CFR Part 63.

e. Oil Pollution Prevention, Environmental Protection Agency Regulations, 40 CFR Part 112.

f. EPA Administered Permit Programs: The National Pollutant Discharge Elimination System (NPDES), Environmental Protection Agency Regulations, 40 CFR Part 122.

g. Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST), Environmental Protection Agency Regulations, 40 CFR Part 280.

h. Approval of State Underground Storage Tank Programs, Environmental Protection Agency Regulations, 40 CFR Part 281.

i. Transportation of Hazardous Liquids by Pipeline, Department of Transportation Regulations, 49 CFR Part 195.

j. Low Impact Development, UFC 3-210-10.

k. Obtain additional data on anti-pollution regulations for specific locations from Service Headquarters Environmental Support Office.

2-13.2.2 Outside U.S.A.

At facilities in other countries, consult appropriate service environmental directives, DODD Overseas Environmental Baseline Guidance Document and for Navy, OPNAVINST 5090.1. It may be appropriate to address the DoD Overseas Environmental Baseline Guidance Document and appropriate Final Governing

Standards for the region/country. If tank is to be installed in a locale or state with more stringent criteria, use the more stringent criteria. If tank is to be installed in a NATO country other than the CONUS, follow the most stringent of local regulations or NATO Airfield Standard Design - Jet Fuel Storage and Dispensing Systems, STD 121-122-01.

2-13.3 Transfer of Fuel at Ports.

2-13.3.1 Bulk Transfer.

Compliance with 33 CFR Part 154 is required for each fixed facility capable of transferring fuel in bulk to or from a vessel with a capacity of 10,500 gallons (39,700 L) or more. These facilities are required to have an operations manual approved by the Captain of the Port. In the operations manual, include the requirement for the following systems:

a. Hose assemblies
b. Loading arms
c. Closure devices
d. Monitoring devices
e. Small discharge containment
f. Discharge removal
g. Discharge containment system components
h. Emergency shutdown
i. Communications
j. Lighting

2-13.3.2 Vapor Collections.

For facilities that collect vapor from vessel cargo tanks, ensure that the requirements of 40 CFR Part 60 for the following items are met:

a. Vapor line connections
b. Vessel liquid overfill protection
c. Vessel vapor overpressure and vacuum protection
d. Fire, explosion, and detonation protection
e. Detonation arrestors, flame arrestors, and flame screens
f. Inerting, enriching, and diluting systems
g. Vapor compressors and blowers
h. Vapor recovery and vapor destruction units

2-13.4 Air Quality Control.

2-13.4.1 Design Requirements.

Regulatory requirements pertaining to air quality control will vary according to locality and to type and size of the petroleum vapor source. Petroleum storage and dispensing facilities are common sources of air pollution. Provide vapor recovery where required by federal (40 CFR Part 60 Subpart Kb), state, and local regulations and other chapters of this UFC. If gasoline is being handled, refer to 40 CFR Part 60 Subpart XX, 40 CFR Part 63 Subpart R, 40 CFR Part 63 Subpart BBBBBB, and 40 CFR Part 63 Subpart CCCCCC for design, installation, and testing requirements.

2-13.4.2 Aboveground Storage Tanks.

Federal regulation 40 CFR Part 60 Subpart Kb requires that tanks used for the storage of fuel with a design capacity greater than 19,000 gallons (72,000 L) having a true vapor pressure greater than 0.75 psia (5. kPa) at operating temperature must be equipped with either: 1) a fixed roof in combination with an internal floating pan; 2) an external floating roof equipped with a dual seal closure device between the wall of the tank and the roof edge; or 3) a closed vent system designed to collect all volatile organic compound (VOC) vapors and gases discharged from the tank and a control device designed to reduce VOC emissions by 95 percent or greater. It is the design intent that most vertical aboveground tanks will have internal floating pans and that vapor recovery will be used only if required by federal, state, or local regulations for the type of fuel and type of tank proposed, except as specifically required by another chapter of this UFC. Refer to Chapter 8 of this UFC for specific requirements for floating pans.

2-13.4.3 Truck and Rail Loading Facilities.

Tank truck and tank car loading facilities constructed or modified after December 17, 1980 which load an annual average of more than 20,000 gallons (76,000 L) per day of fuel having a true vapor pressure (TVP) of 0.75 psia (5 kPa) or greater must discharge the vapors resulting from such operations into a closed system. Ensure this system leads to a vapor recovery or disposal system which is capable of removing 95 percent of the petroleum vapor before final discharge into the atmosphere. Equip bulk gasoline terminals (handling fuels with TVP > 4.003 psia or 27.60 kPa) with a vapor collection system designed to collect total organic carbon (TOC) vapors displaced from tank trucks during loading. Emissions from the vapor control system due to loading must not exceed 35 mg of TOC per liter of gasoline loaded. For facilities with an existing vapor processing system, the TOC emissions must not exceed 80 mg of TOC per liter of gasoline loaded (40 CFR Part 60 Subpart XX).

2-13.4.4 Permit Requirements.

Air quality permits are typically required for the construction of petroleum storage and dispensing facilities. It is essential for designers to review regulatory requirements to ensure incorporation of proper environmental controls. State and local regulations are primary sources for air quality requirements, but for particularly large facilities, it is also beneficial to confer with the EPA regional office. The permit review and air quality controls will further depend on whether the construction site is located in an attainment or non-attainment area for ozone. Different permit programs apply in these areas, but they can both yield strict control requirements depending on the air quality of the area. An emissions offset analysis may be necessary before any construction permit can be granted. This analysis will require and demonstrate a reduction in VOC emissions from other sources in the locality where the new source construction is to take place. The offset can be obtained by providing new or better controls or otherwise decreasing emissions from an existing source.

2-13.5 Water Quality Control.

2-13.5.1 Design Requirements.

Protection of the natural waters against pollution from discharge of petroleum is achieved by complying with federal, state, and local regulations.

2-13.5.2 Stormwater Discharge.

A National Pollutant Discharge Elimination System (NPDES) Permit, 40 CFR Part 122, may be required for the discharge of stormwater. A review of federal, state, and local stormwater regulations is required prior to design and construction. Discharge of stormwater includes:

a. Controlled drainage from storage tank areas with impermeable diked enclosures or drainage systems leading to impoundments.

b. Drainage from treatment systems.

c. Drainage from facility transfer operations, pumping, and tank car and tank truck loading/off-loading areas.

d. Drainage from equipment/vehicle maintenance areas.

2-13.5.3 Spill Prevention Control and Countermeasures (SPCC) Plan.

The minimum requirements for spill prevention in the United States are contained in 40 CFR Part 112. It requires the preparation of a SPCC Plan for facilities that may discharge fuel into navigable waters of the United States. Specific design features are necessary to meet the SPCC objectives at all facilities. The SPCC plan must demonstrate that the fuel facility will be designed and constructed in a manner that will prevent spillage, and should such a spillage occur, prevent the spill from leaving the property and entering a waterway. Review API Bulletin D16 to assist with conformance to regulations. Refer to 33 CFR Part 154 for small discharge containment. Verify the requirements of the SPCC Plan with Base Environmental prior to introducing fuel into a new system. Revisions to the SPCC Plan and registration of tank may be required. Refer to EPA 550-B-13-002 to assist with guidance on SPCC plans.

2-13.5.4 Meeting SPCC Plan Objectives.

40 CFR Part 112 allows SPCC Plan objectives to be met by either spill containment or spill treatment. For facilities covered by this UFC only spill containment systems are acceptable. Spill treatment systems must not be allowed to meet SPCC requirements unless required by regulations. Provide treatment systems (oil/water separators) to treat the discharge from spill containment systems only when required by federal, state, or local regulations, or by Service Headquarters. Typical facilities requiring a spill containment system are fuel storage tanks, tank truck loading/off-loading/parking areas, and tank car loading/off-loading areas.

2-13.5.5 Spill Containment Systems.

The SPCC Plan objectives expressed in 40 CFR Part 112 must be met with impermeable spill containment system designed to prevent a spill from leaving the property unless a spill treatment system is required by federal, state, or local regulations, or by Service Headquarters. See the individual chapters of this UFC for requirements.

2-13.5.6 Spill Treatment Systems (Oil/Water Separators).

Treatment systems (oil/water separators) may not be used to meet the requirements of 40 CFR Part 112 unless required by federal, state, or local regulations, or as determined by the appropriate Service Headquarters. Do not provide oil/water separator to treat the discharge from spill containment systems (e.g. secondary containment dikes, tank truck parking areas, loading/off-loading facilities), unless specifically required by regulations. Select either a conventional rectangular API type gravity oil/water separator or one with inclined parallel plates. Where possible, design the separator as a rectangular vessel with a fully open top with lid for ease of inspection and cleaning.

a. Design and construct the separator in accordance with the following:

   1. UFC 1-200-01, UFC 3-301-01, and UFC 3-240-01.
   2. UFGS 46 25 14.
   3. Army Corps of Engineers ETL 1110-3-466.
   4. ACI 350.4R-04, Design Considerations for Environmental Engineering Concrete Structures.

b. Consider the following items in sizing the oil/water separator:

   1. Anticipated inlet flow rate of a 5-year, 1-hour duration storm event.
   2. Type of fuel.
   3. Specific Gravity and Viscosity of fuel.
   4. Specific ambient and product temperature ranges.
   5. Product storage capacity required.

6. Possible contaminants present.

7. Operating parameters are intermittent or continuous.

c. Require parallel plates to be constructed from non-oleophilic materials such as fiberglass. Arrange the plates in either a downflow or crossflow mode so that the oil collects in the high point of the corrugations and rises to the top without clogging from settleable solids.

d. Consider installing a retention basin upstream of the oil/water separator. This would allow solids to settle prior to reaching the oil/water separator and allow the option of either releasing the stormwater to the oil/water separator or to an appropriate stormwater collection system.

2-13.5.7 Leak Detection.

As required by federal, state, and local regulations install leak detection on aboveground tank bottoms, underground storage tanks, and underground piping. Comply with the latest edition of 40 CFR Part 280.

2-13.5.8 Wastewater Disposal.

Provide a holding tank for wastewater. Wastewater is any water which has been in contact with significant quantities of fuel such as water collected from tank sumps, system component drains, and system component sumps. Ensure that tank construction conforms to federal, state, and local environmental requirements. Provide a means to remove wastewater for off-site disposal.

2-13.5.9 Dewatering.

Where dewatering for construction purposes is necessary and contamination is suspected, test the groundwater prior to construction to determine the extent of contamination. If the groundwater is, or has the potential to be, contaminated with petroleum products, review federal, state, and local regulations for acceptable treatment methods. Permits may be required for treatment and/or disposal of the water. Contact facility Environmental Department for guidance.

2-13.6 Aboveground Storage Tanks.

2-13.6.1 Design Requirements.

Aboveground storage tanks may be single wall, double wall, horizontal, vertical, protected, or fire resistant as discussed in Chapter 8. There is not a single federal regulation that specifically addresses aboveground storage tanks similar to 40 CFR Part 280 that solely governs underground storage tanks. The majority of the federal environmental design requirements come from either 40 CFR Part 112 or 29 CFR Part 1910.106. These regulations include environmental related requirements for:

a. Diking and drainage.

b. Flooding.

c. Corrosion Protection.

d. Inspections, Tests, and Records.

e. Brittle Fracture Analysis.

The designer must consult the latest version of these regulations and comply with all federal, state, and local regulations.

2-13.6.2 Other Requirements.

If a tank is to be installed in a locale or state with more stringent criteria, use the more stringent criteria. If tank is to be installed in a NATO country other than the CONUS, follow the most stringent of local regulations or NATO Airfield Standard Design - Jet Fuel Storage and Dispensing Systems, STD 121-122-01.

2-13.7 Underground Storage Tanks.

2-13.7.1 Design Requirements.

All underground and cut and cover storage tanks are to be double wall type. Single wall underground storage tanks are not allowed. For underground storage tanks larger than 110 gallons (416 L), the following are required by 40 CFR Part 280:

a. Corrosion protection for tanks and associated underground piping.

b. High level alarm.

c. Spill and overfill protection.

d. Release detection.

2-13.7.2 Other Requirements.

If a tank is to be installed in a locale or state with more stringent criteria, use the more stringent criteria. If tank is to be installed in a NATO country other than the CONUS, follow the most stringent of local regulations or NATO Airfield Standard Design - Jet Fuel Storage and Dispensing Systems, STD 121-122-01.

2-14 FIRE PROTECTION.

2-14.1 General Requirements.

Design all petroleum fuel storage, handling, transportation, and distribution facilities with full consideration of the hazardous nature of the fuels to be handled and their vapors. Ensure compliance with UFC 3-600-01.

2-14.2 Fire Protection of Aboveground Storage Tanks.

2-14.2.1 Tank Exterior Fire Protection Water Systems.

Provide fire protection water mains, hydrants, valves, pumps, and application devices to permit control of brush and grass fires and cooling of storage tanks in the event of a fire exposure. Provide a minimum of two hydrants. Locate hydrants and valves outside of diked areas and accessible to fire department pumper vehicles. Locate hydrants so that protected exposures can be reached through hose runs not exceeding 300 feet (90 m). Comply with all requirements of Table 2-6 and Table 2-7 in the "Fire Protection Water Systems" paragraph of this chapter for water supply.

2-14.2.2 Tank Interior Fire Protection Systems.

Tanks containing Class I flammable fuels or mission-critical Class II combustible fuels, such as JP-8, must be equipped with a full contact, aluminum honeycomb floating pan. Other Class II fuels require a full contact, aluminum honeycomb floating pan if the tank does not comply with the spacing and diking requirements of this UFC. Tanks storing mission-critical Class III fuels, such as JP-5 and diesel fuel marine (F-76), if located in hot (desert-like) climate, also require a floating pan to eliminate the fuel/air interface. A single slotted stilling well, that penetrates the floating pan, has a maximum diameter of 8 inches (200 mm) and is used for the automatic tank gauge system, is allowed to be provided without a vapor sleeve (bellow). A single slotted stilling well, that penetrates the floating pan, has a maximum diameter of 6 inches (150 mm) and is used for the water probe, is allowed to be provided without a vapor sleeve (bellow). The slotted well used for manual measurements must be equipped with a floating plug. The 8-inch (200 mm) slotted stilling well for the automatic tank gauge system level sensing device and the 6-inch (150 mm) minimum nominal size slotted stilling well for the automatic tank gauge system water probe are allowed to be provided without floating plugs.

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a. Aboveground Atmospheric POL Tanks. Table 2-6 provides fire flow rates for non-pressurized POL tanks.

b. Aboveground Pressurized POL Tanks. Table 2-7 provides fire flow rates for pressurized POL tanks.

c. Underground Atmospheric Tanks. 500 gpm (1900 L/min) for 240 minutes.

d. Underground Pressurized Tanks. 250 gpm (950 L/min) for 240 minutes.

Table 2-6. Atmospheric POL Tank Cooling Water

Tank Diameter		Fire Flow Rate	
(feet)	(meters)	(gpm)	(l/min)
0 – 64	0 – 19	500	1,900
65 – 119	20 – 35	750	2,840
120 – 154	36 – 46	1,000	3,785
155 – 199	47 – 61	1,250	4,740
200 or greater	61 or greater	1,500	5,680
Minimum duration: 240 minutes			

Note: Provide an additional 500 gpm (1,900 L/min) for each exposed tank, pressure vessel or handling facility within 50 ft (15.3 m) or one tank diameter, whichever is greater, of the largest tank under consideration. The maximum water supply for storage tanks must not exceed 2,500 gpm (9,465 L/m).

Table 2-7. Pressurized POL Tank Cooling Water

Tank Group Size	Fire Flow Rate gpm (l/min)
Single tank less than 30,000 gallon (113,550 L) capacity.	250 (950)
Single tank more than 30,000 gallon (113,500 L) capacity.	500 (1900)
2 to 6 tanks, one or more tanks greater than 30,000 gallon (113,550 L) capacity.	500 (1900)
2 to 6 tanks, each greater than 30,000 gallon (113,500 L) capacity.	1,000 (3785)
7 or more tanks, each tank less than 30,000 gallon (113,500 L) capacity.	1,000 (3785)
7 or more tanks, one or more tanks greater than 30,000 gallon (113,550 L) capacity.	1,500 (5680)
Minimum duration: 240 minutes	

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2-14.3 Fire Protection of Underground Vertical Storage Tanks.

\1\ /1/In accordance with the Installation Fire Protection Plan, provide fire protection water mains, hydrants, valves, pumps, and application devices to permit control of brush and grass fires and for cooling of the aboveground piping and system components associated with underground vertical storage tanks in the event of a fire exposure. Provide a minimum of two hydrants. Locate hydrants so that protected exposures can be reached through hose runs not exceeding 300 feet (90 m). The minimum fire flow rate and minimum duration per hydrant must be calculated using the smallest diameter of aboveground POL tank. **\1\ /1/**

2-14.4 Fire Protection of Pumping Facilities.

2-14.4.1 Fire Department Access.

Provide adequate fire department access for all pumping facilities. Provide fire department access to all open sides of a pumphouse or pump shelter. Provide fire department access to at least two sides of a pump pad.

2-14.4.2 Pump Pad and Pump Shelter Sprinkler Requirements.

Pump pads and pump shelters do not need fire suppression systems.

2-14.4.3 Fuel Issue Pumphouse Sprinkler Requirements.

All of the following criteria must be met for a fuel issue pumphouse (typically a fuel hydrant system or independent fillstand system) to require protection with an automatic fire suppression system, foam water fire suppression system, etc.

a. Pumphouse must directly supply a mission critical asset or supply a refueler (e.g. R-11) which in turn supplies a mission critical asset. Fillstands attached to hydrant systems are counted as a part of the hydrant system.

b. Pumphouse must be in one (enclosed) fire area.

c. Pumphouse must supply over 50% of the fueling capability of a mission critical asset. For fillstands, pump capability and available trucks need to be taken into account.

2-14.4.4 Transfer Pumphouse Sprinkler Requirements.

All of the following criteria must be met for a fuel transfer pumphouse to require protection with an automatic fire suppression system, foam water fire suppression system, etc.

a. Pumphouse must supply a mission critical asset.

b. Pumphouse must be in one (enclosed) fire area.

c. Pumphouse must supply over 50% of the pumping capacity to the mission critical asset.

2-14.4.5 Mobile Fuel Pumping Equipment Sprinkler Requirements.

Readily available mobile fuel pumping equipment with 50% of the total fuel pumping capacities can be used to eliminate need for a fire suppression system. Mobile equipment that may be deployed may not be considered. This option must be approved by the Service Headquarters Subject Matter Expert. Where mobile pumping option is selected, provide connection points in the fuel system for temporary mobile pumps in the event that a pump facility is lost.

2-14.5 Fire Protection of Filtration Facilities.

Provide adequate fire department access for all filtration facilities. Provide fire department access to all open sides of a filtration building. Provide fire department access to at least two sides of a filtration pad.

2-14.5.1 Filtration Pad Sprinkler Requirements.

Filtration pads do not need fire suppression systems.

2-14.5.2 Filtration Building Sprinkler Requirements.

All of the following criteria must be met for a filtration building (typically associated with cut and cover hydrant systems) to require protection with an automatic fire suppression system, foam water fire suppression system, etc.

a. Filtration building associated with a fuel system that directly supplies a mission critical asset or supplies a refueler (e.g. R-11) which in turn supplies a mission critical asset.

b. Filtration building must be in one (enclosed) fire area.

c. Filtration building associated with a fuel system that supplies over 50% of the fueling capability of a mission critical asset.

2-14.6 Fire Protection of Tank Truck and Tank Car Facilities.

For facilities (such as loading stands) used for the transfer of flammable or combustible liquids to or from tank truck, refuelers, tank cars, drums, or other portable containers, provide portable dry chemical extinguishers of appropriate size, number, and location for the exposure.

2-14.7 Fire Protection of Aircraft Parking and Fueling Facilities.

Provide firefighting system components in accordance with service requirements. A minimum fire flow rate of 1,000 gpm (3,785 L/min) for a 2-hour duration is to be provided for all such facilities. Refer to USAF TO 00-25-172, NAVAIR 00-80R-14, NAVAIR 00-80T-109, AR 420-90 and NFPA 407.

2-14.8 Fire Protection of Refueler Vehicle Facilities.

Facilities that are covered and enclosed on at least three sides and that are used for the parking, storage, maintenance, and repair of aircraft refueler vehicles must be protected by an automatic sprinkler system or a closed-head foam-water **\1\ /1/** sprinkler system and utilize Class I Division 2 electrical system components and wiring as defined by NFPA 70

2-14.9 Fire Protection of Fuel Testing Laboratory.

\2 Comply with UFC 4-310-03 for fire protection of Fuel Testing Laboratories. ***/2/***

2-14.10 Fire Protection of Support Facilities.

Comply with UFC 3-600-01 for fire protection of support facilities.

2-14.11 Fire Protection of Fuel Piers.

Provide protection for piers with fixed piping systems used for the transfer of flammable or combustible liquids in accordance with the following:

a. UFC 3-600-01

b. UFC 4-152-01, UFC 4-150-02, and UFC 4-150-06

c. NFPA 30

d. NFPA 30A

e. NFPA 307 (If liquids are handled in bulk quantities across general purpose piers and wharves.)

f. "Guide on Marine Terminal Fire Protection and Emergency Evacuation," Oil Companies International Marine Forum.

2-14.11.1 Fire Protection Water Systems.

Use fire water systems with hydrants located so that vessels alongside can be reached through hose lines not longer than 300 feet (90 m). Consult UFC 3-600-01 to determine total water demands for piers based on an extra hazard occupancy classification.

2-15 EMERGENCY SHUT-DOWN.

Emergency fuel shutoff (EFSO) pushbuttons are required wherever there is a potential for an accidental release. EFSO pushbutton stations are required near tanks (outside of berm area), tank car and tank truck loading and off-loading, refueler truck fillstands, aircraft direct fueling stations, pumps, fuel piers, etc. All pumps must shut down and all motor operated valves must close when an EFSO pushbutton is pressed. An alarm must be annunciated at the master alarm panel. Operation of all pumps and valves must be discontinued until all EFSO pushbuttons are cleared and the alarm acknowledged. Off-base pipeline receipt and tanker receipt may be exceptions; contact Service Headquarters for direction.

2-16 ELECTROMAGNETIC RADIATION HAZARDS.

Potential ignition hazards to petroleum storage, dispensing, or handling facilities may be created by emissions from electromagnetic devices such as radio and radar. Beam/signal strength has been known to cause ignition of flammable vapor-air mixtures from inductive electrical heating of solid materials or from electrical arcs or sparks from chance resonant connections. For additional information, refer to NAVSEA OP 3565/NAVAIR 16-1-529, MIL-STD-461 and NFPA 407. Contact the installation for radio tower locations and confirm with authority having jurisdiction. Incorporate the following specific precautions and restrictions in the design of petroleum fuel facilities:

a. Locate the radio transmitting antennas as far as practically possible from fuel storage or transfer areas.

b. Do not locate the fuel storage or transfer facilities closer than 300 feet (90 m) from aircraft warning radar antennas.

c. Do not locate fuel storage or transfer facilities closer than 500 feet (150 m) from airport ground approach and control system components.

d. Do not locate fuel storage or transfer facilities closer than 300 feet (90 m) from areas where airborne surveillance radar may be operated.

e. Do not locate fuel storage and transfer facilities closer than 100 feet (30 m) from airport surface detection radar system components.

2-17 IDENTIFICATION.

Identify all pipelines and tanks as to product service by color coding, banding, product names, NATO designation, and directions of flow in accordance with MIL-STD-161.

a. Mark valves, pumps, meters, and other system components with easily discernible painted numbers or numbered corrosion-resistant metal or plastic tags attached with a suitable fastener. Ensure numbers correspond to those on the schematic flow diagrams and other drawings for the installation.

b. Mark tanks with easily discernible painted numbers and letters indicating the following in addition to the requirements stated in MIL-STD-161: Tank number, Facility number, “No Smoking” on class 1 tanks, and “Confined Space” on Roof Manhole/Ladder Hatch

c. Mark tanks in accordance with NFPA 704.**\2**

d. Mark underground storage tanks as stated above. The markings must be sized appropriately as to be clearly visible form operating and emergency response positions. The markings must be positioned near the main vehicular or pedestrian access to the tank. The markings are not required to be the same sizing as required in MIL-STD-161. ***/2/***

2-18 ANTISTATIC DESIGN.

Consider static build-up in the design. Refer to CRC Report No. 346 and No. 355, API RP 2003; and UFC 3-460-03. Because of the many variables involved, such as properties of fuels and geometry of system component layouts, no specific limits are established for design factors such as flow velocities.

2-18.1 Piping Inlet Connections.

Design connections to tanks for reduced velocity and to prevent splashing by use of diffusers. Fuel products are not permitted to free fall under any circumstances. Position inlet as close to the tank floor as possible to limit free fall.

2-18.2 Enclosed Vapor Spaces.

Spaces above flammable or combustible Hydrocarbons in tanks or other liquid containers must not have any pointed projection or probes which could be focal points for static electricity discharges.

2-18.3 Filter-Separators.

The heaviest electrostatic charges are usually developed in filtering elements of this system component. The design should attempt to reduce such charges before fuel is transferred into storage tanks, vehicle tanks, or any system component containing vapor spaces.

a. By means of residence time in piping or in a relaxation tank, provide a minimum of 30 seconds relaxation time between this system component and discharging into a tank or vehicle. The only aviation turbine fuel currently in the inventory that requires this minimum relaxation time are JP-5, JPTS and other aviation turbine fuels that do not contain SDA.

b. Relaxation time is not required for projects handling only fuels containing a static dissipater additive (SDA) that provides a conductivity level greater than 50 conductivity units (50 picosiemens per meter) at the fuel temperature of the operations. Examples of this are JP-4 and JP-8.

c. **\2** Provide a means for slow filling through the sump, to prevent static discharge when first filling empty filter-separator vessels. Slow filling through the sump may be bypassed, depending on the type of system, fuel type, and Service Headquarters requirements. ***/2/***

2-18.4 Aircraft Direct Fueling Stations.

Fuel that has not been additized with SDA upon filtration (i.e. JP-5, JPTS, Jet-A, etc.) requires a 30-second residence time in the piping or in a relaxation tank after flowing through filtration and before being discharged into the aircraft to allow separate charges generated by the filtering elements to recombine and neutralize themselves. Where possible, design the piping layout to provide the required 30-second relaxation time without use of a relaxation tank.

2-18.5 Truck Bottom Loading.

Provide facilities only capable of bottom loading of trucks. Army facilities that routinely handle trucks that are not capable of bottom loading must obtain approval for the addition of top loading capability from the Army Service Headquarters. Refer to NFPA 77 and API RP 2003 for additional information and requirements.

2-19 OPERATION AND MAINTENANCE DOCUMENTATION.

2-19.1 Operation and Maintenance Documentation for Systems Components.

\3 In all construction and procurement contracts, require operation and maintenance data for pieces of system components which require maintenance and/or which require setting, adjusting, starting, stopping, calibrating, and similar operational activities. **/3/**

2-19.2 Operation and Maintenance Support Information (OMSI).

An OMSI for all new facilities is required. The determination to include a requirement for a complete OMSI for new facilities or a major rehabilitation will be made by the appropriate Service Headquarters.

2-20 PROTECTION AGAINST SEISMIC ACTIVITY.

Design fuel facility buildings and structures for seismic requirements in accordance with UFC 1-200-01. Design aboveground vertical storage tanks in accordance with Appendix E of API Std 650. Analyze flexible aboveground pipelines using techniques to account for harmonic response.

2-21 STRUCTURAL DESIGN.

Design all buildings and structures in accordance with UFC 1-200-01. General risk categories for fuel facilities are to be in accordance with UFC 3-301-01. The risk categories are:

a. II for operations buildings, canopies, truck load/off-load facilities and similar structures.

b. III for storage tanks**\1**, pumphouses, filter buildings, and control rooms.**/1/**

2-22 CANOPIES.

2-22.1 Canopies to Protect Fixed Assets from Extreme Weather Conditions.

Unless otherwise directed by Service Headquarters, provide a canopy to protect fixed facility assets, operators, and system components from extreme weather conditions. Fixed facilities and system components include but are not limited to: pump pads, filtration pads, meter pads, isolation valve pads, tank truck and tank-car off-loading and loading system component pads, control panels, electrical panels, and motor control centers (MCCs). Ensure structural design is in accordance with UFC 1-200-01 and UFC 3-301-01.

2-22.2 Extreme Weather Condition for Canopies.

The following table provides a guide for determining extreme weather locations where fixed assets, operators and system components should be protected. UFC 3-400-02 provides information on Design Engineering Weather Data. Table 2-8 provides the lower condition limit for each of the Design Engineering Weather Data provided by UFC 3-400-02. A canopy should be considered if the Design Weather Data at the facility meets at least one of the weather data criteria limit.

Table 2-8. Design Engineering Weather Data for Canopies

Weather Data	Criteria	Limit	Limit
Dry Bulb High Temperature	2.0% occurrence	89 °F	32 °C
Mean Daily Range		18 °F	-8 °C
Rain Rate	100 year occurrence	3.6 in/hr	91 mm/hr
Ground Snow	50 year occurrence	25 lb/ft^2	122 kg/m^2

2-22.3 Canopies to Reduce Stormwater.

Do not provide a canopy to preclude rain from reaching the containment area unless it is required by federal, state, or local regulations or if directed by Service Headquarters.

2-22.4 Canopies to Reduce Temperature.

If canopy is intended to protect against direct sunlight, then a solar angle analysis should be performed and the overhang increased if warranted by such analysis. The solar angle analysis should consider the angle of the sun at different times of the day in relationship to the asset being protected during the months when the temperature exceeds the value provided in Table 2-8.

2-22.5 General Canopy Construction.

Canopy edges should overhand the edge of the equipment, facility, or personnel to be protected. To provide adequate protection from precipitation, such overhang should extend at least 4 feet (1.2 m) horizontally for every 10 feet (3 m) of canopy height. At a canopy over a tank truck or tank car loading and off-loading containment area, ensure that the underside of the canopy is high enough to provide headroom for personnel when access is required on top of the truck or car. Ensure structural design is in accordance with UFC 1-200-01 and UFC 3-301-01.

For personnel safety, access to the top of tank trucks or tank cars should not be allowed for loading and off-loading operations. If local circumstances dictate that personnel must routinely gain access to the top of tank trucks or tank cars, at loading and/or off-loading facilities or other locations with canopies, a fall protection system must be provided that is designed to meet all OSHA standards./1/

2-23 CONCRETE.

Concrete where used in this UFC refers to cast-in-place, Portland Cement Concrete (PCC), reinforced as required, finished, and cured. The use of coated or uncoated bituminous asphalt concrete (asphalt), “shotcrete”, or autoclaved cellular concrete (ACC) in its place is prohibited.

2-24 AIRFIELD/AIRSPACE REQUIREMENTS.

Incorporate requirements for airfield and airspace clearances into all construction documents for work near an airfield. Verify compliance with UFC 3-260-01.

2-25 PERMITS.

The planner, programmer, and designer should give consideration to required permits (dredging, air emissions, water discharges, etc.). For all locations, consideration should also be given to storage tank system registration and fuel system operational permit/plan requirements. Considerations are cost of permit, cost impact of project to meet permit requirements, schedule impact of permit, who is to obtain permit, and at what time in the project schedule should application be made.**\2**

2-26 COMMISSIONING AND START-UP.

The designer must include the requirement and the capability for commissioning, equipment performance testing, and start-up of the entire fueling system following the construction. **/2/**

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CHAPTER 3 BULK FUEL STORAGE FACILITIES

3-1 INTRODUCTION.

This chapter provides guidance for the design of bulk fuel storage facilities, including bulk storage tanks and those components normally located within a typical bulk storage compound. These components include pipeline receiving facilities, tank truck and tank car receiving facilities, pipeline dispensing (pumping) facilities, tank truck and tank car loading facilities, and all related piping and system components. Fuel storage tanks are discussed in Chapter 8 and piping systems in Chapter 9 of this UFC. Support facilities, which are discussed in Chapter 11 of this UFC, are often collocated within bulk facilities. Systems used to receive and dispense aviation turbine fuels are discussed in Chapter 4 of this UFC. Systems used to receive and dispense fuel from barges and ships are discussed in Chapter 5 of this UFC. Installation pipelines connecting bulk facilities with marine receiving and dispensing facilities, aircraft fueling facilities, and ground vehicle fueling facilities, as well as interterminal pipelines are discussed in Chapter 6 of this UFC. Refer to Facility Plate 001 for the entire chapter identification plan pertaining to this UFC.

Note: If aviation fuel can be pumped directly from a tank into an aircraft, aircraft direct fueling system or a refueler, treat the tank as an operating storage tank regardless of size and location and must meet the applicable requirements for aviation turbine fuel operating tanks. The exception is bulk storage tanks that are configured to fill refuelers on an emergency basis only.

3-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not begin the design of any fueling system without first becoming completely familiar with Chapter 2 and Chapter 9 of this UFC.

3-2.1 Custody Transfer.

Custody transfer generally takes place at the following locations:

a. Every pipeline receipt station.

b. Every tank truck and tank car loading and offloading position.

c. Every marine loading and offloading system.

3-3 RECEIVING FACILITIES.

Fuel is normally received at bulk fuel storage facilities by pipeline, tank truck, tank car, barge, or ship. In many cases, the fuel is pumped by pipeline from the marine receiving facility to the bulk storage facility. Marine receiving facilities are addressed in Chapter 5 of this UFC. Service Headquarters, with concurrence from the DLA-Energy, will determine the appropriate type of delivery method based on mission requirements and an economic analysis. A secondary method of delivery is normally required for aviation activities.

3-3.1 Pipeline Receiving Facilities.

3-3.1.1 General Criteria.

Petroleum fuels may be supplied to bulk fuel storage tanks by interterminal pipelines which may be dedicated to serving the particular facility or may be commercial pipelines handling a number of types or grades of fuel for more than one user. In some cases, the pipeline will be an installation pipeline. If different fuel types are used, separate each type within the receiving facility. Exercise extreme care to avoid designing a system that could create damaging surges in the pipeline created by quick closing valves.

3-3.1.2 Required System Components.

a. Provide pressure-regulating diaphragm control valves to reduce pipeline pressures to the design pressure of the facility's piping and system components. Provide a manual isolation valve at both the upstream and downstream side of each diaphragm control valve. Prior to designing any features into the system which might affect the flow from a pipeline, contact the operator of the pipeline to ascertain the current operating conditions, evaluate the use of diaphragm control valves, conduct a surge analysis of the pipeline, and determine whether the use of diaphragm control valves is appropriate.

b. Provide a meter at the receiving end of the line to measure quantities of fuel received. Turbine-type meters are commonly used for pipeline receipt above 1200 gpm because of the cost of large positive displacement meters. However, positive displacement meters are acceptable if available at the required flow rate. Compensate for fuel temperature at the point of custody transfer. Provide a basket strainer immediately upstream of the meter and connections for proving the meter with a portable prover. A meter prover connection consists of a manual isolation valve in the main pipeline with a tee on both the upstream and downstream sides of the valve. The branch of each of the tees has a manual isolation valve and a hose connection. The master meter can be attached to the hose connections.

c. Provide a means for sampling each pipeline product at a breakout manifold.

d. Provide provisions for maintenance and ILI pigging on interterminal pipeline receipt location. Consult Service Headquarters for arrangements required to meet commercial pipeline agreements. Provide ILI launcher and receiver on government owned interterminal pipelines. Arrange pig receiving connections to avoid introducing pipeline sludge and sediment into the tanks. Pig launching and receiving provisions are required for interterminal (cross-country) and installation (as described in Chapter 6 of this UFC) underground pipelines.

e. Provide an interface tank to receive mixed fuels at the beginning and ending of a shipment unless the commercial pipeline company can provide this service satisfactorily.

f. Provide a breakout tank only if pipeline flow cannot be stopped due to pipeline operational requirements. Provide valves to divert the flow of fuel from the pipeline to the breakout tank in the event fuel transfer is blocked by a manual or automatic valve within the fuel facility system such that the fuel facility system would be over pressurized from transient surge or high pressure from deadheading a pipeline supply pump. Provide appropriate breakout tank overfill alarms and alarm breakout operation so fuel facility operators can take necessary steps to stop pipeline flow. Provide means of transferring fuel out of breakout tank back to fuel systems after a breakout event. Conduct a thorough review with the pipeline operator and perform a transient surge analysis to determine if surge pressure reduction methods are required to avoid damage to the pipeline. Consider multiple factors when determining size of breakout tank. Factors shall include ability of receiving facility to recognize excursion (over pressure event), ability to notify source of transfer to shutdown pipeline pumps, impact of deadheading pipeline pump, and factor of safety. Increased confidence of ability to shutdown pumps, via receipt pressure sensors with rate of rise PLC assessment, communication to transfer source via fiber optics communication, and automatic transfer pump shutdown will lead to smaller sized breakout tanks. Whereas reliance on receipt staff to respond to alarm and notify source pumpstation via telephone will lead to larger sized breakout tank. Consideration shall also be given to type of surge breakout system, such as side stream pressure relief versus rapid full opening surge dump valve. As a minimum, the surge breakout tank must be sized such that its ullage volume, above a minimum heal level, can safely store not less than two times the volume of fuel resulting from a release event, but not less than two times the receipt volume for a 10-minute flow at normal pipeline flow. When sizing breakout tanks also consider using aboveground shop fabricated UL listed tanks, and that increasing the tank size (and thus safety factor of release) very often is a small cost, compared to the cost of release cleanup. Contact Service Headquarters for design considerations and approval of surge breakout tank system approval.

g. Provide means of inbound filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters, and Haypack coalescers as possible filtration devices. Avoid the use of water slug shutoff diaphragm control valves or other rapid-closing valves on pipeline receipt facilities. For inbound filtration of aviation turbine fuels, refer to "Special In-Bound Filtration" paragraph of Chapter 4 of this UFC.

When a water slug shutoff is not provided, provide sump water detector and alarm panel.

h. Provide manual isolation valves to isolate system components for service.

i. Provide basket strainers immediately upstream of pumps, meters and receipt filtration. On piggable pipeline receipt, provide two parallel strainers with isolation valves so pigging can continue while cleaning one strainer.

j. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

k. Provide a concrete housekeeping pad **\1** , and a canopy for protection from the elements of fixed facility assets and system components in accordance with paragraph 2-22. **/1/**

3-3.2 Tank Truck and Tank Car Off-loading Facilities.

3-3.2.1 General Criteria.

Bulk fuel storage tanks may be supplied with fuel by tank truck or tank car or both. At facilities with pipeline or water transport as their principal supply source, provide tank truck or tank car deliveries as a secondary supply source. Tank truck deliveries are the most common method. However, special transportation considerations or changing circumstances may make the use of rail facilities desirable. Therefore, at an activity with railroad service, arrange a tank truck receiving facility so that the system can be easily and economically extended to the existing rail spur. See Facility Plate 002.

a. The preferred off-loading method is into a drop tank off-loading system. See Facility Plate 003.

b. Provide a packaged off-loading system when a drop tank type off-loading system is not practical for off-loading tank trucks or tank cars due to environmental concerns, site limitations, or cost considerations, and/or when directed by Service Headquarters. See Facility Plate 004.

c. Provide a direct off-loading system when only an occasional tank truck requires off-loading and when directed by Service Headquarters. See Facility Plate 005.

d. Do not locate tank truck or tank car receiving facilities closer than 50 feet (15 m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines, and 25 feet (7.6 m) from the installation interior fence surrounding the fuel farm. See Chapter 8 of this UFC for clearance requirements from tanks.

e. Provide an adequate number (minimum two) of positions to off-load the daily fuel requirements of the facility in an 8-hour period without causing detention or demurrage of delivery conveyances.

f. Provide separate off-loading connections for each type of fuel to be handled. To facilitate the use of tank trucks with multiple independent compartments, provide a hose manifold with a minimum of two connections per tank truck. A manifold with hose connections equal to the number of truck compartments is recommended for quick turnaround. If less than five connections are provided, provide a blind flange on the end of the manifold to accommodate additional connections.

g. Provide a containment area at each truck off-loading position consisting of an impermeable retention and controlled drainage system leading to a concrete remote spill containment system. Pave the containment area consisting of the islands, the spaces between islands and on each side of the outer islands, with concrete pitched a minimum of one percent toward catch basins or trench drains. Design the containment area in accordance with UFC 1-200-01, federal, state, and local regulations. Do not use asphalt within a spill containment area. The maximum slope of any paving within a truck movement or parking area must not exceed 2 percent excepting ramps. If a ramp is provided, the sum of the vertical entrance and exit grades must not exceed 8 percent and the ramp must be aligned perpendicular with direction of truck movement. The designer must assure that adequate ground clearance is achieved for all vehicles utilizing the containment areas.

h. Provide spill containment at each rail tank car off-loading position consisting of an impermeable containment system surrounding the rail car with drainage leading to a concrete remote spill containment basin. Pave the offload equipment area and space between the offload equipment and rail car containment system with concrete sloped a minimum of one percent toward a drainage collection system that leads to the concrete remote spill containment basin.

i. Provide a concrete remote spill containment system for each containment area. Design the remote spill containment system in accordance with UFC 1-200-01, federal, state, and local regulations. Provide the remote spill containment system with capacity greater than the volume of the largest tank truck or tank car compartment to be off-loaded. The top elevation of the remote spill containment basin must not be set less than 6-inches above the top of the refueler truck parking area's maximum ponding elevation. This will prevent overflow of the remote spill containment basin during a heavy rain event. A curbed truck position may be provided in addition to a remote system. Twenty-five percent or more of the total required containment volume must be directed to, and stored at, the remote system before any of the shared containment volume will pond at the truck stand area. Provide a lockable eccentric plug valve with indicator post located outside the containment area at a location that will be safely accessible during a fire. The valve must be lockable and normally closed to allow for containment during fueling operations and which can be opened to drain the area when necessary. Tank trucks can be as large as 10,000 gallons (38,000 L) in capacity and tanks cars as large as 40,000 gallons (150,000 L). Consider combining the remote spill containment system with other spill containment systems on-site, except with tank containment systems. However, take the level of contamination in each containment area into consideration.

j. Construct the drain piping between the containment area and the remote spill containment system, and between the remote spill containment system and lockable plug valve of petroleum-resistant, impermeable materials with water-tight joints such as ductile iron or HDPE pipe with fusion welded joints. Do not use clay, concrete, or fiberglass piping materials.

k. For off-loading tank trucks, arrange the flow of traffic to permit continuous forward movement of tank trucks at all times. Commercial tank trucks off-load on the passenger side.

l. Tank truck configurations vary. Key variables are: the number of compartments per tank, single or multiple trailers, location of connections on each trailers, height of trailer connections, etc. Designer must coordinate with the installation and Service Control Point regarding the type of delivery trucks used at the installation.

m. To determine the number of connections needed for off-loading tank cars, consult with Service Headquarters and consider minimizing tank car movements, tank car shipping schedules, conveyance turn-around times, local rail switching capabilities, and quantity of fuel needed for one day's fuel supply.

n. Provide an electrical design that meets the minimum requirements of NFPA 70, NFPA 77, and NFPA 780. Treat combustible liquids under pressure as a flammable liquid.

o. Provide a canopy for protection from the elements of fixed facility assets and system components **\1** in accordance with paragraph 2-22. **/1/**

p. Provide a canopy to preclude rain from the containment area **\1** in accordance with paragraph 2-22. **/1/**

q. Provide for egress and entrance of emergency response vehicles. The egress and entrance routes need to be large enough to allow both, trucks and emergency vehicles, leaving and entering the facility.

r. When directed by Service Headquarters, provide means of inbound filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters, and Haypack coalescers as possible filtration devices. For inbound filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

3-3.2.2 Tank Truck and Tank Car Drop Tank Off-Loading System.

The introduction of air into a fuel receiving system poses extreme hazards which can result in fire and/or explosion. Hazards are compounded when an air/fuel mixture is passed through receipt filter-separators where static electricity is generated and ignition can occur. Design off-loading facilities so air is not introduced into the system. For facilities with the capability to off-load several tank trucks at once or where newer tank trucks with multiple hoses are connected to multiple isolated compartments, consider providing an underground, gravity-type, receiving tank with submersible transfer pumps and level controls. For smaller systems of one or two tank trucks, consider a low profile, aboveground, receiving tank with a centrifugal transfer pump. For either case, provide level sensors to control the transfer flow rate. Provide a temperature compensated meter on the receipt line to the tank at points of custody transfer and when directed by Service Headquarters. For materials of construction for off-loading drop tanks, refer to Chapter 8. See Facility Plate 003.

3-3.2.3 Tank Truck and Tank Car Packaged Off-Loading System.

For tank truck or tank car off-loading, an off-loading drop tank may not be practical due to environmental concerns, site limitations, or cost considerations. In these instances, provide a 600 gpm (38 L/s) packaged off-loading system. Provide one packaged system, including vertical inline centrifugal pump, diaphragm control valves to control flow, meter, and multiple hose connections (one for each tank truck compartment), for each tank truck or tank car receiving station. Provide an air eliminator tank to remove air from the system, reducing the risk of an air/fuel mixture passing through receipt filter-separators and preventing the metering of air. Level sensors in the air eliminator tank control the pump discharge diaphragm control valves, modulating the flow rate based on the level in the air eliminator tank. Refer to DoD Standard Design AW 078-24-28 and Facility Plate 004.

3-3.2.4 Tank Truck and Tank Car Direct Off-Loading System.

Use when only an occasional tank truck requires off-loading and when directed by Service Headquarters. Refer to Facility Plate 005

3-3.2.5 Required System Components.

a. When tank trucks or tank cars are off-loaded with a drop tank off-loading system, do not provide an off-loading pump. Provide at least two pumps in the drop tank to transfer fuel to the storage tank.

b. When tank trucks or tank cars are off-loaded with packaged off-loading systems, provide one system for each tank truck or tank car that is to be off-loaded simultaneously, at an average capacity of 600 gpm (38 L/s) each. The number of systems will be determined by Service Headquarters but must be a minimum of two. The capacity of the systems may be reduced to 300 gpm (19 L/s) each only when directed by Service Headquarters.

c. When tank trucks or tank cars are off-loaded with direct off-loading systems, provide centrifugal pumps configured to provide automatic air elimination as shown on Facility Plate 005. Provide at least two pumps to allow continued operation if one is out of service. The capacity of the pumps may be increased to 600 gpm (38 L/s) each only when directed by Service Headquarters. The centerline height of suction line from manifold to pump generally should not exceed 23.25 inches (591 mm) above truck unloading, parked position. Confirm this with the activity; in western CONUS, trucks tend to have lower connections. Locate the pump as close as possible to the off-load point to prevent suction problems.

d. Provide lightweight reinforced vacuum rated off-loading hoses and covered hose storage racks for each hose connection at each off-loading position. Eliminate covered hose storage rack if off-load rack is to be covered by a canopy. Ensure that all swivels are non-lubricated aluminum or stainless steel in-line repairable type. Consult with activity to verify the need for hoses, since at some locations, the fuel hauling contractor provides the hoses.

e. Equip each tank truck off-loading position with an electronic, intrinsically safe, automatic, self-monitoring ground verification unit with a lockable bypass. If grounding is not verified and there is an off-loading pump dedicated to that position, ensure the unit prevents the pump from starting. If the pump is not dedicated, ensure an alarm sounds if the off-loading valve is opened prior to grounding verification. Include a separate grounding reel to accommodate vehicles without grounding system components.

f. Provide emergency fuel shutoff (EFSO) pushbutton stations. For truck off-loading stations with multiple positions, an EFSO pushbutton station is required for each position and along routes of personnel ingress and egress between 100 and 200 feet (30 m and 60 m) from the off-loading position. Design in such a manner that activation of the emergency stop will shut off all fueling in the off-loading area and/or the associated pumphouse or pump pad.

g. Provide fuel sampling connections at each position for each product line for collecting test samples.

h. Provide pressure gauges on both sides of each strainer or a differential type gauge across each strainer. Where a strainer is upstream of a pump, the pump suction gauge may function as the strainer downstream gauge.

i. Provide a compound (pressure/vacuum) gauge on the inlet side of pumps and a pressure gauge on the outlet side of pumps.

j. If the system is for JP-5 or other fuel that does not have a static dissipater additive (SDA) which provides a conductivity level greater than 50 conductivity units (50 picosiemens per meter), and a 30-second retention time is not provided between filter-separator and receiving tank, provide a relaxation tank downstream of the filter-separator or design the piping layout to provide the required 30-second relaxation time downstream of filter-separator.

k. Provide basket strainers immediately upstream of pumps, meters, and receipt filtration. Provide duplex straining (two individual basket strainers and isolation valves) on pipeline receipts, including interterminal and installation pipelines upstream of receipt filtration.

l. Provide a combination flow control and non-surge check diaphragm control valve on all off-loading pumps except positive displacement types. If a bulk air eliminator with automatic air release head is included, provide a means of closing the diaphragm control valve with a solenoid pilot.

m. Provide a positive displacement or turbine meter. Provide meter with temperature compensation capability and meter proving connections at each offload position (custody transfer location). Provide a basket strainer immediately upstream of the meter.

n. On each off-loading connection or on the off-loading riser, install a visual fuel flow indicator (maximum pressure 275 psi (1900 kPa) at 100 degrees F (38 degrees C), with Viton Seals with a maximum temperature rating of 350 degrees F (177 degrees C)). This will allow visual quality assurance and provide the operator with a backup system to shut off the pumps when off-loading is complete to prevent air build-up in the receipt lines.

o. Provide manual isolation valves to isolate system components for service.

p. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

q. Where tank trucks or tank cars are off-loaded into drop tanks, provide meters on the downstream side of the drop tank pumps.

r. When directed by Service Headquarters, provide means of inbound filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters, and Haypack coalescers as possible filtration devices. For inbound filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

3-3.3 Marine Off-Loading Facilities.

See Chapter 5 of this UFC.

3-4 DISPENSING FACILITIES.

Fuel is normally dispensed from a bulk facility via an installation pipeline, interterminal pipeline, tank truck, or tank car.

3-4.1 Pipeline Pumping Facilities.

3-4.1.1 General Criteria.

As discussed in Chapter 6 of this UFC, pipelines are either interterminal pipelines or installation pipelines. Installation pipelines are commonly used to transfer fuel to an aircraft fueling facility or a marine dispensing facility. Interterminal pipelines are cross-country between installations. However, since pipeline pumping facilities are typically at a bulk fuel storage facility, they are covered in this chapter.

3-4.1.2 Required System Components.

a. Centrifugal pumps complying with API Std 610 with adequate head and capacity. Always provide one additional pump as back up.

b. Turbine or positive displacement meter with proving connections. Compensate for fuel temperature at custody transfer point.

c. Provide fuel sampling connections for collecting test sample.

d. Pig launching and receiving capability for interterminal and installation pipelines.

e. Strainer immediately upstream of meters and pumps.

f. Manual double block and bleed isolation valves where total isolation is required.

g. Pressure gauges on both sides of the strainer or a differential pressure type gauge across the strainer.

h. Compound (pressure/vacuum) gauges on the inlet side of pumps and pressure gauges on the outlet side of pumps.

i. Provide a combination flow control and non-surge check diaphragm control valve on all pumps except positive displacement types. If a bulk air eliminator with automatic air release head is included, provide a means of closing the diaphragm control valve with a solenoid pilot.

j. Provide manual isolation valves to isolate system components for service.

k. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

l. Provide a concrete housekeeping pad **\1** , and a canopy for protection from the elements of fixed facility assets and system components in accordance with paragraph 2-22. **/1/**

m. When directed by Service Headquarters, provide means of filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters, and Haypack coalescers as possible filtration devices. For filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

3-4.2 Tank Truck and Tank Car Loading Facilities.

3-4.2.1 General Criteria.

This chapter applies to facilities required for loading over-the-road tank truck transports or rail tank cars used for the bulk transfer of fuel. A typical application is the transfer by tank truck from a storage terminal to secondary storage, such as a filling station or a heating plant. In many cases, the receiving and loading facilities are combined. In these cases, both receiving and loading facility requirements must be addressed. This chapter does not include facilities for loading aviation refuelers for direct issue to aircraft. This process requires special design considerations as discussed in Chapter 4 of this UFC. See Facility Plates 002, 003 and 005.

a. Determine the volume of fuel and number of tank trucks or tank cars to be handled by an operational analysis with assistance from Service Headquarters.

b. Do not locate tank truck or tank car loading facilities closer than a minimum of 50 feet (15 m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines, and 25 feet (7.6 m) from the installation interior fence surrounding the fuel farm. Do not locate a tank truck loading facility closer than 100 feet (30 m) from a railroad track (or spur) or rail siding for loading/offloading. See Chapter 8 of this UFC for clearance requirements from tanks.

c. Bottom loading is the only acceptable method of loading tank trucks. Bottom loading results in increased safety, manpower savings, quality control of product, and area cleanliness. At non-U.S. locations where only contracted top loading tank trucks are available, install a top loading rack with an elevated steel platform with approval of Service Headquarters. In this event, provide future bottom loading capabilities.

d. Provide a containment area at each truck loading position consisting of an impermeable retention and controlled drainage system leading to a concrete remote spill containment system. Pave the containment area consisting of the islands, the spaces between islands and on each side of the outer islands, with concrete pitched a minimum of one percent toward catch basins or trench drains. Design the containment area in accordance with UFC 1-200-01, federal, state, and local regulations. Do not use asphalt within a spill containment area. The maximum slope of any paving within a truck movement or parking area must not exceed 2 percent excepting ramps. If a ramp is provided, the sum of the vertical entrance and exit grades must not exceed 8 percent and the ramp must be aligned perpendicular with direction of truck movement. The designer must assure that adequate ground clearance is achieved for all vehicles utilizing the containment areas.

e. Provide spill containment at each rail tank car loading position consisting of an impermeable containment system surrounding the rail car with drainage leading to a concrete remote spill containment basin. Pave the offload equipment area and space between the offload equipment and rail car containment system with concrete sloped a minimum of one percent toward a drainage collection system that leads to the concrete remote spill containment basin.

f. Provide a concrete remote spill containment system for each containment area. Design the remote spill containment system in accordance with UFC 1-200-01, federal, state, and local regulations. Provide the remote spill containment system with capacity greater than the volume of the largest tank truck or tank car compartment to be off-loaded. The top elevation of the remote spill containment basin must not be set less than 6-inches above the top of the refueler truck parking area's maximum ponding elevation. This will prevent overflow of the remote spill containment basin during a heavy rain event. A curbed truck position may be provided in addition to a remote system. Twenty-five percent or more of the total required containment volume must be directed to, and stored at, the remote system before any of the shared containment volume will pond at the truck stand area. Provide a lockable eccentric plug valve with indicator post located outside the containment area at a location that will be safely accessible during a fire. The valve must be lockable and normally closed to allow for containment during fueling operations and which can be opened to drain the area when necessary. Tank trucks can be as large as 10,000 gallons (38,000 L) in capacity and tanks cars as large as 40,000 gallons (150,000 L). Consider combining the remote spill containment system with other spill containment systems on-site, except with tank containment systems. However, take the level of contamination in each containment area into consideration.

g. Construct the drain piping between the containment area and the concrete remote spill containment system, and between the remote spill containment system and lockable eccentric plug valve of petroleum-resistant, impermeable materials with water-tight joints such as ductile iron or HDPE pipe with fusion welded joints. Do not use clay, concrete, or fiberglass piping materials.

h. Provide a canopy for protection from the elements of fixed facility assets and system components **\1** in accordance with paragraph 2-22. **/1/**

i. Provide a canopy to preclude rain from the containment area **\1** in accordance with paragraph 2-22**. /1/**

j. Provide separate piping, pumps, loading connections, and controls for each different type and grade of fuel.

k. Provide electrical systems and apparatus that are properly rated for the environment in which they are installed. Hazardous areas are established in Chapter 2 of this UFC. Installation shall be as required by NEC.

l. Arrange loading rack with a row of islands with sufficient clearance between to allow easy access to all parts of the tank trucks when parked. Arrange islands and approaches in a manner that allows forward motion for all tank trucks at all times with ample room for turning. Space and arrange bottom loading islands to accommodate one tank truck only on the side adjacent to the tank truck's liquid connections, usually the passenger side of the tank truck.

m. Provide for entrance and egress of emergency vehicles. The egress and entrance routes need to be large enough to allow both trucks and emergency vehicles to leave and enter the facility.

n. If top loading is required for tank cars (normally only when commercial contract leaves no other choice) and approved by Service Headquarters, provide a typical tank car loading rack with an elevated steel platform, consisting of a walkway, 4 feet (1.2 m) wide, 10.5 feet (3.2 m) above the top of the rails, and the full length of six tank cars. Ensure that the centerline of the structure is 10.5 feet (3.2 m) above the centerline of the tracks. Equip the platform with a counterweighted or spring-loaded tilting bridge to connect to the tank car dome at each loading station. Design so that when released from the horizontal position, the bridge will automatically move and lock in an upright position away from any part of the tank car under all weather conditions. Ensure conformance with UFC 1-200-01 requirements.

3-4.2.2 Required System Components for Tank Truck Fillstand.

a. Provide a positive displacement or turbine meter for each tank truck fill connection. Protect each meter with a basket strainer located immediately upstream of the meter. Include temperature compensation if rack is to be point of custody transfer. At DFSPs, consider providing meter with preset functions that will shut down the flow by closing the truck loading control valve upon issue of a preset quantity of fuel. To ensure proper operation, meter and control valve must be supplied as a packaged system and installed by a single system supplier.

b. Provide a sample outlet with probe, ball valve, and quick disconnect at each position for each product line.

c. Provide pressure gauges on both sides of the strainer or a differential pressure type across the strainer.

d. Self-closing emergency valve with 165 degrees F (74 degrees C) fusible link. (These valves are neither required nor permitted on Air Force projects).

e. Make provisions to start and stop the pumps with start and stop pump control stations at each position. Include pump status indicator light on control box.

f. Provide a solenoid operated truck loading diaphragm control valve with opening/closing speed control, pressure regulating, check and solenoid shut-off features. Interlock the solenoid with the electronic high-level shutoff, and electronic ground verification control system.

g. Provide each fill position with an electronic high-level shutoff, electronic ground verification, and electronic or hydraulic deadman control system. The system must be intrinsically safe and self-checking. Interlock the system with either the solenoid operated truck loading diaphragm control valve or the pump such that the valve cannot remain open or the pump cannot operate if the tank truck compartment is full, the tank truck is not bonded to the fueling system components, or the deadman is released. Ensure the system is compatible with both electronic and fiber optic sensors with manual-keyed bypass. (May require a parallel effort beyond the project scope to ensure that all trucks using the facility have compatible connections. If facility has trucks that do not have fixed probes, use cane probes instead.) (This unit is optional on Army projects with only tactical refuelers. Contact the Service Headquarters for guidance.)

h. Provide emergency fuel shutoff (EFSO) pushbutton stations. For fillstands with multiple positions, an EFSO pushbutton station is required for each position and along routes of personnel ingress and egress between 100 and 200 feet (30 m and 60 m) from the fillstand. Design in such a manner that activation of the emergency stop will shut off all fueling at that pump house or pump pad.

i. Equip liquid connections to tank trucks for bottom loading with drybreak couplers in accordance with API RP 1004.

j. Refer to Chapter 2 of this UFC for guidelines on vapor collection and recovery or disposal systems.

k. Provide heaters and insulated, heated pipelines, as required, where viscous fuels are to be loaded to maintain the temperature of the fuel at its minimum pumping temperature.

l. Provide stainless steel loading arms (pantograph, without hoses) equipped with non-lubricated swivels may be used instead of hoses, if approved by Service Headquarters. Ensure all swivels are non-lubricated, stainless steel in-line repairable type.

m. Provide meter proving connections as described in the paragraph titled “Pipeline Receiving Facilities”, unless local procedure provides an alternative.

n. Provide relaxation tank or piping configuration with sufficient capacity to retain the maximum flow of the loading station for 30 seconds from the time the fuel leaves the last piece of filtration system component to the fuel reaching the loading nozzle. Applies only to JP-5, Jet A and other fuels which do not have a static dissipation additive that provides a conductivity level greater than 50 picosiemens.

o. Provide basket strainer immediately upstream of meters and pumps.

p. Provide manual isolation valves to isolate system components for service.

q. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

r. Grounding/bonding reel (provided as an integral part of the high level shutoff system).

s. Provide hydraulic shock surge suppressors (if required).

t. When directed by Service Headquarters, provide means of filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters, and Haypack coalescers as possible filtration devices. For filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

3-4.2.3 Required System Components for Tank Car Loading Station.

a. Provide a positive displacement or turbine meter for each tank car fill connection. Protect each meter with a basket strainer located immediately upstream of the meter. Include temperature compensation if rack is to be point of custody transfer.

b. Provide meter proving connections as described in the paragraph titled “Pipeline Receiving Facilities”, unless local procedure provides an alternative.

c. Provide a sample outlet with probe, ball valve, and quick disconnect at each position for each product line.

d. Provide pressure gauges on both sides of the strainer or a differential pressure type across the strainer.

e. Provide fusible link butterfly isolation valves as the first piece of system component (in the direction of the flow) on the loading position. (These valves are neither required nor permitted on Air Force projects).

f. Provide loading connections, controls, valves, etc., on one or both sides of the loading platform as specified by Service Headquarters. Load tank cars from the bottom using counterbalanced, articulated tank car loading assemblies.

g. Provide an electronic, intrinsically safe, portable liquid high level sensor with adjustable height at each loading rack. To prevent an overfill, interlock the sensor with the electronic high-level shutoff and electronic ground verification control system.

h. Provide each fill position with an electronic high-level shutoff, electronic ground verification, and electronic or hydraulic deadman control systems. The system must be intrinsically safe and self-checking. Interlock the system with either the solenoid operated tank car loading diaphragm control valve or the pump such that the valve cannot remain open or the pump cannot operate if: the tank car is full, the tank car is not bounded to the fueling system component, or the deadman is released. Provide the capability to connect the ground verification rack to the rail tank car frame.

i. Provide emergency fuel shutoff (EFSO) pushbutton stations. For tank car loading stations with multiple positions, an EFSO pushbutton station is required for each position and along routes of personnel ingress and egress between 100 and 200 feet (30 m and 60 m) from the tank car loading station. Design in such a manner that activation of the emergency stop will shut off all fueling at that pump house or pump pad.

j. Provide solenoid operated tank car loading diaphragm control valve with opening/closing speed control, pressure regulating, check, and solenoid shut-off features. Interlock the solenoid with the electronic high-level shutoff, and electronic ground verification control system.

k. Provide a basket strainer immediately upstream of meters and pumps.

l. Provide manual isolation valves to isolate system components for service.

m. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

n. Provide relaxation tank or piping configuration with sufficient capacity to retain the maximum flow of the loading station for 30 seconds from the time the fuel leaves the last piece of filtration system component to the fuel reaching the loading nozzle. Applies only to JP-5, Jet A and other fuels which do not have a static dissipation additive that provides a conductivity level greater than 50 picosiemens.

o. Provide hydraulic shock surge suppressors (if required).

p. When directed by Service Headquarters, provide means of filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters, and Haypack coalescers as possible filtration devices. For filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

3-4.3 Marine Loading Facilities.

See Chapter 5 of this UFC.

3-5 PIPING SYSTEMS.

Refer to Chapter 9 of this UFC for more information regarding piping systems.

3-5.1 Product Segregation.

Except as otherwise approved by Service Headquarters provide separate receiving, storage, and distribution systems for each product. Except as otherwise approved by Service Headquarters, prevent misfueling (transferring a type of fuel other than the type intended) by using different size piping, valves, adaptors, nozzles, etc.

3-6 DESCRIPTION OF SYSTEMS COMPONENTS.

The appropriate guide specification and/or standard design provides specific information for selection of system components. Make provisions to drain system components for maintenance. Provide hardpiped drains when a system component holds more than 5 gallons (19 L) of fuel or when a pipe which drains to the product recovery tank is within 12 ft (3.7 m) of a system component. Unless otherwise indicated below, refer to Chapter 15 for description of system components. The following system components are typically used in bulk storage facilities:

a. Bulk Air Eliminators

b. Meters – Positive Displacement, Turbine, and Orifice

c. Pressure Gauges

d. Strainers

e. Surge Suppressors

f. Filtration – Filter-Separators, Micronic Filters, and Haypack Coalescers

g. Pumps – Centrifugal, Vertical Turbine, Jockey, and Rotary

h. Manual Valves – Isolation Valves

i. Manual Valves – Isolation Valve Locations

Provide isolation valves in piping systems to control flow and to permit isolation of system components for maintenance or repair. Provide additional valves at locations necessary to conduct a valid hydrostatic test. Require manually operated valves, except where motor operators are specifically authorized by applicable standard drawings or technical specifications. Use double block and bleed type isolation valves for separation of product services, on tank shell connections (ASTs over 12,000 gallons (45 800 L) only), when piping goes aboveground or underground, between pier and tank storage, and other locations critical to periodic pressure-testing of piping. Quick opening/frequent opening type isolation valves may be used for less critical applications where double block and bleed shutoff is not required. As a minimum requirement, provide isolation valves at the following locations:

1. Where piping goes underground or comes aboveground and requires periodic pressure testing.

2. At all subsurface and aboveground piping connections to storage tanks.

3. On each branch line at the point of connection to the main product pipeline or header.

4. On the product pipeline or header just before the line leaves a pumping station.

5. On the suction side and discharge side of each pumping unit, except the suction side of vertical centrifugal pumps installed in underground tanks.

6. On the upstream and downstream side of each line blind at connections to cross country pipelines.

7. On the inlet and outlet connection of each line strainer, filter-separator, meter, diaphragm control valve, and other system components that requires periodic servicing. One inlet valve and one outlet valve may be used to isolate more than one piece of adjacent system components which are connected in series.

8. On each main distribution pipeline immediately downstream of the branch connection to each existing or future operating storage facility served by the pipeline.

9. On the aboveground piping at each tank car or tank truck off-loading connection, and at each inlet to the gravity drop tank.

10. On the aboveground piping at each tank car and tank truck loading connection.

11. At critical roadway, runway and taxiway crossings, consider isolation valves on both sides of runway/taxiway to facilitate hydrostatic testing and isolation.

j. Other Valves – Check Valves, V-Port Ball Valves, and Thermal Relief Valves

k. Diaphragm Control Valves

l. Thermometers

m. Provide thermometers in Burner Fuel No. 5 and No. 6 distribution piping systems at each loading and receiving point and on the inlet and outlet of each heater.

n. Fuel Hoses – Loading and Off-Loading Fuel Hoses

3-7 CONTROLS.

3-7.1 Control System Philosophy.

Fuel systems that includes pumps to receive, transfer, and issue fuel may be provided with an Automatic Pump Control system with a programmable logic controller (PLC) driven Pump Control Panel (PCP) to control the system. Provide an Automatic Pump Control system when required by Service Headquarters. All systems must be designed to perform all of their functions manually in the event the PCP is down. The PCP must:

a. Start and stop issue and transfer pumps.

b. Provide permissive interface to off-loading system receipt pump(s). Receipt pump must not start or continue to operate when receipt tank high-high level is reached or emergency system activation occurs. Local control will start or stop receipt pump.

c. Provide start and stop or permissive interface to drop tank off-loading system receipt pump(s). Receipt pump must not start or continue to operate when receipt tank high-high level is reached or emergency system activation occurs. PCP control via tank level sensors or local start/stop control of the receipt pump(s) is acceptable.

3-7.2 Exceptions.

The exceptions for systems covered in Chapter 3 where a PCP is not required are:

a. Pumps serving miscellaneous use tanks (see Chapter 8 for definition).

b. Isolated miscellaneous pumps that are not part of a larger system. These 5 horsepower or less size pumps act as sump pumps, pier stripping pumps, truck unloading pumps such as those required for off-loading small vacuum trucks, waste oil trucks, etc.

3-7.3 Design Requirements.

Automatic controls at any facility may include temperature, pressure, fuel level and pump controls, automatic flow controls, alarm and limit switches, motor operated isolation valves, solenoid pilot actuated diaphragm control valves, and remote system condition indicators. Other forms of automatic controls are remote meter indication, electronic access control, data logging, and application of computer techniques. Base the selection of advanced automation and telemetry systems on a study of the particular application with consideration of possible economic justification, operational, and security requirements.

3-7.4 Flow Controls

Where it is possible to achieve flow rates which exceed system component ratings, provide an adjustable flow control valve on the outlet connection of each meter or filter-separator. Use a diaphragm control valve controlled by the pressure differential across an orifice plate in the valve or a venturi in the main line. Where necessary, provide remote-operated valves on storage tank inlet and outlet lines, suction and discharge of transfer pumps, and transfer lines at fuel piers and other locations.

3-7.5 Pump Controls.

Operation of pump suction and discharge valves may be a part of the automatic sequence for the starting of a centrifugal pump and for shutting it down, remotely, locally, or by a protective shutdown device. Remote-operated valves on the discharge side of the pump can be either motor-operated or the solenoid pilot-type, hydraulically operated diaphragm control valves. Remote control valves on the suction side of the pump can be motor-operated valves only. Equip these valves with green and red (open and closed) indicating lights at their pushbutton control locations.

3-7.5.1 All Pumps.

Provide the following controls:

a. A keyed hand/auto button at each pump and a keyed hand-off-auto switch at the motor starter for each remotely operated pump. Both devices will use the same key.

b. Indicator lights at the control station to give positive indications both when a pump is operating and when it is not energized. Use the "push-to-test" type.

c. A signal light or alarm to indicate pump failure when a pump is controlled automatically.

d. Reduced voltage starting if required by electric utility supplier or for all pump motors greater than 50 horsepower (37 kW) and all vertical pumps.

e. Emergency fuel shut-off (EFSO) pushbutton stations, between 100 and 200 feet (30 m and 60 m) from the pump in the expected ingress and egress direction, with maintained contacts. Provide additional EFSO pushbutton stations at the point of fuel delivery or receipt (fillstands, piers, tanks, etc.) using the same spacing and location requirements.

3-7.5.2 Multi-Functions Pumps.

Multi-function pumps are typically used at small facilities and are designed and arranged to be able to perform different functions such as fuel loading, off-loading, or transfer depending on how valves are aligned. Provide each function with the control system requirements for each function described elsewhere in this chapter. For each multi-task pump provide a manual selector switch to choose which set of control and set points the pump is to "look at" when performing a particular function.

3-7.5.3 Transfer Pumps.

Transfer pumps are used to supply fuel to a tank truck loading facility, tank car loading facility, or transfer fuel from one place on the installation to another (e.g., bulk storage tank facility to operating storage tank). If these pumps exceed 150 horsepower (112 kW), comply with the paragraph titled “Pipeline Pumps” in this Chapter. In addition to requirements in the paragraph titled “Pipeline Pumps” in this Chapter, provide transfer pumps with push button start/stop stations. Where these pumps are used for truck and/or car loading, provide push button controls adjacent to the pumps and at each loading station. Use programmable logic controllers (PLC) where multiple pumps supply header loading multiple trucks or cars to obtain desired flow rate to each loading station.

3-7.5.4 Pipeline Pumps.

For pumps over 150 horsepower (112 kW), provide protective shutdown devices with alarm at central supervisory control station in the event of the following:

a. High pump case temperature due to blocked discharge.

b. Excessive pump vibration.

c. Mechanical seal or packing gland failure.

d. High discharge pressure or loss of discharge pressure.

e. Excessive motor vibration.

f. High motor winding temperature.

g. Electrical interlocks which will prevent starting a pump if certain key valve settings are not correct and which will cause a pump shutdown if a key valve setting is changed.

h. Loss of pump suction pressure.

i. High bearing temperature and/or loss of cooling water flow.

3-7.5.5 Temperature Controls.

Provide temperature controls at all fuel oil heaters to control the outlet oil temperature within safe limits. Provide a sensing element in the fuel outlet line which activates a thermostatic valve in the heating medium supply connection to the heater. Use a self-actuating control valve that requires no external power for closure. Use a manually adjustable set point for each temperature variable over the desired temperature range. Provide a bypass around the control valve with a V-port globe or ball valve for manual operation.

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3-8 PRODUCT RECOVERY SYSTEMS.

Provide a product recovery system to collect and store usable aviation turbine fuel that would otherwise become waste from operational or maintenance activities. Consider a product recovery system for other products. See Chapter 8 of this UFC for product recovery systems.

3-9 FUEL ADDITIVES.

If directed by DLA-Energy , provide bulk storage facilities which store aviation turbine fuels and diesel fuels with the system components to inject fuel additives. This will require proportional injectors, storage of additives, and capability of recirculating tanks through piping with injectors. If the additives have a corrosive characteristic, construct the system, including storage tanks, tank appurtenances, pumps, if required, piping and associated fittings, valves, and injector assemblies of stainless steel components.

CHAPTER 4 AIRCRAFT FUELING FACILITIES

4-1 INTRODUCTION.

This chapter provides guidance for the design of aircraft fueling facilities, including operating storage tanks and those components normally located within a typical compound. These components include pipeline receiving facilities, tank truck and tank car receiving facilities, refueler truck fillstands, type III, IV, and V aircraft direct fueling systems, and associated piping and system components. Fuel storage tanks are discussed in Chapter 8 and piping systems in Chapter 9 of this UFC. Systems used to receive fuels from barges and ships are discussed in Chapter 5. Pipelines that transport fuel from off base and pipelines between bulk tanks and operating storage tanks are discussed in Chapter 6 of this UFC.

Note: If aviation fuel can be pumped directly from a tank into an aircraft, aircraft direct fueling system or a refueler, treat the tank as an operating storage tank regardless of size and location and meet the applicable requirements for aviation turbine fuel operating tanks. The exception is bulk storage tanks that are configured to fill refuelers on an emergency basis only.

4-1.1 Function.

Aircraft fueling facilities, as discussed in this chapter, are designed for ground fueling of fixed and rotary wing aircraft. Two methods are used for refueling aircraft: refueler trucks and aircraft direct fueling systems (e.g., hydrant system). The preferred method of fueling used at most Navy, Marine Corps, and Army small aircraft bases is by refueler trucks. For Air Force transport, tanker, cargo, bomber, and other large aircraft, the preferred method of fueling is by hydrant system where the aircraft are fueled on the apron in their parked positions. Where operational/mission requirements dictate a quick return to the air, small-frame aircraft, both fixed and rotary wing, are refueled with the engines running via aircraft direct fueling systems under a "gas and go" or hot pit refueling concept. Install aircraft direct fueling systems only when specifically authorized by Service Headquarters.

4-1.2 Aviation Turbine Fuels.

The fuels covered in this chapter are JP-4, JP-5, JP-8, JPTS, Jet A, additized Jet A (F-24), and Jet A-1. Because of the critical nature of the end use of the fuel, protection of fuel quality, dependability of the system, and safety are very important. Refer to Chapter 2 of this UFC for information on fuel properties.

4-1.3 Special Precautions for Aviation Turbine Fuel Quality.

Take extra care to prevent the contamination of aviation turbine fuels by dirt, water, and other fuels. For additional information, refer to Chapter 2 of this UFC. Aircraft fueling system must be designed with capability to generate sufficient turbulent flow to flush sediment and condensed water from all portions of piping systems. Refer to Chapter 9 of this UFC for fuel velocity criteria.

4-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains information on fueling facilities. Do not begin the design on any fueling system without first becoming completely familiar with Chapters 2 and 9 of this UFC and with the airfield clearance requirements found in UFC 3-260-01.

4-3 RECEIVING FACILITIES.

Fuel deliveries to a military aviation activity are normally made by tank truck, railroad tank car, barge, or pipeline. A secondary method of delivery is normally required. Service Headquarters, with concurrence from the DLA-Energy, will determine the appropriate type of delivery method based on mission requirements and an economic analysis.

4-3.1 Pipeline Receiving Facilities.

4-3.1.1 General Criteria.

Petroleum fuels may be supplied to aviation turbine fuel storage tanks by interterminal pipelines or installation pipelines. Interterminal pipelines may be dedicated to serving the particular facility or may be commercial pipelines handling a number of types or grades of fuel for more than one user. Installation pipelines will normally be a pipe from the bulk facility to the aircraft fueling facility. Provide for separate receiving and distribution piping for each grade of aviation turbine fuel unless otherwise approved by Service Headquarters. Exercise extreme care to avoid designing a system that could create damaging surges in the pipeline created by quick closing valves.

4-3.1.2 Required System Components.

a. Provide pressure-regulating diaphragm control valves to reduce pipeline pressures to the design pressure of the facility's piping and system components. Provide a manual isolation valve at both the upstream and downstream side of each diaphragm control valve. Prior to designing any features into the system which might affect the flow from a pipeline, contact the operator of the pipeline to ascertain the current operating conditions, evaluate the use of diaphragm control valves, conduct a surge analysis of the pipeline, and determine whether the use of diaphragm control valves is appropriate.

b. Provide a meter at the receiving end of the line to measure quantities of fuel received. Turbine-type meters are commonly used for pipeline receipt above 1200 gpm because of the cost of large positive displacement meters. However, positive displacement meters are acceptable if available at the required flow rate. Compensate for fuel temperature at the point of custody transfer. Provide two parallel basket strainers with double block and bleed isolation valves immediately upstream of the meter and connections for proving the meter with a portable prover. A meter prover connection consists of a manual isolation valve in the main pipeline with a tee on both the upstream and downstream sides of the valve. The branch of each of the tees has a manual isolation valve and a hose connection. The master meter can be attached to the hose connections.

c. Provide a means for sampling each pipeline product at a breakout manifold.

d. Provide provisions for maintenance and ILI pigging on interterminal pipeline receipt location. Consult Service Headquarters for arrangements required to meet commercial pipeline agreements. Provide ILI launcher and receiver on government owned interterminal pipelines. Arrange pig receiving connections to avoid introducing pipeline sludge and sediment into the tanks. Pig launching and receiving provisions are required for interterminal (cross-country) and installation (as described in Chapter 6 of this UFC) underground pipelines. See Chapter 9 for pigging requirements.

e. Provide an interface tank to receive mixed fuels at the beginning and ending of a shipment unless the commercial pipeline company can provide this service satisfactorily.

f. Provide a breakout tank only if pipeline flow cannot be stopped due to pipeline operational requirements. Provide valves to divert the flow of fuel from the pipeline to the breakout tank in the event fuel transfer is blocked by a manual or automatic valve within the fuel facility system such that the fuel facility system would be overpressurized from transient surge or high pressure from deadheading a pipeline supply pump. Provide appropriate breakout tank overfill alarms and alarm breakout operation so fuel facility operators can take necessary steps to stop pipeline flow. Provide means of transferring fuel out of breakout tank back to fuel systems after a breakout event. Conduct a thorough review with the pipeline operator and perform a transient surge analysis to determine if surge pressure reduction methods are required to avoid damage to the pipeline. Consider multiple factors when determining size of breakout tank. Factors shall include ability of receiving facility to recognize excursion (over pressure event), ability to notify source of transfer to shutdown pipeline pumps, impact of deadheading pipeline pump, and factor of safety. Increased confidence of ability to shutdown pumps, via receipt pressure sensors with rate of rise PLC assessment, communication to transfer source via fiber optics communication, and automatic transfer pump shutdown will lead to smaller sized breakout tanks. Whereas reliance on receipt staff to respond to alarm and notify source pumpstation via telephone will lead to larger sized breakout tank. Consideration shall also be given to type of surge breakout system, such as side stream pressure relief versus rapid full opening surge dump valve. As a minimum, the surge breakout tank must be sized such that its ullage volume, above a minimum heal level, can safely store not less than two times the volume of fuel resulting from a release event, but not less than two times the receipt volume for a 10-minute flow at normal pipeline flow. When sizing breakout tanks also consider using aboveground shop fabricated UL listed tanks, and that increasing the tank size (and thus safety factor of release) very often is a small cost, compared to the cost of release cleanup. Contact Service Headquarters for design considerations and approval of surge breakout tank system approval.

g. Provide means of inbound filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Avoid the use of water slug shutoff diaphragm control valves or other rapid-closing valves on pipeline receipt facilities. See the "Special In-Bound Filtration" paragraph and Table 4-1 of this Chapter of the UFC for details. When a water slug shutoff is not provided, provide sump water detector and alarm panel.

h. Provide manual isolation valves to isolate system components for service.

i. Provide basket strainers immediately upstream of pumps, meters and receipt filtration. On piggable pipeline receipt, provide 2 parallel strainers with isolation valves so pigging can continue while cleaning one strainer.

j. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

k. Provide a concrete housekeeping pad, and a canopy for protection from the elements of fixed facility assets and system components in accordance with paragraph 2-22.

4-3.2 Tank Truck and Tank Car Off-Loading Facilities.

4-3.2.1 General Criteria.

Fuel system operating tanks may be supplied with fuel by tank truck or tank car or both. At facilities with pipeline or water transport as their principal supply source, provide tank truck or tank car deliveries as a secondary supply source. Tank truck deliveries are the most common method. However, special transportation considerations or changing circumstances may make the use of rail facilities desirable. Therefore, at an activity with railroad service, arrange a tank truck receiving facility so that the system can be easily and economically extended to the existing rail spur. See Facility Plate 002.

a. The preferred off-loading method is into a drop tank off-loading system. See Facility Plate 003.

b. Provide a packaged off-loading system when a drop tank type off-loading system is not practical for off-loading tank trucks or tank cars due to environmental concerns, site limitations, or cost considerations, and/or when directed by Service Headquarters. See Facility Plate 004.

c. Provide a direct off-loading system when only an occasional tank truck requires off-loading and when directed by Service Headquarters. See Facility Plate 005.

d. Do not locate tank truck or tank car receiving facilities closer than 50 feet (15 m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines, and 25 feet (7.6 m) from the installation interior fence surrounding the fuel farm. See Chapter 8 of this UFC for clearance from tanks. Comply with NFPA 30 and assume that the property line is the fuel farm fence. Use the criteria for Class I liquids regardless of product and do not take a reduction for fixed fire protection.

e. Provide an adequate number (minimum two) of positions to off-load the daily fuel requirements of the facility in an 8-hour period without causing detention or demurrage of delivery conveyances.

f. Provide separate off-loading connections for each type of fuel to be handled. To facilitate the use of tank trucks with multiple independent compartments, provide a hose manifold with a minimum of two connections per tank truck. A manifold with hose connections equal to the number of truck compartments is recommended for quick turnaround. If less than five connections are provided, provide a blind flange on the end of the manifold to accommodate additional connections.

g. Provide a containment area at each truck off-loading position consisting of an impermeable retention and controlled drainage system leading to a concrete remote spill containment system. Pave the containment area consisting of the islands, the spaces between islands and on each side of the outer islands, with concrete pitched a minimum of one percent toward catch basins or trench drains. Design the containment area in accordance with UFC 1-200-01, federal, state and local regulations. Do not use asphalt within a spill containment area. The maximum slope of any paving within a truck movement or parking area must not exceed 2 percent excepting ramps. If a ramp is provided, the sum of the vertical entrance and exit grades must not exceed 8 percent and the ramp must be aligned perpendicular with direction of truck movement. The designer must assure that adequate ground clearance is achieved for all vehicles utilizing the containment areas.

h. Provide spill containment at each rail tank car off-loading position consisting of an impermeable containment system surrounding the rail car with drainage leading to a concrete remote spill containment basin. Pave the offload equipment area and space between the offload equipment and rail car containment system with concrete sloped a minimum of one percent toward a drainage collection system that leads to the concrete remote spill containment basin.

i. Provide a concrete remote spill containment system for each containment area. Design the remote spill containment system in accordance with UFC 1-200-01, federal, state, and local regulations. Provide the remote spill containment system with capacity greater than the volume of the largest tank truck or tank car compartment to be off-loaded. The top elevation of the remote spill containment basin must not be set less than 6-inches above the top of the refueler truck parking area's maximum ponding elevation. This will prevent overflow of the remote spill containment basin during a heavy rain event. A curbed truck position may be provided in addition to a remote system. Twenty-five percent or more of the total required containment volume must be directed to, and stored at, the remote system before any of the shared containment volume will pond at the truck stand area. Provide a lockable eccentric plug valve with indicator post located outside the containment area at a location that will be safely accessible during a fire. The valve must be lockable and normally closed to allow for containment during fueling operations and which can be opened to drain area when necessary. Tank trucks can be as large as 10,000 gallons (38,000 L) in capacity and tank cars as large as 40,000 gallons (151,000 L). Consider combining the remote spill containment system with other spill containment systems on-site, except with tank containment systems. However, take the level of contamination in each containment area into consideration.

j. Construct the drain piping between the containment area and the remote spill containment system, and between the remote spill containment system and lockable plug valve of petroleum-resistant, impermeable materials with water-tight joints such as ductile iron or HDPE pipe with fusion welded joints. Do not use clay, concrete, or fiberglass piping materials.

k. For off-loading tank trucks, arrange the flow of traffic to permit continuous forward movement of trucks at all times. Commercial tank trucks off-load on the passenger side.

l. Tank truck configurations vary. Key variables are: the number of compartments per tank, single or multiple trailers, location of connections on each trailers, height of trailer connections, etc. Designer must coordinate with the installation and Service Control Point regarding the type of delivery trucks used at the installation.

m. To determine the number of connections needed for off-loading tank cars, consult with Service Headquarters and consider minimizing tank car movements, tank car shipping schedules, conveyance turn-around times, local rail switching capabilities, and quantity of fuel needed for one day's fuel supply.

n. Provide an electrical design that meets the minimum requirements of NFPA 70, NFPA 77, and NFPA 780. Treat combustible liquids under pressure as a flammable liquid.

o. Provide a canopy for protection from the elements of fixed facility assets and system components **\1** in accordance with paragraph 2-22. **/1/**

p. Provide a canopy to preclude rain from the containment area **\1** in accordance with paragraph 2-22. **/1/**

q. Provide for egress and entrance of emergency response vehicles. The egress and entrance routes need to be large enough to allow both, trucks and emergency vehicles to leave and enter the facility simultaneously.

r. Provide means of inbound filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. See "Special In-Bound Filtration" paragraph and Table 4-1 in this chapter of this UFC.

4-3.2.2 Tank Truck and Tank Car Drop Tank Off-Loading System.

The introduction of air into a fuel receiving system poses extreme hazards which can result in fire and/or explosion. Hazards are compounded when an air/fuel mixture is passed through receipt filter-separators where static electricity is generated and ignition can occur. Design off-loading facilities so air is not introduced into the system. For facilities with the capability to off-load several tank trucks at once or where newer tank trucks with multiple hoses are connected to multiple isolated compartments, consider providing an underground, gravity-type, receiving tank with submersible transfer pumps and level controls. For smaller systems of one or two tank trucks, consider providing a low profile, aboveground, receiving tank with a centrifugal transfer pump. For either case, provide level sensors to control the transfer flow rate. Provide a temperature compensated meter on the receipt line to the tank at points of custody transfer and when directed by Service Headquarters. For materials of construction for off-loading drop tanks, refer to Chapter 8. See Facility Plate 003.

4-3.2.3 Tank Truck and Tank Car Packaged Off-Loading System.

For tank truck or tank car off-loading an off-loading drop tank may not be practical due to environmental concerns, site limitations, or cost considerations. In these instances, provide a 600 gpm (38 L/s) packaged off-loading system. Provide one packaged system, including vertical inline centrifugal pump, diaphragm control valves to control flow, meter, and multiple hose connections (one for each tank truck compartment), for each tank truck or tank car receiving station. Provide an air eliminator tank to remove air from the system, reducing the risk of an air/fuel mixture passing through receipt filter-separators and preventing the metering of air. Level sensors in the air eliminator tank control the pump discharge diaphragm control valves, modulating the flow rate based on the level in the air eliminator tank. Refer to DoD Standard Design AW 078-24-28 and Facility Plate 004.

4-3.2.4 Tank Truck and Tank Car Direct Off-Loading System.

Use when only an occasional tank truck requires off-loading and when directed by Service Headquarters. Refer to Facility Plate 005.

4-3.2.5 Required System Components.

a. When tank trucks or tank cars are off-loaded with a drop tank off-loading system, do not provide an off-loading pump. Provide at least two pumps in the drop tank to transfer fuel to the storage tank.

b. When tank trucks or tank cars are off-loaded with packaged off-loading systems, provide one system for each tank truck or tank car that is to be off-loaded simultaneously, at an average capacity of 600 gpm (38 L/s) each. The number of systems will be determined by Service Headquarters but must be a minimum of two. The capacity of the systems may be reduced to 300 gpm (19 L/s) each only when directed by Service Headquarters.

c. When tank trucks or tank cars are off-loaded with direct off-loading systems, provide centrifugal pumps configured to provide automatic air elimination as shown on Facility Plate 005. Provide at least two pumps to allow continued operation if one is out of service. The capacity of the pumps may be increased to 600 gpm (38 L/s) each only when directed by Service Headquarters. The centerline height of suction line from manifold to pump usually should not exceed 23.25 inches (591 mm) above truck unloading, parked position. Confirm this with the activity; in western CONUS, trucks tend to have lower connections. Locate the pump as close as possible to the off-load point to prevent suction problems.

d. Provide lightweight reinforced vacuum rated off-loading hoses and covered hose storage racks for each hose connection at each off-loading position. Eliminate covered hose storage rack if off-load rack is to be covered by a canopy. Ensure that all swivels are non-lubricated aluminum or stainless steel in-line repairable type. Consult with activity to verify the need for hoses, since at some locations, the fuel hauling contractor provides the hoses.

e. Equip each tank truck off-loading position with an electronic, intrinsically safe, automatic, self-monitoring ground verification unit with a lockable bypass. If grounding is not verified and there is an off-loading pump dedicated to that position, ensure the unit prevents the pump from starting. If the pump is not dedicated, ensure an alarm sounds if the off-loading valve is opened prior to grounding verification. Include a separate grounding reel to accommodate vehicles without grounding system components.

f. Provide emergency fuel shutoff (EFSO) pushbutton stations. For truck off-loading stations with multiple positions, an EFSO pushbutton station is required for each position and along routes of personnel ingress and egress between 100 and 200 feet (30 m and 60 m) from the off-loading position. Design in such a manner that activation of the emergency stop will shut off all fueling in the off-loading area and/or the associated pumphouse or pump pad.

g. Provide fuel sampling connections at each position for each product line for collecting test samples.

h. Provide pressure gauges on both sides of each strainer or a differential type gauge across each strainer. Where a strainer is upstream of a pump, the pump suction gauge may function as the strainer downstream gauge.

i. Provide a compound (pressure/vacuum) gauge on the inlet side of the pumps and a pressure gauge on the outlet side of pumps.

j. If system is for JP-5 or other fuel that does not have a static dissipater additive which provides a conductivity level greater than 50 conductivity units (50 picosiemens per meter), and a 30-second retention time is not provided between filter-separator and receiving tank, provide a relaxation tank downstream of the filter-separator or design the piping layout to provide the required 30-second relaxation time downstream of the filter-separator.

k. Provide basket strainers immediately upstream of pumps, meters and receipt filtration.

l. Provide a combination flow control and non-surge check diaphragm control valve on all off-loading pumps except positive displacement types. If a bulk air eliminator with automatic air release head is included, provide a means of closing the diaphragm control valve with a solenoid pilot.

m. Provide a positive displacement or turbine meter. Provide meter with temperature compensation capability and meter proving connections at each offload position (custody transfer location). Provide a basket strainer immediately upstream of the meter.

n. On each off-loading connection or on the off-loading riser, install a visual fuel flow indicator (maximum pressure 275 psi (1900 kPa) at 100 degrees F (38 degrees C), with Viton Seals with a maximum temperature rating of 350 degrees F (177 degrees C)). This will allow visual quality assurance and provide the operator with a backup system to shut off the pumps when off-loading is complete to prevent air build-up in the receipt lines.

o. Provide filter-separators and other filtration devices as described in Table 4-1 to filter fuel before it enters the storage tank.

p. Provide manual isolation valves to isolate system components for service.

q. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

r. For JP-8 systems, provide a capability to defuel JP-8 refueler trucks back into operating storage as described in the paragraph titled “Defueling and Return-to-Bulk Systems” in this chapter.

s. Where tank trucks or tank cars are off-loaded into drop tanks, provide meters on the downstream side of the drop tank pumps.

4-3.3 Marine Off-Loading Facilities.

See Chapter 5 of this UFC.

4-3.4 Special In-Bound Filtration.

Where fuel is transferred to the base fuel system operating tanks from tankers, barges, or directly from the supplier (off base) by a multi-product pipeline, pass the fuel through strainers, then pre-filtration, then fine filtration. In other cases, pass the fuel through strainers and fine filtration only. See Table 4-1 of this chapter for details.

4-4 DISPENSING FACILITIES.

4-4.1 Refueler Truck Fillstands.

Mission and turn-around times will establish the number of fill positions, with two being the minimum. Service Headquarters can assist in determining the number. See Facility Plates 006 and 007 for general design guidance and also DoD Standard Design AW 078-24-29, Type IV/V. Provide a separate loading system for each grade or type of fuel to be handled.

4-4.1.1 General Criteria.

a. Locate the refueler loading facility as close as practical or permissible to the location of the aircraft to be fueled but not less than 50 feet (15 m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines and 25 feet (7.6m) from the installation interior fence surrounding the fuel farm. See Chapter 8 of this UFC for clearance requirements from tanks.

b. For aircraft direct fueling systems, the fuel supply piping to the refueler truck loading facility may be a spur or extension from that system and constructed of the same material as that system. In this case, the filter-separators are not required since they are provided as part of the aircraft direct fueling system. Where filtration is downstream of the pump house and the spur connects prior to the filtration system components, a filtered lateral is required.

c. Arrange fuel loading system components on one or more concrete islands configured for refueling on one side only. Make the direction of traffic appropriate for the location of the loading connections on the refueler, located on the driver's side. When more than one island is required because of the volume or number of fuel grades to be handled, arrange them in a parallel fashion with approximately 15 feet (4.6 m) between adjacent sides. Arrange the islands and approaches to allow forward motion for all trucks at all times with ample room for turning. Allow for egress and entrance of emergency response vehicles.

d. Provide a containment area at each truck loading position, consisting of an impermeable retention and controlled drainage system leading to a concrete remote spill containment system. Pave the containment area consisting of the islands, the spaces between islands and on each side of the outer islands, with concrete pitched a minimum of one percent toward catch basins or trench drains. Design the containment areas in accordance with UFC 1-200-01, federal, state, and local regulations. Do not use asphalt within a spill containment area. The maximum slope of any paving a within truck movement or parking area must not exceed 2 percent excepting ramps. If a ramp is provided, the sum of the vertical entrance and exit grades must not exceed 8 percent, and the ramp must be aligned perpendicular with direction of truck movement. The designer must assure that adequate ground clearance is achieved for all vehicles utilizing the containment areas.

e. Provide spill containment at each rail tank car loading position consisting of an impermeable containment system surrounding the rail car with drainage leading to a concrete remote spill containment basin. Pave the offload equipment area and space between the offload equipment and rail car containment system with concrete sloped a minimum of one percent toward a drainage collection system that leads to the concrete remote spill containment basin.

f. Provide a concrete remote spill containment system for each containment area. Design the remote spill containment system in accordance with UFC 1-200-01, federal, state, and local regulations. Provide the remote spill containment system with capacity greater than the volume of the largest refueler to be loaded. The top elevation of the remote spill containment basin must not be set less than 6-inches above the top of the refueler truck parking area's maximum ponding elevation. This will prevent overflow of the remote spill containment basin during a heavy rain event. A curbed truck position may be provided in addition to a remote system. Twenty-five percent or more of the total required containment volume must be directed to, and stored at, the remote system before any of the shared containment volume will pond at the truck stand area. Provide a lockable eccentric plug valve with indicator post located outside the containment area at a location that will be safely accessible during a fire. The valve on the drain system must be lockable and normally closed to allow for containment during fueling operations and which can be opened to drain the area when necessary. Tank trucks can be as large as 10,000 gallons (38,000 L) in capacity. Consider combining the remote spill containment systems with other spill containment systems on site, except with tank containment systems. However, take the level of contamination in each containment area into consideration.

g. Construct the drain piping between the containment area and the concrete remote spill containment system, and between the remote spill containment system and lockable eccentric plug valve of petroleum-resistant, impermeable materials with water-tight joints such as ductile iron or HDPE pipe with fusion welded joints. Do not use clay, concrete, or fiberglass piping materials.

h. Load aircraft refueler trucks by bottom loading only. Design the system to deliver a refueling nozzle pressure of 35 psig (240 kPa) with a flow range of 50 to 560 gpm. System design must take into consideration pressure and flow settings to prevent damage to bottom loader. Contact Service Headquarters for further direction.

i. Provide a canopy for protection from the elements of fixed facility assets and system components **\1** in accordance with paragraph 2-22. **/1/**

j. Provide a canopy to preclude rain from the containment area **\1** in accordance with paragraph 2-22. **/1/**

k. Design all electrical systems and apparatus for use in Class I, Division 1, Group D, hazardous areas in accordance with NFPA 70, regardless of the type of fuel dispensed.

l. Provide for egress and entrance of emergency response vehicles. The egress and entrance routes need to be large enough to allow both, trucks and emergency vehicles, leaving and entering the facility.

m. For JP-8 systems, provide a capability to defuel JP-8 refueler trucks back into operating storage as described in the paragraph titled "Defueling and Return-to-Bulk Systems" in this chapter.

4-4.1.2 Required System Components.

\3 Provide separate piping, pumps, loading connections, and controls for each different type or grade of fuel. Provide an individual isolation valve for each fill connection. Include the following system components in each refueler truck fillstand: **/3/**

a. Self-closing emergency valve with 165 degrees F (74 degrees C) fusible link (These valves are neither required nor permitted on Air Force projects).

b. Provide manual isolation valves to isolate system components for service.

c. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

d. Provide filter-separator, unless fillstand is supplied from an aircraft direct fueling system via a non-ferrous branch connection downstream of the issue filter-separator. Ensure that the piping downstream of the filter-separator is non-ferrous or interior coated.

e. Positive displacement or turbine meter with rated capacity equal to the maximum flow of the loading station and the following accessories:

  1. If custody transfer point: a combination ticket printer and large numeral zero reset counter with self-closing weatherproof cover. Ticket printer not required on Army or Air Force projects.

  2. Pulse transmitter of the photoelectric, high resolution type required for projects which employ electronic data acquisition systems.

  3. Temperature compensation if at a custody transfer point.

f. Provide relaxation tank or piping configuration with sufficient capacity to retain the maximum flow of the loading station for 30 seconds from the time the fuel leaves the last piece of filtration system component to the fuel reaching the loading pressure refueling nozzle. Applies to JP-5, Jet A, and other fuels which do not have a static dissipation additive that provides a conductivity level greater than 50 picosiemens per meter.

g. Mechanical loading arm. The preferred device is a non-lubricated, swiveled, stainless steel, counterbalanced mechanical loading arm. As an option, with the approval of Service Headquarters, use a loading hose approximately 10 feet (3 m) long, 3 or 4-inch (75 or 100 mm) nominal diameter, and meeting requirements of EI Std 1529. A spiral protective device (slinky) may be installed around the hose. House the hose in a covered hose tray to protect from ultraviolet damage. Install with a non-lubricated stainless steel in-line repairable swivel.

h. SAE AS5877 pressure refueling nozzle of size and type compatible with truck-loading connections (coded for product use, if more than one type of fuel is issued at the fillstand). Connect the pressure fueling nozzle to the loading arm or hose with a dry-break quick disconnect.

i. Provide a sample outlet with probe, ball valve, and quick disconnect at each position for each product line.

j. Make provisions to start and stop the pumps with start and stop pump control stations at each position. Include pump status indicator light on control box.

k. A hydraulically operated diaphragm control valve with the following functions (care must be taken to select system components which are compatible with electronic or mechanical meter stacks):

  1. Adjustable rate of flow control if fillstand is on a branch line from an aircraft direct fueling system or other multiple pump arrangement which could result in issue exceeding 600 gpm (38 L/s).

  2. Pressure regulating to maintain desired upstream or downstream pressures.

  3. Adjustable time delay for opening and closing speed control.

  4. Control valve to close in the event of diaphragm failure.

5. Thermal relief to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points.

6. Position indicator.

7. Solenoid Shutoff. Interlock the solenoid with the electronic high-level shutoff and electronic ground verification control systems.

l. Provide each fill position with an electronic high-level shutoff, electronic ground verification, and hydraulic or electronic deadman control system. The system must be intrinsically safe and self-checking. Interlock the system with either the solenoid operated truck loading diaphragm control valve or the pump such that the valve cannot remain open or the pump cannot operate if the tank truck compartment is full, the tank truck is not bonded to the fueling system components, or the deadman is released. Ensure the system is compatible with both electronic and fiber optic sensors with manual-keyed bypass. (May require a parallel effort beyond the project scope to ensure that all trucks using the facility have compatible connections. If facility has trucks that do not have fixed probes, use cane probes instead.) (This unit is optional on Army projects with only tactical refuelers. Contact the Service Headquarters for guidance.)

m. Provide emergency fuel shutoff (EFSO) pushbutton stations. For fillstands with multiple positions, an EFSO pushbutton station is required for each position and along routes of personnel ingress and egress between 100 and 200 feet (30 m and 60 m) from the fillstand. Design in such a manner that activation of the emergency stop will shut off all fueling at that pump house or pump pad.

n. Low-intensity area lighting, in accordance with API RP 540, to permit full visibility of all system components and controls during night operations.

o. Refer to Chapter 2 of this UFC for information on vapor collection and recovery or disposal systems.

p. If pumps are dedicated to fillstands, make provisions to start and stop the pumps with start and stop pump control stations at each position. Include pump status indicator light on control box. Grounding reel and grounding plate as detailed in Standard Design AW 078-24-29, Type III with multiple connections.

q. Provide basket strainer immediately upstream of pumps, meters, and where a filter-separator is not provided at the load rack.

r. Pressure gauge.

s. Maintenance drains.

t. Vents.

u. Provide hydraulic shock surge suppressors (if required).

v. For JP-8 systems, to allow defueling of refueler trucks, provide a Return-To-Bulk (RTB) station by providing a MIL-STD MS 24484 aircraft refueling adapter a point upstream of receipt filtration. Acceptable locations include the return line at a truck fillstand, the return line at a hydrant hose truck check-out station, the return line at a pantograph flush station, the product recovery tank, or at a truck off-load station. Provide one single point receptacle (SPR) connection per group of fillstands or truck off-load stations. If into a product recovery tank, do not bypass the level control valve.

w. Provide meter proving connections as described in the paragraph titled “Pipeline Receiving Facilities”, unless local procedure provides an alternative.

4-4.2 Aircraft Direct Fueling Systems.

Aircraft direct fueling systems are fuel systems that deliver fuel directly into an aircraft and require additional fueling hardware, such as a hydrant hose truck, pantograph, or hydrant hose cart. These may be Type III hydrant systems (DoD Standard Design AW 078-24-28) for portable pantographs or hydrant servicing trucks/carts; or may be hard piped with fixed pantographs, which is usually the case for Type V in-shelter fueling (DoD Standard Design AW 078-24-29) and Type IV hot fueling stations (DoD Standard Design AW 078-24-29). For facilities being constructed OCONUS NATO refer to DoD Standard Design STD 121-122-01 USAFE/NATO, Airfield Standard Design US, Jet Fuel Storage Dispensing Systems for Tactical and Wide Body Aircraft for design guidance. While individual components may vary slightly between the various aircraft fueling systems, the basic philosophy of a system configured in a loop with no dead ends, is followed by all the services. The loop is made up of the supply/return piping with a flushing/back pressure control valve that maintains a constant pressure on the supply side piping and relieves excess fuel not taken on by the aircraft(s) into the return portion of the piping and back to the tank. The lead pump is turned on either automatically by a drop in the system pressure or manually by an on/off switch at each direct fueling station. A venturi in the supply piping senses flow rate in the loop and works in conjunction with a venturi in the return loop. Depending on the flow demand, the return venturi turns on/off additional pumps as required. If return flow is below a preset limit (indicating that fuel is being dispensed), a low flow is sensed and additional pump(s) are turned on, one at a time, until a steady flow condition is reached. Conversely, if the return flow is above a preset limit (indicating less fuel is being dispensed), the return venturi senses high flow conditions and turns the pump(s) off, one at a time, until the system is brought to rest. The continued circulation of the fuel not only provides a self-cleaning action but when properly adjusted, the system is able to more closely match the varying fuel filling rates of aircraft. This provides smooth operation and helps eliminate destructive surge pressure spikes. In order to ensure the highest quality of fuel, contact with bare carbon steel is limited to an absolute minimum prior to filtration and is not permitted downstream of the issue filter-separators, unless specifically authorized by Service Headquarters.\

4-4.2.1 General Requirements.

Install aircraft direct fueling systems only when specifically authorized. Service Headquarters assist in determining the number and type of stations required by the activity and with locating hydrant pits in aircraft parking ramps. Construct new facilities only for issuing aviation turbine fuels through pressurized refueling nozzles and closed circuit fueling nozzles. Locate fueling stations at the edge of the aircraft parking apron or taxiways or at apron parking spots for large frame aircraft. Size and configure these systems based on the types of aircraft to be refueled, aircraft fuel capacity, and the number and types of aircraft to be simultaneously refueled. A parking plan must be approved before proceeding with the hydrant pit layout design. Some aircraft, such as fighters and some helicopters, may be refueled with engines running. See Facility Plates 008, 009 and 010. For additional guidance on Air Force projects, refer to **\2** AFMAN 32-1084 **/2/.**

4-4.2.2 Fixed-Wing Small-Frame Aircraft.

Locate aircraft direct fueling stations for small-frame aircraft (carrier aircraft, patrol aircraft, fighter aircraft, and small transports) along the edge of designated access ramps, aprons, or fueling lanes with easy access by aircraft and as close to their normal taxi routes as practical while still meeting centerline clearance requirements. Provide facilities for fueling aircraft with engines or support equipment running. These systems are installed where the mission dictates a continuing need for rapid turnaround without shutting engines down and are located to permit quick return to the runway. Configure taxi patterns to and from fueling stations to keep jet blast away from people. Refer to DoD Standard Design AW 078-24-29 . Use the following design criteria:

a. Outside of the limits prescribed for clear areas by UFC 3-260-01 and UFC 3-260-02, locate the system components aboveground on a concrete slab adjacent to the edge of an access ramp, apron, or fueling lane. Ensure that the width of the slab and location of the system components, including the pantograph when retracted, with respect to the ramp, apron, or fueling lane, does not interfere with any part of the aircraft on its approach to or departure from the fueling station. Equip Army and Navy hot fueling stations with an emergency dry breakaway coupling.

b. Limit the height of the system components, including lighting, on the slab to approximately 30 - 36 inches (762 - 914 mm) above nominal grade. For official height constraints, contact Airfield Manager or the authority having jurisdiction.

c. Provide a nominal maximum flow rate for each direct fueling station of 600 gpm (38 L/s). However, design the system to deliver 400 gpm (25 L/s) with a nozzle pressure of 35 psig (240 kPa). Ensure adequate pump design for 600 gpm flowrate. (In general, systems designed to deliver 400 gpm at 35 psig have been shown to be fully capable of delivering 600 gpm with a nozzle pressure reading of 10 to 20 psig.) Actual fueling rates for small-frame aircraft range from 250 to 550 gpm (16 to 35 L/s). Since the actual flow rate will vary as the nozzle back pressure varies, it is necessary to limit the maximum nozzle pressure to 55 psig (380 kPa) at the skin of the aircraft to protect the aircraft. The issue venturi in a pantograph is a critical component of the aircraft direct fueling system and must be able to correctly simulate nozzle pressure and compensate for all pressure losses up to and including the fueling nozzle. Use maximum rates and the number of required simultaneous refuelings for system sizing.

d. Provide at least two fueling stations, with the system sized for a minimum flow rate of 1,200 gpm (76 L/s). Where more than two fueling stations are required, increase the total system rate by 600 gpm (38 L/s) for every three additional fueling stations. Service Headquarters approval is required for systems exceeding 2400 gpm and less than 1200 gpm. However, systems are not recommended to exceed 3,000 gpm (including spare pump).

e. DOD has two variations of the standard design for fixed-wing, small frame aircraft direct fueling stations – Type IV (DoD Standard Design AW 078-24-29) and Type V (DoD Standard Design AW 078-24-29). Both variations use pantographs for fueling the aircraft. The Type V is the same as the Type IV except that the refueling points are located in hardened aircraft shelters. The Type V variation is also known as in-shelter refueling.

f. Both hose-end and hoseless pantographs can be used with either Type IV or Type V aircraft direct fueling systems. Contact the Service Headquarters for which type of pantograph to use. Use SAE AS5877 pressure refueling nozzles on pantographs.

g. Provide two separate pressure control devices for every aircraft direct fueling station: an aircraft refueling control valve and a hose end pressure regulator. Equip the aircraft refueling control valve with a pressure control pilot set at 45 psig and a surge shutdown pilot set at 50 psig on the fixed station. The hose end pressure regulator is located just before the aircraft refueling nozzle and is set at 55 psig. The hose end regulator is required unless specifically directed otherwise by the Service Headquarters. Refer to DoD Standard Design AW 078-24-29, Type IV/V.

h. In order to ensure that the control valve is always in control and modulating and thus able to protect the aircraft, provide a differential pressure pilot with a set point of 15 psi (100 kPa).

4-4.2.3 Large-Frame Aircraft.

Locate aircraft direct fueling stations for large aircraft (transports, cargo planes, tankers, long-range patrol planes, and bombers) adjacent to their normal parking positions. Use the following design criteria:

a. Individually determine the number of fueling stations required for each activity. This depends on the number of large aircraft based at the activity or the number of aircraft that will need refueling as transients. To accommodate the fueling of a number of aircraft within a given time span without moving them, more fueling stations are normally required than would actually be used at one time.

b. Provide flow rate criteria for each aircraft direct fueling station of 600 gpm (38 L/s) or 1,200 gpm (76 L/s) at 45 psig (310 kPa) nozzle pressure. The selection of 600 gpm (38 L/s) or 1,200 gpm (76 L/s) is based on aircraft. Contact Service Headquarters for guidance. Size combined system requirements in multiples of 600 gpm (38 L/s), starting at a minimum flow rate of 1,200 gpm (76 L/s) up to a maximum flow rate of 2,400 gpm (152 L/s).

c. The default hydrant control valve size for new aircraft direct fueling hydrant systems is 4-inch (nominal 600 gpm flowrate, potential maximum 900 gpm flowrate). Mission requirements of flowrates in excess of that are rare but may occur. In that case the larger 6-inch valve (nominal 1200 gpm delivery flowrate) may be used in new systems. The 6-inch valve may not be used in new systems without Service Headquarters approval. The 6-inch valve may be used in new hydrant pits added to existing systems, if the existing pits retain their existing 6-inch hydrant valves. Alternatively, the new pits can be provided with 4-inch hydrant control valves and the existing 6-inch hydrant valves replaced with 4-inch valves with 6-inch flanges and a spacer plate; contact the Service Headquarters for guidance. Each hydrant pit control valve is equipped with a pressure control and surge shutdown pilot. These pilot controls are set at 45 psig (310 kPa) and 50 psig (345 kPa), respectively. In order to ensure that the control valve is always in control and modulating and thus able to protect the aircraft, provide a differential pressure pilot with a set point of 15 psi (100 kPa).

d. Design the piping, hydraulics, materials, and pumps in accordance with other paragraphs in this chapter.

e. Large aircraft (bombers, transports, tankers, cargo planes, etc.) are typically fueled from flush-mounted in-apron hydrant pits (preferred method for Air Force projects) that conform to DoD Standard Design AW 078-24-28 for Type III hydrant systems.

f. Large aircraft can also be fueled from fixed pantograph assemblies when normal aircraft parking positions are located adjacent to edge of the ramp (fixed long-reach pantographs have a maximum reach of 135 feet (41 m)). This type system is equipped with Type IV (DoD Standard Design AW 078-24-29) pantograph stations. This system has a pantograph station mounted control valve that is hydraulically actuated and operated. In order to ensure that the control valve is always in control and modulating and thus able to protect the aircraft, provide a differential pressure pilot with a set point of 15 psi (100 kPa).

g. Use self-propelled hydrant hose trucks, Type III hydrant hose carts, or detachable pantograph assemblies to provide the connection from the flush-mounted in-apron hydrant pits to the aircraft and the necessary controls. Provide a hydrant control valve in the hydrant pit that is hydraulically or pneumatically actuated and operated, depending on the type of mobile refueling equipment used.

h. Provide two separate pressure control devices for every aircraft direct fueling station. This will either be two control valves in series or a control valve plus a hose end pressure regulator. Use of only a single control valve with two pilots does not meet this requirement, there must be two separate devices.

1. For flush-mounted in-apron hydrant pits with hydrant control valves in the pit, and that are served by self-propelled hydrant hose trucks, Type III hydrant hose carts, or detachable pantograph assemblies with a control valve on the pantograph, use the two control valves method, with a hydrant valve in the pit, and a control valve on the mobile equipment.

2. For flush-mounted in-apron hydrant pits served by detachable pantograph assemblies that do not have a control valve on the pantograph, use the hydrant control valve in the pit plus a hose end pressure regulator on the pantograph method.

3. For apron edge mounted Type IV fixed pantograph assemblies, use the control valve on the fixed pantograph plus hose end pressure regulator on the pantograph method.

4. Hose end pressure regulators are set at 55 psi and located just before the refueling nozzle. Refer to DoD Standard Design AW 078-24-29, Type IV/V.

i. Equip pantographs in accordance with DoD Standard Designs. When incorporating the detachable pantograph into the design, follow USAFE/NATO specifications in which the swivels contain in-line repairable roller bearings. In addition, include the pantograph(s) as part of the construction project. Normally, the number of pantographs required equals the number of simultaneous refuelings to be performed.

j. The Air Force large-frame aircraft direct fueling system is referred to as a Type III pressurized fueling system. The Type III fueling system, or the constant pressure system, is the standard hydrant fueling system for large-frame aircraft. It is comprised of two operating storage tanks, a pump house, a hydrant loop, and hydrants at each parking position. The system is controlled by two redundant programmable logic controllers (PLC) and is constantly pressurized when in operation. Fuel is pumped from the tanks, through filter-separators and a supply venturi into the hydrant loop. It flows through the appropriate hydrant valve, through a hydrant servicing vehicle or mobile pantograph, into the aircraft if refueling is underway. A back pressure control valve keeps system pressure at a pre-set level and a return venturi measures flow back to the storage tank. Working in conjunction with the return venturi, pumps are turned on and off depending on refueling requirements. This system is sized in 600 gpm (38 L/s) increments up to 2,400 gpm (152 L/s). Issue pumps are sized to provide a minimum of 100 psi (690 kPa) at the outlet of the most distant hydrant adapter. The piping has to be non-ferrous or interior coated carbon steel (for the Air Force) from downstream of the issue filter-separators all the way to final hose or hard piped aircraft or refueler nozzle connection. For a Type III fueling system, there are two stages of filtration – fuel is filtered into the tank on receipt and out of the tank on issue. Contact Service Headquarters for specific guidance and sizing of the hydrant control valve. Refer to DoD Standard Design AW 078-24-28 for Type III hydrant systems.

4-4.2.4 Helicopters.

Refer to DoD Standard Design AW 078-24-29, Type IV, and use the following design criteria for designing direct fueling systems for helicopters:

a. Design piping, pumps, controls, accessories, and auxiliary systems in accordance with other applicable paragraphs of this chapter. For each direct fueling station, provide a nominal maximum flow of 300 gpm (19 L/s). Design system to be capable of delivering 275 gpm (17 L/s) at 35 psig (240 kPa) nozzle pressure. Make the minimum size system 600 gpm (38 L/s) with at least two fueling stations. For diversity usage, increase by 300 gpm (19 L/s) for every three additional fueling stations. At outlying fields and with Service Headquarters' approval, a single fueling station may be used.

b. Provide aboveground direct fueling stations equipped identical to fixed-wing small-frame aircraft fueling stations. Design the horizontal position and vertical projection of fueling system components to avoid interference with the helicopters' blades when in the drooped attitude.

c. Coordinate the type of pressure refueling nozzle, SAE AS5877 or closed-circuit, with the end user. In order to ensure that the control valve is always in control and modulating and thus able to protect the aircraft, provide a differential pressure pilot with a set point of 15 psi (100 kPa).

4-4.2.5 Surface Effect Hovercraft.

Turbine-powered, surface-effect hovercraft can be fueled on the parking apron with aircraft direct fueling systems. Use a 200 gpm (13 L/s) maximum fueling rate at 30 psig (207 kPa) nozzle pressure. The fueling hardware components are similar to those required for aircraft direct fueling with JP-5. Orient fueling stations so that the blast generated from the turbine engine does not damage the direct fueling station components. Refer to DoD Standard Design AW 078-24-29, Type IV.

4-4.3 Marine Loading Facilities.

See Chapter 5 of this UFC.

4-5 PIPING SYSTEMS.

Refer to Chapter 9 of this UFC for information and guidelines regarding piping systems.

4-5.1 Product Segregation.

Except as otherwise approved by Service Headquarters, prevent contamination of aviation turbine fuel by providing separate receiving, storage, and distribution systems for each product. Except as otherwise approved by Service Headquarters prevent misfueling (transferring a type of fuel other than that intended) by using different size piping, valves, adaptors, nozzles, etc.

4-5.2 Pigging.

Hydrant loop piping and long runs of truck fillstand piping (runs over one-half mile in length) must be smart piggable including 1.5 diameter (D) elbows and barred tees unless otherwise directed by Service Headquarters in accordance with Chapter 9.

4-6 DESCRIPTION OF SYSTEMS COMPONENTS.

The appropriate guide specifications and/or standard design will provide specific information for selection of system components. Make provisions to drain system components for maintenance. Provide hard piped drains when a system component holds more than 5 gallons (19 L) of fuel or when a pipe which drains to the product recovery tank is within 12 feet (3.7 m) of the system component. Unless otherwise indicated below, refer to Chapter 15 for description of system components. The following system components are typically used in aircraft fueling facilities:

a. Bulk Air Eliminators

b. Meters – Positive Displacement and Turbine

c. Pressure Gauges

d. Strainers

e. Surge Suppressors

f. Filtration – Filter-Separators

g. Pumps – Centrifugal, Vertical Turbine, Rotary, and Jockey

h. Manual Valves – Isolation Valves

i. Manual Valves – Isolation Valve Locations

Provide isolation valves in product piping systems to control flow and to permit isolation of system components for maintenance or repair. Provide additional valves at required locations necessary to conduct a valid hydrostatic test. Require manually operated valves, except where motor operators are specifically authorized by applicable standard drawings or technical specifications. Use double block and bleed type isolation valves for separation of product services, on tank shell connections (ASTs over 12,000 gallons (45,800 L) only), when piping goes aboveground or underground, between pier and tank storage, and other locations critical to periodic pressure-testing of piping. Quick opening/frequent opening type isolation valves may be used for less critical applications where double block and bleed shutoff is not required. As a minimum requirement, provide isolation valves at the following locations:

1. Provide double block and bleed valves where piping goes below/aboveground and requires periodic pressure testing.
2. At all subsurface and aboveground piping connections to storage tanks.
3. On each branch line at the point of connection to the main product pipeline or header.
4. On the product pipeline or header just before the line leaves a pumping station.
5. On the suction side and discharge side of each pumping unit, except the suction side of vertical centrifugal pumps installed in underground tanks.
6. At all aircraft fuel dispensing points.
7. On the inlet and outlet connection of each line strainer, filter-separator, meter, diaphragm control valve, and other system components that requires periodic servicing. One inlet valve and one outlet valve may be used to isolate more than one piece of adjacent system components which are connected in series.
8. On the aboveground piping at each tank car or tank truck off-loading connection. This requirement does not apply to gravity off-loading lines unless isolation valves are specifically called for on applicable drawings.
9. On the aboveground piping at each refueler loading connection.
10. At critical points where pipes cross runways, roads, and taxiways.

j. Other Valves – Check Valves, V-Port Ball Valves, and Thermal Relief Valves

k. Diaphragm Control Valves

l. System Components for Pigging

Equip all piggable pipelines with pig launchers and receivers, kicker lines into launcher, and receipt by-pass piping from receiver. Where directed by Service Headquarters, design pipelines for bi-directional pigging. Design pigging barrels so that they can accommodate internal nondestructive inspection trains. Provide sufficient curvature of bends in the pipeline to permit free passage for such equipment. Back to back 1.5 diameter (D) elbows must not be provided. If back to back direction changes are required, use 3 D sweeps. Provide tees with internal guide bars, at branch connections where indicated. See Chapter 9.

m. Fuel Hoses – Loading and Off-Loading Fuel Hoses

4-7 CONTROLS.

4-7.1 Control System Philosophy.

a. Fuel systems that include pumps to receive, transfer, and issue fuel must be provided with an Automatic Pump Control system with a programmable logic controller (PLC) driven Pump Control Panel (PCP) to control the system. All systems must be designed to perform all of their functions in the event the PCP is down. The PCP must:

b. Control hydrant systems as per the DoD Standard Designs AW 078-24-28 and AW 078-24-29.

c. Control truck fillstand systems that are designed with a pumphouse that operates in a fashion similar to hydrant systems as per the hydrant system DoD Standard Design AW 078-24-28.

d. Control cut and cover tank pumphouses per the DoD Standard Design AW 078-24-33.

e. Start and stop issue and transfer pumps.

f. Provide permissive interface to off-loading system receipt pump(s). Receipt pump must not start or continue to operate when receipt tank high-high level is reached or emergency system activation occurs. Local control will start or stop receipt pump.

g. Provide start and stop or permissive interface to drop tank off-loading system receipt pump(s). Receipt pump must not start or continue to operate when receipt tank high-high level is reached or emergency system activation occurs. PCP control via tank level sensors or local start/stop control of the receipt pump(s) is acceptable.

4-7.2 Exceptions.

The exceptions for systems covered in Chapter 4 where a PCP is not required are:

a. Pumps serving miscellaneous use tanks (see Chapter 8 for definition).

b. Isolated miscellaneous pumps that are not part of a larger system. These 5 horsepower or less size pumps act as sump pumps, pier stripping pumps, truck unloading pumps such as those required for off-loading small vacuum trucks, waste oil trucks, etc.

4-7.3 Design Requirements.

Automatic controls at any facility may include temperature, pressure, fuel level and pump controls, automatic flow controls, alarm and limit switches, motor operated isolation valves, solenoid pilot actuated diaphragm control valves, and remote system condition indicators. Other forms of automatic controls are remote meter indication, electronic access control, data logging, and application of computer techniques. Base the selection of advanced automation and telemetry systems on a study of the particular application with consideration of possible economic justification, operational, and security requirements.

4-7.4 Flow Controls.

Where it is possible to achieve flow rates which exceed system component ratings, provide an adjustable flow control valve on the outlet connection of each meter or filter-separator. Use a diaphragm control valve controlled by the pressure differential across an orifice plate in the valve or a venturi in the main line. Where necessary, provide remote-operated valves on storage tank inlet and outlet lines, suction and discharge of transfer pumps, and transfer lines at fuel piers and other locations.

4-7.5 Pump Controls.

Operation of pump suction and discharge valves may be a part of the automatic sequence for the starting of a centrifugal pump and for shutting it down, remotely, locally, or by a protective shutdown device. Remote-operated valves on the discharge side of the pump can be either motor-operated or the solenoid pilot-type, hydraulically operated diaphragm control valves. Remote control valves on the suction side of the pump can be motor-operated valves only. Equip these valves with green and red (open and closed) indicating lights at their pushbutton control locations.

4-7.5.1 All Pumps.

Provide the following controls:

a. A keyed hand/auto button at each pump and a keyed hand-off-auto switch at the motor starter for each remotely operated pump. Both devices will use the same key.

b. Indicator lights at the control station to give positive indications both when a pump is operating and when it is not energized. Use the "push-to-test" type.

c. A signal light or alarm to indicate pump failure when a pump is controlled automatically.

d. Reduced voltage starting if required by electric utility supplier or for all pump motors greater than 50 horsepower (37 kW) and all vertical pumps.

e. Emergency fuel shut-off (EFSO) pushbutton stations, between 100 and 200 feet (30 m and 60 m) from the pump in the expected ingress and egress direction, with maintained contacts. Provide additional EFSO pushbutton stations at the point of fuel delivery or receipt (fillstands, piers, tanks, etc.) using the same spacing and locations requirements.

f. Equip pantographs with 55 psi hose end pressure regulators located just before the refueling nozzle as described previously, unless directed otherwise by the Service Headquarters.

4-7.5.2 Multi-Function Pumps.

Multi-function pumps are typically used at small facilities and are designed and arranged to be able to perform different functions such as fuel loading, off-loading, or transfer depending on how valves are aligned. Provide each function with the control system requirements for each function described elsewhere in this chapter. For each multi-task pump provide a manual selector switch to choose which set of control and set points the pump is to "look at" when performing a particular function.

4-7.5.3 Transfer Pumps.

Parallel transfer pumps supplying an issuing facility with varying demand flow rates must be sequenced automatically by flow-sensing sequence equipment. Lead pumps can be started by a pushbutton at an issuing facility, or automatically by a pressure switch actuated by a decrease in system pressure as might be caused by opening a valve at the issuing facility. This method requires the system to be pressurized at all times and is normally incorporated in the Type III hydrant system design. Incorporate the following control features:

a. Automatically controlled pumps with emergency stop buttons with lock-key reset at issuing stations and at the central supervisory control station.

b. Automatic shut-off of transfer pumps on loss of suction or no flow for more than 3 minutes. Upon automatic shut-off, a corresponding alarm at the central supervisory control station is activated.

4-7.5.4 Pipeline Pumps.

For pumps over 150 horsepower (112 kW), provide protective shutdown devices with alarm at central supervisory control station in the event of the following:

a. High pump case temperature due to blocked discharge.

b. Excessive pump vibration.

c. Mechanical seal or packing gland failure.

d. High discharge pressure or loss of discharge pressure.

e. Excessive motor vibration.

f. High motor winding temperature.

g. Electrical interlocks which will prevent starting a pump if certain key valve settings are not correct and which will cause a pump shutdown if a key valve setting is changed.

h. Loss of pump suction pressure.

i. High-bearing temperature and/or loss of cooling water flow.

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4-8 FUEL ADDITIVES.

Provide storage facilities which store aviation turbine fuels with the system components to inject fuel additives if directed by Service Headquarters. This will require proportional injectors with manual bypass, storage of additives, and recirculation of tanks through piping with injectors. If the additives have a corrosive characteristic, construct the system, including storage tanks, tank appurtenances, pumps if required, piping and associated fittings, valves, and injector assemblies of stainless steel components. Consult Service Headquarters for guidance as to which additives must be included.

4-9 DEFUELING AND RETURN-TO-BULK (RTB) SYSTEMS.

4-9.1 General Criteria.

Acceptable locations for defueling and RTB Systems include the return line at a truck fillstand, the return line at a hydrant hose truck check-out station, the return line at a pantograph flush station, the product recovery tank, or at a truck off-load station.

4-9.2 JP-5 Systems.

4-9.2.1 Hydrant Systems.

Because the degradation of flash point below the minimum JP-5 requirement can occur when other than JP-5 is defueled from aircraft directly into operating tanks, ensure that JP-5 direct fueling systems are not capable of defueling an aircraft back into hydrant systems and operating storage. Defuel aircraft into mobile tanker vehicles or into fixed dedicated defuel tanks.

4-9.2.2 Other.

Do not provide a capability to defuel JP-5 refueler trucks back into storage unless directed by Service Headquarters.

JP-5 systems do not use fuel bowsers (mobile defuel tanks).

4-9.3 JP-8 Systems.

4-9.3.1 Hydrant Systems – Hydrant Loop.

Provide JP-8 hydrant systems with capability to defuel aircraft back into the hydrant systems and operating storage through the hydrant pit diaphragm control valves.

4-9.3.2 Hydrant Systems – Other.

To allow defueling of refueler trucks provide a Return-To-Bulk (RTB) station on the return line of a hydrant hose truck check-out station or a pantograph check-out station, or a pantograph flushing station. Provide one adapter per group.

4-9.3.3 Tank Truck and Tank Car Off-Loading.

To allow defueling of refueler trucks, provide a Return-To-Bulk (RTB) station by providing a MIL-STD MS 24484 aircraft refueling adapter at a tank truck or tank car off-loading station. Provide one adapter per group of tank truck or tank car off-load stations. If defueling into a product recovery tank, do not bypass the level control valve.

4-9.3.4 Refueler Truck Fillstands.

To allow defueling of refueler trucks, provide a Return-To-Bulk (RTB) station by providing a MIL-STD MS 24484 aircraft refueling adapter at a point upstream of receipt filtration when the fillstand has a return line. Provide one adapter per group of refueler truck fillstands. If defueling into a product recovery tank, do not bypass the level control valve.

4-9.3.5 Fuel Bowsers (Mobile Defuel Tanks).

Provide a capability to empty JP-8 fuel bowsers mobile defuel tanks by providing a gravity drain connection on underground product recovery tanks, or by providing a pump at aboveground product recovery tanks. Do not bypass the product recovery tank level control valve.

4-10 PRODUCT RECOVERY SYSTEMS.

Provide a system with pumps, piping, valves, and tanks to collect and store usable aviation turbine fuel which would otherwise become waste from operational or maintenance activities. See Chapter 8 of this UFC.

4-10.1 Tank Trucks and Fuel Bowsers.

Provide a capability to receive fuel from JP-8 tank trucks and JP-8 fuel bowsers into the product recovery tank, either at the product recovery tank location, the truck fillstands, or through a connection at the fuel receipt facility.

4-10.2 Return to Bulk.

Provide a capability to return aviation turbine fuel from JP-5 and JP-8 product recovery tank back into operating storage by pumping the fuel into the receipt piping upstream of receipt filtration.

Table 4-1 Aviation Turbine Fuel Receipt Filtration Table [(1)(3)]

ITEM	DESCRIPTION	PIPELINE				MARINE				TRUCK/RAIL			
		SPP(IB) (1)	SPP(IOT) (1)	MPP(IB) (1)	MPP(IOT) (1)	B(IB) (1)	B(IOT) (1)	T(IB) (1)	T(IOT) (1)	OTRTT(IB)	OTRTT(IOT)	RC(IB)	RC(IOT)
a.	Provide strainers upstream of filter-separators.	✓	✓	✓	2	✓	✓	1	1	✓	✓	✓	✓
b.	Provide pre-filtration consisting of pre-filter or coalescer vessels, or both. For a receipt rate of 1200 gpm or less, provide at least two equal sized vessels of each type in parallel, each sized to handle at least 100% of the normal off-loading flow rate. When the flowrate is over 1200 gpm, provide two sets of each type of vessel installed in parallel, each set sized for 100% of the normal off-loading flow rate.			✓	2	✓	✓	1	1				
c.	Consider pre-filtration consisting of pre-filter or coalescer vessels, or both.	✓	✓		2					✓	✓	✓	✓
d.	When receiving from a non-government controlled source: Provide fine filtration. For a receipt rate of 1200 gpm or less, provide two equal sized filter-separators in parallel, each sized to handle at least 100% of the normal off-loading flow rate. When the flowrate is over 1200 gpm, provide two sets of filter-separators installed in parallel, each set sized for 100% of the normal off-loading flow rate.	✓		✓	2	✓	✓	1	1				
e.	When receiving from a non-government controlled source: Provide fine filtration consisting of a sufficient number of equally sized receipt filter-separators to handle 100% of the maximum expected flow, plus provide an equally sized spare filter-separator.		✓		2					✓	✓	✓	✓
f.	When receiving from a government controlled source: Provide fine filtration consisting of a sufficient number of equally sized receipt filter-separators to handle 100% of the maximum expected flow.		✓		2			1	1	✓	✓	✓	✓
g.	Provide each vessel with a feature to automatically switch the fuel stream to the other vessel when the differential pressure across the vessel reaches a preset limit. Require a warning signal to the	✓	✓	✓	2	✓	✓	1	1				

ITEM	DESCRIPTION	PIPELINE				MARINE				TRUCK/RAIL			
		SPP(IB) (1)	SPP(IOT) (1)	MPP(IB) (1)	MPP(IOT) (1)	B(IB) (1)	B(IOT) (1)	T(IB) (1)	T(IOT) (1)	OTRTT(IB)	OTRTT(IOT)	RC(IB)	RC(IOT)
	operator that the switching operation has occurred. In cases of emergency, include the capability to bypass the inlet filter-separator bank.												
h.	Disable filter-separator control valve water slug feature. Provide water conductance probe tied to an alarm in place of water slug float. Provide differential pressure alarm and differential pressure-actuated bypass valve.	✓	✓	✓	2	✓	✓	1	1				
i.	Provide filter-separator sump with automatic water drain valve connected to the bottom of the water sump. (4)				2	✓	✓	1	1				
j.	Consider providing filter-separator sump with automatic water drain valve connected to the bottom of the water sump when large quantities of water are expected. (4)	✓	✓	✓	2			1	1				

Notes:

(1) Tankers always, and barges and pipelines may, receive at greater than 2,800 gpm. In these cases, fuel is typically received into a breakout tank, usually for economic reasons. Contact Service Headquarters to determine what filtration is needed.

(2) MPP(IOT) included for information only. NEVER receive fuel from a Multi-Product Pipeline into an Operating Tank.

(3) This table will not typically apply to receipt into regional bulk storage centers such as Defense Fuel Support Points (DFSPs). These typically have not filtration on receipt. Contact Service Headquarters for guidance.

(4) Consider also in any situation where large quantities of water are expected.

SPP(IB) - Single Product Pipeline (Into Bulk)
SPP(IOT) - Single Product Pipeline (Into Operating Tank)
MPP(IB) - Multi-Product Pipeline (Into Bulk)
MPP(IOT) - Multi-Product Pipeline (Into Operating Tank)
B(IB) - Barge (Into Bulk)
B(IOT) - Barge (Into Operating Tank)
OTRTT(IB) - Over the Road Tank Truck (Into Bulk)
OTRTT(IOT) - Over the Road Tank Truck (IOT)
RC(IB) - Rail Car (Into Bulk)
RC(IOT) - Rail Car (Into Operating Tank)
T(IB) - Tanker (Into Bulk)
T(IOT) - Tanker (Into Operating Tank)

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CHAPTER 5 MARINE AND DISPENSING FACILITIES

5-1 FUNCTION.

Design marine fuel receiving and dispensing facilities for the purpose of receiving fuel and/or loading fuel aboard ships, barges and boats for consumption or as cargo. In many cases, the marine receiving and dispensing facilities will be combined. Special requirements for aviation turbine Fuels are in Chapter 4 of this UFC.

5-2 FUEL PIERS AND WHARVES.

Ensure that the structural design of fuel piers and wharves is in accordance with UFC 4-152-01. When required and approved by the appropriate Service Headquarters, design fuel piers for dispensing and receiving fuel. Ensure that the size of the facility is compatible with the fuel requirements of the activity and the number of simultaneous loadings and off-loadings to be accommodated. For dispensing of fuel, consider the number, type, and size of vessels to be fueled or loaded to provide the required number and locations of fuel outlets. In most cases, use dedicated fuel piers and wharves for fuel receipt. Include in the design an energy absorbing fender system. Refer to NAVFAC Definitive Drawings **\2** 10009724 through 10009734 **/2/**.

5-3 BERTHING PIERS.

In some cases, permanent fuel piping and system components may be installed on berthing piers which were not primarily designed for handling fuel. Design such piers in accordance with UFC 4-152-01. These facilities are normally used only for dispensing fuel to surface combatants for consumption. Operational requirements usually dictate a clear berthing pier surface area. This imposes restrictions on the use of loading arms and above deck piping. For these areas, trench-contained piping may be considered. Prior to designing facilities on berthing piers for receiving and/or dispensing of bulk fuel for transport, review plans with appropriate port operations agency.

5-4 OFFSHORE MOORINGS.

When operations of an activity do not warrant construction of fuel piers, provide offshore moorings for vessels to discharge or receive fuel through underwater pipelines connecting to the shore facility. Clearly mark the moorings so that the vessel, when moored, will be in the proper position to pick up and connect to the underwater connection. Coordinate offshore mooring systems with Naval Facilities Engineering and Expeditionary Warfare Center, Oceans Technical Department (NAVFAC EXWC, OC).

5-5 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, of this UFC contains important information on fueling facilities. Do not start the design of any fueling system without first becoming completely familiar with Chapter 2 of this UFC. In particular, refer to Chapter 2 for guidance on spill prevention, air quality control, and other environmental, safety and fire protection issues.

5-6 GENERAL LAYOUT.

Provide pier loading and off-loading connections, with blind flange and with ball valve for throttling and isolation, at the pier edge for each product to be transported. The intent is for a loading arm manifold with a separate manual isolation plug valve for each product connection. This will allow simultaneous loading and off-loading of different products, each through a dedicated arm. Provide a double block and bleed plug valve at the point which the line is being stripped. Use the following criteria:

a. Provide each branch line to the pier edge with a manual isolation valve located at the main line. Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

b. Do not provide a gauge outboard of the hose connection shutoff valve because hose movement will indicate the presence or absence of pressure in the hose.

c. If required, provide one or more loading arms at each station.

d. Provide a liquid-filled pressure gauge for each loading arm, located to be easily read from the operator position. This gauge is provided because the drybreak check valve at the end of the loading arm and the rigid piping will not intuitively indicate the presence or absence of pressure at the loading arm.

e. Provide for venting and draining of the branch lines and loading arm manifolds. Provide for manual venting of the branch lines, connect the vents to the oil waste line, similar to a sanitary vent system to avoid spillage. When pier drain lines cannot be sloped back to the pierhead stripping pumps, a design including separate oil waste drain lines, holding tank and dedicated stripping pump is a viable alternative.

f. Provide segregated handling of multiple products through the loading arms, while allowing easy selection of the products to be transported. Double block and bleed valves can be used for this application.

g. Provide a separate pipe and connection for ballast water or offspec fuel if the size of the facility and level of activity warrants it.

h. Provide each hose handling and loading arm area with fixed spill containment as defined in 33 CFR Part 154.

i. Provide hydraulic shock surge suppressors (if required).

5-7 PIPING SYSTEMS.

Refer to Chapter 9 of this UFC for information regarding piping systems.

5-7.1 Piping Arrangement.

In addition to complying with Chapter 9, use the following criteria:

a. Where simultaneous deliveries of the same fuel may be made by more than one vessel, size fuel headers and related system components for the total flow rates of all vessels discharging into the headers. Ensure that flow rates are in accordance with Chapter 2 of this UFC.

b. Place pier piping above the pier deck within a containment area for fueling piers and within a trench on berthing piers. Slope piping toward shore to permit stripping. Use gratings as required to allow access across the piping.

c. Provide flexibility in the piping between the pier and the shore to allow for small movement of the pier relative to the shore. Use a suitable pipe bend or offset configuration, preferably in a horizontal plane, that will allow three-dimensional movement. If vertical bends are used, install vents and drains.

d. Provide flexibility in the piping along the pier to allow for pipe growth due to thermal expansion. Horizontal expansion loops are preferred. In cases where space is tight provide vertical expansion loops or bellows expansion joints where necessary. Where practical provide vertical expansion loops with vents and drains.

e. Include in the pier facilities, pipe manifolds for each fuel type arranged parallel to the face of the pier.

f. Pipe hangers are not allowed.

5-8 DESCRIPTION OF SYSTEMS COMPONENTS.

Unless otherwise indicated below, refer to Chapter 15 for description of system components. The following system components are typically used in marine receiving and dispensing facilities:

a. Loading/Off-Loading Arms

Provide articulated marine loading arms for receiving and shipping fuel cargoes so that the connected vessel can move 15 feet (4.6 m) forward, 15 feet (4.6 m) aft, and 10 feet (3 m) off the face of the pier and vertically as caused by loading or off-loading of the vessel and tidal changes, without damage to the arm. Provide a hydraulic power assist system for operating loading arms larger than 8-inch (200 mm) nominal size. Equip the end of the loader to be connected to the ship's manifold with an insulating section, a standard ANSI forged steel flange, and a steel quick coupling device, manually or hydraulically operated. Refer to NAVFAC Drawings. 2\10009724 through 10009734/2/.. Consider breakaway couplings for locations with strong current.

b. Fuel Hoses – Submarine Fuel Hoses

c. Meters – Positive Displacement and Turbine

d. Strainers

e. Surge Suppressors

f. Filtration – Filter-Separators, Micronic Filters, and Haypack Coalescers

g. Manual Valves – Isolation Valves

h. Manual Valves – Isolation Valve Locations

1. Provide an isolation valve on each line at the shore end. For piping used only for receiving fuel, also provide a check valve at the shore end. Use double block and bleed type, which may be motor-operated with remote control. To minimize surge potential, use a slow-closing speed, if possible.

2. Provide double block and bleed isolation valves on the aboveground piping at each barge or tanker off-loading and loading connection.

3. Provide double block and bleed isolation valves near the shoreline of a submerged pipeline to offshore moorings.

4. Provide double block and bleed isolation valves on the inlet and outlet connection of each line strainer, filter-separator, meter, diaphragm control valve, and other system components that requires periodic servicing. One inlet valve and one outlet valve may be used to isolate more than one piece of adjacent system components which are connected in series.

i. Other Valves – Check Valves and Thermal Relief Valves

j. Pressure Gauges

k. Pumps – Stripper Pumps

l. Excess Flow Sensors

In piping used for both loading and off-loading, provide a sensor that will alarm both the control room and at the pier to detect excess flow that might occur in the event of a line break.

m. Solid Cyclonic Separators

In facilities which receive product by tankers or barge, consider the use of solid separators in the receiving lines as part of pre-filtration to remove gross impurities from the incoming product. In systems equipped with filter-separators in the receiving lines, locate strainers or cyclonic separators upstream of the filter-separator. Ensure that there is no slug valve feature on the filter-separator. Consider the use of automatic water drains. Do not allow reverse flow thru cyclonic separators.

5-8.1 Grounding Systems.

Provide grounding systems for barges in accordance with **\1** paragraph 2-11.3. **/1/**

5-8.2 Special Considerations for Aviation Turbine Fuels.

For inbound filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

5-9 CONTROLS.

5-9.1 Control System Philosophy.

Fuel systems that includes pumps to receive, transfer, and issue fuel must be provided with an Automatic Pump Control system with a programmable logic controller (PLC) driven Pump Control Panel (PCP) to control the system. All systems must be designed to perform all of their functions manually in the event the PCP is down.

5-9.2 Exceptions.

The exceptions for systems covered in Chapter 5 where a PCP is not required are:

a. Pumps serving miscellaneous use tanks (see Chapter 8 for definition).

b. Isolated miscellaneous pumps that are not part of a larger system. These 5 horsepower or less size pumps act as sump pumps, pier stripping pumps, etc.

5-10 PRODUCT RECOVERY SYSTEMS.

Provide a product recovery system to collect and store usable aviation turbine fuel that would otherwise become waste from operational or maintenance activities. Consider a product recovery system for other products. See Chapter 8 of this UFC for product recovery systems.

5-11 WEATHER SHEDS.

Provide adequate shelter for personnel, as well as for spill containment booms, absorbent material, and other weather-sensitive system components.

5-12 CANOPIES.

\1 Provide a canopy for protection from the elements of fixed facility assets and system components in accordance with paragraph 2-2**. /1/**

5-13 SPECIAL CALCULATIONS.

Calculate pipeline filling/venting times and draining/stripping times. The larger and the longer the pipeline, the greater the volume of fuel required to fill the line and, therefore, the greater the volume of air required to be vented. Undersized vent lines will delay filling the lines and delay changeover of products in multiproduct lines. Size the vent lines to allow filling of the line at not more than four times the design transit time of the line. Connect vent line to the drain line to avoid spills to the environment. Check vent line air velocity, which must not exceed the allowable air velocity to avoid electrostatic buildup, in accordance with API RP 2003. Vent rate must be not less than the lowest allowable pumping rate from ship or shore. Vent rate must be less than the design transit velocity to minimize hydraulic shock.

5-14 EMERGENCY SHOWERS AND EYEWASH STATIONS.

Provide manual shutoff valves on the potable water branch to the emergency shower and eyewash station. Provide a means to seal shutoff valve in the open position. This will ensure operation in an emergency, yet allow for servicing a single shower without shutting off potable water to the whole pier. Design for freeze protection in climates subject to freezing. **\1\ /1/**

5-15 TRAFFIC BOLLARDS.

Provide traffic bollards to protect fueling piping and system components on piers and wharves. Utilize concrete-filled steel pipe of minimum 4-inch (100 mm) diameter and 4-foot (1.2 m) height, embedded in concrete or welded to a steel plate mounted on the structure.

5-16 SPECIAL DRAINAGE FOR FUELING PIERS.

a. Provide an intercept system to collect oil spills. Place pipes on piers in a curb containment area with a drain system independent of the deck drainage. Provide containment also for loading arms and risers. Provide locking valves in normally closed positions on all containment areas along with sump pumps or other means of removing the spilled fuel to a collection point or tank.

b. In cases where the stormwater collected in the intercept system is contaminated, the water/fuel mixture should be treated as an oil spill as described previously.

5-17 BALLAST RECEIVING AND SLUDGE REMOVAL.

5-17.1 Ballast Receiving and Treatment Facilities.

5-17.1.1 Design Requirements.

It is the policy of the United States that there should be no discharge of oil or hazardous substances into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone. For OCONUS, follow the most stringent of the United States policy or local national regulations. Petroleum fuel facilities, which transfer fuel by barge or tanker or which fuel large ships, require ballast water collection and treatment facilities to receive and treat oily ballast from cargo or fuel tanks. Also:

a. Blend the fuel oil which has been reclaimed from the ballast water during the collection and treatment process with boiler fuel oil for use in shoreside boilers. Perform a quality assurance check on the reclaimed fuel oil to ensure that it meets the minimum requirements for shoreside boiler fuel. Dispose of sludge accumulated during the collection and treatment of ballast water in accordance with applicable hazardous waste management disposal procedures.

b. Select and design the appropriate treatment system based on an evaluation of the types of oil/water mixtures that may be encountered at the particular facility. If possible, base the evaluation on samples of typical ballast water receipts and tank washings including the following:

   1. Whether they are simple mixtures, simple gravity suspensions, or chemically stable emulsions.

   2. The specific gravity and viscosity of the oil in the mixture.

   3. Whether other substances, such as chemicals or bacteria, in the mixtures must be removed.

   4. The general condition of the ship's tanks expected to be discharged (e.g., new, clean, coated, well maintained, or dirty and normally full of sludge, scale, and rust).

   5. Whether ballast water is clean sea water or polluted harbor water.

   6. Whether the treatment system proposed ("ship's waste off-load barge" or fixed shore-based facilities) meets the standards of effluent water quality established by local environmental regulations.

c. If it is determined that both simple mixtures and emulsions are present, consider the possibility of using two segregated separate systems, one for gravity separation and the other for breaking emulsions. Avoid mixing the two types of suspensions when possible. For bilge water and other contaminated oily wastes which require additional treatment, refer to UFC 4-832-01N, Industrial and Oily Wastewater Control or for Army and Air Force projects **\2** UFC 3-240-01. ***/2/***

d. For typical schematic arrangement of ballast water treatment and disposal systems, refer to UFGS 46 25 14.

5-17.1.2 Receiving and Settling Tanks.

The minimal ballast water receiving facility usually requires two storage tanks, usually of equal capacity, to be used alternately as receiving and settling tanks. If these tanks are sized to allow 4 to 5 days undisturbed settlement, separation of simple suspensions of light oils in water can be achieved. Use welded steel vertical aboveground storage tanks designed and constructed in accordance with Chapter 8 of this UFC. In addition to complying with Chapter 8 of this UFC for construction appurtenances, provide the following fittings and appurtenances:

a. An automatic float gauge suitable for use with transmitting device for remote readout.

b. One cable-operated swing-line assembly on the oil outlet pipe.

c. One shell fill nozzle.

d. Valved sample connections in the shell, having nonfreezing-type valves in cold climates, every 2 feet (0.6 m) vertically, easily accessible from the ladder or stairway.

e. When chemical feed is provided, a chemical feed inlet valve, to be nonfreezing type in cold climates.

f. When air blowing is provided, a perforated pipe air sparger for mixing. Make the perforations in the sides of the pipe to avoid plugging by settling solids. Use nonfreezing-type air inlet valve(s) in cold climates.

g. Sight glass or look box on oil outlet line.

h. Sight glass or look box on water outlet line.

i. Oil sump tank with high-level alarm.

j. Water and oil pumps as required to move fluids from receiving tanks or from oil sump tanks. For transfer of oily water, use low-speed-type pumps to minimize emulsification.

k. If heaters are required to reduce oil viscosity and promote separation, use either tank wall heaters or internal pipes. Keep internal pipes at least 2 feet (0.6 m) above the tank floor.

l. Insulation for tanks that will be regularly heated.

m. Provide automatic temperature controls and thermometers for all heated tanks.

5-17.1.3 Oil/Water Separators.

Separate water/fuel mixtures from storage or settling tanks with an API oil/water separator. Recycle the fuel portion and pass the water portion to another treatment process. Do not discharge water drawn from tanks to surface water without additional treatment and permits. Chapter 2 of this UFC contains design information for an API oil/water separator.

5-18 SLUDGE REMOVAL SYSTEMS.

5-18.1 Design Requirements.

Install sludge removal systems where the accumulation of sludge in substantial quantities is likely to occur on a regular basis. Sources of such sludge are a ballast water treatment system, a contaminated fuel recovery system, or frequent cleaning of shore or ships' tanks. If routine cleaning of clean product storage tanks occurs on an irregular basis, sludge removal systems are not required.

5-18.2 Sludge Disposal.

a. Where possible, provide pumps, tanks, and piping to return sludge containing recoverable oil to the contaminated oil recovery system. If this is not possible, consider transferring the sludge to a refinery or waste oil treatment facility. For additional details, refer to **\2** UFC 3-240-01 **/2/**

b. Provide a tank or tanks with transfer pump(s) for pumpable sludges that are unreclaimable. Include piping for receiving sludge and for mixing other low viscosity waste oils for thinning as required. Ensure that tanks are dike-enclosed and have cone bottoms.

c. Provide tank heating where climate conditions prove necessary.

d. Coordinate sludge disposal method and design with facility environmental office.

e. Enclose the sludge disposal facility with a security fence to prevent unauthorized entry. Do not use this facility for disposal of sand, gravel, rust scale, or other solid nonpumpable matter found on tank bottoms

5-18.3 Piping Materials.

Refer to Chapter 9 of this UFC for information regarding piping materials.

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CHAPTER 6 INTERTERMINAL AND INSTALLATION PIPELINES

6-1 INTRODUCTION.

This chapter provides guidance for the design of pipelines. Military pipelines are typically either interterminal pipelines which are cross country and connect government installations, or installation pipelines which connect POL facilities within an installation. The primary differences are that interterminal pipelines cross public and private properties, streets, highways, railroads, and utility rights-of-way, whereas installation pipelines do not. Interterminal pipelines may be dedicated lines connecting two or more facilities or privately owned common carrier lines serving several commercial or military shippers. In some cases, the shipping facility may consist of a relatively short spur which delivers the fuel to the suction side of a pumping station which is part of the main line of a larger pipeline system. Interterminal pipeline receipt and transfer facilities are normally part of a bulk fuel storage facility, which is discussed in Chapter 3 of this UFC. Installation pipelines are usually for aviation turbine fuels. Special requirements for aviation turbine Fuels are in Chapter 4 of this UFC.

6-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not start the design of any fueling system without first becoming completely familiar with Chapter 2 of this UFC.

6-3 DESIGN REQUIREMENTS.

6-3.1 Fuel Segregation.

Clean products, such as diesel fuel and distillate-type burner fuels, may be shipped in the same system without segregation. Batches are usually pumped product to product, but they may be separated by fresh or suitably treated water. Separate piping systems are required for residual fuels. For DoD projects, provide a dedicated pipeline for aviation turbine fuels.

6-3.2 Applicable Regulations.

Interterminal and installation pipelines must be designed as described below. Where federal, state, or local regulations are more restrictive than the requirements indicated, the more restrictive requirements must apply.

6-3.2.1 Installation Pipelines.

All installation pipelines must be designed in accordance with ASME B31.3.

6-3.2.2 Interterminal Pipelines.

The U.S. Department of Transportation regulates the design, construction and operation of commercially-owned interterminal pipelines for liquid petroleum. Intrastate interterminal pipelines must be designed in accordance with ASME B31.4. Interstate interterminal pipelines, must be designed in accordance with the requirements of 49 CFR Part 195.

6-3.3 Sampling.

\3 Provide a means for taking samples of the products shipped. ***/3/***

6-3.4 Pigging.

Pipelines must be smart piggable including 1.5 diameter (D) elbows and barred tees (where indicated) unless otherwise directed by Service Headquarters in accordance with Chapter 9. Provide permanent launchers and receivers suitable for smart pigging.

6-3.5 Surge Suppressions.

Provide surge suppressors for hydraulic shock when required by results of a computer based dynamic transient surge analysis.

6-3.6 Filtration.

When directed by Service Headquarters, provide means of filtration for all products. The selection of filtration depends on anticipated impurities, the source of fuel, and the shipping methods. Consider the use of filter-separators, micronic filters and Haypack coalescers as possible filtration devices. For filtration of aviation turbine fuels, refer to Chapter 4 of this UFC.

6-4 PIPING SYSTEMS.

Refer to Chapter 9 of this UFC for information regarding piping systems.

6-5 DESCRIPTION OF SYSTEMS COMPONENTS.

The appropriate guide specification and/or standard design provides specific information for selection of system components. Make provisions to drain and vent piping for maintenance. Unless otherwise indicated below, refer to Chapter 15 for description of system components. The following system components are typically used in interterminal and installation pipelines:

a. Meters – Positive Displacement and Turbine

b. Pressure Gauges

c. Manual Valves – Isolation Valves

d. Manual Valves – Isolation Valve Locations

   Provide valves in product piping systems to control flow and to permit isolation of system components for maintenance or repair. Provide additional valves at required locations necessary to conduct a valid hydrostatic test. Provide manually operated valves, except where motor operators are specifically authorized by applicable standard drawings or technical specifications. Use double block and bleed type isolation valves for separation of product services, on tank shell connections (ASTs over 12,000 gallons (45,800 L) only), when piping goes aboveground or underground, between pier and tank storage, and other locations critical to periodic pressure-testing of piping. Quick opening/frequent opening type isolation valves may be used for less critical applications where double block and bleed shutoff is not required. Before adding isolation valves, evaluate piping system and make modifications to prevent pressure buildup caused by thermal expansion. Review paragraph on "Thermal Relief Valves" in Chapter 9 of this UFC. As a minimum requirement, provide isolation valves at the following locations:

1. Provide a double block and bleed isolation valve on each branch line at the point of connection to the main product pipeline or header.

2. Provide a double block and bleed isolation valve on the product pipeline or header just before the line leaves a pumping station.

3. Provide a double block and bleed isolation valve at the inlet and outlet connection of each line strainer, filter-separator, meter, diaphragm control valve, thermal relief valve, and other system components that requires periodic servicing. One inlet and one outlet double block and bleed isolation valve may be used to isolate more than one piece of adjacent system components which are connected in series.

4. Provide a double block and bleed isolation valve on the upstream and downstream side of each line blind at connections to cross country pipelines.

5. Provide a double block and bleed isolation valve on each main distribution pipeline immediately downstream of the branch connection to each existing or future operating storage facility served by the pipeline.

6. Provide full-bore double block and bleed isolation valve at intermediate points of approximately 10 miles (16 km) in cross country distribution pipelines to facilitate isolation of a section of the line for maintenance and repair.

7. Provide a double block and bleed isolation valve on each side of water crossing exceeding 100 feet (30 m) in width, and near the shoreline of a submerged sea pipeline.

8. Provide a double block and bleed isolation valve at critical points where pipes cross under runways, taxiways, and roadways.

9. For low-point drains and high-point vents.

e. Other Valves – Check Valves and Thermal Relief Valves

f. Diaphragm Control Valves

g. Strainers

h. Surge Suppressors

i. Filtration – Filter-Separators, Micronic Filters, and Haypack Coalescers

j. System Components for Pigging

Provide all piggable pipelines with pig launchers and receivers, kicker lines into launcher, and receipt by-pass piping from receiver. Where directed by Service Headquarters, design pipelines for bi-directional pigging. Design pigging barrels so that they can accommodate internal nondestructive inspection trains. Provide sufficient curvature of bends in the pipeline to permit free passage for such equipment. Back to back 1.5 diameter (D) elbows must not be provided. If back to back direction changes are required, use 3 D sweeps. Provide tees with internal guide bars, at branch connections where indicated. See Chapter 9.

k. Pumps

Primary pumping facilities are discussed in Chapter 3 of this UFC. If multiple pump stations are required to keep pipeline pressure within safe limits, provide them at appropriate locations. Chapter 3 also provides guidance for those pumping facilities.

l. Sampling Connections

Provide connections for sampling fuels on each section of a fuel transfer piping system. Install sampling and testing connections at receiving points, tank outlets, inlet and outlet sides of filter-separators, fuel dispensing points, truck off-load header, and between isolation valves so that remaining fuel in each portion of a fuel transfer pipeline can be sampled. Where possible, install sampling connections in vertical runs. Provide a 1/4-inch (8 mm) diameter sample point with a probe, ball valve, and quick disconnect with dust cap.

6-6 CONTROLS.

6-6.1 Control System Philosophy.

Fuel systems that includes pumps to receive, transfer, and issue fuel must be provided with an Automatic Pump Control system with a programmable logic controller (PLC) driven Pump Control Panel (PCP) to control the system. All systems must be designed to perform all of their functions manually in the event the PCP is down.

6-6.2 Exceptions.

The exceptions for systems covered in Chapter 6 where a PCP is not required are:

a. Pumps serving miscellaneous use tanks (see Chapter 8 for definition).

b. Isolated miscellaneous pumps that are not part of a larger system. These 5 horsepower or less size pumps act as sump pumps, pier stripping pumps, etc.

6-7 PRODUCT RECOVERY SYSTEMS.

Provide a product recovery system to collect and store usable aviation turbine fuel that would otherwise become waste from operational or maintenance activities. Consider a product recovery system for other products. See Chapter 8 of this UFC for product recovery systems.

\1\ /1/

6-8 SPECIAL CALCULATIONS.

Calculate pipeline filling/venting times and draining/stripping times. The larger and the longer the pipeline, the greater the volume of fuel required to fill the line and, therefore, the greater the volume of air required to be vented. Undersized vent lines will delay filling the lines and delay changeover of products in multiproduct lines. Size vent lines to allow filling of the line at not more than four times the design transit time of the line. Where applicable, connect vent lines to system drain lines to avoid spills to the environment. Check vent line air velocity, which must not exceed the allowable air velocity to avoid electrostatic buildup, in accordance with API RP 2003. Vent rate must be not less than the lowest allowable pumping rate from ship or shore. Vent rate must be less than the design transit velocity to minimize hydraulic shock.

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CHAPTER 7 GROUND PRODUCTS FUELING FACILITIES

7-1 INTRODUCTION.

This chapter provides guidance for the design of ground products (gasoline, diesel, biodiesel, and E-85)) fueling facilities and covers government vehicle motive fuel filling stations and tactical refueler truck loading facilities. Private vehicle filling stations, such as exchange service stations, are not included. Refer to DoD Standard Design STD 123-335-03 for Military Service Station and Factory Fabricated Tank Engineering Standard.

7-1.1 Types of Facilities.

The following three types of ground products fueling facilities may be required (see Facility Plates 011, 012 and 013):

a. A filling station for dispensing motive fuel gasoline, diesel, biodiesel, and E-85 into government (commercial type) sedans, vans, and small trucks. See Facility Plate 011.

b. A filling station for dispensing motive fuel gasoline, diesel, biodiesel, and E-85 into tactical vehicles. See Facility Plate 011.

c. A truck loading facility for loading gasoline, diesel, biodiesel, and E-85 into tactical refueler vehicles. See Facility Plates 012 and 013.

7-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not start design of any fueling system without first becoming completely familiar with Chapter 2 of this UFC.

7-3 DESIGN REQUIREMENTS.

7-3.1 Fuel Segregation.

Provide separate receiving, storage and distribution systems for each grade or type of fuel. Except as otherwise approved by Service Headquarters, prevent misfueling (transferring a type of fuel other than the type intended) by using different size piping, valves, adaptors, nozzles, etc.

In the CONUS, use color coding in accordance with API RP 1637. In non-CONUS facilities, use host nation standard if it is different than API RP 1637. Use API RP 1637 if no other standard is in effect. For Air Force projects to refer to 37-1-1.

7-3.2 Facility Size.

In each filling station, provide one commercial-type dispensing unit which displays volume only for each 100 vehicles assigned to the activity. The total amount of storage capacity in each station should be approximately twice the capacity of all vehicle fuel tanks, by grade or type of fuel, assigned to the activity. Minimum storage capacity for any grade or type of fuel is 5,000 gallons (19,000 L) unless approved by Service Headquarters. For tactical refueler truck loading facilities, see Chapter 3 of this UFC.

7-3.3 Facility Configurations.

In general, for control and safety, separate the three types of filling stations. For a relatively small installation or one on which there is a limited amount of activity expected at one time, it may not be practical to provide totally separate facilities. In those cases, separate the functions as much as possible to minimize mixing traffic of commercial-type vehicles from tactical vehicles and, more importantly, from mixing tactical refuelers which are being loaded with relatively large quantities of fuel from other vehicles which are being fueled for their own engine (motive fuel). Filling stations must be configured to comply with all NFPA 30A siting and storage requirements.

7-3.4 Bulk Operations.

A motive fuel filling station located at a bulk plant must be separated from areas in which bulk plant operations are conducted by a fence or another approved barrier. Dispensing devices at the motive fuel filling station must not be supplied by aboveground tanks located in the bulk plant. Storage tanks at motive fuel filling station must not be connected by piping to aboveground tanks located in the bulk plant. Tactical refueler truck loading may be conducted at a motor fuel dispensing facility. Filling stations must be configured to comply with NFPA 30A.

7-3.5 Shelters.

For staffed facilities, provide a shelter for personnel, records, and tools.

7-3.6 Concrete Fueling Area – Filling Stations.

Create a fueling area constructed of concrete by surrounding fueling islands with a concrete slab graded at a minimum of 1 percent away from the islands.

7-3.7 Canopies.

7-3.7.1 Canopies to Protect Fixed Assets from Extreme Weather Conditions.

\1 Provide a canopy for protection from the elements of fixed facility assets and system components in accordance with paragraph 2-22**. /1/**

7-3.7.2 Canopies to Reduce Stormwater of Filling Stations.

Do not provide a canopy to preclude rain from reaching the concrete fueling area unless it is required by federal, state, or local regulations or if directed by Service Headquarters. Ensure structural design is in accordance with UFC 1-200-01 and UFC 3-301-01.

7-3.8 Regulations.

Design must comply with 40 CFR Part 112, NFPA 30, NFPA 30A, and API RP 1615.

7-3.9 Bottom Loading.

The bottom loading of refuelers is required if the refuelers are equipped for it. However, there are Army refuelers which are not equipped for bottom loading and which will be in inventory for several years. Therefore, provide top loading racks with elevated steel platforms at tactical refueler fillstands, when approved by Service Headquarters.

7-3.10 Truck Offload and Loading Facilities.

Design of service station truck offload and loading facilities must comply with NFPA 30, NFPA 30A and 40 CFR Part 112. Also, do not locate truck offload or tactical refueler loading facilities/vehicles closer than 25 feet (7.6 m) from above ground tanks, buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines with the following exceptions:

a. The minimum separation distance from truck offload facilities/vehicles governed by NFPA 30A may be reduced as allowed by NFPA 30A.

b. The minimum separation distance from overhead power lines may be reduced to 15 feet (4.6 m) for Class II or III liquids.

7-3.11 Tactical Refueler Truck Loading Facilities.

Equip similar to truck loading facilities covered in Chapter 3 of this UFC except provide a grounding reel in lieu of the high-level shutoff/ground detecting system. Verify with the user, the type of nozzle required.

7-3.12 Spill Containment.

All areas subject to fuel spills or drips must be concrete surfaced, including truck offload and fuel dispenser areas.

a. Tactical Refueler Truck Loading Facilities: Provide sized concrete spill containment areas and a concrete remote spill containment system as described for truck loading facilities in Chapter 3 of this UFC.

b. Other Fuel Transfer Areas: General spill containment, as defined by 40 CFR Part 112.7, must be provided for all other fuel transfer areas at a military service station. General secondary containment requires controls to address typical failures and the most likely spill volume to occur and to size a secondary containment system to prevent a release of spilled fuel to the environment before cleanup occurs. Fuel transfer areas must be provided with general spill containment including truck offload and vehicle dispensing areas. General spill containment should also be provided around double wall ASTs to capture leaks from vents, fittings and other devices on the tanks or fuel lines within the immediate area of the tank. A simple system typically consists of a 6-inch high concrete curb around the perimeter of a concrete pad with a 2-inch stainless steel pipe and lockable stainless steel ball valve located at a low point that discharges to grade.

c. Drainage: Storm water runoff from spill containment areas should be collected separately from general runoff and controlled by a lockable containment drain valve. Design the spill containment drainage system in accordance with federal, state, and local regulations.

7-4 STORAGE TANKS.

Chapter 8, Atmospheric Storage Tanks, contains information on aboveground and underground storage tanks. For ground products fueling facilities underground, horizontal tanks are preferred. Follow federal, state, and local regulations when determining use of AST or UST.

7-4.1 Distance from Power Lines.

Minimum separation of underground and aboveground tanks from overhead electric power transmission, pad-mounted transformers, and distribution wires must be 25 feet (7.6 m), with the exception that these minimum separation distances may be permitted to be reduced to 15 feet (4.6 m) for Class II or III liquids.

7-5 PIPING SYSTEMS.

7-5.1 Piping System – Tactical Refueler Facilities.

For systems serving tactical refueler fillstands see the requirements for tank truck loading facilities in Chapter 3 of this UFC.

7-5.2 Aboveground Piping System – Filling Stations.

Follow state or local regulations when they exceed these requirements. When they do not exceed them, provide as described in Chapter 9 of this UFC with the following exceptions:

a. Piping 2-1/2 inches (65 mm) and larger must be butt welded. Use flange connections for joining pipe to system components.

b. Piping smaller than 2-1/2 inches (65 mm) may be butt welded or socket welded. Use flange connections or socket weld connections with unions for joining pipe to system components. Threaded end connections may be used only where butt welded or socket welded connections cannot physically be provided.

c. Branch outlet fittings do not have to be designed to be radiographed.

7-5.3 Underground Piping System – Filling Stations.

Follow state or local regulations when they exceed these requirements. When they do not exceed them, provide as described in Chapter 9 of this UFC with the following exception:

a. Use of double wall flexible piping (≤ 4 inches (100 mm)) in conformance with UL971 is permitted. Use of FRP piping is discouraged because of issues with underground joints and requires Service Headquarters approval.

7-6 CONTROLS.

7-6.1 Control System Philosophy.

Fuel systems that includes pumps to receive, transfer, and issue fuel must be provided with an Automatic Pump Control system with a programmable logic controller (PLC) driven Pump Control Panel (PCP) to control the system. All systems must be designed to perform all of their functions manually in the event the PCP is down.

7-6.2 Exceptions.

a. The exceptions for systems covered in Chapter 7 where a PCP is not required are:

b. Motive fuel filling stations that only dispense motive fuel into vehicles.

c. Motive fuel filling stations that also include attached tactical refueler truck loading station(s) whose flowrate is under 200 gpm for each station.

d. Pumps serving miscellaneous use tanks (see Chapter 8 for definition).

e. Isolated miscellaneous pumps that are not part of a larger system. These 5 horsepower or less size pumps act as sump pumps, pier stripping pumps, etc.

7-6.3 Card and Key Locks.

Provide an electronic card or key system which permits 24-hour unmanned operation of the facility. These types of systems are comprised of a card/key reader which is located near the service pump. The reader is activated by a card or key and accumulates issues and customer data which is downloaded to a central computer on a periodic basis.

7-7 DESCRIPTIONS OF SYSTEM COMPONENTS.

Unless otherwise indicated below, refer to Chapter 15 for description of system components. For systems serving tactical refueler fillstands see the requirements for tank truck loading facilities in Chapter 3 of this UFC. The below requirements apply to filling stations only. The following system components are typically used in ground product fueling facilities:

a. Fuel Dispensers – Filling Stations

Use a commercially available dispenser with a self-contained electric motor and pumping unit or a remote pumping type where the pump and motor are located in the storage tank. If an in-tank type of pump is used, ensure that it is equipped with a reduced start volume as a leak check. Provide a meter for each dispenser. Dispenser flow rates are typically a maximum of 10 gpm (0.6 L/s); follow state and local regulations for actual maximum. Designer must check with state and local regulations for limitations on dispenser flowrates. Dispensing system will include management control system, printers, computers, and microprocessors. Equip fuel dispensers with an inline filtration system with 5-micron or smaller porosity filters for gasoline and ethanol products, and 25-micron or smaller porosity filters for diesel and biodiesel products. Add emergency break-away hose connections at each fuel dispenser in accordance with NFPA 30A. Where liquid is supplied to the dispenser under pressure, provide an emergency shutoff valve, incorporating a fusible link, in the supply line at the base of each dispenser as required by NFPA 30A. Equip dispensing islands with impervious spill containment pans under the dispensers.

b. Manual Valves – Isolation Valves

Materials of Construction – Require valves to have carbon steel bodies and bonnets. Do not allow valves with aluminum, cast iron, or bronze materials. Use only API fire-safe valves complying with API Std 607.

c. Manual Valves – Isolation Valve Types

1. Ball Valves: These are the only approved quick opening/frequent opening isolation valves.

2. Double Block and Bleed Isolation Valves: Do not provide unless directed by Service Headquarters or required to perform hydrostatic test.

3. Lubricated Plug Valves: Lubricated plug valves are not allowed.

4. Gate Valves: Gate valves are not allowed.

5. Butterfly Valves: Butterfly valves are not allowed.

d. Manual Valves – Isolation Valve Operators

Manually operate valves not specified for remote, automatic, or emergency operation. Use geared operators for ball valves larger than 6 inches (150 mm). Provide locking tabs on isolation valves to allow padlock to be used to lock out the valves during maintenance. Provide chain operators on valves which are located 72 inches (1800 mm) or higher above grade.

e. Manual Valves – Isolation Valve Locations

Provide isolation valves in piping systems to control flow and to permit isolation of system components for maintenance or repair, or as necessary to conduct a valid hydrostatic test. As a minimum requirement, provide isolation valves at the following locations:

1. Where piping goes underground or comes aboveground and requires periodic pressure testing.
2. At all subsurface and aboveground piping connections to storage tanks.
3. On the suction side and discharge side of each pumping unit, except the suction side of vertical centrifugal pumps installed in underground tanks.
4. On the inlet and outlet connection of each line strainer, meter, diaphragm control valve, and other system components that requires periodic servicing. One inlet valve and one outlet valve may be used to isolate more than one piece of adjacent system components which are connected in series.

f. Diaphragm Control Valves

These valves are not required in filling stations.

g. Anti-Siphon Valve

Use anti-siphon valves to prevent release of fuel by siphon flow from an aboveground storage tank. These valves are generally installed on the tank drain lines.

h. Solenoid-Controlled Anti-Siphon Ball Valve

Use solenoid controlled anti-siphon ball valves to prevent release of fuel by siphon flow from an aboveground storage tank. These valves are generally installed on the discharge side of the fuel dispenser pumps. These valves are normally closed and open upon an electronic signal when a dispenser pump is turned on.

i. Other Valves – Check Valves

Use check valves to prevent backflow through pumps, branch lines, meters, or other locations where runback or reverse flow must be avoided. Check valves may be of the swing disk, globe, dual plate hinged disk, spring-loaded poppet, ball, or diaphragm-actuated types. Use checks of soft-seated non-slamming type with renewable seats and disks. Ensure check valves conform to API Spec 6D.

j. Other Valves – Thermal Relief Valves

7-8 VAPOR RECOVERY.

Provide vapor recovery in accordance with guide specifications unless there are more stringent federal, state, and local codes or regulations. If gasoline is being handled, refer to 40 CFR Part 63 Subpart CCCCCC. Per 40 CFR Part 63 Subpart CCCCCC, gasoline storage tanks located at gasoline dispensing facilities with a monthly throughput of 100,000 gallons or more are required to be equipped with a vapor balance system. The vapor balance system needs to be tested at the time of installation and every three years thereafter. Only install Stage II vapor recovery piping if required by local or state regulations at time of installation.

CHAPTER 8 ATMOSPHERIC STORAGE TANKS

8-1 INTRODUCTION.

This chapter provides guidance for the design of bulk storage tanks, operating storage tanks, ground vehicle fueling tanks, miscellaneous use tanks, product recovery system tanks, contaminated fuel storage tanks, and jet engine test cell fuel storage tanks. Design guidance on issues related to storage tanks such as protection, location, coatings, product recovery, and spill containment systems are also covered in this chapter. Ballast water storage tanks are covered in Chapter 5 and pressurized tanks for storage of LPG are covered in Chapter 10 of this UFC. This chapter generally applies to new tanks. Refer to Chapter 12 for repair or refurbishment of existing tanks.

8-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not start design of any fueling system without first becoming completely familiar with Chapter 2 of this UFC.

8-3 GENERAL CRITERIA.

Design liquid fuel storage tanks to comply with the operational requirements of the particular Command having jurisdiction of the facility. Ensure that the design is appropriate for the mission of the facility. Consider the operational requirements of the users of the fuel.

8-3.1 Materials.

All aboveground storage tanks must be constructed of steel or concrete encased steel.

8-3.2 Protection.

Provide protection to preserve product quality and ensure minimal losses by evaporation, dilution, leakage, substitution, theft, contamination, attack, sabotage, fire, and damage to the environment. Use aboveground steel tanks unless the mission of the facility or other practical considerations dictate that underground tanks be used. Cut and cover (buried vertical) tanks are not normally used in the CONUS. Cut and cover tanks may be required if the dispensing system is located in clear zones or explosive cordon areas. Conduct economic, operational, and mechanical analyses of remotely locating the pump house/system from the hydrant system versus constructing cut and cover tanks. For all fuel storage tanks, design in accordance with NFPA 30, NFPA 30A, and this document.

8-3.3 Design Requirements.

Fuel storage facilities provide an operating and reserve supply of fuel. The types and sizes of storage tanks depend on safety, economics, terrorist activity, locality, and intended service. Provide separate storage for each type and grade of fuel.

8-3.4 Storage Capacity.

The capacity or size of each fuel storage tank is based upon the logistical and mission requirements for the facility and any other facility to be supported from it. For a stated volume of each fuel, fewer tanks of larger size will result in maximum economy. The appropriate Service Headquarters with DLA-Energy approval will determine the number and size of tanks required. Rule of thumb guidance for operating storage and bulk storage capacity is available in Navy UFC 2-000-05N/P-80. Provide a minimum of two tanks for each type of fuel to receive and isolate new receipts until tested and checked for quality and quantity while the facility continues to function with stocks on hand. The exception to this is at military service stations where one tank for each product is usually acceptable. In general, capacities of individual tanks should not exceed 50 percent of the total storage volume required for each type and grade of aviation fuel. Do not provide tanks with capacities greater than 100,000 barrels (16,000,000 L) except when larger tanks are specifically authorized by Service Headquarters.

8-3.5 Tank Spacing.

8-3.5.1 Vertical Tanks.

\3 Provide a minimum distance between the shells of vertical tanks, both aboveground and underground, of not less than one diameter. ***/3/***

8-3.5.2 Horizontal Underground Tanks.

Provide a minimum clearance between shells of adjacent horizontal underground tanks of 3 feet (0.9 m).

8-3.5.3 Horizontal Aboveground Tanks (Single Wall and Double Wall Steel) (Non-Fire Resistant and Non-Protected).

Provide a minimum clearance between **\2** the shells of ***/2/*** aboveground horizontal tanks with capacities 50,000 gallons (189,300 L) or under as follows:

a. Arrange tanks in pairs with a minimum of 5 feet (1.5 m) between **\2** the shells of the ***/2/*** tanks in each pair and 10 feet (3 m) between **\2** the shells of the ***/2/*** adjacent tanks of two pairs in the same row.

b. Space adjacent groups of more than two pairs in a single row with at least 20 feet (6 m) between **\2** the shells of ***/2/*** the nearest tanks of the groups.

c. Provide a minimum end-to-end spacing between **\2** the shells of ***/2/*** tanks in longitudinal rows of 20 feet (6 m).

d. Provide a UL nameplate on tanks stating that the tanks are approved for that material and service.

e. In addition to requirements listed in this paragraph, tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, must comply with NFPA 30A.

8-3.5.4 Horizontal Aboveground Tanks (Fire Resistant).

Provide minimum clearance and spacing between **\2** the shells of **/2/** fire resistant, secondarily contained aboveground horizontal tanks in compliance with NFPA 30 and NFPA 30A as applicable.

8-3.5.5 Horizontal Aboveground Tanks (Protected).

Provide minimum clearance and spacing between **\2** the shells of **/2/** protected, secondarily contained aboveground horizontal tanks in compliance with NFPA 30 and NFPA 30A as applicable.

8-3.6 Distance from Buildings and Property Lines.

Locate tanks a sufficient distance from buildings and property lines to prevent the ignition of vapors from the tank and to protect buildings and their occupants or contents from damage by a tank fire. Ensure that the maximum internal pressure in a fire exposure will not exceed 2.5 psig (17 kPa). As a minimum, comply with requirements of the following paragraphs.

8-3.6.1 Underground Tanks.

Locate underground tanks with respect to buildings or similar structures so that the soil pressure created by the building foundations will not be transmitted to the tank. Pumping facilities which are often located directly above underground tanks are accepted. Locate **\2** the shell of **/2/** horizontal cylindrical tanks less than or equal to 12 feet (3.7 m) in diameter not less than 10 feet (3 m) from the nearest point of an adjacent building or property line. Locate **\2** the shell of **/2/** vertical underground tanks, **\2** or the vent if the vent is located away from the shell of the tank, **/2/** at least 25 feet (7.6 m) from the nearest point of an adjacent building and 50 feet (15 m) from the nearest property line.

8-3.6.2 Aboveground Tanks.

Locate aboveground tanks with consideration of fire safety. The first consideration is to prevent the ignition of vapors from the tank, and the second consideration is to protect the building and its occupants or contents from damage by a tank fire. As a protective measure, provide all aboveground tanks with some form of emergency relief venting for fire exposure in accordance with NFPA 30. Required minimum distances **\2** between the normal vent, emergency vent, or the overflow vent (for tanks with floating roofs) **/2/** for aboveground tanks from buildings and property lines are as follows:

a. Tanks, all sizes and types, not protected or fire-resistant, containing petroleum fuels with a flash point less than 100 degrees F (38 degrees C), 100 feet (30 m) or one tank diameter, whichever is greater, with the exception that tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, must comply with NFPA 30A guidelines.

b. Tanks, not protected or fire-resistant, containing petroleum fuels with a flash point of 100 degrees F (38 degrees C) or greater in accordance with the following:

Tank Capacity gallons (L)	Minimum Distance from Nearest Property Line Feet (m)	Minimum Distance from Nearest Building Feet (m)
275 or less (1040 or less)	10 (3.0)	5 (1.5)
276 to 750 (1041 to 2800)	20 (6.0)	10 (3.0)
751 to 12,000 (2801 to 45 400)	30 (10)	15 (4.5)
12,001 to 30,000 (45 401 to 113 500)	40 (12)	20 (6.0)
30,001 to 50,000 (113 501 to 189 000)	60 (18)	60 (18)
50,001 to more (189 001 or more)	100 (30)	100 (30)

c. For aboveground, fire-resistant tanks, use NFPA 30 guidelines. Fire-resistant tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, must comply with NFPA 30A criteria.

d. For aboveground, protected tanks, use NFPA 30 guidelines. Protected tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, must comply with NFPA 30A criteria.

8-3.7 Distance from Roadway, Railroads and Power Lines.

For tanks located in facilities governed by NFPA 30A, use NFPA 30A guidelines and Chapter 7 of this UFC. For all other storage tanks, the minimum distances **\2** between the normal vent, emergency vent, or the overflow vent (for tanks with floating roofs) and ***/2/*** adjacent roadways, railways, railroads, and overhead electric power lines are as follows:

8-3.7.1 Underground Tanks.

Spacing and clearances for underground tanks must be:

a. A minimum of 25 feet (7.6 m) from regularly traveled roads and highways, not including tank farm utility and fire access roads.

b. 25 feet (7.6 m) from railroad spur tracks not used for through traffic.

c. No less than 100 feet (30 m) from main railroad tracks carrying through traffic.

d. 50 feet (15 m) from overhead electric power transmission and distribution wires.

8-3.7.2 Aboveground Tanks.

a. The greater of 100 feet (30 m) or one tank diameter from regularly traveled roads and highways, not including tank farm utility and fire access roads. For protected and fire-resistant tanks, roads and highways must match the clearance provisions specified in paragraph 8-3.6.2.

b. 50 feet (15 m) from railroad spur tracks not used for through traffic.

c. 200 feet (60 m) from main railroad tracks carrying through traffic.

d. 50 feet (15 m) from overhead electric power transmission and distribution wires.

8-3.8 Distance from Tank Truck and Tank Car Off-Loading and/or Loading Facilities.

For tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, use NFPA 30A guidelines and Chapter 7 of this UFC. For all other tanks, use guidelines indicated within this UFC and NFPA 30. For fire resistant or protected horizontal aboveground tanks and underground tanks, provide a minimum separation of 25 feet (7.6 m) from tank truck and tank car off-loading and loading facilities, including tanker trucks. For all other tanks, provide a minimum separation of 50 feet (15 m) from tank truck and tank car off-loading facilities**\2** and tank truck and tank car loading facilities ***/2/***. **\2**

8-3.9 Distance and Location of Tanks from Photovoltaic Arrays

Provide a minimum separation of 100 feet (30 m) between the normal vent, emergency vent, or the overflow vent (for tanks with floating roofs) for above and under ground tanks and the photovoltaic array and components (batteries and inverters). The photovoltaic array must not be accessible to or from the tank farm, or located in the tank farm. The photovoltaic array must not restrict emergency assess to the tank farm. ***/2/***

8-3.10 Interior Coatings.

To extend the life of steel storage tanks, coat new tanks according to the following guidelines:

a. Vertical tanks

1. All aviation, diesel fuel marine (F-76), additive, and lube oil tanks. Except for stainless steel tanks referenced in paragraph 3-10, interiors must be 100 percent coated, including floor, shell, and underside of the roof.

2. Other products. Coat the floor, the underside of the fixed roof, and the bottom 40 inches (1000 mm) of the tank shell. Additional coating of up to 100 percent requires economic justification and Service Headquarters approval. Tanks containing E85 are not to be coated internally unless otherwise approved by Service Headquarters.

b. Horizontal tanks

1. For all products, tank interiors must be 100 percent coated. Tanks containing E85 are not to be coated internally unless otherwise approved by Service Headquarters.

c. For all products, coat the interior of 3 inch and larger carbon steel piping and exterior of all carbon steel piping located inside the tank, and steel appurtenances inside all tanks. Carbon steel piping, and carbon steel appurtenances located inside of tanks containing E85 are not to be coated internally unless otherwise approved by Service Headquarters.

8-3.11 Exterior Coatings.

a. Protect the exterior surface of all aboveground steel tanks by coating in accordance with appropriate guide specifications.

b. Protect the exterior surfaces of all underground horizontal steel tanks with a factory-applied coating specified in the appropriate guide specifications.

c. For protected tanks, with exterior steel containment, consider exterior fiberglass cladding for extremely corrosive atmospheres or seaside locations.

8-3.12 Fill Piping.

Size the pipe so that the velocity does not exceed 12 feet (3.7 m) per second at maximum flow rate. Provide a means for reducing the velocity of flow of the receipt pipeline to 3 feet (0.9 m) per second until the filling inlet nozzle is completely submerged and/or the floating pan has lifted off its legs.

8-3.13 Vapor Emission Control Systems.

Provide a vapor emission control system for tanks that store products having a true vapor pressure of 0.75 psia (5 kPa) or more located in air pollution control areas in which the discharge of petroleum vapors is controlled or prohibited. Ensure that the system has sufficient capacity to control the vapor discharged from the tank vents at maximum filling rate in conformance with local air quality regulations. If gasoline is being handled, provide, as a minimum, Stage I vapor recovery and the piping for Stage II. If not required by local or state regulations at time of construction, connect the Stage II piping to the tank and cap it at the dispenser.

8-3.14 Strapping Tables.

Provide two certified strapping tables for all tanks. Provide one of the tables in U.S. Customary units reading in 1/16-inch increments, gallons and barrels and one in metric units reading in 2mm increments, liters and cubic meters. Provide electronic media data files. Determine strapping table volumes for all field fabricated tanks using the procedures stated in API MPMS Chapter 2. The tables are to be calibrated for critical measurement **\1\ /1/**. Determine strapping table volumes for all factory fabricated tanks of 5,000 gallons (19,000 L) and larger using physical measurements, not calculated values. For factory fabricated tanks of less than 5,000 gallons (19,000 L), provide strapping tables certified by the tank manufacturer.

8-3.15 Product Recovery Systems.

8-3.15.1 General Design Considerations.

Provide pumps, piping, valves, and tanks to collect and store usable aviation turbine fuel which would otherwise become waste from operational or maintenance activities. Consider a product recovery system for other products. Include a tank to collect fuel/water mixtures from tank and system component sumps, system component drains, product saver tanks, high point vents, low point drains, and any other system components from which fuel/water mixtures can be collected. Separate the fuel and water portions. Filter the fuel portion and return to operating storage tanks. Do not discharge the water portion to surface water or treat the water portion as wastewater without additional treatment and permits. Refer to Chapter 2 of this UFC for information on handling of wastewater. Product recovery systems are included in DoD Standard Design AW 078-24-28.

8-3.15.2 Product Recovery Tanks.

For hydrant and aircraft direct fueling systems provide the tank indicated in DoD Standard Design AW 078-24-28. For other systems equipped with product recovery tanks, provide a tank with, at a minimum, the following appurtenances:

a. Level gauge.

b. Overfill protection level control valve.

c. High and low level switches with alarms and controls.

d. A motor driven fuel transfer pump that returns recovered fuel back to the system through a hard piped connection.

e. A motor driven sump pump for emptying the tank.

f. Manual gauging hatch.

g. Vent.

h. ATG system for aboveground product recovery tanks having a capacity more than or equal to 4,000 gallons (15,000 L).

i. Do not allow sight flow indicators to be installed on product recovery tanks.

8-3.15.3 Product Saver Tanks.

In addition to the product recovery tank(s) for the facility, all vertical storage tanks storing aviation turbine fuel should include a product saver tank with electric pump, unless the tank is equipped with a filter-separator to remove water from the sump. A product saver tank is a small aboveground tank piped and valved to allow drawing water from the bottom of the storage tank and returning the product after the water has been separated and disposed of in accordance with environmental regulations.

8-3.16 Registration.

Register all tanks with the appropriate state and local agencies as required.

8-3.17 Nameplates.

All tanks must have a nameplate installed in accordance with the standard of construction.

8-4 HORIZONTAL ABOVEGROUND TANKS (SINGLE WALL STEEL).

8-4.1 General Design Considerations.

If small factory-built aboveground storage tanks are required, use horizontal tanks. Limit tank diameter to 12 feet (3.7 m) or less and capacity to 50,000 gallon (191,000 L) or less. Require tank to be of welded steel construction in accordance with UL 142. Plastic and/or fiberglass aboveground storage tanks are not allowed. Requirements for all horizontal aboveground storage tanks must comply with NFPA 30. However, tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, must comply with NFPA 30A guidelines.

8-4.2 Tank Design Requirements.

a. Install tanks 5,000 gallons (19000 L) and less on a level surface. Install tanks greater than 5,000 gallons (19000 L) so that the bottom slopes downward toward one end at a slope of 1 percent. Locate transfer pumps or suction piping at the high end of the tank; locate water draw-off at low end of the tank.

b. Provide water draw-off lines in each tank. For aviation fueling systems, arrange piping so that the fuel in the tanks may be recirculated through the filter-separators.

c. Provide steel tanks with steel saddles or skids in accordance with UL 142. Mount steel supports on a reinforced concrete foundation.

d. Tanks must be inspected in accordance with STI SP001 by a STI certified inspector prior to commissioning.

8-5 HORIZONTAL ABOVEGROUND TANKS (DOUBLE WALL STEEL).

8-5.1 General Design Considerations.

Limit tank diameter to 12 feet (3.7 m) or less and capacity to 50,000 gallon (191,000 L) or less. Require tank to be of welded steel construction in accordance with UL 142. No fiberglass aboveground storage tanks are allowed. The main advantage of double wall steel storage tanks over single wall steel storage tanks is that separate spill containment may not be required. Secondary containment-type tanks can be used to provide spill control per NFPA 30, if the capacity of the tank is no more than 50,000 gallons (191,000 L). All of the criteria in the NFPA regulations for the appropriate application must be met before a secondary containment-type tank is used without separate spill containment. Requirements for double wall steel horizontal aboveground storage tanks must comply with NFPA 30. However, tanks located in facilities governed by NFPA 30A, such as marine/motor fuel dispensing facilities, must comply with NFPA 30A guidelines.

8-5.2 Tank Requirements.

a. For flammable liquid installations, require additional curbing containment based on tank filling rates if there is a chance of a fuel spill entering a critical area.

b. Install tanks 5,000 gallons (19000 L) and less on a level surface. Install tanks greater than 5,000 gallons (19000 L) so that the bottom slopes downward toward one end at a slope of 1 percent. If there is to be a product recovery and/or water draw-off, locate transfer pumps or suction piping at the high end of the tank; locate water draw-off at low end of the tank. Otherwise, locate transfer pumps at the low end.

c. Provide water draw-off lines in each tank. For aviation fueling systems, arrange piping so that the fuel in the tanks may be recirculated through the filter-separators.

d. Provide protective bollards for tanks not surrounded by a dike. Bollards must not be less than four (4) feet (1.2 m) high and 4-inches (100 mm) in diameter, of steel construction, filled with concrete, and spaced not more than four (4) feet (1.2 m) on center.

e. Provide steel tanks with steel saddles or skids in accordance with UL 142. Mount steel supports on a reinforced concrete foundation. Mount rectangular (flat bottomed) tanks of 4,000 gallons (15,100 L) or greater 12 inches (300 mm) above grade to allow inspection and maintenance of the tank bottom.

f. Require the tank to be tested after installation in accordance with STI SP001 and STI R912 accepted air test and manufacturer's instructions.

g. Require tanks to be inspected in accordance with STI SP001 by a STI certified inspector prior to commissioning.

h. A primary tank constructed of stainless steel is permitted when required.

i. Require support channels with anchor holes for earthquake/hurricane/flood restraint tie down.

j. Require steel thickness to be in accordance with UL142 but not less than a minimum thickness of 3/16-inch (5 mm) for interior carbon steel tank.

8-6 HORIZONTAL ABOVEGROUND TANKS (FIRE-RESISTANT).

8-6.1 General Design Considerations.

When small (250 to 50,000 gallon (900 to 191,000 L) capacity) aboveground storage tanks are required and there are clearance or fire exposure problems and the additional cost can be justified, consider the use of fire-resistant storage tanks. The main advantage of fire-resistant tanks over the single wall steel tanks is that separate spill containment may not be required and the vault system provides an added measure of fire protection.

a. Secondary containment-type tanks can be used to provide spill control per NFPA 30, if the capacity of the tank is no more than 50,000 gallons (191,000 L).

b. All of the criteria in the NFPA regulations for the appropriate application must be met before a secondary containment-type tank is used without separate spill containment.

c. Require tanks to be factory-constructed with a UL 142 welded steel primary tank.

d. Tanks may be used in applications where, in addition to the above considerations, construction of a separate spill containment system for secondary containment purposes would have a negative impact on operations and/or aesthetics.

e. Tanks located close to buildings or with integral fuel dispensers must be UL-listed secondary containment tanks, utilizing steel inner and outer tanks that can provide interstitial containment which is both pressure testable and verifiable.

   1. Such tanks usually have a fill of regular or insulating concrete or may be encased in a reinforced monolithic concrete vault.

   2. Do not provide rectangular UL2080 tanks that are greater than 5,000 gallons (19,000 L) except when approved by Service Headquarters.

f. Ensure the two-hour fire rating meets or exceeds all requirements of NFPA 30A for “fire resistance” tanks and provides a minimum two-hour fire rating in accordance with UL 2080.

8-6.2 Tank Design Requirements.

a. For flammable liquid installations, require additional curbing containment based on tank filling rates if there is a chance of a fuel spill entering a critical area.

b. Install tanks 5,000 gallons (19000 L) and less on a level surface. Install tanks greater than 5,000 gallons (19000 L) so that the bottom slopes downward toward one end at a slope of 1 percent. Locate transfer pumps or suction piping at the high end of the tank; locate water draw-off at low end of the tank.

c. Provide water draw-off lines in each tank. For aviation fueling systems, arrange piping so that the fuel in the tanks may be recirculated through the filter-separators.

d. A primary tank constructed of stainless steel is permitted when required.

e. Require support channels with anchor holes for earthquake/hurricane/flood restraint tie down.

f. Require steel thickness to be in accordance with UL142 but not less than a minimum thickness of 3/16-inch (5 mm) for the interior carbon steel tank.

g. Mount rectangular (flat bottomed) tanks of 4,000 gallons (15,100 L) or greater 12 inches (300 mm) above grade to allow inspection and maintenance of the tank bottom.

h. Provide protective bollards in traffic areas. Bollards must be not less than four (4) feet (1.2 m) high and 4-inches (100 mm) in diameter, of steel construction, filled with concrete and spaced not more than four (4) feet (1.2 m) on center.

i. Require the tank to be tested after installation in accordance with STI SP001 and STI R912 accepted pressure test.

j. Tanks must be inspected in accordance with STI SP001 by a STI certified inspector prior to commissioning.

8-7 HORIZONTAL ABOVEGROUND TANKS (PROTECTED TANKS).

8-7.1 General Design Considerations.

When small (250 to 50,000 gallon (900 to 191,000 L) capacity) aboveground storage tanks are required and there are clearance or fire exposure problems and the additional cost can be justified, consider the use of protected storage tanks. The main advantages of protected tanks over the single wall steel tanks are that a separate dike (containment) may not be required and the vault system provides an added measure of fire protection.

a. Secondary containment-type tanks can be used to provide spill control per NFPA 30, if the capacity of the tank is no more than 50,000 gallons (191,000 L).

b. All of the criteria in the NFPA regulations for the appropriate application must be met before a secondary containment-type tank is used without separate spill containment.

c. Additional benefits include added protection from ballistic and vehicular impact and reduced evaporation of volatile fuels in warm climates.

d. Require tanks to be factory-constructed with a UL 142 welded steel primary tank.

e. Tanks may be used in applications where, in addition to the above considerations, construction of a separate dike for secondary containment purposes would have a negative impact on operations and/or aesthetics.

f. Tanks located close to buildings or with integral fuel dispensers must be UL-listed secondary containment tanks, utilizing steel inner and outer tanks that can provide interstitial containment which is both pressure testable and verifiable.

1. Such tanks usually have a fill of regular or insulating concrete or may be encased in a reinforced monolithic concrete vault.

2. Do not provide rectangular UL 2085 tanks that are greater than 5,000 gallons (19,000 L) except when approved by Service Headquarters.

g. Ensure the two-hour fire rating meets or exceeds all requirements of NFPA 30A for "fire resistance" tanks, meets the requirements of UFC 3-600-01 and provides a minimum two-hour fire rating in accordance with UFC 3-600-01 and UL 2085.

8-7.2 Tank Design Requirements.

a. For flammable liquid installations, require additional curbing containment based on tank filling rates if there is a chance of a fuel spill entering a critical area.

b. Install tanks 5,000 gallons (19000 L) and less on a level surface. Install tanks greater than 5,000 gallons (19000 L) so that the bottom slopes downward toward one end at a slope of 1 percent. Locate transfer pumps or suction piping at the high end of the tank; locate water draw-off at low end of the tank.

c. Provide water draw-off lines in each tank. For aviation fueling systems, arrange piping so that the fuel in the tanks may be recirculated through the filter-separators. Locate the water draw-off piping at the low end of the tank.

d. A primary tank constructed of stainless steel is permitted when required.

e. Require support channels with anchor holes for earthquake/hurricane/flood restraint tie down.

f. Require steel to be a minimum thickness of 3/16-inch (5 mm) for the interior carbon steel tank.

g. Mount rectangular (flat bottomed) tanks of 4,000 gallons (15,100 L) or greater 12 inches (300 mm) above grade to allow inspection and maintenance of the tank bottom.

h. Provide protective bollards in traffic areas. Bollards must be not less than 4 feet (1.2 m) high and 4-inches (100 mm) in diameter, of steel construction, filled with concrete, and spaced not more than four (4) feet (1.2 m) on center.

i. Require the tank to be tested after installation in accordance with STI SP001 and STI R912 accepted air test and manufacturer's instructions.

j. Tanks must be inspected in accordance with STI SP001 by a STI certified inspector prior to commissioning.

8-8 ABOVEGROUND VERTICAL STORAGE TANKS.

8-8.1 General Design Considerations.

Provide cylindrical single wall steel aboveground vertical storage tanks meeting one of the following criteria (as approved by Service Headquarters):

a. Factory-fabricated tanks complying with UL 142 criteria. The diameter of the tanks is limited by transportation restrictions. Although these tanks are fabricated in sizes up to 50,000 gallon (191,000 L), they become quite tall due to the diameter limitation. Give special consideration to height/diameter ratio to ensure tank stability.

b. Field-erected tanks not requiring an internal pan must comply with DoD Standard Design AW 078-24-27 and the design considerations included herein for tanks without a floating pan. Tanks must be site-adapted by the designer. The standard design includes tanks ranging in capacity from 5,000 barrels (800,000 L) through 100,000 barrels (16,000,000 L). For tanks larger than 100,000 barrels (16,000,000 L), use the multicolumn API Std 650 design.

c. Field-erected tanks requiring an internal floating pan must comply with DoD Standard Design AW 078-24-27. The standard design includes tanks ranging in capacity from 5,000 barrels (800,000 L) through 100,000 barrels (16,000,000 L) with internal pan and requires site-adapting by the design team. For tanks larger than 100,000 barrels (16,000,000 L), use the multicolumn API Std 650 design.

8-8.2 Tank Roofs.

For tanks with internal floating pans, design the roofs in conformance with DoD Standard Design AW 078-24-27.

8-8.3 Internal Floating Pans.

a. Field-erected tanks containing Class I flammable fuels or mission-critical Class II combustible fuels, such as JP-8, must be equipped with a full contact, aluminum honeycomb floating pan. Other Class II fuels require a floating pan if the tank does not comply with the spacing and diking requirements of this UFC. Tanks storing mission-critical Class III fuels, such as JP-5 and diesel fuel marine (F-76), if located in hot (desert-like) climate, also require a floating pan to eliminate the fuel/air interface. A single slotted stilling well, that penetrates the floating pan, has a maximum diameter of 8 inches (250 mm) and is used for the automatic tank gauge system, is allowed to be provided without a vapor sleeve (bellow). The slotted well used for manual measurements must be equipped with a floating plug. The 8 inch (200 mm) slotted stilling well for the automatic tank gauge system level sensing device and the 6-inch (150 mm) minimum nominal size slotted stilling well for the automatic tank gauge system water probe are allowed to be provided without floating plugs.

b. For cone roof tanks with floating pans, provide roof vent/inspection hatches in the fixed roof and overflow port/vents near the top of the shell near a device(s) in the floating pan which is (are) sized by the tank erector to evacuate air and gases from underneath the pan when the pan is on its supports during filling operations.

c. Provide grounding bonds between the floating pan and shell as follows:

 1. Two lengths of bare, 1/8-inch (3 mm) diameter, stranded, extra-flexible, stainless steel wire rope, each extending from the top of the floating pan to the underside of the fixed roof.

 2. Attach two of the wires near the tank periphery, 180 degrees apart. Attach an additional third wire from the floating pan to the floating pan manhole cover.

 3. Securely connect the wires to the pan and extend vertically to the tank roof. Ensure wires are accessible for inspection.

 4. Ensure wires are long enough to accommodate the full travel of the pan. Locate wires to miss all interior tank appurtenances and structure.

d. Provide anti-rotation cables in accordance with DoD Standard Design AW 078-24-27.

e. For cone roof tanks with floating pans, provide gauge and sampling hatches in accordance with DoD Standard Design AW 078-24-27.

f. Provide a 36-inch (900 mm) diameter covered manhole in the floating pan.

g. Provide a pressure/vacuum vent sized by the internal floating pan manufacturer.

8-8.4 Tank Bottoms.

Slope the tank bottoms downward in accordance with DoD Standard Design AW 078-24-27. A slope of 5 percent is required for positive drainage and self-cleaning action for tanks storing fuels. After tank construction is complete perform a hydrostatic test prior to tank coating. In addition, conduct all tests in accordance with DoD Standard Design AW 078-24-27.

8-8.5 Foundations.

Design tank foundations on the basis of a soils exploration program including preliminary exploration as a minimum and detailed exploration and testing, if existing soil data is not available and/or inadequate. Refer to UFC 3-220-10N. Analyze the results of the exploration program to determine the most practical and economical design to provide a stable foundation for the tank. See DoD Standard Design AW 078-24-27. As a minimum, use the following criteria for all tank designs:

a. Prevent external corrosion of tank bottoms by locating the tank bottom perimeters well above the general tank field grade, provide adequate tank field drainage away from the tank, and construct the foundation pad as specified in AW 078-24-27.

b. Ensure a minimum electrical resistance of 35,000 ohm-cm. Foundation material should be neutral or alkaline with a pH greater than 7, a chloride concentration less than 300 ppm, and a sulfate concentration less than 150 ppm as specified by DoD Standard Design AW 078-24-27 and UFGS 33 56 13.15. The sand may be washed and the pH may be raised to meet the requirements. Include cathodic protection to prevent external corrosion of the tank bottoms. Do not use oil in the sand under the tank. Do not use dredge material or beach sand.

c. Provide good drainage under the tank.

d. Provide a reinforced concrete ringwall foundation. Locate the top of the foundation a minimum of 12 inches (300 mm) above the dike basin.

e. Cover the area beneath the tanks with a fuel-impermeable liner complying with DoD Standard Design AW 078-24-27, UFGS 33 56 13.15 and meeting local and state requirements. Install all liners according to the manufacturer's requirements.

f. Over the liner, provide a minimum of 12 inches (300 mm) of compacted clean sand or similar material as described above. Securely attach and seal the liner to the inside of the concrete foundation ring wall beneath the tank shell.

g. Provide a leak detection system for the tank bottom by installing a pipe or pipes through the concrete foundation ring wall as a telltale for tank bottom leaks in accordance with DoD Standard Design AW 078-24-27. These pipes will also permit water beneath the tank to escape by gravity.

h. Perform subsurface investigation in sufficient detail to determine if any compressible, weak, organic, or otherwise objectionable soils exist within a distance of two tank diameters below ground surface.

i. Estimate the magnitudes and rates of settlement (uniform, differential, and seismic induced) as part of the design. Provide adequate flexibility in piping, appurtenances, and other systems to accommodate anticipated settlements. Accomplish flexibility by using pipe offsets or ball joints. Do not use corrugated or bellows type expansion compensators. Do not exceed differential settlement values given in UFC 3-220-10N.

j. Where objectionable materials exist or magnitudes of anticipated settlement are sufficient to cause damage or unacceptable distortion, consider subsurface improvement. Potential improvement techniques may include removal of objectionable materials and replacement with clean compacted granular fill, preloading or surcharging in conjunction with drainage wicks, deep dynamic compaction, vibrocompaction, stone columns, compaction grouting, or similar techniques.

k. Where justified by subsurface conditions and economics, consider using deep foundations such as driven piling or drilled shafts. Design foundation in accordance with UFC 3-220-01N.

8-8.6 Post Installation Inspection.

Require tanks to be inspected by a STI Registered Inspector or an API Std 653 Certified Inspector, where applicable, prior to the tanks being put into service.

8-9 UNDERGROUND HORIZONTAL STORAGE TANKS.

8-9.1 General Design Considerations.

Where underground storage tanks of 50,000 gallon (191,000 L) or less capacity are required, use factory-built horizontal cylindrical double wall tanks (welded steel or fiberglass reinforced plastic (FRP)). Ensure that the design and installation are in accordance with 40 CFR Part 280 and NFPA 30 or any more stringent state or local criteria. Require separation of exterior tank walls from the interior walls with standoffs, thus creating an open space, or interstitial, for monitoring of leaks. UL 58 defines this type of tank as a Type II tank. Ensure that factory-fabricated tanks comply with UL 58 and STI P3 criteria.

8-9.2 Installation.

a. Install tanks in accordance with NFPA 30 and also in strict accordance with the manufacturer's installation instructions.

b. Install the tank so that the bottom slopes downward toward one end at a slope of 1 percent. If there is to be a product recovery and/or water draw-off, locate transfer pumps and suction piping at the low end of the tank; locate water draw-off at low end of the tank. Otherwise, locate the transfer pumps at the low end.

c. Provide straps and anchors designed to prevent flotation of tanks located in areas with high groundwater levels or subject to flooding. **\2** Design the concrete anchor pad with a factor of safety of 1.50 for resisting buoyant forces. ***/2/*** Provide electrical isolation strips between hold-down straps and metal tanks. Anchors may be a concrete anchor slab under the tank or concrete deadmen.

d. Place tanks on a uniform bed of homogeneous granular material at least 12 inches (300 mm) thick. If a concrete anchor slab is used, place a minimum of 6 inches (150 mm) of bedding for steel tanks and 12 inches (300 mm) of bedding for fiberglass tanks between the tank and the concrete anchor slab. Do not use blocks, chocks, or rocks.**\2**

e. All fuel storage tank nozzle fittings must be located above ground. If the tank nozzle penetrates a manway, the nozzle must be flanged so that the manway can be removed without requiring the nozzle piping to be cut. If any product recovery tank nozzle fittings are direct buried, the fittings are to be coated and wrapped with appropriate materials (i.e., anticorrosion tape wrap). Contact the appropriate Service Headquarters SME for approval. **/2/**

f. The tank must be installed by state-certified contractor, if state has a certification program.

g. The tank must be installed by a contractor that is certified by the tank manufacturer.

h. Tanks must be inspected in accordance with STI SP131 by a STI certified inspector prior to commissioning.

8-10 UNDERGROUND VERTICAL STORAGE TANKS (CUT AND COVER).

Underground vertical storage tanks are steel-lined reinforced concrete with leak monitoring capability. These tanks may be completely buried, surface-constructed and then covered with embankment, or any variation in between. OCONUS Pacific they are only required in high threat areas or when tanks are required to be constructed within the explosive cordon area or clear zone. Tanks being constructed OCONUS NATO refer to Standard Design STD 121-122-01 USAFE/NATO, Airfield Standard Design US, Jet Fuel Storage Dispensing Systems for Tactical and Wide Body Aircraft for design guidance. They are not used within CONUS except when tanks are required to be constructed within clear zones or explosive cordon areas. Design underground vertical steel storage tanks in accordance with DoD Standard Design AW 078-24-33 Aircraft Fueling System with Underground Vertical Storage Tanks (Cut and Cover), except as modified herein. These standards include tank sizes of 10,000 through 100,000 barrels (1,600,000 L through 16,000,000 L) capacity. In general, do not exceed 100,000 barrels (16,000,000 L) capacity. Alternative designs using prefabricated/pre-stressed tank sections must be approved by the appropriate Service Headquarters. Provide leak detection for underground storage tanks in accordance with federal, state, and local regulations.

8-11 APPURTENANCES.

Table 8-1 describes appurtenances for atmospheric storage tanks larger than 12,000 gallons and identifies the type of tank to which they should be mounted. Full seal weld all tank attachments to prevent moisture/water from corroding the tank shell and attachments. Threaded connections must not be used for mounting of any appurtenances to the tank (i.e. thread-o-let).

8-12 HEATERS.

8-12.1 General Design Considerations.

Provide tank heaters and controls for tanks intended for storage of high viscosity products, such as lube oils, or burner fuels No. 4, No. 5, and No. 6, in climates where the ambient tank temperature would be less than 20 degrees F (11 degrees C) above the fuel's pour point temperature. Heat heavy burner fuel oils and lube oils to a temperature of 20 degrees F (11 degrees C) above the fuel's pour point prior to pumping. Use one of the types of heaters listed below.

8-12.2 Heating Medium.

Use the appropriate heating medium for the particular application based on temperature, pressure, and availability. Saturated steam is the preferred heating medium, but consider using hot oil, hot water, and electric heating where steam is not available from existing sources.

8-12.3 Convection-Type.

Use convection-type heaters installed inside a storage tank and capable of passing through a 36-inch (900 mm) diameter manhole with a capacity to raise the temperature of a full tank of burner fuel oil approximately 60 degrees F (33 degrees C) in 24 hours. The appropriate Service Headquarters and/or DLA-Energy will determine if the capacity of the heater could be reduced if it is not necessary to heat a full tank of fuel within 24 hours.

8-12.4 In-Line Type.

In-line heaters consist of two general types: tank suction and straight tube. All in-line heaters are of the shell and tube construction. A tank suction or suction in-line heater is installed inside the tank on the tank issue line. The fuel oil enters the exchanger at the end within the tank and exits at the opposite end outside of the tank. The steam or another heating medium enters and exits the exchanger at the end outside of the tank. A straight tube or pipe in-line heater is installed directly into the pipeline. The fuel oil enters the exchanger at one end and exits from the other. The entry and exit points for the steam side can vary. The following criteria applies to in-line heaters:

a. Capable of heating fuel oil passing through them from the ambient tank temperature to a minimum of 20 degrees F (11 degrees C) above the fuel oil's pour point temperature at required flow rate.

b. If installed in tanks, allow removal of heater tube bundles without emptying the tank.

c. If multipass in-line heaters are used, do not allow the oil temperature rise to exceed 30 degrees F (17 degrees C) per pass.

d. Use carbon steel shells designed for a minimum 175 psig (1210 kPa) cold working pressure on both steam and oil sides.

e. Do not exceed 0.2 psig (1.4 kPa) for the pressure drop on the oil side of pump suction line nor exceed 10 psig (70 kPa) of pressure drop for heaters installed on pump discharge.

8-12.5 Insulation and Tracing.

In cases where fuels are heated, examine the possible economic incentives for insulating heated storage vessels and piping. In many cases, piping carrying heated products must be heat traced to prevent possible solidification of the fuel during a shutdown period. Insulate traced lines. Consider possible incentives for installing a condensate collection and return system. If a condensate return system is installed, include a monitor to detect oil in the condensate.

8-13 UNDERGROUND STORAGE TANK SPILL CONTAINMENT SYSTEMS.

8-13.1 General Design Considerations.

Provide drainage structures to impound escaping fuel where rupture of an underground tank in a hillside location would endanger other activities and structures at elevations lower than the tank.

8-14 ABOVEGROUND TANK SPILL CONTAINMENT SYSTEMS.

Provide a spill containment system for all aboveground tanks to prevent spilled petroleum from leaving the property.

8-14.1 General Design Considerations.

Tank Capacity barrels (L)	Method of Spill Containment
Individual Single Wall Tanks larger than 10,000 barrels (1,600,000 L)	Individual Diked Enclosure
Group of Single Wall Tanks with - no tank larger than 10,000 barrels (1,600,000 L), and - not exceeding 15,000 barrels (2,400,000 L) in aggregate capacity	Single Diked Enclosure with subdivisions between each tank 2,000 barrels or larger
Double Wall Tanks	Exempt by exception granted by NFPA 30 or NFPA 30A, if all provisions of that document are met and if local, state, and federal regulations permit

Refer to DoD Standard Design AW 078-24-27. Use the following criteria for tank spill containment systems:

a. The preferred method of containment is by diked enclosure (impounding spilled fuel around the tank by means of dikes) to prevent the accidental discharge of petroleum.

b. As an alternative to diked enclosures, use a remote impoundment spill collection system consisting of a series of drains leading from storage tank areas to a remote containment or impoundment designed to prevent the accidental discharge of petroleum. This is not the preferred method and requires approval of Service Headquarters. Generally, this system is used for tanks on a hillside.

c. Slope the area within the containment at no less than 1 percent to carry drainage away from the tank to a sump located at the low point of the enclosure.

d. Construct the drain line from the sump of petroleum-resistant, impermeable material with water-tight joints such as ductile iron or HDPE pipe with fusion welded joints. Do not use clay, concrete, or fiberglass piping materials.

e. Control drainage from the sump to the outside of the enclosure by an eccentric plug valve with indicator post located outside of the enclosure in an area that will be safely accessible during a fire.

f. Do not allow fuel to run off or escape from the containment area under any circumstances. Provide means for disposing or for treating contaminated water from the containment to meet the most stringent of applicable federal, state, or local requirements.

g. When subdividing is required, use subdivisions not less than 18 inches (450 mm) in height.

8-14.2 Spill Containment System Capacity.

8-14.2.1 Diked Enclosures.

Design diked enclosures in accordance with the most stringent of NFPA 30, 40 CFR Part 112, and other federal, state and local regulations. Additionally, ensure that the capacity of the diked enclosure is, at a minimum, greater than the largest tank volume located within the diked enclosure, plus sufficient freeboard equal to the greater of a 24-hour, 25-year storm or one foot (0.3 m) over the entire area of containment, or the flow of the water from firefighting activities. In appropriate environmental climates, consider snow and ice accumulation as well. Limit dike heights to 6 feet (1.8 m) or less, if possible. If dike height is higher than 6 feet (1.8 m) follow the requirements of NFPA 30 and confined space requirements.

8-14.2.2 Remote Impoundments.

If approved by Service Headquarters, design remote impoundments in accordance with the most stringent of NFPA 30, 40 CFR Part 112, and other federal, state and local regulations. Additionally, ensure the capacity of the remote impoundment is, at a minimum, greater than the largest tank volume located within the area of containment plus sufficient freeboard equal to the greater of a 24-hour, 25-year storm or one foot (0.3 m) over the entire area of containment or the flow of water from firefighting activities on neighboring storage tanks sharing the same spill collection system. When sizing the remote impoundment consider the total drainage area from all tanks that are included within the spill collection system. In appropriate environmental climates, consider snow and ice accumulation as well.

8-14.3 Remote Containment/Impoundment Spill Collection Systems.

Construct the remote impoundment as generally described for diked enclosures and in accordance with UFC 1-200-01.

8-14.4 Diked Enclosure – Earthen Dike Type.

Construct earthen dikes of earthen materials with fuel impermeable liner cover. Where space is a premium, construct dikes of vertical concrete walls. For earthen dikes, make the minimum distance from the toe of the dike to the tank foundation 5 feet (1.5 m) and provide a flat surface on the top of the dike at least 3 feet (0.9 m) wide. Do not make earthen dike slopes steeper than 2.5 horizontal to 1 vertical. If space is restricted, dike slopes may be increased to 2 horizontal to 1 vertical if the sloped dikes are concrete surfaced. Cover the sides and top of the earthen dike and the floor around the tank with one of the following materials (Refer to AW 078-24-27):

a. A fuel impermeable liner. If liner is exposed, the exposed areas must be resistant to the effects of direct sunlight and to wind uplift. Provide sandbags in accordance with the appropriate UFGS, or other means approved by the liner manufacturer, to assure the liner is resistant to wind uplift. Follow the liner manufacturer's recommendations for protecting the liner by the use of geotextile cover or other recommended means. Provide a concrete maintenance pad for personnel access to the tank and for work areas around tank manholes and valves.

b. Do not use Bentonite or a Bentonite composite material in the construction of dikes or basins.

c. Do not use asphalt.

8-14.5 Diked Enclosure – Reinforced Concrete Dike Type.

Design reinforced concrete (prefabricated or cast-in-place) dikes and their foundations to resist and contain the full hydrostatic load when filled to capacity. Use vertical reinforced concrete dikes where space is a premium. Seal all concrete surfaces with a flexible, UV-resistant, fuel-resistant coating if required by local or State regulations. Use a fuel impermeable liner as described above for the dike floor. When concrete is used as the secondary containment system, it must meet American Concrete Institute (ACI) 350 Code Requirements for Environmental Engineering Concrete Structures.

8-14.6 Diked Enclosure – Combination Dike Type.

A vertical concrete wall backed by an external earthen berm may be used. Design the combined earthen and concrete unit and its foundation to resist and contain the full hydrostatic load when filled to capacity. Use a fuel impermeable liner as described above for the dike floor.

8-14.7 Stormwater Collection Systems.

Design a stormwater collection system to contain, transport, treat, and discharge any stormwater that collects in the tank enclosure. Refer to Chapter 2 of this UFC. Review state and local regulations for design requirements and permitting of stormwater treatment systems.

8-14.8 Dike Access.

Provide concrete, steel, or aluminum steps with pipe handrails for passage across a dike. Steps and handrails must comply with 29 CFR Part 1910.36. Include a removable section of the handrail to provide access to the flat top of earthen dikes. If steel steps are used, they should be hot-dipped galvanized after fabrication. Provide a minimum of two access locations for safe emergency egress and for normal operation. This will normally include steps over the dikes separating adjacent tanks, as well as on one wall without an adjacent tank. Locate steps at the most accessible points, preferably on the same side as the access stairs to a tank roof. For tanks 20,000 barrels (3,200,000 L) and larger, consider providing earth-filled ramps to permit vehicle access into the dike when approved by Service Headquarters. If there is sufficient need to provide vehicle access into diked areas, provide a concrete paved road and/or earth-filled ramp for vehicle travel-ways. Where the vehicle access road crosses the dike, provide a security gate and prominent sign indicating that access is limited to a light duty vehicle that is rated for use in NFPA 70 Class I, Group D, Division 2 hazardous locations.

8-15 MISCELLANEOUS USE TANKS.

This paragraph provides design guidance for miscellaneous use tanks. These tanks are typically less than 550 gallons (2,100 L) in capacity. Check state and local regulations before beginning design. If a miscellaneous use tank has a capacity greater than 12,000 gallons (45,800 L), follow the requirements of Table 8-1. Otherwise, use the standards described below. For interior and exterior protective coating systems, consider using manufacturer's standard coating systems. Ensure coating system is compatible with application and products being stored.

8-15.1 Installation.

Install the tank in conformance with the requirements of NFPA 30. The exception used in NFPA 30 for the deletion of dike containment is acceptable if all of the criteria associated with that exception are met. Provide containment for all tanks, regardless of size, except small residential heating oil tanks, by complying with the paragraph titled "Aboveground Tank Spill Containment Systems" in this chapter of this UFC or by using properly installed aboveground concrete-encased tanks in accordance with the paragraph titled "Horizontal Aboveground Tanks (Protected Tanks)" in this chapter of this UFC.

8-15.2 Heating Oil Tanks.

Comply with NFPA 31.

8-15.3 Generator Fuel Tanks.

Comply with NFPA 31, NFPA 37, and NFPA 110.

8-15.4 Fire Pump Fuel Tanks.

Comply with NFPA 20, NFPA 30, and NFPA 31.

8-15.5 Waste Oil Tanks.

Check local and state environmental regulations for any additional requirements for storage of waste oil.

8-15.6 Containment.

As discussed previously in this chapter, provide containment, under and around all aboveground tanks except home heating oil tanks.

8-15.7 Underground Tanks.

Ensure all underground tanks are double-walled and have overfill protection, as described previously in this chapter.

8-16 SHIPBOARD OFF-LOAD FUEL STORAGE TANKS.

8-16.1 Function

In addition to regular storage, consider a storage tank for fuel removed from ships that may be off-specification or otherwise not satisfactory for its intended use. This fuel may be downgraded to heating oil or diesel fuel marine.

8-16.2 General Design Considerations.

Determine the volume requirements of the contaminated fuel storage tank by an activity survey. Provide bottom loading facilities for tank truck loading and off-loading of contaminated fuel.

8-16.3 Locations.

Locate the contaminated fuel storage tank(s) in or near the facility tank farm. Clearly mark the tank(s) as to the type or grade of fuel.

8-17 JET ENGINE TEST CELL FUEL STORAGE TANKS.

Design jet engine test cell fuel storage and issue systems to the same standards as operating storage tank fuel systems (e.g., high level alarms, gauging, shut-offs, etc.). Normally, tanks are refilled using station aircraft refueling trucks through aircraft single-point refueling adaptors.

8-18 FUELS AUTOMATED SYTEM.

The Defense Logistics Agency's Business System Modernization (BSM Enterprise Resource Programs (ERP) - Fuels section) is an Automated Information System (AIS) designed to support the DLA-Energy and the Military Services in performing their responsibilities in fuel management and distribution. FAS is a multi-functional AIS which provides for point of sale data collection, inventory control, finance and accounting, procurement, and facilities management. BSM-ERP is composed of an integrated set of commercial off the shelf (COTS) software applications, based around an oracle relational database management system (RDBMS), which is hosted on commercially available computer hardware. The system will provide interfaces to existing logistics/financial AIS's or to be used only when directed by DLA-Energy.

Table 8-1 Appurtenances

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
Manhole							
a	A 30-inch (750 mm) diameter manhole, a minimum of one manhole for tanks between 1,000 gallons (4,000 L) and 5,000 gallons (19,000 L) capacity, and a minimum of two manholes (both are to be at least 36 inches (900 mm), for tanks larger than 5,000 gallons (19,000 L) capacity.		✓	✓	✓	✓	✓
b	A dedicated manhole, other than required above, as the primary point for piping penetrations into a tank (may be as small as 22 inches (559 mm)). * For horizontal underground tanks located at military service stations, refer to DoD Standard STD 123-335-03. Diesel and bio-diesel tanks at military service stations are to be provided with a 32-inch access manway in addition to Item a above.			✓ *			
c	A shell manhole located above the internal floating pan's high position to aid in venting the tank during cleaning and to provide access to the floating pan's elastomeric wiper seals as required by DoD Standard AW 078-24-27.	✓					
d	Containment sumps and extension manhole.			✓			
e	Internal ladder access hatch in accordance with API Std 650. Locate the internal ladder access hatch near the perimeter of the roof.	✓					
f	Shell manholes in accordance with API Std 650. Two 36-inch (900 mm) shell manholes 180 degrees from each other. Align shell manholes parallel with prevailing wind direction. Support shell manhole covers by davits.	✓					
g	A bolted cover in the roof for installation and removal of the internal floating pan as required by the tank supplier based on the pan manufacturer.	✓					
Inspection Hatches							
h	A minimum of four roof perimeter vents/inspection hatches on fixed roof tanks with floating pans. Inspection hatches are not required for tanks without floating pans.	✓					
Ladder/Stairs							
i	Internal ladders (in accordance with OSHA criteria) for tanks of 5,000 gallons (19,000 L) or larger. * with floating pans. ** Ladders are optional per STD 123-335-03.	✓ *	✓ **	✓ **	✓ **	✓ **	✓
j	An external ladder and platform with safety railing for gauging and sampling in accordance with 29 CFR Part 1910.23 (if height justifies it).		✓		✓	✓	

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
k	Ladders, railings, toe boards, a spiral stairway, bottom platform (for internal floating roof only), intermediate platform, top platform, and handrail in accordance with API Std 650 and OSHA requirements. Provide stairways and platform to access high level shut-off and alarms. Provide bar grating stair tread and platforms. Provide stair tread with non-slip nosings. **\2** In locations where there is severe corrosion, these components may be fabricated from nonmetallic composite material (e.g. fiberglass reinforced plastic, carbon fiber, or other nonmetallic composite). Stair treads may be bolt-on type to facilitate replacement when required. ***/2/***	✓					
Item	**Appurtenance**	**V-A**	**H-A**	**H-U**	**F-A**	**P-A**	**V-U**
Level Alarms							

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
I	1. Tanks Greater ≥ 30,000 gallons (112 500L): 1. An individual automatic level alarm system, independent of the gauging device or system for each tank. Include high, high-high, low and low-low level alarms. On aboveground tanks: provide a means to manually test each alarm sensor to ensure system operability without a full tank; locate level alarm system component for ready access from ground level, stairway platforms, or roof access. On aboveground vertical tanks set level alarms as defined in AW 078-24-27. On tanks without floating pans, set the low level alarm to actuate 5 minutes above the low-low level alarm, and the low-low level alarm as defined in AW 078-24-27. **\2** On Cut and Cover tanks, set level alarms as defined in AW 078-24-33. For horizontal underground tanks and aboveground tanks, high and high-high will be 90 and 95 percent, respectively (although this may have to be adjusted downwards for horizontal tanks). **/2/** In determining the low level, consider the time it would take for the pump or system to shut down. Provide both audible and visible alarms in a manned area responsive to the alarm. Review facility size and operating method to determine the most desirable location for audible and visible alarms, this will usually be in the tank farm or near the operations building. Interface the alarm output to stop issue pump on low level alarm and receipt pump/valve on high-high level alarm. Install alarms on winter sun side of the tank. Comply with most stringent of federal, state, or local regulations.	✓ *	✓ *	✓ *	✓	✓	✓

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
I (cont)	2. Tanks < 30,000 gallons (112,500 L): An automatic level alarm system for each tank to include high, high-high, low and low-low level alarms. On aboveground tanks: provide a single multi-set point Automatic Tank Gauge (ATG) level probe with continual/dynamic testing for both gauging and alarm; locate ATG level alarm system component for ready access from roof or platform access. Additional redundancy level sensors or switches that interface with the ATG may be added. On aboveground vertical tanks, in general conformance with API RP 2350, set high-level at 95 percent and high-high at 98 percent; on tanks with floating pans locate the low level alarm to actuate 5 minutes above the low-low level alarm and locate the low-low level alarm at 2 percent above the low level of the floating pan. For underground tanks and horizontal aboveground tanks, high and high-high will be 90 and 95 percent, respectively (although this may have to be adjusted downwards for horizontal tanks). On all tanks without floating pans, set the low level alarm 5 percent before loss of suction, and the low-low level alarm 2 percent before loss of suction to avoid pump cavitation. In determining the low level, consider the time it would take for the pump or system to shut down. Provide both audible and visible alarms in a manned area responsive to the alarm. Review facility size and operating method to determine the most desirable location for audible and visible alarms, this will usually be in the tank farm and in or near the operations building. Interface the alarm output to stop issue pump on low-low level alarm and receipt pump/valve on high-high level alarm. Comply with most stringent of federal, state, or local regulations. For vertical aboveground tanks, refer to AW 078-24-27 or STD 123-335-03 as applicable.	✓ *	✓ *	✓ *	✓	✓	✓

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
l (cont)	3. Product Recovery Tanks (PRT): An automatic level alarm system for each tank to include high and high-high level alarms. On aboveground tanks: provide a single multi-set point Automatic Tank Gauge (ATG) level probe with continual/dynamic testing for both gauging and alarm; locate ATG level alarm system component for ready access from ground level or stairway platforms. Additional redundancy level sensors or switches that interface with the ATG may be added. On aboveground tanks, in general conformance with API RP 2350, set high-level at 95 percent and high-high at 98 percent. For underground tanks, high and high-high will be 90 and 95 percent, respectively (although this may have to be adjusted downwards for horizontal tanks). **\1** On cut-and-cover tanks, set level alarms as defined in AW 078034-33. **/1/** Provide both audible and visible alarms in a manned area responsive to the alarm. Review facility size and operating method to determine the most desirable location for audible and visible alarms, this will usually be in the tank farm and in or near the operations building. Interface the alarm output to receipt pump/valve on high-high level alarm. Comply with most stringent of federal, state, or local regulations. Refer to STD 123-335-03.	✓ *	✓ *	✓ *	✓	✓	✓
***Note:** State and local regulations may be more restrictive. Because underground and aboveground horizontal tanks will fill extremely fast in the last 5 percent, values of high level alarm positions should be chosen based on filling rate, tank size, and time needed to respond to the alarm condition. Adjust values as well for extremely large vertical tanks with small receipt rates and extremely small vertical tanks with high receipt rates.							
Vents							
m	Open atmospheric vents with weather hoods and bird screens for tanks to be used for products with true vapor pressure of 0.75 psia (5 kPa) or less, when a full contact internal floating pan is provided.	✓	✓	✓	✓	✓	✓
n	For higher vapor pressure, or if a vapor recovery system is used, provide pressure/vacuum vents in lieu of open vents. Consider using pressure/vacuum vents if product quality is at risk by blowing sand, dust, or snow. Comply with NFPA 30, host nation requirements, Chapter 2 of this UFC, API Std 650, API Std 2000, 29 CFR Part 1910.106, and DoD Standard Design AW 078-24-27, where applicable.	✓	✓	✓	✓	✓	✓

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
o	Do not use flame arrestors unless required by host-nation and/or NATO regulations.	✓	✓	✓	✓	✓	✓
p	Emergency relief venting with capacity in accordance with NFPA 30 and UL 142, as applicable. For vertical aboveground tanks, a floating roof or weak roof-to-shell seam, as specified in API Std 650, may be used to fulfill emergency relief requirements.	✓	✓		✓	✓	✓
	Gauge/Gauge Hatch/Stilling Wells						
q	A mechanical tape level gauge calibrated in 1/16-inch (2 mm) graduations mounted at 60 inches (1500 mm) above the walking surface. For tanks with internal floating pans, attach mechanical tape level gauge to the manufacturer provided floating roof anchor weight that rests on top of the floating pan.	✓					✓
r	A clock-type mechanical gauge. Gauge must be accurate to plus or minus 1/4 inch (6 mm) and must measure the liquid level over the full range of a tank's height. See DoD Standard Design STD 123-335-03.		✓	✓	✓	✓	
s	Automatic Tank Gauging (ATG) for all tanks with fuel managed through the Defense Logistics Agency's Business Modernization {BSM Enterprise Resource Programs (ERP) - Fuels section}, that complies with API MPMS Chapter 3. Key features include: measures fluid level to ±0.05 inch (1 mm); measures standard volume ±0.1 percent; measures average product temperature ±1 F (0.5 C); measures product density ±1 percent; detects water in the tank sump to a level equal to or slightly above the water draw-off pipe; converts volume to API standard conditions; local tank readout; For tanks that are 30K gallons or less certain ATG systems (Veeder-Root and Ronan) can provide backup alarms for high, high-high, low, and low-low level conditions; meet American Standard Code for Information Interchange (ASCII) interface.	✓	✓	✓	✓	✓	✓
t	A 4-inch (100 mm) gauge hatch with drop tube to within 3 inches (75 mm) of the bottom of the tank.* * Lowest point in the tank not the sump.						✓
u	A 4-inch (100 mm) opening without a drop tube or gauge hatch.		✓	✓	✓	✓	✓
v	One 10-inch (250 mm) roof flanged nozzle with an 8-inch (200 mm) aluminum, fully slotted, stilling well for ATG near the edge of the roof near the top of the stairway platform.	✓					✓

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
w	One 8-inch (200 mm) roof flanged nozzle with a 6-inch (150 mm) aluminum, fully slotted, stilling well for temperature and water bottom sensor, as close to or in the tank sump as possible. See DoD Standard Design AW 078-24-27.	✓					✓
x	One 10-inch (250 mm) roof nozzle and an aluminum, slotted stilling well for gauging and sampling. A datum plate to establish a gauging zero point. See DoD Standard Design AW 078-24-27.	✓					✓
Piping Connection							
y	Inlet fill connection. Refer to AW 078-24-27 or STD 123-335-03 as applicable.	✓	✓	✓			
z	Main suction and low suction. See DoD Standard Design AW 078-24-27.	✓					
aa	Inlet fill pipe with horizontal exit perpendicular to a tank radial. Discharge is approximately 4 inches (100 mm) above tank floor and enlarged to reduce fuel velocity. An u-trap is placed in the line to serve as a liquid lock to prevent entry of fire or an explosion from outside the fill pipe.						✓
Overfill Protection							
bb	Overfill protection with a hydraulically operated diaphragm control valve. Tanks connected to commercial pipelines or marine offload systems with restrictions on shut-off may require diversion to additional tankage. On vertical tanks, valve typically closes midway between high and high-high levels, but ensure valve closes no later than on high-high level. For underground tanks, (per NFPA 30) and in aboveground horizontal tanks, automatically shut off the flow into the tank when the tank is no more than 95 percent full. Comply with most stringent of federal, state, or local regulations. Use API RP 2350 to establish the proper overfill level setting. On gravity drop fills, horizontal aboveground storage tanks, fire resistant aboveground storage tanks, and protected aboveground storage tanks, replace valve with an integral high level shut-off valve in the drop tube. Prior to designing automatic valve closure features, conduct a surge analysis on pressure filled systems. Refer to AW 078-24-27 or STD 123-335-03 as applicable. * If pressure-filled.	✓	✓	✓ *	✓	✓	✓
cc	A lockable, welded steel overfill protection box (5 gallon (20L) minimum) and a manual drain valve to return spills to the inner tank (omit the drain feature on aviation turbine fuel tanks).				✓	✓	

Item	Appurtenance	V-A	H-A	H-U	F-A	P-A	V-U
Water Draw-off							
dd	A 2-inch (50 mm) double block and bleed, plug valve at the low end of the tank, unless tank contains aviation turbine fuels with icing inhibitors. In those cases, the water draw-off valve may be a ball valve.		✓				
ee	Water draw-off connections. See DoD Standard Design AW 078-24-27.	✓					
ff	A 1-inch (25 mm) connection from the low end of the tank to approximately 3.5 feet (1.1 m) above the ground and equipped with a positive displacement-type, hand-operated pump for water draw-off. For Air Force projects, use electrical pumps only.			✓			
gg	A water removal suction tube at low end of tank with connection for water removal by truck. Consider installing a fixed, hand-operated pump as an alternative.		✓	✓	✓	✓	
hh	A central sump pump.						✓
Ball Joints							
ii	Ensure that contract specifications do not allow piping connections to be made until after the tank has been completely tested and allowed to settle. As an alternative, ball joints on pipes to relieve strain caused by tank settling or seismic activity or settlement calculations can be made, and piping flexibility can be designed to account for settling and pipe can be connected prior to testing. * May be required on tanks 25,000 gallons (94,600 L) and larger.	✓	✓ *				
Cable Supports							
jj	On the fixed roof of all tanks, provide two scaffold cable supports in accordance with API Std 650. Locate the supports near the center of the tank so that supported cables will have maximum range and flexibility of operation with minimum interference with other tank fittings.	✓					
Striker Plates							
kk	Striker plates under all openings used for manual gauging in steel tanks and all openings in fiberglass tanks.	✓	✓	✓	✓	✓	✓
Monitoring Port							
ll	A 2-inch (50 mm) monitoring port including a tube which provides a means to detect product leakage from the primary tank into the secondary tank.				✓	✓	

V-A = Vertical Aboveground Storage Tank
H-A = Horizontal Aboveground Storage Tank
H-U = Horizontal Underground Storage Tank
F-A = Fire-Resistant Aboveground Storage Tank
P-A = Protected Aboveground Storage Tank
V-U = Vertical Underground Storage Tank

CHAPTER 9 PIPING SYSTEMS

9-1 INTRODUCTION.

This chapter provides guidance for the design of new piping portions of fueling systems, as discussed in other chapters of this UFC. The criteria provided is intended to be general in scope except where specific criteria are necessary for given situations.

9-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not start design of any fueling system without first becoming completely familiar with Chapter 2 of this UFC. Follow the requirements listed in Chapter 13, when connecting a new system to an existing system, to prevent contamination of the new system.

9-2.1 Design Requirements.

Ensure that piping design, materials, fabrication, assembly, erection, inspection, and pressure tests for fuel piping systems are in accordance with ASME B31.3. See Chapter 6 of this UFC for design requirements for interterminal and installation pipelines. Follow appropriate guide specifications for piping design and materials selection. Use the following design criteria for piping systems:

a. Unless otherwise specified by Service Headquarters, provide underground piping systems in and around areas subject to aircraft ground movements. When directed by Service Headquarters, install piping in concrete trenches. When trenches are employed, comply with NFPA 415. The use of common trenches for more than one utility is prohibited. Fueling system components may be aboveground where it does not interfere with aircraft or service vehicle movements. Design all clearances in accordance with UFC 3-260-01 and DoD Standard Design AW 078-24-28.

b. In other cases, aboveground piping is preferred where it is not aesthetically objectionable or not exposed to accidental damage, vandalism, blast damage, or sabotage. Small diameter (≤4 inches (100mm)) pipe associated with the aboveground storage of petroleum, oil, and lubricants must be single wall aboveground piping. Exemptions may be granted by the Service Headquarters in cases where routing aboveground could result in catastrophic damage to the pipe. If an exemption is granted, double wall piping must be installed in accordance with the paragraph titled “Double Wall Piping” in this chapter of this UFC.

c. The preferred method of routing aboveground piping out of a diked area is over the top of the dike. However, avoid creating an inverted “U” on the suction side of a pump to avoid an air trap. Provide high point vents and low point drains as required, refer to AW 078-24-27.

d. Steel reinforced, high-density polyethylene (HDPE) flexible piping manufactured in accordance with API 17J may be used in underground piping systems. Service Headquarters approval is required prior to use of this material in place of carbon or stainless steel piping. It is preferred that all underground piping end connections are located within service pits. However, if it is not feasible, piping connections can be direct buried. Direct buried piping connections must be liquid-tight and provided with an adjacent monitoring well and a suitable pipeline marker above the connections. Steel reinforced, high-density polyethylene (HDPE) flexible piping is not to be used as aboveground piping.

e. Provide thermal relief devices around all installed double block and bleed valves and other isolation valves within the piping system.

f. Refer to UFC 3-130 series for construction of aboveground and underground piping in arctic and subarctic conditions.

9-2.1.1 Hydrostatic Testing Requirements.

a. Hydrostatically test new piping systems in accordance with ASME B31.3 and the UFGS specification appropriate for the system service. During testing, disconnect system components such as storage tanks or system components which were not designed for the piping test pressure or protect them against damage by over-pressure. Hydrostatically test aboveground piping systems to the maximum allowable working pressure of the ASME B16.5 piping system flanges at 100 degrees F (38 degrees C). Hydrostatically test underground piping systems to 1.5 times the maximum allowable working pressure of the ASME B16.5 piping system flanges at 100 degrees F (38 degrees C). See Table 9-1 for the maximum allowable maximum_allowable_working_pressure.

b. **\1** Hydrostatically test **/1/** fuel systems and pipelines with the fuel that will be used in the system or pipeline or, at a minimum, a fuel with the same minimum specification flashpoint as the fuel that will be used when the piping is in service, except as may be allowed in the following paragraph. The temperature of the fuel used for testing, and the ambient temperature, must be at least 20 degrees F (11 degrees C) below its flashpoint throughout the test.

c. Hydrotesting with water requires explicit, written Service Headquarters approval except in the case of fuel piping systems containing fuels with a flash point of less than 100 degrees F (i.e., JP-4, mogas, avgas, etc.); without that approval, hydrotesting with water is forbidden. When water is authorized for hydrostatic testing of fuel piping, ensure that all water is removed from the piping by a combination of pigging the piping, followed by dehydrating the line either with dehumidified air or vacuum extraction. Verification of pipeline dehydrating must be confirmed by measuring dew point of exhausted air. Do not allow water to remain in piping for more than 48 hours after testing. Schedule hydrotesting such that the pipeline can be filled with fuel as soon as possible (no more than two weeks) after testing is complete as it is nearly impossible to assuredly remove all water and corrosion can occur if the time to fuel introduction is extended. Considerations when deciding when to hydrotest with water include the following. As noted previously, except for JP-4, mogas, and avgas piping, all require Service Headquarters approval:

1. Fuel piping systems must be hydrotested with water for pipelines containing fuels with a flash point of less than 100 degrees (i.e. JP-4, mogas, avgas, etc.)

2. Interterminal pipelines that are constructed piggable should be hydrotested with water if permitted by the Service Headquarters in order to avoid exposing off-Base personnel and property to the risks inherent in pressure testing with fuel. Test prior to tie-in to piping at point of receipt complex and pumphouses that cannot be readily dewatered. This can be the point of connection between new and existing transfer piping, or the system connection at the receipt pig barrel.

3. Installation pipelines that are constructed piggable may be tested with water if permitted by the Service Headquarters. Test prior to tie-in to piping at point of receipt complex and pumphouses that cannot be readily dewatered. This can be the point of connection between new and existing transfer piping, or the system connection at the receipt pig barrel.

4. Hydrant systems that have been identified as having been contaminated by solids/soil during assembly should be hydrotested with water if permitted by the Service Headquarters.

5. Hydrant systems may be hydrotested with water if permitted by the Service Headquarters.

6. Determine required water discharge permitting requirements and provide a water handling/cleanup/disposal system to meet those requirements.

9-2.1.2 Pipeline Flushing Requirements.

a. Flush fuel system and pipelines with the fuel that will be used in the system or pipeline, except as may be allowed in the following paragraphs.

b. Flushing with water requires explicit, written Service Headquarters approval. Without that approval, flushing with water is forbidden. Approval must be obtained as a part of the original project programming and reconfirmed as a part of the 35% project design submission. The engineering design must include confirmation of water source, and impact on installation water distribution from high velocity water flushing as well as means of preventing particulates present in water distribution systems from being introduced into the hydrant loop. When water is authorized for flushing of fuel piping, ensure that all water is removed from the piping by a combination of pigging the piping, followed by dehydrating the line either with dehumidified air or vacuum extraction. Verification of pipeline dehydrating must be confirmed by measuring dew point of exhausted air. Determine required water discharge permitting requirements and provide a system to meet it. Do not allow water to remain in piping for more than 48 hours after testing. Schedule flushing such that the pipeline can be filled with fuel as soon as possible (no more than two weeks) after testing is complete as it is nearly impossible to assuredly remove all water and corrosion can occur if the time to fuel introduction is extended. As always, without explicit Service Headquarters approval, fuel must be used for flushing.

c. Flushing of soil contaminated hydrant loops with water requires explicit, written Service Headquarters approval. Without that approval, flushing with water is forbidden. In cases where a hydrant loop is contaminated during construction with trench soil having characteristics of clay, it is impossible to remove the clay with any form of fuel flushing and pigging. The contamination will only be pushed further into the system and then into the pumphouse. If complete hydrant loop flushing with water per above is not feasible, consider batch water pigging using fuel as propulsion. Considerations for removing clay and other solids from hydrant loop piping with water include:

1. This is a specialty operation and should only be conducted by organizations having specific prior experience in this type of effort. It is suggested that the project Systems Supplier be engaged in the process.

2. Batches of water, between batch pigs (or defueling pigs) will need to be run multiple times until foam pigs are no longer fouled with particulate contamination.

3. Water from installation water supply systems may not have sufficient pressure to seat a pig. It may be necessary to momentarily pressurize pig barrel with fuel and hydrant system pumps to move the batch pig into the head of the launcher.

4. The water batch must be diverted to a product reclaim tank and not be through filter-separators.

5. All flushing water should be considered fuel contact water and must be properly stored, tested, treated, and/or disposed.

6. It is recommended that the system be drained after flushing with water and then inspected by video equipment where possible. Tractor driven tethered cameras can be introduced at loop access point at the pumphouse, and by removal of isolation valves in the loop. The distance a tractor driven camera can progress is limited by slopes and bends but can be up to several hundred feet. In

hydrant systems, pushrod cameras can be introduced through the hydrant laterals (if no pig bars installed on branch tee) and then used to investigate the primarily loop several hundred feet in each direction.

9-2.1.3 Pipeline Pigging Requirements.

a. Design interterminal and installation pipelines between piers and storage tanks, cross-country pipelines, and between bulk storage and operating tanks to accommodate maintenance pigging and ILI smart pigging operations. Use 1.5 diameter (D) elbows, or 3 D sweeps, full port valves, barred tees where indicated. Do not design with back to back 1.5 D elbows as they can restrict smart pig trains. If back to back elbows are required, provide 3 D sweeps. Provide permanent launchers and receivers suitable for smart pigging. Provide associated launcher kicker piping and receipt bypass piping, not less than 3-inch in size for 6-inch lines and 4-inch for up to 10-inch and 6-inch for up to 14-inch pipelines. Launcher and receiver configuration must be able to accommodate current technology in ILI tools that assess piping for geometry, corrosion loss (UT and MFL) and X-Y-Z orientation as a minimum as directed or approved by Service Headquarters. For general guidance review pig barrel design in Type III Standard Design AW 078-24-28 .

b. Design aircraft hydrant system piping to accommodate maintenance pigging and ILI smart pigging operations. Provide piggable design and pig launchers and receiver as noted above for Installation and Interterminal pipelines.

c. Design long runs of truck fillstand piping (runs over one-half mile in length) to accommodate maintenance pigging and ILI smart pigging operations. Provide piggable design and pig launchers and receiver as noted above for Installation and Interterminal pipelines.

d. Provide barred tees on piggable systems using the following guidelines. Barred tees are required for all branch outlets 2-inch and larger when within 20 feet of pig launcher or receiver barrel, including the barrels. Barred tees are required on all outlets on the bottom half of the pipe, greater than 2-inch in size. Barred tees are required on all branch connections equal to or greater than 50% of piggable line size. Barred tees should not be provided on 4, 6, and 8-inch hydrant laterals so that video equipment can be inserted into the main hydrant loop from the hydrant pit. For details on barred tees, refer to Facility Plate 014.

9-2.1.4 Certified Inventory.

DLA-E requires that a fuel system volume be calculated using as-constructed pipe lengths, internal diameters, fittings, and components of a system i.e. all items containing fuel with the exception of tanks. A detailed list with sizes, lengths, quantity, and volumes must be provided for each of the systems.

9-2.1.5 Hydraulic Design.

In general, provide a hydraulic design with a velocity of 7 to 12 feet per second (2.1 to 3.7 m/s) on pump discharge and 3 to 5 feet per second (0.9 to 1.5 m/s) on pump suction at full flow. If project-specific conditions make it advisable to exceed these values, consult the appropriate Service Headquarters. Consult with appropriate Service Headquarters for outlet pressure requirements. Design suction piping to ensure that the net positive suction head required by the pumps is available under all conditions of operation. Consider the following factors in selecting pipe sizes:

a. Operating requirements of the facility to be served.

b. Capital cost of the pipe

c. Capital cost of pumping stations and attendant facilities

d. Operating cost of the system

e. Harmful effects of excessive velocity of flow including hydraulic shock and static generation.

f. Fatigue failure cause by cyclic loading

9-2.2 Piping Arrangement.

Wherever possible, arrange piping in parallel groups to facilitate multiple use of supports, to minimize the amount of trenching for underground piping, and to minimize the number of steps or stiles needed across pipe runs. For underground applications, consider constructability when determining amount of spacing between pipes. Use the following criteria:

a. Provide looped piping systems whenever practical. Loops add to the flexibility and reliability of the system, contribute to product cleanliness by making circulation possible, and can be used to reduce the magnitude of hydraulic shock. Sectionalize loops by double block and bleed valves to provide verifiable isolation and to facilitate pressure testing. All line valves on piggable lines must be true full port through conduit opening without protrusions that could impede pig passage.

b. Between mains, install cross connections for flexibility of operation and as an auxiliary means of continuous operation in emergency situations. In addition, permit the use of full thickness line blinds where space limitations preclude the use of removable pipe sections or fittings. Provide a separate piping system for each grade of fuel to be handled. Do not provide cross connections between grades except when approved by Service Headquarters; typically for large Defense Fuel Support Points and other large multi-fuel depot style bulk fuel farm installations.

c. As described under "Pipeline Pigging Requirements" paragraph 9-2.1.3, lay out the following underground piping systems to accommodate maintenance pigging and ILI smart pigging operations:

1. Interterminal and installation pipeline piping between piers and storage tanks, cross-country pipelines, and between bulk storage and operating tanks.

2. Aircraft direct fueling system piping hydrant loops.

3. Truck fillstand piping runs that are over one-half mile in length.

d. For short runs of piping, provide a line slope of at least 0.2 percent. For long runs of piping (except **hydrant systems** and long runs of truck fillstand piping, see below), make line slope sufficient to establish positive drainage by gravity, but without excessive bury depth. Make gradients uniform between high point vents and low point drains. Traps are undesirable because they provide a place for water and sediment to accumulate. High points are undesirable because they trap air in the piping affecting their hydraulic performance; install high point vents to remove trapped air. Install low point drains at all low points to allow for removal of any water from condensation. These low point drains also provide the capability to remove fuel for line maintenance. For piggable **installation pipelines**, the low point drains and high point vents may be deleted when approved by **Service Headquarters**. Low point drains are not required on **interterminal pipelines**.

e. To help maintain fuel quality, design aircraft **hydrant system** piping and long runs of truck fillstand piping with as steep a slope a possible (0.5 percent or greater) to allow for better draining capability. This is typically done by following the slope of the terrain in order to minimize the number of high point vent and low point drain pits. In no case slope the pipe less than 0.2 percent without **Service Headquarters** approval.

f. As a general rule of thumb, provide spacing between aboveground piping and piping in valve pits that will allow a minimum clearance of 3 inches (75 mm) between adjacent flanges. In certain situations, such as in a piping trench or other restrictive location, it may be necessary to reduce the spacing. A minimum of 12 inches (300 mm) or one pipe diameter, whichever is greater, should still be maintained between pipe walls.

9-2.3 Surge Analysis.

Conduct a complete surge analysis of system operation using a computer simulation program for all systems with quick closing valves and for aircraft hydrant and direct fueling systems with more than two outlets. Give full consideration to the causes and effects of hydraulic shock. This is especially important in closed fueling systems such as aircraft fueling systems where the receiving tanks or dispensing system components may be damaged by shock pressure. Reduce the possibility of shock by limiting flow velocity and avoiding the use of quick opening/closing valves except where required for system operation such as hydrant pit valves. Do not reduce flow velocities below minimum velocity indicated in the paragraph titled “Hydraulic Design” in this chapter of the UFC. Every reasonable effort must be made to control hydraulic surge or shock within acceptable limits by the design of the piping system rather than by the use of surge suppressors. Surge suppressors are strictly a last resort solution and require the approval of Service Headquarters prior to designing into a system. For all aircraft direct fueling/hydrant system designs, the loop back pressure control valve is critical in preventing excessive hydraulic shock. Use the following design criteria and Table 9-1 for piping design pressures:

a. For all complex piping systems (main header, several laterals, mobile equipment), employ computer modeling techniques to determine if surge suppression is required. Conduct a run at steady state flow conditions to establish system flow rates for the scenario being modeled. After that, conduct a transient surge analysis imposing worst-case operating conditions on the system. For hydrant systems incorporating the use of a back pressure control valve, simulate this valve as an active modulating valve. If acceptable peak pressures are exceeded, discuss the results with the Service Headquarters fuels engineer to review parameters used and consider alternatives. If this consultation produces no workable solution, perform a second surge analysis to model the use of surge suppressors in the system. This analysis must indicate that damaging peak pressures are not exceeded. Do not use manual surge calculations, except as found under (c) below, because they do not account for dampening effects of the system and yield overly conservative results.

b. Most systems designed in accordance with this manual will have ANSI Class 150 flanges and the maximum allowable operating pressures seen in Table 9-1. Design the system such that the total pressure including surge, pump shutoff pressure, thermal fuel expansion effects, and static pressure in any part of the system never exceeds the maximum allowable operating pressure. Other equipment items such as tank trucks, aircraft fuel tanks, or shipboard fuel tanks which may be damaged by shock pressures may require lower maximum surge pressure. Assume a near instantaneous shut-off by the aircraft in the design of aircraft hydrant systems.

c. Do not use manual calculations instead of computer modeling when system surge pressures are crucial and the piping system is complex. However, for simple piping systems that operate under 80 psi (550 kPa) the manual calculations contained in Appendix A can be used to ascertain if surge will be a problem.

Table 9-1 Allowable Pressure Table – ANSI Class 150 Flanged Joints

	ASTM A 105	ASTM A 182 Gr. F304
Maximum Allowable Working Pressure	285 psig (1970 kPa)	275 psig (1900 kPa)
Maximum Hydrostatic Test Pressure	450 psig (3100 kPa)	425 psig (2930 kPa)
Minimum Hydrostatic Test Pressure	425 psig (2930 kPa)	400 psig (2760 kPa)
Maximum Allowable Operating Pressure	285 psig (1970 kPa)	275 psig (1900 kPa)
Maximum Allowable Surge Pressure	380 psig (2620 kPa)	366 psig (2525 kPa)

Notes:
(1) All pressure values are taken from ASME B16.5, ASME B16.47 and ASME B31.3 at 100 degrees F (38 degrees C).
(2) Values are presented for information only. Confirm actual values with ASME B16.5, latest edition, based on actual temperatures, bolting and gasket materials, etc.
(3) For other materials, see ASME B16.5 and ASME B31.3.
(4) For lower hydrostatic test pressures, the maximum allowable operating pressure will be lower than indicated. See ASME B31.3.

9-3 ABOVEGROUND PIPING.

Support aboveground piping so that the bottom of the pipe is a minimum of 18 inches (450 mm) above the ground surface or higher if required to service valves and system components. In areas subject to flooding, greater clearance may be desirable. At intersections with roadways, allow enough clearance for the passage of tank trucks, cranes, and similar heavy vehicles. In areas subject to seismic activity, provide the piping configuration and support in accordance with the seismic design criteria in **\3** UFC 3-301-01. Refer to 3-301-01 **/3/** for considerations in extremely cold climate. Wherever possible, arrange piping in parallel groups to facilitate multiple uses of supports, to minimize the amount of trenching for underground piping, and to minimize the number of pipe stiles needed. Consider constructability and maintenance in spacing of piping.

9-3.1 Identification.

Identify piping in accordance with Chapter 2 of this UFC. In addition, mark fuel lines at head of fueling pier near valves, and mark valve “open” and “close" positions.

9-3.2 Pipe Supports.

Provided engineered pipe supports for all aboveground piping systems must meet the applicable requirements of ASME B31.3 or ASME B31.4. All supports must be to the bottom of the pipe. Rest piping on supports, both insulated and uninsulated, preferably on a steel shoe (tee) welded to the bottom of the pipe. Leave the shoe free to move on the support when both in-line and lateral motion of the pipe is acceptable (no restraint). Where guides are designed with lift control, hold down brackets must be of welded construction, not bolted. Facility Plate 015 shows the design of typical "slide/guide" pipe supports for use when in-line flexibility is required, and vertical or lateral motion must be restrained. Facility Plate 017 shows the design of typical pipe supports with U-bolt restraints with a half round slide surface when use of a welded steel shoe is not required. Facility Plate 018 shows the design of a typical pipe support with U-bolt restraints with a half round slide surface that can be used for smaller piping systems (≤ 4 inches). Construct the portion of pipe supports in contact with the ground with concrete. Use of concrete piers is preferred over structural steel supports whenever feasible. Other support configurations are acceptable provided the support does not contain rollers**,** does not allow movement of the pipe on a metal surface**,** and does not include hangers. See AW 078-24-27, AW 078-24-28, AW 078-24-29, and STD 123-335-03 for specialized pipe supports particular to system layout requirements. General guidelines for pipe supports include:

a. Ensure that support shoe is the same as the pipe material (carbon steel or stainless steel).

b. Welded pipe shoes must be fully seal welded to prevent moisture pockets.

c. Pipe shoes may be manufactured products or custom designed and fabricated. Pipe static loads as well as dynamic loads must be addressed with a safety of factor not less than 4.

d. Strap-on, bolt on pipe attachments must not be used.

e. Cradle type supports must not be used when subject to weather or condensing climates due to water collection and increase in corrosion.

f. Welded carbon steel pipe shoe (tee), and shoe base must be hot dipped galvanized for all waterfront facilities and facilities located in the tropics with a condensing chloride climate. Special procedures for welding are required to remove the galvanization at the pipe to shoe weld. Galvanized shoes must receive proper surface preparation, then coated with the intermediate and topcoat system specified for piping.

g. Selection of pipe support type, vertical only support, pipe shoe with restraints, pipe shoe with no restraints, restrained or loose U-bolt on slide half round must consider all load factors (thermal, wind, seismic) and flexibility (thermal). Avoid excessive restraint supports that can result in damaged pipe, pipe shoes and supports. Avoid lack of restraint in high seismic regions that can lead to excessive pipe motion and failure.

9-3.3 Arrangement.

Arrange pipes to provide for expansion and contraction caused by changes in ambient temperature. Where possible, accommodate expansion and contraction by changes in direction in piping runs, offsets, loops, or bends. Where expansion loops or off-sets are not possible, use flexible ball joint offsets or bellows style expansion joints. Provide in-line restrained sliding (guided slide) pipe supports or other method of maintaining alignment on each side of the expansion joint. Do not use expansion devices which employ packings, slip joints, friction fits, or other non-fire resistant arrangements. Use ball-type offset joints to accommodate possible settlement of heavy structures such as storage tanks, if piping design cannot provide enough flexibility. Design expansion bends, loops, and offsets within stress limitations in accordance with ASME B31.3 and/or ASME B31.4. Thermal expansion of pipes should also be calculated based on the pipe being empty to include considerations for when the pipe is being installed or drained. For complex systems, computerized code compliant pipe stress analysis programs must be used to assure proper pipe support selection for load conditions.

9-3.4 Anchors.

Anchor aboveground piping at key points so expansion will occur in the desired direction. Anchors and guides may also be required to control movement in long runs of straight pipe or near a connection to fixed system components such as a pump or filter. See **Facility Plate 016**. Space anchors to provide maximum amount of straight runs of piping from expansion points to the anchors. In general, place anchors at all points of the system where only minimum piping movement can be tolerated, such as at branch connections and system component connections. Key locations are pump houses or other buildings, manifolds, at changes of direction if not used as an expansion joint, at points where the pipe size is drastically reduced related to adjacent piping, and at all terminal points. Limit the use of anchors to the situations described above. Thrust anchors must be directly welded to the pipe and must not include strap or bolt restraints. Where an anchor is welded directly to a pipe, ensure that the anchor material is compatible with the pipe material (carbon steel and stainless steel). Welded carbon steel pipe anchors must be hot dip **galvanized** for all waterfront facilities and facilities located in the tropics with a condensing chloride climate. Special procedures for welding are required to remove the **galvanization** at the pipe to shoe weld. **Galvanized** shoes must receive proper surface preparation, then coated with the intermediate and topcoat system specified for piping. Anchors must be designed for engineered load case and must take into account the type of expansion control device/concept. Pipe hold-down restraints are considered a form of anchors and are only suitable for use when in-line forces are limited, and not suitable for thrust restraint.

9-3.5 Thermal Relief Valves.

The coefficient of expansion of liquid petroleum in the range of 35 degrees to 60 degrees API (0.8498 to 0.7389) at 60 degrees F (16 degrees C) is 0.0005 gallon per gallon per degree F (0.0009 L per L per degree C). The total volume generated in most cases is very small, but the pressure increase resulting from this expansion can equate to as much as 75 psi for every degree rise in the fuel temperature if not relieved. For this reason, provide any section of pipe that has the potential to be isolated by a shut-off valve or other means with a thermal relief valve to relieve the isolated piping section. Provide a thermal relief of the internal cavity of valves where pressure is trapped when the valve is in the closed position (double block and bleed plug valves for example).

9-3.5.1 Construction of Thermal Relief Valves.

The thermal relief valves must match the material of the piping in which it is installed. When a stainless steel valve is provided, all components including bonnet and adjustments must also be stainless steel. Carbon steel components are not acceptable in a stainless steel thermal relief valve.

There are two types of thermal relief devices that can be used to protect a piping system: Balanced type thermal relief valves or ASME type thermal relief valves. Valves used for relief of thermal expansion must be not less than 3/4-inch (20 mm) nominal pipe size. Valve nameplate must list liquid flow capacity in gpm only. **\2** Provide with testing tees and isolation ball valves with removable handles, on the inlet and outlet sides of the valve. ***/2/*** The set pressure of the relief valve will vary, but consider a set pressure of about 10 percent above the dead-head pressure of the pump. This should keep the valve from opening during normal fueling operations. Ensure the set point is within the design limitations of the piping. Do not provide thermal relief piping with sight flow indicators.

9-3.5.2 Discharge of Thermal Relief Valves.

Thermal relief valves should never discharge to grade or to a stormwater drainage system. Ideally, the relief valve should discharge to a header which is piped directly to an atmospheric source such as a storage tank or product recovery tank; in this situation, consider using ASME Type relief valves. Often, the practical alternative is to use the balanced type relief valve (in lieu of the ASME type) arranged into a cascading system, where each relief valve bypass the shut-off valve that is isolating the piping section and discharges back into the main product piping. The excess volume may pass through two or more relief valves before finally making its way back to an atmospheric source. Caution must be taken to ensure that the relief valves have the capacity to handle the additive relief flows this type of system creates and that the total relief pressure does not exceed that system maximum allowable operating pressure. Balanced type relief valves limit pressure buildup that is created in a cascading system, because the balanced type relief valves relieve at a point independent of downstream pressure.

In some cases, a small atmospheric tank may need to be placed to properly relieve a piping system. This may be the case if a system component has a lower maximum allowable pressure then the rest of the system or in a remote location where a cascading system will not work. Equip the tank with self-checking high level alarms and containment. See Facility Plates 020, 021, 022 and 023.

9-4 UNDERGROUND PIPING.

Provide underground piping which passes under public roadways or railroad tracks in accordance with Department of Transportation regulations 49 CFR Part 195 and API RP 1102. Refer to Chapter 2 of this UFC for corrosion protection and for environmental protection. Before installing underground pipelines, review all federal, state, and local regulations for double wall pipe, leak detection, and corrosion protection requirements.

9-4.1 Depth of Cover.

Use the following criteria for depth of cover over buried fuel pipelines:

a. Locate top of lines at a minimum of 3 feet (0.9 m), except that less cover is permissible for occasional stretches where overriding conditions exist, such as the need to pass over a large culvert or beneath drainage ditches. At such locations, build sufficient slack into the line to allow for vertical and lateral movement due to frost heave. Refer to UFC 3-130 series for additional guidance. Protective measures, such as the installation of reinforced concrete slabs above the pipe, may also be required where depth is less than required under Paragraph (b) below.

b. Subject to Paragraph (a), provide minimum depths in accordance with 49 CFR Part 195 and federal, state and local regulations. Under roadways and shoulders of roadways, provide a minimum depth of 4 feet (1.2m).

9-4.2 Parallel and Crossing Pipes.

Provide a minimum clearance of 12 inches (300 mm) between the outer wall of any buried POL pipe and the extremity of any underground structure including other underground pipe. Where pipelines cross and a minimum clearance of 12 inches (300 mm) cannot be achieved, provide an insulating mat between the pipes and centered vertically and on the point of intersection. Insulating mat must be constructed of neoprene or butyl rubber and must be 36 inch (900 mm) by 36 inch (900 mm) and 1/8 inch (3 mm) thick. Provide a test station with two test leads from each pipe. See UFC 3-570-01, Electrical Engineering Cathodic Protection for more information. Where non-government and government owned pipe cross or are in proximity of less than 150 feet, contact owner of non-government pipe for coordination to prevent/mitigate cathodic protection interference. In areas where multiple utilities are routed in the same area (e.g., a utility corridor), make sure electrical and communication ducts/conduits are kept a minimum of 36 inches (900 mm) from all other underground utilities especially fuel, steam, and high-temperature water pipes. Refer to IEEE C2, ASME B31.4, and 49 CFR Part 195 for additional requirements. For pipes in concrete trenches, provide a minimum clearance of 6 inches (150 mm) between flanges and the trench wall and between adjacent flanges. If there are no flanges, provide a minimum clearance of 12 inches (300 mm) or one pipe diameter (based on largest pipe), whichever is greater, between the pipe and the trench wall and between adjacent pipes within the concrete trench.

9-4.3 Casing Sleeves.

The use of casings on underground pipelines is highly discouraged due to increase problems with pipe corrosion and inability to provide cathodic protection to the pipe in the sleeve. Use steel casing sleeves only for those crossings where sleeves are required by authorities having jurisdiction (i.e.: Airfield Managers), or where it is necessary to place stainless steel lines under the roadway or railroad tracks while avoiding interference with traffic. Consider installing carbon steel and stainless steel pipelines under roadways by the traditional trenching method, or use alternative trenchless pipe construction methods for carbon steel pipelines to avoid the need for a casing. Do not use directional drilling for stainless steel lines. When using alternative trenchless methods for carbon steel lines, provide supplemental abrasion resistant coatings applied in addition to the fusion bonded epoxy exterior pipe coating. When required to construct open trench cased crossings, consider the economics of installing spare casing sleeves to eliminate excavating for future fuel lines. Ensure that the casing design electrically isolates fuel-carrying pipes from contact with the casing pipes. Require a seal of the annular space at each end of the casing and spacers properly spaced in the casing, and within 12-inches of casing ends. Include a vent on the higher end of each casing and a low point drain on the lower end of the casing. Locate crossings at a minimum depth of 36 inches (900 mm) beneath the bottom of drainage ditches. If this depth cannot be obtained, install above, but not in contact with, the casing or pipe, a 6-inch (150 mm) thick reinforced concrete slab of adequate length and width to protect the casing or pipe from damage by equipment such as ditch graders and mowers. In areas with high normal or seasonal groundwater tables consider the use of a water excluding casing fill material. Refer to API RP 1102 for additional information on the use of casings. Provide cathodic protection test leads to the pipe and casing to monitor for electrical isolation.

9-4.4 Line Markers.

Except where prohibited by national security considerations, install line markers over each buried line and allow for maintenance provisions in accordance with 49 CFR Part 195.

9-4.5 Warning Tapes.

Provide buried warning tape for all underground pipelines as required by the appropriate guide specification.

9-4.6 Thermal Relief Valves.

The isolation valves installed in underground piping are generally located aboveground or underground in valve pits. Because these segments of underground piping are open to the atmosphere, they are subjected to the effects of atmospheric temperature changes and therefore, require thermal relief. Provide any section of underground piping that can be isolated by a shut-off valve (or other means) with a thermal relief valve to relieve the isolated piping section. Provide also a thermal relief of the internal cavity of valves where pressure is trapped when the valve is in the closed position (double block and bleed plug valves for example). Refer to Paragraph 9-3.5 for more details on materials, discharge, and operation of thermal relief valves.

9-4.7 Double Wall Piping.

Provide double wall piping for Ground Vehicle Fueling Facilities and any other small diameter (< 4 inches (100 mm)) underground pipe installations. For other applications (pipes ≥ 4 inches (100 mm)) in diameter do not use double wall piping unless required by state or local regulations, and approved by Service Headquarters. Service Headquarters approval to use large diameter (≥ 4 inches (100 mm)) double wall pipe must be obtained at the programming level and at the 35 percent design level. Low point drains and high point vents associated with large diameter piping systems must not be double-walled, unless required by state or local regulations, and approved by Service Headquarters. Use of FRP piping as part of double wall piping (or as single wall) is discouraged because of issues with underground joints and requires Service Headquarters approval.

9-4.8 Single Wall Piping Leak Detection Systems.

For all single wall buried pipe not used in aircraft direct fueling systems, consider providing a leak detection system similar to leak detection for aircraft direct fueling systems when approved by Service Headquarters. Do not use cable type leak detection systems for single wall piping unless required by state and local regulations.

9-4.8.1 Leak Detection for Aircraft Direct Fueling Systems.

For aircraft direct fueling systems, provide an automatic leak detection system approved by Service Headquarters, to test all buried portions of the piping system. Automatic leak detection systems measure changes in either the volume or pressure of the fuel in a fixed piping system, while accounting for variations in ambient temperature. The pressure type leak detection system works by measuring the time rate of change of line pressure at two different pressures. The volume type leak detection system works by measuring the amount of fuel required to maintain a constant pressure in a line, also at two different pressures. The system must detect leaks as required by regulations or as listed with the National Work Group on Leak Detection Evaluations (NWGLDE).

9-4.9 Double Wall Piping Leak Detection Systems for Ground Vehicle Fueling Facilities.

For all underground double wall pipe used in ground vehicle fueling facilities, provide automatic line leak detector systems that continuously and automatically monitor piping for leaks. Automatic line leak detector systems are to be provided for pressurized piping only. Detector must detect a minimum leak rate of 3 gallons per hour (0.003 L/s) at 10 psig (69 kPa) line pressure within 1 hour. Detector must detect leaks against a minimum 6 feet (1.8 m) of head pressure. Detector must detect leaks from any portion of the underground product piping. In conjunction with the automatic line leak detector system, the use of double wall piping and a continuous monitoring/alarm system must be considered. Slope double wall piping from containment sump to dispenser sump and provide leak sensors for immediate notification of piping failure. Do not use cable type leak detection systems for double wall piping unless required by state and local regulations.

9-4.10 Double Wall Piping Leak Detection Systems for Non-Ground Vehicle Fueling Facilities.

For leak detection of double wall piping at locations other than the ground vehicle fueling facilities, contact Service Headquarters for direction.

9-4.11 Service Pits.

Grading around service pits (hydrant pits, isolation valve pits, low point drain pits, high point vent pits, transition sumps, etc.) must be designed to prevent water intrusion into the pits. The pits and pit lids must be designed and constructed to be liquid tight. Concrete pits must be constructed in accordance with ACI-350. Where required by federal, state, and/or local regulations, provide leak detection systems within service pits.

9-5 UNDERWATER PIPING.

To receive fuel from offshore moorings, provide one or more underwater pipelines from the shore facility to the mooring. Limit the design of these systems to engineers with this type of experience. Coordinate offshore piping systems with Naval Facilities Engineering and Expeditionary Warfare Center, Oceans Technical Department (NAVFAC EXWC, OC).

9-5.1 Special Arrangements.

At the mooring end of each pipeline, provide lengths of submarine fuel hose equal to 2.5 times the depth at high water. At the pipe end of the hose, provide a flanged removable section of hose 10 feet (3 m) long. At the free end of the hose, provide a steel valve with a marker buoy attached to a cable or chain which has sufficient strength and suitable fittings for the vessel to lift the hose and valve aboard.

9-5.2 Connections.

Lay out multiple fuel lines and connections so that they correspond to the layout of the ship’s discharge manifold.

9-5.3 Unique Considerations.

In piping design, consider fuel characteristics as they may be affected by the sea water temperature, particularly in cold water. For diesel fuel, aviation turbine fuel, or other light fuels, small individual lines are preferable as follows:

a. Minimum nominal pipe size of 6 inches (150 mm).

b. For transfers of fuels exceeding 3,000 gpm (189 L/s), use 12-inch (300 mm) to 16-inch (400 mm) diameter pipe.

c. Instead of pipes larger than 16 inches (400 mm) in diameter, consider using two smaller diameter pipes.

d. At an accessible upland location, as close to the water entry as practical, provide a double block and bleed valve and a manually operated check valve or bypass to allow reversal of flow when required.

e. Provide a dependable means of communication between the vessel in the offshore berth and the shore facility.

9-5.4 Corrosion Protection.

Wrap, coat, and cathodically protect underwater pipelines in accordance with Chapter 2 of this UFC.

9-5.5 Depth of Burial.

Provide sufficient burial depth of underwater pipelines to prevent damage by dredging of the waterway, by ships' anchors, trawls, or by scouring action of the current. Specifically, ensure depth conforms to the requirements of 49 CFR Part 195. Where lines cross ship channels or anchorages, ensure the top of the pipe is at least 12 feet (3.7 m) below the theoretical, present or planned future bottom elevation, whichever is deeper. Recommended backfill in such areas is 2 feet (0.6 m) of gravel directly over the pipe, followed by stones weighing 50 to 60 pounds (23 kg to 27 kg) up to the bottom elevation.

9-5.6 Pipe Thickness and Weight.

Provide sufficient pipe wall thickness to keep stresses due to maximum operating pressure and other design loads within design limits. Include full consideration to extra stresses which may occur in laying the pipe. It is common practice to use heavier wall pipe for water crossings of more than 200 feet (60 m) from bank to bank at normal water level. This affords greater stiffness and resistance to buckling during handling of the assembled crossing pipe and requires less weighting material to obtain the necessary negative buoyancy to keep the line in place while empty or containing a light product. Reinforced sprayed-on concrete is an acceptable weighting material. Use of "river weights" is discouraged. Hydrostatically test assembled crossing pipe before placing, unless crossing pipe is too long for prior assembly in one segment. In this case, separately test each segment as described.

9-6 PIPING MATERIALS.

9-6.1 Non-Aviation Systems.

Use carbon steel piping material for interterminal pipelines (regardless of product) and for all portions of non-aviation turbine fuel systems. FRP is not to be used in aviation turbine fuel system applications. The appropriate Unified Federal Guide Specification (UFGS) includes the necessary requirements. See Facility Plate 019.

9-6.2 Aviation Systems.

New aviation turbine fuel systems must use stainless steel issue piping downstream of the last issue filter-separator all the way to the final hose or hard piped aircraft or refueler nozzle connection. Interior coated carbon steel may be used downstream of the last issue filter-separator only with the approval of the Service Headquarters. Return piping must be interior coated carbon steel, unless stated otherwise. Return piping on Navy/Marine Corps systems must be stainless steel, unless authorized by Service Headquarters. Give special consideration to the pressure rating of both the pipe and fittings to ensure adequacy to accommodate surge pressure. See Facility Plate 019 for piping material options.

9-7 WELDING CRITERIA.

Ensure that the contract requires welding and welding inspections in accordance with appropriate guide specifications and/or standard design. Proper welding, done in accordance with the guide specifications, will prevent loose and adhered slag on the inside of the pipeline. Use 100 percent radiographed weld joints meeting the standards for severe cyclic service contained in ASME B31.3 for piping downstream of the pump in hydrant systems. For all other underground steel pipes, use 100 percent radiographed weld joints meeting the requirements of ASME B31.3. Use of alternates to radiography must be approved by Service Headquarters and should be considered where radiography is prohibited or impractical (off shore). If used, Phase Array UT (PAUT) with permanent digital recording/record must be used.

9-8 PIPING CONNECTIONS.

a. For steel piping systems, use weld neck forged flanges with raised faces having a modified spiral serrated gasket surface finish, except for piping 2-inch (50 mm) and less located in contained pumphouses, contained truck offloads, contained truck fillstands, and other visibly contained areas, where socket weld flanges may be used. Slip-on flanges are not permitted in new systems. Use of slip on flanges may be considered in connections between new and existing systems/components only when dimensional factors prevent the effective use of weld neck flanges. Use flat face flange and gasket only when connecting to flat face system component flange, such as aluminum vessels and some pump flanges.

b. Do not use cast iron flanges.

c. Do not use grooved pipe type couplings or similar fittings in permanent fixed piping systems.

d. Do not direct bury flanges, valves, mechanical couplings, threaded fittings, or any mechanical system component. If they must be used in an underground system, enclose them in an accessible pit.

e. Use welded connections for joining steel pipe. Use flange connections for joining pipe to system components. Use threaded connections only where unavoidable such as on differential pressure gauges, pressure snubbers, and fuel sample connections. Do not back weld threaded piping.

f. Use carbon steel bolts, studs, and nuts with carbon steel flanges. Use stainless steel bolts, studs, and nuts with stainless steel flanges. Stainless steel bolts may be used on carbon steel flanges in corrosive environments. Select stainless steel bolts, studs, and nuts based on seizing and elongation. Coordinate both strength with force needed to compress selected gasket. In locations where severe corrosion (typically chloride laden salt air) on carbon steel piping is susceptible use flange protectors and bolt seals (caps), filled with non-expansive grease preservative, as required to prevent and control corrosion.

g. In steel piping systems, use socket weld joints on 2-inch (50 mm) diameter nominal size and smaller pipe, except underground low point drains must be butt welded only.

h. Make branch connections with butt welded tees except where the branch is at least two pipe sizes smaller than the run, in which case the branch connection can be made with a forged or seamless branch outlet fitting. The branch outlet fitting must be designed in such a way that the connection can be radiographed. The branch outlet fittings may be a non-radiographicable if: the piping it is connected to is aboveground, the branch outlet size is 2.5-inches or less in diameter, and the branch outlet is located either in a pumphouse or on a system component pad equipped with containment curb.

i. Do not use wrinkle bends or mitered bends for changes in direction.

j. Except for unions and control tubing couplings, do not use threaded joints in stainless steel systems. Socket weld stainless steel drain, vent, and thermal relief valve lines 2-inch (50 mm) in diameter or less. If aboveground, flanges may be used.

k. Provide over-voltage protection (OVP) devices for all above grade flanges with insulating flange kits. Provide insulating flange kits elsewhere where electrical isolation is needed as specifically required by DoD Standard Designs, such as in hydrant pits.

l. Provide insulating flange kits at locations required for the proper performance of cathodic protection systems on underground piping. This is to include insulating gaskets, bolt sleeves and washers of compatible materials, matching the flange types and ratings. Attention must be given to electrically isolating alternate ground paths such as thermal relief lines, instruments and conduit brackets. Insulating sleeves must pass through all bolt washers and OVP brackets. Washers must be assembled in the proper sequence and bolts tightened to recommended torque.

9-9 INTERIOR PIPE COATINGS.

To protect aviation fuel quality and extend the life of the piping, minimize bare carbon steel piping (except interterminal pipeline) which comes in contact with aviation turbine fuels especially downstream of initial filtration system components. Maximize the use of internally coated pipe. This is not intended to allow the use of lined carbon steel piping as a substitute for areas requiring non-ferrous piping. Comply with other paragraphs of this chapter for material selection. Interior pipe coating is not required on non-aviation piping except for carbon steel piping that connects to the tank within the lower 36 inches (900 mm) of aboveground vertical storage tanks, and ballast lines on piers.

9-10 EXTERIOR PIPE COATINGS.

a. Protect the exterior surfaces of all aboveground and underground steel piping systems in accordance with applicable service requirement.

b. For coating of underwater piping, coordinate with Naval Facilities Engineering and Expeditionary Warfare Center, Oceans Technical Department (NAVFAC EXWC, OC).

9-11 SAMPLING FACILITIES.

Provide connections for sampling fuels on each section of a fuel transfer piping system. Install sampling and testing connections at receiving points, tank outlets, inlet and outlet sides of filter-separators, all fuel dispensing points, and between isolation valves so that the remaining fuel in each portion of a fuel transfer pipeline can be sampled. Where possible, install sampling connections in vertical runs. Provide a sample point with a probe, ball valve, and quick disconnect with dust cap.

CHAPTER 10 ALTERNATE POL FACILITIES

10-1 INTORDUCTION.

This chapter provides guidance for design of alternate POL facilities. The alternate fuels discussed are: LPG, CNG, hydrazine, and OTTO fuel. This chapter contains information on products which are unique. Therefore, some special considerations are discussed, in addition to information provided in Chapter 2, General Design Information, which contains important information on fueling facilities. Do not start the design of any fueling system without first becoming completely familiar with Chapter 2 of this UFC.

10-2 LIQUEFIED PETROLEUM GAS (LPG).

10-2.1 Uses.

The uses for which LPG fuel is procured and the methods of transportation of the fuel are as follows:

a. LPG fuel is used for general heating, metal cutting and brazing, and in laboratories. LPG is procured in cylinders or for bulk storage by tank car or tank truck. Cylinders usually contain 100 pounds (45 kg) of gas, in a liquid state.

b. Fuel supply for firefighting trainers and crash and rescue training facilities.

c. Where economically justified, LPG facilities supplement utility-supplied gas systems for meeting peak loads and as a standby where interruption to a supply is possible.

    1. Standby LPG facilities serving large capacity system components, such as boilers of 200,000 British thermal units (Btu's) per hour (58 000 W) and above, may consist of a separate gas system to an alternate set of burners on the system components.

    2. For a gas system serving multiple small appliances, provide the standby equipment with means for air mixing to dilute the LPG with the proper amount of air to match combustion characteristics of either natural or manufactured gas serving the system in place of the utility-supplied gas, or in conjunction with it to reduce utility peak loads.

10-2.2 General Design Considerations.

LPG is odorless, colorless, non-toxic, heavier than air, and explosive. To permit easier leak detection, an artificial odor may be introduced when shipped from a refinery. Under standard atmospheric conditions, LPG is in a vapor phase, but it is liquefied under moderate pressure for shipping and storage. The maximum vapor pressure for LPG design is 215 psig (1480 kPa) at 100 degrees F (38 degrees C). All LPG purchased by the military should emit a distinct odor at a concentration required by NFPA 58. See Facility Plates 024, 025, 026 and 027.

10-2.2.1 Fire Hazards.

In the vapor phase, LPG is a hazard comparable to flammable natural or manufactured gas. The explosive range is 2.16 to 9.6 percent by volume of air-gas mixture.

a. Provide ventilation in accordance with NFPA 58.

b. In the liquid phase, LPG is a highly volatile, flammable liquid. Because of rapid vaporization, an LPG fire is basically a gas fire. Therefore, in the event of a fire, provide means to automatically shut off the LPG supply feeding the fire.

c. Provide emergency shut-off consisting of the combination of three modes: manual shut-off, remote shut-off, and thermal shut-off. Remote shut-off normally consists of a nitrogen system with plastic tubing at the controlled point so that the pressure holds open the valve. The plastic tubing acts as a fusible link. Provide a cable release shut-off with remote shut-off for combination shut-off. Refer to UFC 4-179-01 and API Std 2510.

d. Provide leak detection in accordance with NFPA 59.

e. For LPG system component located inside buildings where there is a potential for loss of LPG, provide an alarm/detection system with local and remote alarms (audible and visual), high and low ventilation, doors with panic hardware, a leak detector readout with the readout outside, and a leak detector kit located outside.

10-2.2.2 Refrigerating Effects.

At normal atmospheric pressure, the boiling point of propane is -45 degrees F (-43 degrees C). Propane in a liquid state and open to the atmosphere will evaporate (not boil).

a. Provide means to address operational concerns as described in the following paragraph. When LPG is expanded through a regulator from its vapor pressure to normal service pressures, the cooling effect may freeze the regulator if water is present in the LPG. Freeze-up can also occur on system components which accumulates water such as strainers and control valves. The freezing effect can also result in exterior ice formations which disrupts the valve operator. Freeze-ups can be avoided by cleaning and nitrogen-purging the system.

b. Although it is dehydrated at the refinery, provide a means to keep LPG dry.

c. In flashing to vapor from the liquid phase, the refrigerating effect can be severe if an abrupt pressure drop occurs. Therefore, design a system which provides means to avoid this problem.

10-2.2.3 Design Standards.

Use the following references for general design and safety standards for all LPG facilities. (Follow particular sections of standards applicable to types of facilities. Where conflicts occur, use the more stringent requirements.) Appropriate standards are as follows:

a) Factory Mutual Engineering Corp. (FM), Loss Prevention Data, Liquid Petroleum Gas, Section 7-55.

b) NFPA 54, NFPA 58, and NFPA 59.

c) API Std 2510.

d) Gas Processors Association Standard 2140.

e) Commercial Item Description A-A-59666, Sections ICC 4BW, ICC 4E, and ICC 4BA.

f) UFC 4-179-01.

10-2.3 Receiving Facilities.

10-2.3.1 General Design Considerations.

LPG may be received by truck, rail, or water for either cylinder (bottled gas) or bulk systems.

10-2.3.2 Transfer Methods.

\3 Design the facility to accommodate one of the following transfer methods: ***/3/***

a. No pumping or pressurizing facilities are required for small bulk systems utilizing truck delivery. Use pumping system components provided on trucks instead of stationary pumps.

b. Provide LPG vapor piping, pumps, and compressors for off-loading tank cars or waterborne LPG tanks to operate, as follows:

    1. Provide compressor and piping to take suction from the vapor space of the storage tanks to be filled through an equalizing line and pressurize the tank to be off-loaded. This forces the LPG out through the liquid off-loading line into the storage tank.

    2. Arrange the piping so that after all liquid has been evacuated, the compressor suction can be reversed to pump the LPG gas from the delivery tank to the storage tank through a subsurface dip tube.

    3. Provide connections and valving to allow bleeding of the liquid propane from the connection after shutting off the valve at both the

hose end and at the off-loading piping. This is done after off-loading the liquid from either a transport truck or a tank car. Provide a bleed attachment built into the off-loading system components for this purpose.

4. See Facility Plates 024, 025, 026 and 027 for typical installation. Provide liquid pumps as standbys for compressors.

c. Provide the transfer point from trucks or tank cars with a substantial concrete bulkhead. Anchor the piping in the bulkhead. Do not use pipe sleeves. Provide with the bulkhead hose or swivel-type piping connections. The bulkhead provides a breakaway point if the truck or tank car moves away without first disconnecting the hoses. Also provide emergency shut-off and excess flow valves. Refer to NFPA 58 and UFC 4-179-01 for additional information.

10-2.3.3 Flow Rates.

Use the following flow rates:

a. Provide flow rates commensurate with the storage capacity and the size of pumps, compressors, and loading devices.

b. Provide flow rates that allow operators adequate time to shut down facilities before tanks or trucks are filled beyond maximum allowable. Limit flow rates from tanks by setting excess flow valves.

c. Provide off-loading lines with manually operated throttle valves so operators can adjust flow rates to points below shut-off settings of excess flow valves.

10-2.4 Storage Facilities.

10-2.4.1 Types of Storage.

Types of storage facilities include cylinders or bulk storage tanks.

a. Provide cylinders or containers conforming to ASME and/or DOT criteria as described in guide specifications. Used tanks are not allowed. The number of cylinders at a facility depends on the maximum required flow rate and the vaporization rate per cylinder at the minimum operating temperatures.

b. Provide bulk storage tanks as follows:

1. For storage tanks up to 30,000 gallons (114,000 L) capacity, use horizontal steel tanks.

2. For storage tanks above 30,000 gallons (114,000 L) capacity, use spherical or spheroidal steel tanks.

3. Do not use underground tanks for LPG.

10-2.4.2 Number and Size of Bulk Tanks.

Storage capacity depends on requirements, frequency of deliveries, and dependability of supply. Consider a multi-tank system for more dependability.

10-2.4.3 Design Requirements.

Design requirements are as follows:

a. Tanks and tank appurtenances require conformance with NFPA 58 and API Std 2510. Design LPG tanks for a minimum working pressure of 250 psig (1700 kPa).

b. Tank spacing requires conformance with UFC 4-179-01 and FM criteria. See Facility Plates 026 and 027.

c. Provide sufficient flexibility in piping connections to tanks to allow for differential settlement of tank and system components.

d. Provide cathodic protection in accordance with Chapter 2 of this UFC.

e. If using compressor transfer systems, fit tanks with dip pipes a minimum of 3/4 inches (20 mm) diameter, and gas inlet lines from compressors, so that gas pumped into storage tanks from empty delivery vessels is bubbled through liquid LPG to prevent overpressuring tanks.

f. Provide float-actuated high-level alarms set at maximum permissible filling level of 80 percent on all tanks of 3,000 gallon (11,000 L) capacity and above.

g. If using installed transfer systems, provide pressure switches on tanks set to open at pressures 5 psig (35 kPa) below set pressures of safety valves to stop compressor pumps transferring LPG to tanks.

h. Ensure that tanks are ASME coded and have the ASME national registration number.

i. Size storage tanks for 120 percent of required storage volume.

j. Electrically ground all storage tanks.

10-2.4.4 Inspections, Testing, and Certifications

Inspect, test, and certify all new unfired pressure vessels prior to placing into operation. Do not operate the unfired pressure vessel (UPV) without a valid certificate. Perform the following tests on the UPV:

a. A general UPV site inspection

b. An external UPV inspection

c. An internal UPV inspection

d. A hydrostatic test (strength and tightness tests)

e. An operational test

The inspector must be registered by the National Board of Boiler and Pressure Vessel Inspectors (NBBI) and must possess a Certificate of Competency and a NBBI National Board Inspection Code (NBIC) Commission. Upon completion and passing of the inspections and tests, the tank will be certified. Post a current, valid certificate on or near the UPV under a protective coating.

10-2.5 Distribution Facilities.

See Facility Plates 024, 025, 026 and 027.

10-2.5.1 General Design Considerations.

The following distribution system requirements apply to the transfer of both the gas and liquid phases of LPG:

a. Lay all distribution piping underground when practicable.

b. Provide the required flow rates.

c. Install electrical system components in accordance NFPA 70 and API RP 500. Use only system components approved for each classified area. Ensure electrical design conforms to API RP 540.

d. Ground and bond all piping, tanks, and system components in accordance with API RP 2003, API Std 2510, API RP 540, and NFPA 70.

e. Refer to Chapter 2 of this UFC for corrosion protection requirements of underground pipe.

10-2.5.2 Piping Materials.

Provide pipe, valves, and fittings in accordance with applicable sections of API Std 2510. Use Schedule 80 welded carbon steel. Threaded connections are only allowed for valves and system components. Provide design characteristics and features for gas and liquid pipelines in accordance with Chapter 9 of this UFC. The minimum design pressure for liquid LPG piping is 350 psig (2400 kPa) as required by NFPA 58. Use Class 300 ANSI flanges as a minimum.

10-2.5.3 Accessories.

a. Provide totalizing-type meters, pressure gauges, thermometers, strainers, and surge suppressors.

b. Ensure that meters are turbine-type with pressure and temperature compensation and have electronic/digital readout capability.

c. Install meters, if required, in accordance with requirements of API MPMS Chapter 5.

d. Provide pressure gauges of suitable range on all tanks, on suction and discharge of pumps and compressors, on inlet and outlet of vaporizers and on downstream of throttle valves.

e. Provide thermometers on all tanks, in all transfer lines for both liquid and gas, and on inlet and outlet of vaporizers.

f. Provide strainers in compressor suctions, upstream of meters and control valves.

g. Provide surge suppressors on liquid lines, if required.

h. Provide knock-out drums or scrubbers of suitable capacities in suction lines of compressors to remove entrained liquid. Provide drums with high level, shut-down devices, automatic liquid drainers, glass gauges, and drains.

i. Ensure all valves are UL listed or FM approved for LPG service. At a minimum, use Class 300 valves.

j. Provide equipment to inject alcohol into the LPG off-loading line. Provide equipment capable of injecting alcohol at a rate of 1:800 alcohol to LPG by volume.

10-2.5.4 Pumps and Compressors.

Design and install pumps and compressors in accordance with API Std 2510 and NFPA 58.

10-2.5.5 Vaporizers.

Provide vaporizing system component for distribution facilities as follows:

a. Provide vaporizers at locations where liquid temperatures are too low to produce sufficient vapor pressure to meet the maximum required flow rate.

b. Use vaporizers that are indirect fired-type utilizing steam or hot water as a heating medium or direct fire waterbath-type.

c. Size vaporizers to provide at least 125 percent of expected peak load.

d. Design and install vaporizers in accordance with NFPA 58.

e. Use waterbath vaporizers approved by Factory Mutual.

f. Space waterbath vaporizers in accordance with FM Section 7-55, except provide a minimum of 75 feet (23 m) between truck off-load stations and tank storage. Where space is limited, provide a blast wall at the truck off-load stations.

g. When using waterbath vaporizers, provide fire-safe fusible link shut-off valves in LPG supply piping at the vaporizers. Provide remote shut-off capability and 24-hour remote monitoring.

h. When using waterbath vaporizers, provide an automatic excess flow/emergency shut-off valves in LPG supply lines to vaporizers. Use a hydraulically operated diaphragm control valve and locate at tank storage.

10-2.5.6 Controls.

Provide the following controls.

a. Use pumps and/or compressors that can be started and stopped by manual pushbutton.

b. Provide automatic limit switches as follows:

   1. Pressure switches on storage tanks set 5 psig (35 kPa) below relief valve settings.

   2. Liquid level switches on storage tanks set at maximum filling levels.

   3. Liquid level switches on knock-out drums set to shut off compressor at high liquid levels.

   4. High pressure switches in compressor discharges to shut off compressor at safe pressure levels.

c. Provide manually operated throttle valves in liquid off-loading lines to adjust flow rates below excess flow valve settings on delivery tanks.

d. Provide a sight flow indicator in liquid lines near throttle valves.

e. Provide automatic temperature, pressure, and limit controls on vaporizers in accordance with NFPA 58.

10-2.6 Air Mixing Facilities.

10-2.6.1 Pressure Controls.

Provide pressure control valves in both air and gas lines to air mixing system component. Provide a low pressure alarm in both lines to shut-off air and gas in the event of low pressure.

10-2.6.2 Volumetric Controls.

Provide volumetric controls at all distribution facilities as follows:

a. Provide displacement-type or flow-type meters in both air and gas lines to maintain a proportional flow of air and gas.

b. Use a venturi-type proportioner where the variation in demand flow rate does not exceed the limited range of the venturi proportioner. Where the demand flow rate varies excessively, use a venturi-type proportioner in conjunction with a downstream storage tank, if economically justified. The storage tank will permit a varying rate of flow to the system while being filled continually or intermittently at a constant rate of flow through the proportioner.

10-2.6.3 Specific Gravity Indication.

Provide a specific gravity indicator and recorder with high and low-limit switches to sound an alarm if the variation of specific gravity of an air-gas mixture exceeds acceptable limits of the system. For air mixing systems using LPG with a propane content of 90 percent and above, the specific gravity of the air-gas mixture is a sufficiently accurate index of its Btu or joule (J) content, so calorimetric controls and indication are not required.

10-2.6.4 Calorimetric Controls.

Where economically justified, provide an automatic calorimeter to indicate and record the Btu or J content of the air-gas mixture. Provide high- and low-limit switches to calorimeter to sound an alarm if the variation of Btu content exceeds acceptable limits of the system.

10-3 COMPRESSED NATURAL GAS (CNG).

Design CNG storage and dispensing facilities to comply with NFPA 52 and appropriate sections of NFPA 55.

10-3.1 Uses.

CNG is primarily used as an alternative fuel in light duty vehicles although it and its cryogenic counterpart liquid natural gas are gaining acceptance in heavy duty applications. Energy policy has mandated with certain reservations that by fiscal year 2000 and thereafter, 75 percent of the light-duty vehicles purchased by the government will use alternative fuels. Therefore, there will be a significant increase in alternative fuel consumption.

10-3.2 General Design Considerations.

10-3.2.1 System Sizing.

To size the system, determine the total daily fuel consumption of base liquid natural gas vehicles. Based on daily miles driven, determine the number to be refueled each day. The number of vehicles refueled during surges limits the capacity of most fast fill (3 to 6 minutes) operations. Scheduling vehicles to refuel through the day will effectively increase system capacity. Use a computer program to size the system because manual calculations usually result in larger systems than needed. Refer to the Gas Technology Institute GTI-02/0136 in the References section of this UFC for ordering information of one possible program. Use the latest version.

10-3.2.2 Future Requirements.

Anticipate future requirements when sizing the system but normally limit the project to 100 to 150 standard cubic feet per minute (scfm) (47 to 71 L/s). If additional capability will be needed in the future, plan a second system later or consider other options such as slow fill systems for overnight fueling. This will provide redundancy and reduce initial cost. Usually, surge requirements drive machine size and can be controlled by management actions. Additionally, boosters operating from system pressure or special control systems may increase surge handling capacity (e.g., 25 to 30 percent of the gas in a cascade system is available for fast fill operations. A booster or special control system can increase it to 60 percent.) The combination of these actions could delay installing a second system many years at most installations.

10-3.2.3 Pressures.

Most vehicle conversions use 3,000 psig (21 000 kPa) storage systems while original system component manufacturers use 3,600 psig (25 000 kPa) systems. The compressors should operate up to 5,000 psig (35 000 kPa) to refuel at either pressure.

10-3.2.4 Connections.

Design the systems to be skid-mounted with compressor system, cascade storage, and controls. Limit field tie-ins to connecting electricity and high and low pressure gas.

10-3.2.5 Compressors.

Use crosshead guide type compressors for CNG service. Although more expensive, the design life of these units is significantly longer. Another option is a conventional style compressor designed specifically for CNG service. Do not use modified air compressors. Choose the type compressor after comparing maintenance and reliability data. Test all compressors at the factory with natural gas before shipping.

10-3.2.6 Compressor Drives.

Use either electric or engine-driven compressor drives. Gas engine drives are less expensive to operate, but maintenance costs are higher. Use a life cycle cost analysis to determine which compressor drive is best. Although an engine-driven compressor is more expensive than an electric motor, electrical upgrade costs may be reduced. It also may be able to operate during power outages.

10-3.2.7 Compressor Inlet Pressure.

Suction pressure is a key factor in selecting a compressor. Use high pressure gas mains to reduce both initial and operating costs. Avoid pressures less than 20 psig (140 kPa). If high and low pressure lines are near each other and the pressure differential is at least 150 psig (1030 kPa), 250 psig (1720 kPa) is preferred, and the low pressure line has a continuous load, a system can be installed and powered by the differential pressure. Such systems are extremely effective and have low initial and operating costs. Where a high pressure differential exists, another option is a turbine to drive the compressor.

10-3.2.8 Storage.

Install a cascade system using ASME vessels; either tubes or spheres. Avoid banks of DOT cylinders since they must be inspected every 5 years.

10-3.2.9 Controls.

Use either pneumatic or electronic controls depending on local practices. Electronic controls are preferred in most areas because they provide more accurate compensation for temperature effects. Pneumatic controls are simpler, but do not fill tanks to their limits. Normally, this is not a problem, since base vehicles do not normally operate to their maximum range in one day. Since vehicle tank pressures are rated at 70 degrees F (21 degrees C), tanks will fill to a higher pressure when outside temperatures are warmer and to a lower pressure when temperatures are cooler.

10-3.2.10 Dispensers.

Although more expensive, provide conventional rather than post style dispensers. To reduce installation costs, use dispensers with the electronics internally mounted and calibrated at the factory. A dispenser makes CNG refueling similar to conventional refueling. Depending on funds, a post style dispenser is an option.

10-3.2.11 Nozzles.

Use the industry standard nozzle. It comes in three pressure ranges: 2,400 psig (16 500 kPa), 3,000 psig (21 000 kPa), and 3,600 psig (25 000 kPa). These nozzles are designed so that a fill system cannot connect to a vehicle tank with a lower pressure rating, yet it can connect to vehicle tanks with higher ratings.

10-3.2.12 Environmental Considerations.

a. The compressor unit’s receiver is usually blown-down automatically, releasing about 0.06 gallons (0.2 L) of oil to the base and subsequently the ground. Discharges from other components, such as intercoolers, add to the contamination. Therefore, drip gutters with drains are required at each corner of the base. Develop a means of collection and retention of these wastes. Deactivating the automatic dump features and manually draining is an alternative to a collection system.

b. Provide gas recovery system as part of the compressor package to recover gas into an ASME recapture tank when off-loading the compressor.

c. At the dispenser, provide a vent 8 feet (2.4 m) to 10 feet (3 m) above ground level to discharge vent gas from dispenser hoses. Oversize the conduit from the dispenser to the cascade for a vent line to a future gas recovery system.

d. Locate units with care because of noise. Use landscaping to conceal units and attenuate the sound.

e. Natural gas engine drives, if used, may require an air emissions permit.

10-3.2.13 Weather.

As a minimum, protect compressor units from the weather with a canopy. In colder climates, use a heated shelter/enclosure with sound attenuation. Some vendors have enclosures as normal options. Costs vary widely depending on the degree of protection. Enclosures may require ventilation and Class I, Division 1 classified electrical components. They should also be accessible by inspectors and servicing personnel. In lieu of a heated facility/enclosure, crankcase heaters and/or circulating block heaters may be suitable in moderately cold climates.

10-3.2.14 Coatings.

The CNG system component comes factory-painted. Specify special coatings where climatic conditions warrant. Select a color from the base color scheme. Light beige is a practical choice. White is a poor choice since the heat of operation discolors it. Storage containers may have to be painted white with blue letters to meet codes.

10-3.2.15 Water Content.

Water content in natural gas varies with region. Gas in the Southeast United States is usually dry, while gas from West Virginia is very wet. Provide dryers to dry the gas to a pressure (storage pressure) dew point (PDP) at least 10 degrees F (6 degrees C) below the winter design dry bulb temperature.

10-3.2.16 Design Standards.

Design CNG systems to NFPA 52. Use NFPA 54 for the gas supply to the compressor. Use the ASME Boiler and Pressure Vessel Code (BPVC) for cascade storage. Electrical work must conform to NFPA 70. When collocating CNG and gasoline stations, also use NFPA 30A.

10-3.3 Warning.

During peak demand periods, some suppliers mix propane air mixtures with natural gas. When the amount added exceeds 10 percent by volume, the CNG produced from this gas will normally not perform properly in CNG vehicles because propane becomes a permanent liquid in storage tanks. Oxygen sensors can be installed to shut down the station during such periods. Installations with this situation should use dual fuel vehicles.

10-4 HYDRAZINE STORAGE AND SERVICING FACILITIES.

10-4.1 Uses.

A blend of 70 percent hydrazine and 30 percent water, known as H-70 fuel, is used to operate the F-16 emergency power unit (EPU). The F-16 H-70 tank carries 56 pounds (25 kg) of fuel and requires servicing after the fuel has been used. The H-70 tanks are removed from the aircraft when the fuel is depleted below a level specified by the using activity. The tanks are delivered to the servicing facility where any remaining fuel is drained into a closed 55-gallon (210 L) stainless steel drum. The aircraft H-70 tank is filled using a closed system charging unit and is either returned to the aircraft or placed in a handling/storage container for future use. The bulk H-70 storage tank is a 55-gallon (210 L) stainless steel drum containing approximately 51 gallons (190 L) of H-70. Nitrogen gas is used as an inert pressure head in the bulk drum to transfer H-70 to the charging unit. The charging unit is 75 inches (1900 mm) long by 36 inches (900 mm) wide by 92 inches (2340 mm) high and weighs approximately 475 pounds (216 kg). An F-16 tactical wing is expected to use approximately 100 gallons (380 L) of H-70 per 20,000 flight hours with an additional minimum of 150 gallons (570 L) held in reserve to handle deployment/safety stock requirements.

10-4.2 General Design Considerations.

a. H-70 carries the compatibility group designation of Group C.

b. Separate H-70 fuel storage and liquid/gaseous oxygen storage in accordance with AFMAN 91-201. Locate the facility a minimum of 50 feet (15 m) from aboveground explosive storage in accordance with AFMAN 91-201.

c. Locate the facility a minimum of 100 feet (30 m) from public highways; civilian or government living areas; public facilities such as schools, churches, clubs, sewage treatment plants; or rivers, lakes, or streams because of bio-environmental considerations.

d. Segregate the servicing and storage facility from large population concentrations within the confines of a military installation and subject to the criteria stated above.

e. Store 55-gallon (210 L) drums of hydrazine in facilities no less than 80 feet (24 m) apart. The spacing is also subject to the other criteria stated in this chapter. This criterion is limited to ten 55-gallon (210 L) drums and 20 EPU tanks (provided the tanks are stored inside an approved shipping container).

f. Refer to Air Force TO 42B1-1.

10-4.3 Construction Concepts.

Provide the H-70 facility with space for tank servicing, storage, and personnel hygiene.

10-4.3.1 Access.

a. Provide security fencing with a vehicle entrance gate surrounding the facility to restrict access.

b. Provide a doorway leading into storage areas to allow for forklift access.

10-4.3.2 Architectural.

a. The total area recommended for the facility is 783 square feet (73 m2) with H-70 and N2 bulk storage occupying 210 square feet (20 m2), a servicing and storage area of 449 square feet (42 m2), and a personnel area of 124 square feet (12 m2).

b. Provide ceiling height of 12 feet (3.7 m) in storage and servicing areas and 8 feet (2.4 m) in personnel areas.

c. Provide hollow, metal, exterior and interior doors with panic hardware and automatic closure. Provide double doors, 6 feet (1.8 m) wide to allow for system component movement. Ensure single doors are standard size.

d. Provide a rack in the servicing and storage area for vertical drum storage (bung side up) to allow for drainage of flush water. Construct storage rack of hydrazine compatible materials such as stainless steel, plastic, or high-density polyethylene (HDPE).

e. Design floors to permit drainage and prevent collection of liquids on any floor surface.

10-4.3.3 Fire Protection Systems.

A wet pipe sprinkler system is recommended. Consider above-ceiling detectors, as well as room detectors. Provide fire extinguishers of a type approved for use in combating hydrocarbon fuel fires in regulated areas. **\1\ /1/** Do not use halogens or CO_2 extinguishers. Refer to Air Forces TO 00-25-172.

10-4.3.4 Spill Containment.

a. Provide spill containment in the H-70 storage area with a capacity equal to the larger of 110 percent of the largest drum present or 10 percent of the total volume present.

b. Spill containment for facilities which store only one or two drums of H-70 can be individual containers for each drum.

c. Provide a diked containment area for facilities which store multiple drums of H-70.

   1. Provide ramps for vehicle access.

   2. Provide a coating or liner for concrete containment areas. Do not allow exposed iron or rebar in the containment area.

10-4.3.5 Floor Drains.

a. Provide a concrete floor in the regulated areas, sloped to floor drains which lead to a containment tank.

b. Provide a floor trench drain 18 inches (450 mm) wide by 6 inches (150 mm) deep by 9 feet (2.7 m) long, covered with an open stainless steel grate in the H-70 fuel tank servicing area. The trench is required to contain any possible H-70 spillage and periodic draining of the H-70 servicing stand. Construct the trench parallel to the wall separating the storage area from the servicing area. Locate the servicing stand so the drain spigot from the scrubber is in-line with the trench drain. A polypropylene or polyethylene elbow connection directly from the drain spigot to the trench drain is required.

c. Ensure emergency shower and eyewash station in the servicing area drain into the containment tank.

d. Ensure industrial sink in the protective system component room drains into the containment tank.

e. Equip drains leading to the containment tank with traps to prevent vapors from contaminating the area.

f. Provide access to the sanitary sewer for both clean change room and shower facilities.

g. Construct floor drains which are subject to carrying H-70 residue of polypropylene or polyethylene.

10-4.3.6 Collection Tank and Piping.

a. Provide a collection tank and piping of materials compatible with hydrazine, water, and neutralizer.

b. Size the collection tank to contain 100 times the maximum quantity of H-70 that could spill with a minimum capacity of 1,000 gallons (4,000 L).

c. Provide piping of 304 stainless steel, HDPE, or to a limited extent, galvanized steel.

d. Provide gaskets of suitable materials such as Viton.

e. Test the system annually with water.

10-4.3.7 Grounding.

In the storage area, provide a ground strap or grounding point system to ground each drum of H-70. Locate the grounding strap around the interior walls of the storage room, 54 inches (1370 mm) above the floor. The grounding system must have a resistance of 25 ohms or less. The facility must also have an approved lightning protection system.

10-4.3.8 Hygiene Support Criteria.

a. Provide lavatory washing facilities in a non-regulated area close to the exit from the regulated area and contiguous to the clean change room.

b. Provide shower facilities for each 10 or less workers.

c. Provide a clean change room. Provide a separate area for the removal of contaminated clothing to prevent the spread of potential contamination from the regulated area.

d. Provide toilet facilities if the H-70 facility is isolated from other buildings where toilet facilities are available.

e. Post signs which state that consumption of food, beverages, cosmetics, tobacco products, and chewing materials are prohibited.

10-4.3.9 Lighting.

Provide lighting intensities of 50 foot-candles (540 lux) in the servicing area and 30 foot-candles (320 lux) in the remainder of the facility. Provide exterior lighting at all entrances and security lighting as required.

10-4.3.10 Safety.

a. Provide vapor sniffers for use in the H-70 fuel drum storage area and servicing area to alert personnel to excessive levels of H-70 fuel vapors. Provide sniffers capable of detecting 10 ppb of H-70.

b. A facility respirator air system is recommended. Breathing air must meet at least the minimum Grade D breathing air requirements of 29 CFR Part 1910.134 and Compressed Gas Association (CGA) Pamphlet G-7.1.

c. Provide an explosion-proof observation window (4 feet (1.2 m) by 4 feet (1.2 m)) between the H-70 fuel drum storage area and the tank servicing area.

d. All lighting fixtures, electrical outlets, and electrical components located within the storage and servicing area should be explosion-proof.

e. Provide emergency shower and eyewash station within sight of and on the same level as locations where direct exposure to H-70 might occur. Pipe eyewash and showers to the H-70 collection tank.

f. Post signs at entrances to all areas. Signs should warn personnel that “H-70 is a cancer suspect agent,” “Authorized Personnel Only,” and “No Smoking.”

g. All tools and system components must be constructed of hydrazine compatible, rust-free, corrosion-resistant materials.

10-4.3.11 Utilities.

a. For electricity, provide 120-VAC, 60-Hz, single phase, three-wire, 20 amperes, duplex convenience outlets in each area of the facility (minimum six outlets). Two-way switching is preferred to control lighting in the H-70 fuel drum storage area from the H-70 fuel tank servicing area. Provide explosion-proof, Class I, Division 2, Group C electrical fixtures.

b. Provide 15 gpm (1.0 L/s) hose bibb water outlets with backflow prevention. Size hose bibb for standard lawn hose connections. Locate the hose bibb to provide water to service stand on the inside of the exterior wall, on the center of the servicing trench, about 2.5 feet (0.8 m) above the finished floor (below the 4-inch (100 mm) pipe sleeve). Water with a reduced pressure-type backflow preventer will also be required for the fire suppression system and potable water systems.

10-4.3.12 Ventilation.

a. Segregate mechanical ventilation for regulated versus non-regulated areas. Exhaust regulated areas through a common manifold. Evaluate the need for an air pollution control system on a case-by-case basis and consider federal, state, or local emissions criteria applicable to the construction location.

b. Design ventilation systems for regulated areas to maintain a negative pressure of 0.05 to 0.1 inches of water (12 to 25 Pa) with respect to adjacent non-regulated areas.

c. Design ventilation for servicing and storage areas to provide a minimum of 20 air changes per hour.

d. Design the ventilation system for automatic shutdown in the event of a fire within the facility.

e. Use flexible exhaust vent of the “elephant trunk” type to exhaust vapors that are released when full hydrazine drums are opened. Design for air flow at the vent nozzle to be approximately 150 cfm (71 L/s). Refer to American Conference of Governmental Industrial Hygienists (ACGIH), Industrial Ventilation: A Manual of Recommended Practice for Design.

f. Place exhaust ports at approximately 18 inches (450 mm) above the floor. To avoid exhausting H-70 vapors into areas where personnel are present, such as walkways or escape paths, consider placing exhaust ports above the roof line.

g. Place a switch on the outside of the building, near an entrance that will allow personnel to turn on all exhaust fans prior to entering the facility. This will purge the facility of any H-70 vapors that may have collected in the facility while not in use.

h. Maintain temperature in regulated areas below 120 degrees F (49 degrees C). Provide environmental controls consistent with ventilation for personnel comfort.

10-4.3.13 Waste Product Disposal.

a. Add water to H-70 spills in a 100 to 1 ratio to reduce the H-70 concentration to less than 1 percent. Size collection tank accordingly.

b. Use neutralizers, such as 65 percent granular calcium hypochlorite (HTH), 14 percent bleach, and 5 percent bleach to stabilize the H-70/water mixture.

c. Provide storage for HTH away from hydrazine and other potentially reactive materials. HTH is extremely corrosive.

d. Consult with local base bio-environmental engineer as to procedures for emptying the collection tank.

10-5 OTTO FUELS.

Information on OTTO fuels is contained in NAVSEA S6340-AA-MMA-010. Distribution of this document is restricted. Requests for information are handled by Naval Sea Systems Command. Refer to Chapter 2 of this UFC for additional information.

CHAPTER 11 SUPPORT FACILITIES

11-1 INTORDUCTION.

This chapter provides design criteria for facilities which may be required to support fueling activities. Specifically, operations buildings, contaminated fuel recovery systems, roads, utilities, and aircraft refueler parking areas are detailed in this chapter.

11-2 OPERATIONS BUILDING.

Review the fueling activity to establish a need for each component of this building. Factors which will affect these reviews are number of people required for fueling activity, level of activity, types of fuels handled, on-site quality control, availability of replacement parts, availability of maintenance support, and level of training required.

11-2.1 Design Standards.

The support facilities must be designed in accordance with UFC 1-200-01, General Requirements. See UFC 3-600-01 for fire protection requirements.

11-2.2 Fuel Office.

Provide a fuel office with sufficient space to perform the necessary planning, administrative, and management functions associated with the accomplishment of the fuel division's mission. Refer to **\2** AFMAN 32-1084 **/2/** for size on Air Force projects.

11-2.3 Training/Conference Room.

Provide a multipurpose room with system components for training, conferences, and briefings. Design this room to accommodate furniture and have built-in features such as markerboard, tack board, book shelves, screen, clock, coat hooks, and storage cabinets.

11-2.4 Fuel Maintenance Workshop.

Provide a fuel maintenance workshop with an adequately sized and convenient work bench with compressed air and electrical outlets available. Provide slip and fuel-resistant floor, emergency shower and eyewash station, and adequate storage space adjacent to the workbench for frequently used tools, spare hardware items and accessories. If facility is large enough and mission warrants, consider overhead crane, laundry facility, and shower facility. Refer to Chapter 2 of this UFC for electrical hazard classification and requirements and NFPA for ventilation requirements.

11-2.5 Storeroom.

Provide an adequate storeroom for spare hoses, nozzles, filtration elements, special tools, special clothing, test equipment, and fuel spill clean-up equipment. Determine size and location of each facility to provide sufficient space for orderly storage and location for ready access to needed material by fuels division personnel.

11-2.6 Laboratory.

\2 Laboratories must comply with the general facility requirements of UFC 4-310-03. DoD Fuels Laboratory Standards and UFC 3-600-01 Fire Protection Engineering for Facilities. **/2/**

11-2.7 System Components for Miscellaneous Safety.

Provide firefighting, fire alarm, and emergency shower and eyewash station system components. Provide emergency shower and eyewash station with tempered water in cold weather climates. Also see applicable service-specific guidelines.

11-2.8 Control Room.

Where computerized control system components are anticipated, provide a control room of adequate size and with a maximum view of outside activities. Allow extra space along the ceiling/wall interface for future installation of security monitors. Consider electrical receptacles and data outlets for future use.

11-2.9 Miscellaneous Spaces.

Provide toilets, shower facilities, lockers, dressing rooms, mechanical room, electrical room, janitor closet, break room, etc. based on the size of the facility and the planned activities. Provide exhaust for locker rooms through the back or top of the lockers.

11-2.10 Communications.

Make provisions for telephone, data transmission, and other planned communications system components.

11-3 ROADS.

Design roads within a fueling facility to accommodate maintenance activities, operations personnel, and fuel delivery and/or issues. In addition, evaluate the roads leading to the facility for their adequacy of width, access, geometrics, and weight restrictions. For vehicle access roads in diked areas around tanks, see Chapter 8 of this UFC. Refer to **\2** UFC 3-201-01 **/2/** and **\2** UFC 3-250-01 **/2/** for design guidance.

11-4 UTILITIES.

In most cases, a fueling facility requires water (domestic and fire protection), sanitary sewer, storm sewer, communications, and electricity.

11-5 AIRCRAFT REFUELER AND FUEL DELIVERY VEHICLE PARKING.

11-5.1 General.

Ensure aircraft refueler and ground fuel delivery vehicle parking areas meet the following criteria at a minimum. For additional design guidance, refer to NAVAIR 00-80T-109 and Air Force TO 00-25-172.

11-5.2 Clearances.

a. Provide a minimum of 25 feet (7.6 m) between the centerlines of adjacent aircraft refueler trucks and ground fuel delivery vehicles when in the parked position or 10 feet (3 m) minimum of clear space between parked trucks, whichever is greater.

b. Provide a minimum of 50 feet (15 m) between aircraft refueler/ground fuel delivery vehicle parking area and the following:

1. Low Occupancy buildings as defined in Appendix A of UFC 4-010-01.
2. Taxiing aircraft.
3. Fence, if space is a limitation (100 feet (30 m), if space is available).
4. Roads outside of a security fence.
5. Overhead power and communication lines.
6. Pad-mounted transformers.
7. Parked aircraft.

c. Provide a minimum of 100 feet (30 m) between aircraft refueler/ground fuel delivery vehicle parking area and the following:

1. POL Operations Buildings and Inhabited Buildings
2. Aboveground Storage Tanks
3. Truck or tank car off-loading station.
4. Truck fillstand.
5. Property lines.
6. Highways.
7. Airport surface detection radar system components.

d. Provide a minimum of 300 feet (90 m) between an aircraft refueler/ground fuel delivery vehicle parking areas and the following:

1. Aircraft warning radar antennas.
2. Areas where airborne surveillance radar may be operated.

e. Provide a minimum of 500 feet (150 m) between an aircraft refueler/ground fuel delivery vehicle parking areas and airport ground approach and control system components.

f. Provide a distance as great as practically possible between an aircraft refueler/ground fuel delivery vehicle parking areas and radio transmitting antennas.

g. Contact the installation safety office to obtain distance criteria from an aircraft refueler/ground fuel delivery vehicle parking areas to aircraft carrying explosive materials.

11-5.3 Arrangement.

The preferred arrangement is parallel positions, but "front-to-back" and variations of the two are acceptable. Provide "front-to-back" clearance between vehicles such that the aircraft refueler/ground fuel delivery vehicle in the "back" position would not have to back up to pull out of the parking position. This distance will vary according to the turning radius of each aircraft refueler/ground fuel delivery vehicle. Arrangement should satisfy functional requirements of users and provide for safe operation and efficient use of available space. Provide for parking of all refueling vehicles expected to use this facility and include identification of positions.

11-5.4 Ingress/Egress.

Provide for "drive-ahead" motion of vehicles at all stages to avoid backing up vehicles under normal circumstances. Provide for smooth and efficient movement from the truck fillstand area to the parking positions and from the parking positions to the aircraft apron. Where necessary, provide adequate markings to ensure safe and efficient vehicle movements. At a minimum, provide two means of ingress/egress.

11-5.5 Paving.

Use concrete pavement, capable of withstanding design vehicle wheel loads. Seal joints with fuel-resistant materials. For circulation pavements, provide bituminous flexible pavements unless an economic analysis shows rigid concrete is more cost-effective. Use concrete pavement in aircraft refueler/ground fuel delivery vehicle parking areas.

11-5.6 Containment Area.

Provide a containment area consisting of an impermeable retention and controlled drainage system leading to a concrete remote spill containment system. Pave the area with concrete pitched a minimum of 1 percent toward catch basins or trench drains. Design the containment area in accordance with UFC 1-200-01, federal, state, and local regulations. Do not use asphalt within a spill containment area. The maximum slope of any paving within a truck movement or parking area must not exceed 2 percent except ramps. If a ramp is provided, no single slope must exceed 8 percent and the ramp must be aligned perpendicular with direction of truck movement. The designer must assure that adequate ground clearance is achieved for all vehicles utilizing the containment areas.

11-5.7 Remote Spill Containment System.

Design the spill containment system in accordance with UFC 1-200-01, federal, state, and local regulations. Provide the spill containment system with capacity not less than the volume of the largest refueler to be parked since this is most likely the maximum spill volume to occur for unattended vehicles. Precipitation is not required to be accounted for in the volume calculations. The top elevation of the remote spill containment basin must not be set less than 6-inches above the top of the refueler truck parking area's maximum ponding elevation. This will prevent overflow of the remote spill containment basin during a heavy rain event. Twenty-five percent or more of the total required containment volume must be directed to, and stored at, the remote system before any of the shared containment volume will pond at the truck parking area. Provide a lockable eccentric plug valve with indicator located outside the containment area at a location that will be safely accessible during a fire.

Consider combining the remote spill containment system with other remote spill containment systems on site, except with tank containment systems. Construct the drain lines between the containment area and the remote spill containment system, and between the remote spill containment system and the lockable eccentric plug gate valve of petroleum-resistant, impermeable material with water-tight joints such as ductile iron or HDPE pipe with fusion welded joints. Do not use clay, concrete, or fiberglass piping materials.

11-5.8 Fire Protection.

Refer to Chapter 2 of this UFC for fire protection requirements.

11-5.9 Security.

Provide fencing and lighting for security as required in Chapter 2 of this UFC.

11-5.10 Lighting.

Provide a minimum of 1-footcandle (10 lux) lighting with a uniformity ratio of 15:1 maximum/minimum to ensure that a fuel leak from the refueler is seen.

11-5.11 Block Heater Connections.

At facilities where aircraft refuelers/ground fuel delivery vehicles have engine block heaters, provide connections for those heaters.

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CHAPTER 12 MAJOR REHABILITATION

12-1 INTORDUCTION.

Decisions concerning major rehabilitation will be based on economics, mission, safety, or environmental factors. It is not the intent of this chapter to mandate rehabilitation, but only to provide guidance if the decision is made. The most common reasons for rehabilitation are to meet environmental needs or to extend the usable life of the facility. If a tank or major component is taken out of service for rehabilitation, review other chapters of this UFC. However, consider each change based on its merits and its compliance with this UFC. It is not the intent of this UFC to initiate changing and upgrading of existing facilities. Before initiating a facility improvement or major rehabilitation fuel project, it is recommended that a Physical Condition Survey be conducted to survey the condition of the facility with the goal of identifying major deficiencies and prioritizing the work required. Contact the appropriate Command Fuels Engineer, Naval Facilities Engineering Component Commands and the Naval Facilities Engineering and Expeditionary Warfare Center, or Army Corps of Engineers regional design office. For Naval Air Stations and Marine Corps Air Stations, include a representative from NAVAIR on the survey team. In most cases, coordinate major rehabilitation proposals with the base master plan.

12-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not begin the design or modification of any fueling system without first becoming completely familiar with Chapter 2 of this UFC.

12-3 ABOVEGROUND FUEL STORAGE TANK REHABILITATION.

Existing aboveground storage tanks can be modified to meet fuel quality standards, safety requirements, and environmental regulations. To maintain the structural integrity of aboveground storage tanks and to ensure a complete and usable facility, ensure all designs are accomplished by an engineering firm regularly engaged in tank modification or have all plans and specifications reviewed by an API Std 653 certified inspector. Complete all tank modifications, repairs, alterations, or inspections in accordance with API Std 653 and API Std 650. Require a new strapping table after any major tank rehabilitation.

12-3.1 Aboveground Vertical Tank Inspections.

Prior to modifying the tank**,** conduct a thorough inspection consistent with the requirements of API Std 653. This inspection will reveal any repairs that need to be made in order to comply with current regulations. If the tank is suspected of leaking, a helium test may be conducted.

12-3.2 Increase Manhole Sizes.

Many older aboveground vertical tanks have inadequately sized shell manholes. The ventilation and system components requirements for maintenance have created a need for 36-inch (900 mm) diameter manholes. If they do not exist, consider rehabilitation. Provide in accordance with Chapter 8 of this UFC. When considering the increase in manhole size, the risk of damaging the tank must be taken into account. Also the need for stress relieved manhole inserts must be considered (larger tanks). Indiscriminate installation of larger manholes has been known to severely damage tanks.

12-3.3 Replace Tank Floors.

Replace existing tank floors only when an API Std 653 inspection (including a magnetic flux leakage test) indicates that the useful life of the bottom has expired, or that the bottom requires more than minor repairs or upgrades, or if significant fuel quality problems due to ponding water exist. Contact Service Headquarters for guidance. Whenever a tank bottom is replaced it must comply with current design standards including either a double bottom or single bottom with liner. In no case must a tank with a single bottom remain in service when the bottom warrants replacement, unless other provisions such as a programmed MILCON or SRM project has been approved to replace the tank and/or bottom. Conduct an analysis of the existing tank and local conditions to determine the most desirable approach. The type of new bottom to be installed depends upon a number of factors, including: condition of the existing bottom, tank foundation, shell condition, and amount of tank capacity which can be "lost." Install double bottoms or replacement bottoms in accordance with API Std 653. Install sloped bottoms (3 to 5 percent) either above the existing bottom if the user can accept the resulting loss in tank capacity or remove the existing bottom and install a new sloped bottom in its place. A slope of 5 percent is preferred, but not required. If conditions and cost make the recommended slope impractical, provide a minimum slope of 2 percent. The installation of a new cone up floor above an existing cone up floor may be considered only for large (80,000 Bbl and larger) bulk storage tanks, and must be approved by the Service Headquarters. In either case, install an impermeable liner in accordance with DoD Standard Design AW 078-24-27, as well as leak detection between the two floors. The technology exists and it may be cost effective to raise the tank off its foundation to accomplish under tank modifications or repairs (e.g., adding containment liner/tell-tale system, cathodic protection, ringwall, etc.).

12-3.3.1 Double Bottom with Washed Sand Layer and Liner.

Clean and repair the existing tank bottom, install a liner on top of the existing tank bottom, add a 4- to 6-inch (100 to 150 mm) silica sand layer on top of the liner, and install the new steel tank bottom on top of the sand layer. Refer to Chapter 8 of this UFC for suitable sand criteria. Leak detection consists of tell-tale slotted **\3** pipes within the sand layer at regularly spaced intervals and extending out through the outer shell of the tank. PVC pipe materials are not allowed. **/3/** Provide cathodic protection by sacrificial anodes or impressed current close to the liner to allow maximum clearance from the new tank bottom. Install adequate numbers of a cathodic protection reference cells between the two bottoms.

12-3.3.2 Double Bottom with Concrete Layer and New Steel Bottom.

Clean and repair the existing tank bottom, install a liner on top of the existing tank bottom, pour 4 to 6 inches (100 to 150 mm) of fiber reinforced (low slump mix - typically 3,000 psig (21 000 kPa)) concrete over the liner and existing bottom, shape the concrete to provide adequate slope, and install the new steel tank bottom on top of the concrete. Slope the concrete towards a sump and form with a series of grooves along the top surface to collect any product which may leak through the new bottom. Slope the channels to a collection point with a pipe extending to an observation well. Provide concrete with an alkalinity of 13 or higher.

12-3.3.3 Double Steel Bottom.

Clean and repair the existing tank bottom, place a structural support system on top of the existing tank bottom, and install the new tank bottom. Design the structural support system to prevent excessive deflections resulting from loads on the primary (new) tank bottom. Allow for an interstitial space between the two tank bottoms to detect and collect any product from a leak. Purge the interstitial space between the two bottoms with nitrogen to remove the oxygen, thus creating a non-corrosive, non-combustible environment. The elimination of condensation and oxygen within the space minimizes corrosion formation for the upper (new) bottom. Provide leak detection with sensors which can detect pressure changes within the space. A pressure increase results from a leak in the upper tank bottom as product enters the space. A decrease in pressure indicates a leak or steel failure has occurred in the lower tank bottom.

12-3.3.4 Single Bottom with Liner.

Remove the existing tank bottom and prepare the sub-base for bearing capacity. Place sand layer on the sub-base to support the primary tank bottom, install a liner with a slope to a center liner sump, place a minimum 12-inch layer of sand on top of the liner, and install a new tank bottom on top of the sand layer. The liner sump is the collection point for any leaks from the bottom and consists of a drain pipe leading to an observation well. An alternative method is to use tell-tale slotted **\3** pipes in accordance with DoD Standard Design AW 078-24-27. PVC pipe materials are not allowed. **/3/** Provide cathodic protection by sacrificial anodes or impressed current close to the liner to allow maximum clearance from the new tank bottom. Install adequate numbers of a cathodic protection reference cells between the two bottoms. Place cathodic protection in the sand layer approximately 6 inches (150 mm) below the new tank bottom and above the liner.

12-3.4 Replace Floating Roof tank with Fixed Roofs.

If an external floating roof requires significant repair work, is corroded beyond economic repair, or for any reason is considered unserviceable (by an API Std 653 inspection), consider replacing it with a fixed cone roof and internally sealed honeycomb cell floating pan, as required in the "Protection of Aboveground Storage Tanks" paragraph of Chapter 2. When a fixed cone roof is added to an existing tank the roof manufacturer and the designer must determine that the tank has sufficient strength to support the new roof. If the shell is structurally insufficient, a geodesic dome may be considered. Install structural supported roofs in accordance with API Std 650, API Std 653, and DoD Standard Design AW 078-24-27. In general, all open top, floating roof tanks containing aviation fuel should be programmed to receive a cover, as should all tanks in northern climates where snow and ice is a problem.

12-3.5 Product Recovery Systems.

Provide storage tanks with pumps, piping, valves, and tanks to collect, recover, and return usable aviation turbine fuel which would otherwise become waste. Include a tank(s) to collect fuel/water mixtures from tank and system component sumps, system component drains, high point vents, low point drains, and any other system components from which fuel/water mixtures can be collected. Separate the fuel and water portions. Filter the fuel portion and return to bulk storage tanks. Do not discharge the water portion to surface water without additional treatment and permits or treat the water portion as wastewater. Refer to Chapter 2 of this UFC for information on handling of wastewater. Design in accordance with DoD Standard Design AW 078-24-27.

12-3.6 Coatings.

In tank coating projects, minimize the generation of hazardous waste associated with coating removal. Some alternatives to traditional sand blasting include shot "blasting", chemical stripping, high pressure water, carbon dioxide, or chemical stabilizer additive process. Designs for maintenance painting, both interior and exterior, should be based on a coating condition survey, as discussed in the notes to UFGS 09 97 13.15, 09 97 13.17, and 09 97 13.27. An evaluation of shell coating should be based not only on condition but on the need for coating the shell and an evaluation of apparent corrosion pressures on the shell. Corrosion pressure on shell coatings is generally fairly low; therefore, there is not the same need for coating thickness and integrity that is required for floors and ceilings. Refer to Chapter 8 of this UFC for additional information on interior and exterior coatings for storage tanks. Re-coat the portion of the tank that is already coated. When tanks are taken out of service for inspection or repairs, inspect the underside of the roof for rust. If conditions merit, coat the underside of the roof in conformance with Chapter 8 of this UFC.

12-3.7 Isolation Valves.

Require tank isolation valves to prevent the accidental release of fuel into the environment. On aboveground tanks larger than 12,000 gallons (45,800 L), provide double block and bleed tank shell valves located between the tank shell and the high level shut-off valve.

12-3.8 Alarms and High Level Shut-off Valves.

Equip storage tanks with a means to prevent accidental overfill. Remove solenoid pilots, if present, on high level shut-off valves. Design in accordance with DoD Standard Design AW 078-24-27. Refer to Chapter 8 of this UFC for applicable requirements for alarm and valve installation.

12-4 UNDERGROUND OPERATING TANKS.

If major rehabilitation is required, upgrade existing underground operating tanks to conform with 40 CFR Part 280 and 40 CFR Part 281 and applicable state and local underground storage tank regulations. As a minimum, provide leak detection, cathodic protection, and overfill protection. Careful study of cut and cover tanks is necessary since construction features may make it impossible to comply.

12-4.1 Manholes.

Provide a 36-inch (900 mm) diameter manhole for tanks. Extension necks and internal ladders are required for cleaning and inspection. Provide a minimum of one manhole for tanks between 1,000 gallons (4,000 L) and 5,000 gallons (19,000 L). Provide a minimum of two manholes for tanks larger than 5,000 gallons (19,000 L). Provide manhole containment sumps for all manholes.

12-4.2 Interior Coatings.

Coat underground operating tanks in accordance with Chapter 8 of this UFC.

12-5 HYDRANT SYSTEMS.

Decisions concerning major rehabilitation of existing direct aircraft refueling systems will be made by Service Headquarters. This paragraph addresses existing direct aircraft refueling systems (Type I and Type II) which can be rehabilitated or modified to meet fuel quality standards, safety requirements, mission requirements, and environmental regulations. All designs should be accomplished by an engineering firm regularly engaged in the design of direct aircraft fueling systems. The provisions of Chapter 4 of this UFC are applicable.

12-5.1 Pumps.

Repair or replace existing pumps to meet increased fuel demands. Rebuild pumps including complete bearing replacement, additional bowls or increased impeller size, replacement of mechanical seals, shaft lengthening or shortening to match replacement tanks, etc. In some cases, additional capacity can only be achieved by total pump replacement or rearrangement of piping. Consider pump replacement where, due to system component age or condition, it is more economical to replace than to rebuild. Pump and motor replacement may also result in higher efficiency units with lower power demands and increased spare part availability.

12-5.2 Filter-Separators.

Existing filter-separators must be capable of meeting requirements of EI Specification 1581 (Edition 5). Existing filter-separator vessels built to earlier editions of API 1581 may be able to be reutilized with EI Specification 1581 (Edition 5) coalescer and separator elements. Where possible, the replacement elements must be of the same size as other elements at the activity. Contact the Service Headquarters for guidance. Replace existing vessels if they cannot be converted to use EI Specification 1581 (Edition 5) elements or if the vessel with EI Specification 1581 (Edition 5) elements fails to meet quality standards. Issue filter-separators should be given priority for upgrade on a stand-alone project. Upgrade of all filter-separators is mandatory on any major rehabilitation project.

12-5.3 Fuel Quality Monitors.

Existing fuel quality monitors will be removed. Fuel quality monitor elements degrade when they come in contact with fuel additives (FSII) in aviation turbine fuel causing fuel quality issues.

12-5.4 Control Systems.

Pump houses and hydrant systems typical of the Panero (circa 1952) and Pritchard (circa 1958) designs utilize hard-wired, high-voltage mechanical relays. Control systems installed from the pump house to the lateral control pits, emergency stops, and pit activation switches are typically high voltage. Age, elements, and exposure to fuels may deteriorate control system wiring and render it no longer reliable or safe to operate. Consider control system replacement whenever a significant portion of the pump house is repaired or when fire, safety, or electrical codes indicate a hazard exists. Generally, hard-wired relay logic systems are expensive to build and maintain and do not offer the flexibility of programmable logic controller (PLC) based systems. Control systems should be of low voltage design incorporating industry standard programmable logic controllers (PLC). If control facilities are isolated from the pump house (not subject to atomized fuel) and the facility has positive ventilation, then non-explosion-proof fixtures may be incorporated into the design. Existing control wiring has probably deteriorated and numerous conduits are no longer intrinsically safe. Replace control wiring and wherever possible run control wiring in overhead conduit. If necessary, replace kill switch and emergency stop circuits as part of the pump house rehabilitation. Cable wiring systems are easier to install and troubleshoot and should be considered whenever the wiring to hydrant system is replaced.

12-5.5 Electrical Systems.

Replace secondary electrical systems, including lighting and motor conductors and motor control centers, as part of pump house repairs. Ensure circuits within the pump house, exposed to the possibility of atomized fuel, comply with the provisions of NFPA 30 and are classified Class I, Division 1. If the motor control center is isolated from the pump house (not subject to atomized fuel) and the facility has positive ventilation, then the area may be derated and non-explosion-proof lighting fixtures may be incorporated into the design. Existing secondary wiring has probably deteriorated and numerous conduits are no longer intrinsically safe. Replace motor wiring and wherever possible run control wiring in overhead conduit.

12-5.6 Lateral Control Pits.

Lateral control pits are typically concrete structures with heavy metal-hinged lids containing valves, pumps, filters, and piping associated with the supply of fuel from a pump house to a hydrant outlet. Repair or replace pits to prevent the accidental release of aviation turbine fuel to the environment and water infiltration. Slope pit floors to a sump and provide manually operated sump pumps to aid in water removal. Use either rolling or light-weight hinged aluminum pit lids with a water-tight design. Comply with DoD Standard Design AW 078-24-28.

12-5.7 Distribution Piping.

Minimize the use of unlined carbon steel pipe, especially with jet aircraft. A number of alternatives exist which reduce the exposure of aviation turbine fuel to unlined carbon steel pipe. One option is to internally coat existing systems without pipe removal. In-situ coatings can prevent fuel degradation; however, final filtration must still be provided at the aircraft by either a mobile or fixed filter-separator. Another option is to sleeve the piping with a non-ferrous material (stainless steel). Consider this option if reduced flow rates are acceptable.

12-5.8 Diaphragm Control Valves.

Consider reusing existing diaphragm control valves wherever possible. Diaphragm control valves can typically be refurbished by either the original manufacturer or by a factory authorized repair facility for less than the replacement cost. Ensure refurbishers modify, remove, or replace pilot assemblies, tubing, and solenoids to meet specifications as outlined in DoD Standard Design AW 078-24-28. As a minimum, replace non-ferrous pilot tube assemblies with a stainless steel unit. Provide stainless steel control tubing and replace all internal valve components. If the valve body is carbon steel, request Service Headquarters to determine if the valve body should be sand-blasted and cleaned or replaced. Coat or plate carbon steel bodies to meet DoD Standard Design AW 078-24-28.

12-5.9 Hydrant Control Valve Differential Pressure Control Pilots.

If the aircraft direct fueling system hydrant control valves (including the one at a hydrant hose truck (HHT) or pantograph checkout stand do not have a differential pressure control pilot (maintains a minimum differential pressure across the valve to ensure it remains in control) modify or replace the control valve to provide one. Set it for 15 psig differential pressure and verify it at flowrates from 50 to 600 gpm.

12-5.10 Hydrant Outlets.

Remove and replace existing hydrant outlets and connections (e.g., Buckeye) with API adapters. Conversion to API adapters ensures compatibility with all refueling system components. If adequate pressure control (regulating and surge) in accordance with DoD Standard Design AW 078-24-28 does not exist at the hydrant pit or at the lateral control pit, then install a control valve at either location.

12-6 DIKES, LINERS, AND BASINS.

If dikes, liners, and basins do not comply with the requirements of this UFC, 40 CFR Part 112, state, or local spill containment regulations and the potential for accidental fuel discharges exists, repair or replace the existing structures. The provisions of Chapter 8 of this UFC are applicable. In general, if the dike does not retain rainwater, improvements are necessary.

12-7 LEAK DETECTION.

When rehabilitating fuel facilities, install leak detection, if necessary, as detailed in Chapter 2 of this UFC.

12-8 CATHODIC PROTECTION.

When rehabilitating any fuel facility, install or upgrade cathodic protection. Ensure cathodic protection systems are designed by a NACE certified Corrosion Specialist or Cathodic Protection Specialist or a registered professional Corrosion Engineer. Install cathodic protection on all steel structures including, but not limited to, aboveground storage tanks, underground storage tanks, and underground piping systems. The provisions of Chapters 2 and 8 of this UFC are applicable.

In the event it is determined the tank floor cathodic protection system has failed, or is non-existent, and evidence is produced that floor backside corrosion is occurring (from an API 653 out-of-service floor scanning inspection), consider the use of Vapor Corrosion Inhibitors (VCI) to reduce the potential for backside corrosion. As the use of VCI is not as effective as original studies reported, and it is not possible to test their performance, any application of VCI must only be with the approval of the Service Specific Fuels Subject Matter Expert (SME) for Cathodic Protection from each Service. If the backside corrosion is of a low level, and projections of remaining useful life of the floor do not indicate the need for a floor replacement, the use of VCI may be indicated. If the API 653 Inspection is not finding low level backside corrosion, the use of VCI may not be warranted.

12-9 ISOLATION VALVES.

Provide valves in product piping systems to control flow and to permit isolation of system components for maintenance or repair. Provide additional valves at required locations necessary to conduct a valid hydrostatic test. Provide manually operated valves, except where motor operators are specifically authorized by applicable standard drawings or technical specifications. Use double block and bleed type isolation valves for separation of product services, on tank shell connections (ASTs over 12,000 gallons (45,800 L) only), when piping goes aboveground or underground, between pier and tank storage, and other locations critical to periodic pressure-testing of piping. Quick opening/frequent opening type isolation valves may be used for less critical applications where double block and bleed shutoff is not required. Before adding isolation valves, evaluate piping system and make modifications to prevent pressure buildup caused by thermal expansion. Review paragraph on "Thermal Relief Valves" in Chapter 9 of this UFC. Except for those serving tactical refueler fillstands, this paragraph does not apply to systems covered by Chapter 7 of this UFC unless otherwise directed by Service Headquarters.

12-10 SOIL AND GROUNDWATER REMEDIATION.

Monitor, store, and dispose of petroleum-contaminated soil disturbed during rehabilitation in accordance with state and local environmental regulations. Collect, test (if appropriate), and treat petroleum-contaminated groundwater removed during dewatering by one of the following methods:

a) Off-site disposal at an industrial waste facility.

b) On-site treatment with a portable groundwater treatment system.

c) Treatment through an oil/water separator.

d) Treatment through the sanitary sewer.

Prior to selecting a treatment method, review state and local environmental regulations and consult the facility for acceptable alternatives and permits required for on-site treatment and disposal.

12-11 LIQUEFIED PETROLEUM GAS (LPG) FACILITIES.

When rehabilitating an LPG facility, back weld (seal weld) all existing threaded piping.

12-12 PIPELINE INSPECTION.

12-12.1 Inspection.

Conduct pipeline inspections in accordance with API 570 and NACE SP0169.

12-12.2 In-Line Inspections (Smart Pigging).

To determine if or how a pipeline requires rehabilitation, information on the pipeline's structural integrity is essential. One method to survey the condition of the pipeline is to use smart pigs.

12-12.2.1 General.

An in-line inspection (ILI), or “smart” or “intelligent” pig is one of a variety of instrumented tools using one or more physical or electro-mechanical principles for recording and measuring information for positioning and relative severity of anomalies in a pipeline. Different configurations of ILI tools can detect cracks, metal loss, geometry (ovality, curvature, bends) and even geoposition. Other types available can map and profile pipe, detect leaks, perform photographic inspection, and sample product. Use of smart pigs may require modifying the pipeline to increase the radius of sharp elbows and eliminate obstructions caused by valves that are not full port type.

12-12.2.2 Types.

The three basic types of smart pigs are ultrasonic, magnetic flux leakage (MFL), and eddy current. Ultrasonic, MFL, and eddy current pigs can be used in liquid pipelines. An alternative form of ultrasonic inspection is an electromagnetic acoustic transducer (EMAT). An EMAT can be used in either a liquid or gas pipeline. MFL can also be used in gas pipelines. Prior to choosing a smart pig, consider expected results, cost of various options, and expected pipeline condition.

In order to consider the use of ILI tools, an engineer specializing in the execution of ILI inspections must prepare a piggability assessment that determines if it is feasible to pig the lines, and what changes may be necessary to make the line piggable. The piggability assessment must also include an assessment of fuels management from the perspective of fuel source, and ullage required at receipt tank. Preservation of fuel quality as well as minimizing loss of product must also be considered, including the installation of filtration at point of receipt prior to introduction into the installation tank. Fuel filtration has been found to be far more preferable than introducing dirty fuel into an installation tank.

12-13 PIPELINE REPAIRS.

Pipeline repairs must be identified as part of the pipeline inspection. Any areas of pipe where defects or anomalies exceed the limits outlined in the API 570 assessment must be repaired. Pipeline repairs must be made in accordance with API 570, ASME B31.3, and/or ASME B31.4 as applicable.

12-13.1 Pipeline Repair Methods.

All permanent pipeline repairs must be engineered. Where possible the preferred method of repair is to remove the section of defective pipe and provide a like-for-like replacement pup. Reinforcing the deficient piece of pipe with an encircling repair sleeve or other repairs are acceptable provided they are in accordance with applicable codes.

12-13.2 Pipe Support Upgrades.

Pipe support repairs requiring replacement of the support must be engineered. Where possible updating supports with galvanized metal support steel and updating support type to a U-bolt and half round slide pad must be considered. Any changes to support type must be accompanied by a seismic and thermal flexibility analysis. For complex systems, computerized code compliant pipe stress analysis programs must be used to assure proper pipe support selection for load conditions.

12-14 CHECKLIST.

The following is a checklist of items to be considered in a major rehabilitation.

a. Aboveground storage tank rehabilitation

1. API Std 653 inspection.
2. 36 inch (900 mm) diameter manholes for maintenance.
3. Add double bottom.
4. Repair and slope tank floor.
5. Repair or replace floating roof.
6. Product recovery system.
7. Internal and external coating systems.
8. Tank isolation valves.
9. Fill and overfill protection.
10. Corrosion protection to tank bottom.
11. Leak detection.
12. Automatic tank gauging system.
13. Thermal expansion relief.

b. Underground storage tank rehabilitation

1. 36 inch (900 mm) diameter manhole(s).
2. Leak detection.
3. Corrosion protection.
4. Overfill protection.
5. Interior coating.

c. Aviation/Hydrant system rehabilitation

1. Repair or replace pumps to API Std 610.
2. Upgrade filter-separators to comply with EI Specification 1581 (Edition 5).
3. Remove automatic water drains from filter-separators.
4. Repair or replace control systems.
5. Repair or replace electrical systems.

6. Repair or replace lateral control valve pits and lids, including an impervious liner.
7. Internal coating to carbon steel distribution pipe.
8. Refurbish diaphragm control valves.
9. Provide hydrant control valve differential pressure control pilots
10. Hydrant outlets to API adapters.
11. Replace lubricated valves and swivels with non-lubricated.

d. Truck fill/off-load stands

1. Grounding, deadman, and high level shut-off systems.
2. Pantographs - convert from 3-inch **\1** off-loading pantographs and hoses **/1/** to 4-inch (75 mm to 100 mm).
3. Low profile filters.
4. Fusible link butterfly valves (These valves are not required nor permitted on Air Force projects).
5. Piping of thermal reliefs to contained tank.
6. Updated meters and meter diaphragm control valves.
7. Adequacy of piping and system grounding.
8. Adequacy of spill collection and containment.
9. Upgrade military specification filter-separators to comply with EI Specification 1581 (Edition 5). (Issue filters have priority over receipt filters.)
10. Remove automatic water drains on filter-separators and ensure that any liquid drained from separators is properly handled.
11. Convert top loading to bottom loading fillstands.

e. Add isolation valves and blind flanges throughout system.

f. Use smart pigging to determine the condition of the distribution piping.

g. Monitor, remove, and dispose of petroleum-contaminated soil and groundwater.

h. Spill Containment and collection.

1. Concrete containment areas for dikes, system component pads, fillstands, etc.
2. Impervious lining system for dikes, containment areas, and catch basins.
3. When required to meet federal, state, and local regulations, refer to Chapter 2 of this UFC for information on design and sizing of oil/water separators for treatment of stormwater discharges from

containment areas (e.g., dike areas, fillstands, system component pads, etc.).

i. Pipeline Inspections

1. Areas of metal to metal contact should be noted.

j. Pipeline Repairs

1. Eliminate metal to metal contact.
2. Complete seismic and thermal flexibility analysis to verify support type and location.
3. Repair pipe anomalies or defects with engineered repairs only.

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CHAPTER 13 FUELING FACILITY TEMPORARY DEACTIVIATION

13-1 INTRODUCTION.

Follow the more stringent of local, state, or applicable guidelines of this chapter during the initial deactivation of a fueling facility. Follow the applicable subsection when temporarily deactivating a fueling facility for three months or more. The requirements of this chapter are also applicable when connecting a new system to an existing system to prevent contamination of the new system. For continuing maintenance issues and reactivation of a deactivated facility, refer to inactive document UFC 4-911-01N, which is required for these circumstances. Additional guidelines for the deactivation of storage tanks and pipes are provided in API Std 2610 and Appendix C of NFPA 30,. Federal regulations addressing out-of-service underground storage tank systems are in 40 CFR Part 280.

13-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not begin the design of any deactivation plan without first becoming completely familiar with Chapter 2 of this UFC.

13-3 FUEL STORAGE AND DISTRIBUTION FACILITIES.

13-3.1 Tanks.

The following items apply to deactivation of all tanks in general.

a. Empty and clean tanks in accordance with API Std 2015 and UFGS 33 65 00

b. Provide water ballast with a copper sulphite solution (1 part copper sulphite to 3 million parts water) to discourage organic growth. Verify compatibility with environmental regulations prior to employing this solution.

c. Follow the procedures of UFC 3-460-03 and 29 CFR Part 1910 when entering tanks or performing maintenance on tanks.

d. For tanks equipped with cathodic protection systems, inspect for proper operation and repair if necessary. For tanks not equipped with cathodic protection systems, investigate the economic trade-offs of installing those systems at deactivation versus the associated caretaker maintenance costs and various environmental protection concerns.

e. Mark each tank clearly with its status. Place a warning sign on the tank to indicate its current and former contents.

f. If required by state or local regulatory agencies, submit required documentation for “out-of-service” storage tanks.

13-3.1.1 Aboveground Tanks.

a. Empty and evaluate for hazardous atmosphere as defined by 29 CFR Part 1910.146.

b. Wash and dry tank interior until visibly clean in accordance with API Std 2015.

c. Physically disconnect all fuel connections.

d. Treat the interiors of tanks that have been used to store fuel oil with a corrosion-preventive compound. For all other steel tanks, coat the unpainted interior surfaces with a preservative lubricating oil.

e. Close vents on lubricating oil tanks. Vents on other tanks should remain open.

f. Partially fill tanks subjected to high winds to prevent overturning. Use water except where there is the possibility of it freezing and rupturing the tanks. In those environments, use kerosene. Add caustic soda to the water to obtain a pH of 10 or a corrosion inhibitor. Determine the amount of liquid ballast required based on the expected winds, size of the tank, and specific gravity of the liquid used.

g. Comply with API Std 2015.

h. Comply with state and local environmental requirements.

13-3.1.2 Underground Tanks.

a. Empty, evaluate for hazardous atmosphere as defined by 29 CFR Part 1910.146, and clean underground metal and concrete tanks.

b. Partially fill tanks insufficiently anchored against flotation with water to prevent buoyancy. Provide adequate safeguards where there is danger of the water freezing.

c. Provide a minimum of 12 inches (300 mm) of water in rubber-lined concrete tanks.

d. Leave vent lines on underground tanks open and make sure the vents are adequately screened.

e. Tightly cap or plug all other tank openings after removal of system components.

f. Provide release detection where fuel is left in the tank.

g. Comply with 40 CFR Part 280 and any applicable state and local environmental regulations.

3-3.1.3 Tank Level Controls.

a. Remove controls such as float control valves, float-operated gauges, low level cutoffs, water detector locks, and probes from tanks.

b. Clean, treat with corrosion-preventive compound, and store controls in a dry place.

13-3.2 Pipelines.

a. Drain and vacuum extract all fuel from the pipeline.

b. If possible, pig the pipeline to remove any residual fuels.

c. Blind all flange connections and vents.

d. Charge the line with nitrogen gas.

e. Continue to provide cathodic protection and maintain the nitrogen charge.

f. Externally coat unpainted and unwrapped lines exposed to the weather with a corrosion-preventive compound.

13-3.2.1 Pipeline System Components.

a. Remove, clean, coat inside and outside with a light oil, and reinstall strainers.

b. Remove, clean, treat with corrosion-preventive compound, and store meters in a dry place.

c. Keep gaskets tight to prevent dirt and water from entering.

d. Remove, clean, grease, and store hydraulically operated diaphragm control valves in a dry place.

e. Paint exterior or treat with a corrosion-preventive compound and leave all other valves, such as plug valves and check valves in place.

f. Lubricate plug valves and leave in an open position.

g. Remove, tag, date, and store hoses in dry storage.

13-3.2.2 Fueling Pits.

a. Inspect, tag, and secure fueling pits.

b. Make provisions for pumping pits dry.

13-4 FACILITIES.

13-4.1 General Considerations.

a. Make arrangements to retain the minimum amount of maintenance equipment.

b. Check and label all keys to all doors, gates, hatches, and other moving items.

c. Clean and repair as necessary all storm sewers, drainage ditches, and other drainage structures to prevent flooding and storm damage to roads, runways, tracks, and structures.

13-4.2 Fencing.

a. Tighten connections at gates, posts, braces, guys, and anchorages to ensure stability and correct alignment.

b. Clean and lubricate all hinges, latches, locking devices, and all other alignment hardware.

c. Confine painting to those parts of fences and gates that show signs of corrosion.

13-4.3 Paved Surfaces.

a. Unpaved shoulders

1. Provide unpaved shoulders with only the repairs necessary to ensure positive drainage of surface water from the adjoining pavement.
2. Fill holes and ruts and blade ridges to eliminate standing water.
3. Backfill depressions when the undermining of pavement is threatened.
4. When possible, retain existing ground cover.

b. Concrete pavements

1. Repair concrete pavements only as required to perform service activities and to prevent severe disintegration.
2. Patch bituminous surfaces of depressed or broken slabs to prevent ponding of water and the resultant saturation of the subgrade.
3. Seal joints and cracks in concrete pavement with bituminous material.

c. Bituminous pavements

1. Limit surface repairs of bituminous pavements to the repair of holes, raveled areas, edge failures, and open cracks.
2. Repair unused surfaces only as necessary to maintain drainage and to prevent the ponding of surface water.

CHAPTER 14 FUELING FACILITY CLOSURE

14-1 CLOSURE REQUIREMENTS.

Follow the more stringent of local, state, or applicable guidelines in this chapter when permanently closing a fuel facility or a portion of a fuel facility. Additional guidance on closure and disposal of storage tanks is available in Appendix C of NFPA 30 and API Std 2610.

14-1.1 Aboveground Tanks.

a. Physically disconnect all fuel connections.

b. Remove fuel.

c. Clean tank in accordance with API Std 2015.

d. Dismantle the tank and dispose of as scrap steel.

e. Comply with API Pub 2202.

f. Comply with state and local environmental requirements.

14-1.2 Underground Tanks.

a. Perform a soil and groundwater analysis to determine if a fuel release occurred.

b. Review and comply with 40 CFR Part 280 and any applicable state and local environmental regulations.

c. If allowed by federal, state and local regulations, perform closure in place, as outlined in API RP 1604. However, this alternative may be more expensive than removal for small volume tanks. Abandoning in place also impedes soil clean-up and future land use.

d. If removal is required, excavate and dispose of the tank in accordance with API RP 1604.

e. Comply with applicable guide specifications and EM 1110-1-4006.

14-1.3 Pipelines.

a. Physically disconnect the pipeline from any active fuel systems.

b. Drain and vacuum extract all residual liquids from the pipeline.

c. Remove all fuel and pig to remove any residual fuel.

d. Purge the pipeline to remove all vapors. Do not use water as flushing media because it will typically generate large quantities of hazardous waste with high disposal costs.

e. Excavate the line only if required by federal, state, or local regulations or if deemed necessary by Service Headquarters for land reuse.

f. Report any contaminated soil or groundwater discovered during excavation to the appropriate state and local environmental authorities.

g. If excavation is not performed, fill the pipeline with cellular concrete or other acceptable inert solid material allowed by regulations requiring the filling. Consider the lowest cost from the acceptable materials list. As an option, the pipeline can be capped, where it meets environmental regulations and with approval from Service Headquarters.

14-2 GENERAL REQUIREMENTS.

Chapter 2, General Design Information, contains important information on fueling facilities. Do not begin the design or modification of any closure plan without first becoming completely familiar with Chapter 2 of this UFC.

14-3 INVENTORY.

Prepare an inventory of valuable fueling hardware which could be easily salvaged and reused at another base. System components such as pantographs, control valves, pumps, and filtration system component are always in demand. Submit list to your Command Fuels Engineer.

CHAPTER 15 FUEL SYSTEM COMPONENTS

15-1 INTRODUCTION.

This chapter contains the descriptions of various fueling system components used in DoD fuel facilities such as bulk storage facilities (See Chapter 3), aircraft fueling facilities (See Chapter 4), marine receiving and dispensing facilities (See Chapter 5), ground product fueling facilities (See Chapter 7), and interterminal and installation pipelines (See Chapter 6).

15-2 BULK AIR ELMINATORS.

Use flange-connected, steel bodied bulk air eliminator of the appropriate pressure and flow rating to meet applicable service requirements. Include an automatic air release head and interlock the system component with a float or solenoid-operated hydraulically operated diaphragm control valve. Provide discharge piping to the product recovery tank or other safe means of containment.

15-3 METERS.

15-3.1 Custody Transfer versus Non-Custody Transfer Meters.

Meters are used to quantify the amount of fuel that is transferred between two points or systems. They can be of the custody transfer or the non-custody transfer type. The meters that are not designed for custody transfer are used for operational control and to determine approximately how much fuel is being transferred. The meters designed for custody transfer are used for inventory transfer and financial accounting control and require an accuracy of plus or minus 0.5 percent or better. Positive displacement and turbine meters can be used as custody transfer meters with the addition of temperature compensation.

15-3.2 Meters – Positive Displacement.

Use flange-connected, cast steel bodied (aluminum or stainless steel, only if downstream of the issue filter-separator in aircraft fueling facilities) positive displacement meters of the appropriate pressure and flow rating to meet applicable service requirements. Ensure meter has case drain and register. Provide each meter with temperature compensation and adjustable calibration where there is custody transfer. Ensure meter accessories are compatible with either the mechanical or electronic support system component selected. For positive displacement meters, the measurement error in the normal flow direction must be within plus or minus 0.3 percent of actual quantity delivered. Consult the appropriate Service Headquarters for requirements for the meter to communicate to a remote location or system component. Consider the use of a card-operated or key-operated data acquisition system. Cards or keys, as appropriate, are coded to identify the receiver of the fuel and to allow access to the fuel. The quantities taken are transmitted to a data-receiving device by electronic pulse transmitters mounted on each meter, and each transaction is automatically recorded. For bulk storage facilities, refer to “Cards and Key Locks” under “Controls” paragraph of Chapter 3. For ground product fueling facilities, refer to “Cards and Key Locks” under “Filling Stations” paragraph of Chapter 7.

15-3.3 Meters – Turbine.

Use flange-connected carbon steel bodied (stainless steel, if used in aircraft fueling facilities) turbine meters of the appropriate pressure and flow rating to meet applicable service requirements. Provide a flow straightener before turbine meters or provide a straight length of pipe at a minimum of ten pipe diameters upstream and five pipe diameters downstream of all turbine meters, or as required by manufacturer. Ensure meter has case drain and register. Provide each meter with temperature compensation and adjustable calibration where there is custody transfer. For turbine meters, the measurement error in the normal flow direction must be within plus or minus 0.5 percent of actual quantity delivered. Ensure all supporting system components for meter is compatible with the turbine meter selected. Consult the appropriate Service Headquarters for requirements for the meter to communicate to a remote location or system components. Consider the use of a card-operated or key-operated data acquisition system. Cards or keys, as appropriate, are coded to identify the receiver of the fuel and to allow access to the fuel. The quantities taken are transmitted to a data-receiving device by electronic pulse transmitters mounted on each meter, and each transaction is automatically recorded. For bulk storage facilities, refer to “Cards and Key Locks” under “Controls” paragraph of Chapter 3. For ground product fueling facilities, refer to “Cards and Key Locks” under “Filling Stations” paragraph of Chapter 7.

15-3.4 Meters – Orifice.

Use this type of meter only where custody transfer or accounting/inventory control is not required. Provide with flange connections. Provide a flow straightener before orifice meters or provide a straight length of pipe at a minimum of ten pipe diameters upstream and five pipe diameters downstream of all orifice meters, or as required by manufacturer. Indicate the date of calibration, temperature, and flow on the meter.

15-4 PRESSURE GAUGES.

Use liquid-filled gauges of range and dial size, as necessary, but not less than 0 to 160 psig (0 to 1100 kPa) pressure range and 4.5-inch (115 mm) diameter dial. Gauges must be all stainless steel construction, with black graduations on a white face. For locations where the temperature exceeds 100 degrees F (38 degrees C), consult Service Headquarters for direction on the possible use of gas-filled gauges. For locations where the temperature is less than -40 degrees F (-40 degrees C), use an appropriate gauge liquid that will not freeze to prevent damaging the gauge.

a. Consider the location, year-round weather conditions, and service requirements for the type of liquid filling to be used.

b. Install compound (pressure/vacuum) gauges on the suction side of each pump at fuel storage tanks.

c. Gauge liquids and service ranges:

Liquid	Range
Glycerin	0F to 400F (-18C to 204C)
Silicone	-40F to 600F (-40C to 316C)

d. Provide a lever handle gauge cock and pressure snubber in each pressure gauge connection.

e. Provide indicating and recording pressure gauges on suction and discharge lines for interterminal pipeline pumping stations and on the incoming line at the delivery terminal of each such pipeline, if required by Service Headquarters.

f. Pressure gauges must be installed so that they are testable without removing them from the piping.

g. Use pressure gauges upstream and downstream of strainers and filter-separators. A differential pressure gauge may be used in lieu of gauges on each side.

For marine receiving and dispensing facilities (See Chapter 5), provide the following in addition to the above requirements:

a. Provide a pressure gauge on each side of the pipeline shutoff valve at the shore end of each pier-mounted pipeline. Provide the indicating pointer with a high-pressure-reading tell-tale indicator suitable for reporting the highest pressure experienced since last reset. Provide for non-contact resetting of the tell-tale by means of a small magnet.

b. Provide a pressure gauge on each branch line at each fueling station on each pier-mounted pipeline. Ensure that the pressure gauge is legible from the fuel hose connection array and from the pantograph loading arm location (if provided).

c. Provide a pressure gauge on each marine loading arm assembly (if provided). Ensure that the gauge is visible by the operator.

15-5 STRAINERS.

Require a strainer to protect centrifugal pumps, unless it precludes meeting the net positive suction head of the pump. Whether or not strainers are installed on the suction side of centrifugal pumps, install a spool piece so that temporary strainers can be installed during startup of the system. Strainers are required on the suction side of all pumps, meters, and receipt filtration. Strainers are not required upstream of issue filter-separators or diaphragm control valves.

a. Use flanged basket strainers constructed of steel and fitted with removable baskets of stainless steel mesh with large mesh reinforcements. Provide quick opening, single screw type with a drain connection on the bottom.

b. Unless otherwise specified, provide a fine screen mesh as follows:

	Mesh	Size of Opening
Pump suctions (Centrifugal)	7	0.108 inch (2.74 mm)
Pump suctions (Positive Displacement)	40	0.016 inch (0.40 mm)
Receipt Filtration	40	0.016 inch (0.40 mm)
Meter inlets (unless downstream of a filter-separator)	40	0.016 inch (0.40 mm)

c. In all cases, ensure the effective screen area is not less than three times the cross-sectional area of the pipe.

d. Provide pressure gauges on both sides of the strainer or a differential type gauge across the strainer.

e. Consider providing a manifold with two individual strainers and isolation valves for pipeline receipt, marine receiving facilities, and any other locations where uninterrupted flow is required for extended periods of time.

15-6 SURGE SUPPRESSORS.

Every effort should be made to control hydraulic surge or shock to acceptable limits by the design of the piping system rather than by the use of surge suppressors. Where this is not possible or becomes extremely impractical, surge suppressors may be incorporated. Use the diaphragm or bladder type equipped with a top-mounted liquid-filled pressure gauge, wafer-style check valve at the bottom, drain above the check valve, and isolation valve. Provide a needle valve around the check valve to permit controlled bleed back of the surge suppresser without rebounding. Locate surge suppressors as close as possible to the point of shutoff that is expected to cause the shock. Surge suppressors can reduce shock pressure but will not eliminate it entirely. The preferred solution to hydraulic shock is conservative piping design, use of loops, and slow-closing valves. Surge suppressors are strictly a last resort solution and require the approval of Service Headquarters prior to designing into a system.

15-7 FILTRATION.

The common contaminants for every fuel are water, solids, surfactants, micro-organisms, and miscellaneous contaminants. Solid contaminants are generally those which are insoluble in fuel, most common are iron rust, scale, sand, and dirt. However, metal particles, dust, lint from filter material and rags, gasket pieces, and even sludge produced by bacterial action are included. The maximum amount and size of solids that an engine can tolerate vary by engine type and fuel system. Ensure that the design provides the filtration for the fuel as required before reaching any truck fillstand or the motive fuel tank on the vehicle being refueled, hydrant pit, or aircraft direct fueling station.

The most common filtration equipment are filter separators. Less common are micronic pre-filters and hay packs.

15-7.1 Aviation Turbine Fuel Filter-Separators.

Filter-separators remove the common contaminants from aviation turbine fuel in three steps using two separate elements:

a. Removal of solid contaminant in the filter portion of the coalescer cartridge.

b. Removal of large particles of free water in the second stage of the coalescer cartridge.

c. Removal of fine particles of water in the separator cartridge.

The maximum amount and size of solids that an aircraft can tolerate vary by aircraft type and fuel system. Close Tolerance mechanisms in turbine engines can be damaged by particles as small as 1/20th the diameter of a human hair. Filter-separators continually remove dirt and free water from aviation turbine fuels. Ensure that the design requires two separate filtrations using two separate filter separators (or banks of filter-separators) prior to the fuel reaching the refueler truck fillstand, hydrant pit, or aircraft direct fueling station.

15-7.1.1 Design Requirements.

All aviation turbine fuels received into an operating tank must pass through a filter-separator. All aviation turbine fuels issued from an operating tank must pass through a second filter-separator. Filter-separators are required for all aviation turbine fuel systems in facilities where the fuel is dispensed directly to aircraft or is loaded on refuelers that eventually dispense the fuel to aircraft. Refer to aviation turbine fuel receipt filtration table, Table 4-1. As a minimum for such facilities, provide filter-separators as follows:

a. Design and construct filter-separators in accordance with EI Specification 1581 (Edition 5).

b. Elements for filter-separators should be of the same size as other elements at the activity.

c. Provide horizontal filter-separators. Provide vertical filter-separators only where space constraints prohibit horizontal units. Provide access to at least one side of every vertical unit via a separate (not attached to the filter-separator), stand alone, fixed platform.

d. Design and construct filter-separators in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC). Construct metal parts which will be in contact with the fuel, including the shell, head, and internal attachments of 3003 or 5083 aluminum alloy, stainless steel, or interior epoxy-coated carbon steel. Include the following accessories:

1. Piston-type differential pressure gauge with 1 psi (5 kPa) graduations across the elements. Pressure gauge must be testable without removal from the piping.

2. Sight glass on the water sump.

3. Hydraulically operated diaphragm control valve in the main discharge piping with rate of flow and water slug features.

4. Include a manual check mechanism external to the filter-separator to check the float. (The water slug feature must not be included on pipeline, barge, or tanker receipt lines. In those cases, use a differential pressure alarm and a differential pressure-actuated bypass valve.)

5. Only at barge-receiving locations or where large quantities of water are expected, automatic water drain valve connected to the bottom of the water sump.

6. Manual water drain valve from the bottom of the water sump.

7. Safety relief valve in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC).

8. Thermal relief valves. Provide a thermal relief valve on the vessel or integrate thermal relief via piloting on the filter-separator control valve.

9. Automatic air release with check valve.

10. Basket strainers immediately upstream of all receipt filter-separators.

11. Connect automatic water drains, manual drains, safety relief valve, and air releases to a permanently installed product recovery tank as described in Chapter 8 of this UFC or a suitable other container if a product recovery tank is not directly accessible.

12. Fuel sample connections upstream and downstream.

e. Do not provide sight gauges (sight flow indicators) on drain piping and thermal relief valves. Do not allow sight flow indicators to be installed on any filtration device.

f. Do not allow reverse flow thru filter-separators or any other filtration devices.

g. **\2** Provide a means for slow filling through the sump, to prevent static discharge when first filling empty filter-separator vessels. Slow filling through the sump may be bypassed, depending on the type of system, fuel type, and Service Headquarters requirements. ***/2/*** DoD Standard Design AW 078-24-28 gives details for this design feature.

15-7.1.2 Arrangement.

Arrange the system piping so that fuel from the discharge side of the fueling system transfer pumps can be recirculated back through the inlet filter-separators into the operating storage tank. Inlet filter-separators may serve more than one operating storage tank. In aircraft direct fueling systems on the downstream side of operating storage tanks, arrange the piping so that the fuel can be circulated from the operating storage tanks, through the filter-separators, to each aircraft fixed fueling station and back through the inlet filter-separators to the operating storage tanks. Provide dispensing filter-separators of the same number and capacity as the transfer pumps; that is, for three 600 gpm (38 L/s) pumps, provide three 600 gpm (38 L/s) filter-separators.

15-7.2 Micronic Pre-Filters.

Many aviation turbine fuel systems receive such a large amount of solid contaminants that the filter-separator coalescer elements are frequently changed out because the filter portion of the coalescers is loaded up with dirt and other solids. In such a case, it is often more economical to provide micronic pre-filters (with cheaper paper elements) ahead of the filter-separators to take out the majority of the solid contaminants before they reach the filter-separators. These devices are most often associated with intrastate interterminal and interstate interterminal pipelines as these lines generally have the largest amounts of solid contaminants in them. Contact Service Headquarters for guidance on when to use them as these will be installed only selectively. As a minimum for such facilities, provide micronic filters as follows:

a. Design and construct vessels in accordance with EI Specification 1590.

b. Provide horizontal vessels. Provide vertical units only where space constraints prohibit horizontal units. Provide access to at least one side of every vertical unit via a separate (not attached to the filter-separator), stand alone, fixed platform.

c. Design and construct vessels in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC). Construct metal parts which will be in contact with the fuel, including the shell, head, and internal attachments of 3003 or 5083 aluminum alloy, stainless steel, or interior epoxy-coated carbon steel. Include the following accessories:

1. Piston-type differential pressure gauge with 1 psi (5 kPa) graduations across the elements. Pressure gauge must be testable without removal from the piping.
2. Hydraulically operated diaphragm control valve in the main discharge piping with rate of flow features.
3. Manual drain valve.
4. Safety relief valve in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC).
5. Thermal relief valves. Provide a thermal relief valve on the vessel or integrate thermal relief via piloting on the filter-separator control valve.
6. Automatic air release with check valve.
7. Connect manual drains, safety relief valve, and air releases to a permanently installed product recovery tank as described in Chapter 8 of this UFC.
8. Fuel sample connections upstream and downstream.

d. Do not provide sight gauges (sight flow indicators) on drain piping and thermal relief valves. Do not allow sight flow indicators to be installed on any filtration device.

e. Do not allow reverse flow thru any filtration devices.

15-7.3 Haypack Coalescers.

Many aviation turbine fuel systems receive such a large amount of water that the filter-separators in the receiving lines would be quickly overwhelmed. In such a case, it is often economical to provide Haypack coalescer vessels ahead of the filter-separators to take out the majority of the gross water before it reaches the filter-separators. These devices are most often associated with barge and ship marine receipt systems as these generally have the largest amounts of water contamination. Contact Service Headquarters for guidance on when to use them as these will be installed only selectively.

Haypack coalescers are single-stage water coalescers with horizontal, cylindrically shaped housings designed to protect filtration systems from gross amounts of water and some of the larger solid contaminants. The media is excelsior (stranded wood fiber) although coarse fiberglass is also sometimes used. As a minimum for such facilities, provide Haypack coalescers as follows:

a. Provide horizontal vessels. Provide vertical units only where space constraints prohibit horizontal units. Provide access to at least one side of every vertical unit via a separate (not attached to the filter-separators), stand alone, fixed platform.

b. Use wafer style repack coalescers since they allow the first two sections to be replaced when required. The third and successive sections require fewer change outs since they may remain relatively free of solids. Coalescing first starts as the product enters the vessel. Due to the substantially reduced velocity, free water will fall out by gravity. While the product progresses through the mass packed media, further coalescing occurs by impingement of water droplets on the media. At the same time, solids tend to fall out as the liquid enters the housing at a reduced velocity, but are further removed by filtration as the flow continues through the mass media.

c. Design and construct vessels in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC). Construct metal parts which will be in contact with the fuel, including the shell, head, and internal attachments of 3003 or 5083 aluminum, stainless steel, or interior epoxy-coated carbon steel. Include the following accessories:

1. Piston-type differential pressure gauge with 1 psi (5 kPa) graduations across the elements. Pressure gauge must be testable without removal from the piping.

2. Hydraulically operated diaphragm control valve in the main discharge piping with rate of flow features.

3. Manual drain valve.

4. Safety relief valve in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC).

5. Thermal relief valves. Provide a thermal relief valve on the vessel or integrate thermal relief via piloting on the filter-separator control valve.

6. Automatic air release with check valve.

7. Connect manual drains, safety relief valve, and air releases to a permanently installed product recovery tank as described in Chapter 8 of this UFC.

8. Fuel sample connections upstream and downstream.

d. Do not provide sight gauges (sight flow indicators) on drain piping and thermal relief valves. Do not allow sight flow indicators to be installed on any filtration device.

e. Do not allow reverse flow thru any filtration devices.

15-8 PUMPS.

15-8.1 Design Requirements.

Design pumps to deliver the full range of operating conditions anticipated with flow rates as presented in Chapter 2 and Chapter 4 of this UFC. Ensure pumps develop sufficient head to overcome the friction and static head losses in the system at the rated flow. Consider the specific gravity, temperature, viscosity, vapor pressure, corrosive, and solvent properties of the fuel. If a range is given for the specific gravity, etc., in the "Fuel Properties and Additives" paragraph of Chapter 2, use the larger value for the purpose of calculations. For any single grade of fuel, connect pumps in parallel. Select according to the type most suitable for the particular application.**\2** Do not use positive displacement or reciprocating pumps for aircraft, truck or vessel product issue or product issue or installation pipelines. Positive displacement pumps can be used for product recovery return. ***/2/***. For bulk storage facilities, provide enough pumps to allow the system to operate at full capacity with the largest pump out-of-service. For aircraft fueling systems, provide at least two separate pumps for each type of aviation turbine fuel and at least two transfer pumps, each capable of delivering the required system capacity.

15-8.2 Centrifugal Pumps.

Use API Std 610 centrifugal pumps to pump from aboveground tanks with continuously flooded suctions.

15-8.3 Vertical Turbine Pumps.

Use API Std 610 vertical turbine pumps to pump from underground tanks. Do not use horizontal transfer pumps in a pit alongside the underground tank. Provide a foot valve on all vertical turbine pumps on Navy and USAFE Projects.

15-8.4 Jockey Pumps.

Use jockey pumps when tightness testing of underground pipelines is required. These pumps are ANSI type centrifugal pumps.

15-8.5 Rotary Pumps.

Use rotary self-priming pumps for applications such as stripping pipelines, direct off-loading stations, or similar service where the pump may frequently lose its prime. There are two main types of self-priming pumps permitted.

15-8.5.1 Positive Displacement Pumps.

Positive displacement pumps do not require prime but are required to be equipped with a pressure relief valve to prevent damage to the pump if the pump is started against a closed valve. If the positive displacement pump is used with a flow control valve, then an additional modulating pressure relief valve must be included at the discharge of the pump. This modulating pressure relief valve must not be used to modulate the pump discharge pressure as this will void the pump warranty.

15-8.5.2 Self-Priming Centrifugal Pumps.

Self-Priming centrifugal pumps are not completely self-priming, as they cannot pump only air; they require a mixture of fluid and air for priming. These pumps do not need a pressure relief valve at the discharge of the pump as they function like a standard centrifugal pump. These pumps require proper air venting at the pump discharge.

15-8.5.3 Stripper Pumps.

Provide positive displacement stripper pumps for emptying loading arms, hoses, and manifolds. Provide a stripper pump to reclaim each clean product from each main product line, or connect the product lines to the oil waste drain line. Conduct an economic analysis of the two alternatives to determine the appropriate choice. Larger, longer, or more frequently drained lines will favor the stripper pump choice. Use a stripper pump on multi-product lines, but do not exceed acceptable limits of cross contamination. Provide a dedicated stripper pump to each separate product line, such as aviation turbine fuels.

15-8.6 Drivers.

Drive permanently installed pumps by an electric motor which is properly classified in accordance with NFPA 70. Size drivers to be non-overloading at any point on the curve. Provide anti-reversing ratchets on all vertical turbine pump motors.

15-8.7 Materials of Construction.

For bulk fuel storage facilities, use carbon steel or nodular iron casings and components. For aviation turbine fuels, use cast steel or nodular iron casings and stainless steel impellers and trim. Consider nonferrous materials in severe corrosive environments and consult Service Headquarters.

15-8.8 Installation.

Mount permanently installed pumps on substantial foundations of reinforced concrete, designed in accordance with Hydraulic Institute Standards.

15-9 MANUAL VALVES.

15-9.1 Material of Construction – General Service.

Valves are required to have carbon steel bodies and bonnets except for aviation turbine fuels (see below). Valves in general service may be internal nickel plated, or internal epoxy-coated. Do not allow valves with aluminum, cast iron, or bronze materials. Use only API fire-safe valves complying with API Std 607.

15-9.2 Materials of Construction – Aviation Turbine

Fuel service valve materials in contact with aviation turbine fuel must either be stainless steel, chrome plated carbon steel, or electroless nickel plated carbon steel. Do not allow zinc, zinc-coated, copper, or copper bearing materials in contact with the fuel. Do not allow internally epoxy-coated valves. Manual valves in aviation turbine fuel systems are required to have stainless steel bodies and bonnets. Carbon steel bodied valves are permitted provided they are internally plated with nickel plating. Do not allow aluminum, cast iron, or bronze bodied valves. Use only API fire-safe valves complying with API Std 607.

15-9.3 Isolation Valves Types.

15-9.3.1 Double Block and Bleed Isolation Valves.

Except for those serving tactical refueler fillstands, double block and bleed valves are not allowed in systems covered by ground product fueling facilities in Chapter 7 of this UFC unless otherwise directed by Service Headquarters.

a. Plug Valves (Double Block and Bleed): Use lockable, double-seated, tapered lift, plug type valves with an automatic body bleed between the seats (double block and bleed) in critical applications such as separation of product services, on each line at the shore end, when piping goes aboveground or underground, between pier and tank storage, and other locations critical to pressure-testing of piping. Valves must be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to ensure closure and comply with API Std 607. Lubricated plug valves are not allowed. Include integral body cavity thermal relief valve.

b. Ball Valves (Double Block and Bleed): Use double-seated, trunnion mounted, lockable, ball type valves with a body bleed between the seats (double block and bleed). These will be very rarely used but are acceptable as an alternative to double block and bleed plug valves in applications where the valve is operated very infrequently. Examples are isolation valve pits or isolation valves in the middle of piers, where they are only closed to perform pressure testing of piping. Valves must be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Include integral body cavity thermal relief valve.

c. Gate Valves (Double Block and Bleed): Use double-seated, lockable, gate type valves with a body bleed between the seats (double block and bleed). These will be very rarely used but are acceptable as an alternative to double block and bleed plug valves and double block and bleed ball valves only when other double block and bleed valves will not physically fit. Valves must be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Single seated gate valves are not allowed. Include integral body cavity thermal relief valve.

15-9.3.2 Quick Opening/Frequent Opening Isolation Valves.

Use full port valves with exact same diameter of the pipe when line pigging is required.

a. Ball Valves: Ball type valves may be used as valves for quick or frequent opening applications when a double block and bleed valve is not required. Ball type, lockable, valves must be designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Use Teflon or Viton synthetic seals or seating material. Use full port ball valves with exact same diameter of the pipe within ten pipe diameters upstream and/or five pipe diameters downstream of a flow or pressure control valve, or a flow-sensing device such as a venturi. Valves should comply with API Std 608.

b. Butterfly Valves: High-performance wafer trunnion butterfly type valves designed so that if the synthetic seating material is burned out in a fire, a metal-to-metal seat will remain to affect closure and comply with API Std 607. Use Teflon or Viton synthetic seals or seating material. Use valves of high performance type with eccentric disc shaft and clamping action for bubble-tight shutoff. Provide only at inlet to truck fillstand and on supply and return risers at aircraft direct fueling stations with fusible link set to release at 165 degrees F (74 degrees C). These valves are not required nor permitted on Air Force projects. Butterfly valves are not allowed in aircraft fueling facilities, marine receiving and dispensing facilities, and filling stations at ground product fueling facilities.

15-9.4 Isolation Valve Operators.

Provide manually operated valves not specified for remote, automatic, or emergency operation. Double block and bleed gate, ball, and plug valves specified for remote, automatic, or emergency service may have electric motor operators with suitable torque limiting controls, if approved by Service Headquarters. For remote valves, consider using solar battery packs to reduce cost of routing power for the motor operators. Provide geared operators for ball and double block and bleed valves larger than 6 inches (150 mm). Provide locking tabs on isolation valves to allow padlocks to be used to lock out valves during maintenance. Provide chain operators on valves which are located 72 inches (1800 mm) or higher above grade.

15-9.5 Isolation Valve Pits.

Provide fiberglass or concrete pits with a rolling or hinged cover designed in accordance with the DoD Standard Design AW 78-24-28 for all isolation valves installed in nontraffic areas on underground fuel systems. Design valve pits and valve operators so that the valves can be operated by personnel, without confined space entry.

15-10 OTHER VALVES.

15-10.1 Check Valves.

Use check valves to prevent backflow through pumps, branch lines, meters, or other locations where runback or reverse flow must be avoided. Check valves may be of the swing disk, globe, dual plate hinged disk, spring-loaded poppet, ball, or diaphragm-actuated types. Use checks of soft-seated non-slamming type with renewable seats and disks. Ensure check valves conform to API Spec 6D. Use non-surge check diaphragm control valves with flow control feature on the discharge of all pumps. When using non-surge check diaphragm control valves on pump discharge, consider the use of a spring type wafer check before the diaphragm control valve to prevent sudden flow reversals during shutdown from passing back through the pump before the diaphragm control valve diaphragm chamber is filled and reacts by closing the valve.

15-10.2 V-Port Ball Valves.

Valve must conform to requirements as specified for “Ball Valves” paragraph in this section. Valve must be provided with characterized linear v-port for flowrate control, and with infinite position lever bracket with locking bolt for set position. These valves are to be used only in packaged off-loading systems.

15-10.3 Thermal Relief Valves.

Provide thermal relief valves around isolation and check valves to relieve excessive pressures caused by thermal expansion of liquid trapped between shutoff points. See Facility Plates 020, 021, 022 and 023.

15-11 DIAPHRAGM CONTROL VALVES.

Hydraulically operated, single-seated, globe type, diaphragm actuated control valves are used extensively in fueling systems as control valves. These valves consist of a main valve and a pilot control system. The main valve consists of body, diaphragm, and cover and is operated by varying the amount of pressure above the diaphragm. Since the chamber above the diaphragm exposes a greater area of the diaphragm to chamber pressure than the area of the disc exposed to line pressure, an equal pressure in the chamber and pipeline results in a greater force being applied to the top of the disc. This forces the disc against the seat, thus closing the valve. By selecting the proper pilot control system, these valves can be used in numerous ways to control flow, pressure, and level within fueling systems. Use extreme care when including these valves on pipelines as they can significantly contribute to surge potential, if closing time is too short. When properly adjusted, they can reduce surges.

15-11.1 Open/Close Operation.

This is the most basic function of hydraulically operated diaphragm control valves. The operation is accomplished by applying pressure above the diaphragm to close the valve and relieve that pressure to allow line pressure to open the valve. The pilot trim used to perform this operation is a three-way valve which can be controlled by a solenoid, hand, pressure, pressure differential, or a float.

15-11.2 Throttling Operation.

This is the other main method of controlling the hydraulically operated diaphragm control valve. In this case, the valve modulates to any degree of opening, in response to changes in the throttling control. The throttling control reacts to a pressure, or a pressure differential across the main valve, or pressure differential across an orifice plate to regulate the position of the disc in the main valve. For proper operation these valves should be installed with straight pipe on both sides of the valve. Ten pipe diameters on the upstream side and five pipe diameters on the downstream side is sufficient; provide full port manual isolation valves if they are placed within these limits.

15-11.3 Check Valve Function.

This is a unique function of a control valve. In this case, the main valve outlet pressure is connected to the diaphragm cover. Therefore, if the downstream outlet pressure exceeds the inlet pressure, which normally holds the valve open, the valve will close and prevent backflow. Note: In order for the valve to close, it must backflow, sometimes for a substantial amount of time. Consider putting a regular check valve in series with this valve in cases where this is a concern.

15-11.4 Remote Operations.

Hydraulically operated diaphragm control valves can be operated remotely. This is accomplished by installing tubing from the point of pressure sensing to the valve or by using remote-controlled solenoids within the trim.

15-11.5 Materials of Construction.

Use stainless steel pilot control valves and stainless steel tubing. Use bodies, bonnets, and covers made of stainless steel, internally plated (chrome) steel, or internally plated (nickel) nodular iron. Provide Viton or Buna-N diaphragm and disc ring. Enclose all electrical apparatus according to classification of the area in which they are installed. Provide a means to wire seal all adjustable pilots. Do not use aluminum valves.

15-11.6 Applications.

These valves are not required in filling stations at ground product fueling facilities (Chapter 7). Use hydraulically operated diaphragm control valves in the following applications:

a. Water slug shutoff.

b. Rate of flow control.

c. Pressure reduction.

d. Pressure relief.

e. Liquid level control.

f. Non-surge check control.

g. Deadman control.

h. Electrical block control.

i. Excess flow shutdown.

15-11.7 Combinations.

A combination of these controls is also possible. A typical use of these controls is on a filter-separator for water slug shutoff and rate of flow control.

15-12 FUEL HOSES.

Use sizes as required for design flow rates. For hose flanges and nipples, use carbon steel or brass, except at aviation turbine fuel issue points use brass, stainless steel, or aluminum where metal parts contact the fuel.

15-12.1 Loading Fuel Hoses.

Provide pressurized loading hoses and connections complying with EI Std 1529.

15-12.2 Off-Loading Fuel Hoses.

Provide lightweight, flexible, non-pressurized off-loading hoses constructed of nitrile rubber, rigid polyvinyl chloride (PVC) helix, synthetic braiding, smooth bore, and corrugated outer diameter. Provide non-pressurized hoses with a 65 psi (450 kPa) rating at 72 degrees F (22 degrees C) and 27 in Hg (90 kPa) vacuum rating.

15-12.3 Submarine Fuel Hoses.

Loading/off-loading arms are the preferred method to be used. Provide a facility for storing and protecting the hose as near as practical to the pier if hose is provided in lieu of loading/off-loading arm.

Provide submarine fuel hose where offshore moorings are used. Use heavy duty, smooth bore, oil and gasoline, marine cargo, discharge hose rated for a working pressure of not less than 225 psig (1550 kPa) and built-in nipples with Class 300 flanges with stainless steel bolts and Monel nuts. **\2** Hoses must meet U. S. Coast Guard requirements. ***/2/***

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CHAPTER 16 AUSTERE LOCATION FUEL SYSTEM REQUIREMENTS

16-1 INTRODUCTION.

This chapter provides guidance for the design of fuel systems in austere locations. An austere location is an installation where real property infrastructure is present, but does not have any permanently assigned operational assets such as aircraft, ships, tanks, or other weapons systems. These locations are typically maintained in a caretaker status. If DLA fuel system capitalization is required, DLA must be included during the decision making to provide approval of designing the fuel system in accordance with this chapter. Approval by the Service Headquarters Subject Matter Expert (SME) is required to use the sections in this chapter. The Mission Owner described in this chapter is combatant or supporting command unit that is requiring the fuel system. Approval may be given on a line item basis.

16-1.1 Qualifications.

To use this chapter, one or more of the following qualifications must be met.

a. The location is geographically separated from other installations.

b. The location does not have assigned operational assets.

c. The location does not have assigned personnel. Personnel required to maintain the installation in a caretaker status may be present.

d. Ability to connect to local utility services is restricted.

16-2 GENERAL REQUIREMENTS (REF. CHAPTER 2).

Chapter 16 provides supplemental guidance for locations that meet the qualifications outlined in paragraph 16-1.1 and have written Service Headquarters Subject Matter Expert approval. Designers must follow UFC 3-460-01 Chapters 1 through 15 except when approval to follow chapter 16 has been provided by the Service Headquarters Subject Matter Expert.

16-2.1 Operational Capabilities (Ref. Paragraph 2-1).

Design austere fuel systems to meet the specified mission requirement as coordinated with the SCP. This may include a certain amount of redundancy for various reasons to include continued operation due to natural disaster, attack, or continued operation. However, these systems are not required to have the same redundancies typically seen in primary fuel systems.

16-2.2 Transfer Flow Rates (Ref. Paragraph 2-5).

The receipt and transfer flow rates established in Table 2-4 are a guide and not required. Greater or slower flow rates may be acceptable depending on the mission. The issue flow rates are well established and should be followed.

16-2.3 Voice Communications (Ref. Paragraph 2-8).

Where possible, provide a direct line for voice communications between separated areas such as receiving, dispensing, pump stations, and fuel storage areas to coordinate operations involved in fuel transfer. Where not possible, ensure a reliable form of communication is established and the Service Control Point (SCP) concurs with the selected solution.

16-2.4 Safety Showers and Eyewash Fountains (Ref. Paragraph 2-10.1).

The designer is to review the availability of existing utilities and evaluate individual circumstances at these locations. At a minimum, showers are required within 15 second reach of any corrosive chemicals, such as hydrazine and some additives, IAW OSHA and service safety requirements. At all other fuel facilities, either a fixed or portable eyewash is required. Coordinate with the SCP if portable eyewash units are planned to be used.

16-2.5 Corrosion Control.

Corrosion control is extremely important in these types of facilities. Corrosion prevention strategies should be based on the climate of the location. Refer to UFC 1-200-01 for Environmental Severity Classification and humidity design requirements for these locations and their corrosion prevention requirements. Every effort should be made to prevent corrosion by material selection, construction practices and standard corrosion prevention practices.

16-2.6 Cathodic Protection (Ref. Paragraph 2-12).

In addition to paragraph 2-12, the use of cathodic protection in these facilities should be minimized to the maximum extent possible through material selection and other mitigating measures.

16-2.7 Fire Protection (Ref. Paragraph 2-14).

In many of these locations, adequate utilities to support water based fire protection measures will not be available. A fire prevention and protection strategy needs to be established for the entire fuels related compound, including tanks, pump facilities, filtration facilities, tank truck and tank car facilities, aircraft parking and fueling facilities, refueler vehicle facilities, fuel testing laboratories, support facilities, and fuel piers to prevent the spread of fire beyond the level of an acceptable risk. The Mission Owner, Subject Matter Expert and host installation (if applicable) need to agree to the level of risk and cost of protection that is acceptable.

- Alternate forms of fire protection should be considered such as fire valves, fire breaks, and fire barriers. Distance remains the best method to prevent fire from spreading to other assets and should be carefully considered.

- Fuel driven pumps should be rated for the fuel that is available at the location. A separate logistical trail should be avoided.

16-2.8 Emergency Fuel Shut-Off (Ref. Paragraph 2-15).

Follow paragraph 2-15 to the maximum extent possible. The installation of an emergency fuel shut-off may be problematic due to system configuration or extensive maintenance. A request to install emergency bypass to the emergency fuel shut-off switch or to deviate from the prescribed EFSO switch locations must be submitted to the Service SME for review and approval. This approval will only be for a specific location and fuel system.

16-2.9 Material Acquisition.

Material acquisition, such as sand for under the tank bottoms, in these environments can be extremely difficult. Where possible, procure locally available materials that meet the technical requirements and comply with federal and host nation regulations.

16-3 BULK FUEL STORAGE FACILITIES (REF. CHAPTER 3).

16-3.1 Tank Truck and Tank Car Off-loading Facilities (Ref. Paragraph 3-3.1.3).

a. Where possible, do not locate tank truck or tank car receiving facilities closer than 50 feet (15m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines, and 25 feet (7.6m) from the installation interior fence surrounding the fuel farm. Where tank truck or tank car receiving facilities need to be closer than the prescribed distances, determine potential ignition risks and install other means of fire protection to mitigate the risk. The mitigation measure must be approved by the Service Headquarters Subject Matter Expert. Receiving facilities should maintain as much distance as possible if they are unable to meet the recommended stand-off distances.

b. Provide a spill containment system in accordance with Chapter 3 if possible. Alternate methods of containment must be approved by the Service Headquarters Subject Matter Expert on a case-by-case basis.

c. For off-loading tank trucks, arrange the flow of traffic to permit continuous forward movement of tank trucks. If space does not permit this, the tank truck off-loading area will be limited to two truck positions per lane, with space behind the second truck to back up.

d. Provide for adequate response of emergency vehicles. This is to be determined by the site layout and in conjunction with representatives of the emergency vehicle community.

16-3.2 Tank Car and Tank Truck Off-loading Facility Required System Components (Ref. Paragraph 3-3.1.7).

a. Provide an emergency fuel shutoff (EFSO) at the ingress and egress of the truck off-loading stations in accordance with paragraph 16-2.8.

b. Follow the recommended system components. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-3.3 Pipeline Pumping Facilities Required System Components (Ref. Paragraph 3-4.1.2).

Follow the required system components. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-3.4 Controls (Ref. Paragraph 3-7).

Controls for these type of systems must be simplified versions. Use the control scheme that provides the greatest reliability and the lowest maintenance for the mission of the location.

16-4 AIRCRAFT FUELING FACILITIES (REF. CHAPTER 4).

16-4.1 Pipeline receiving Facilities Required System Components (Ref. Chapter 4.3.1.2).

Follow the required system components. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-4.2 Tank Truck and Tank Car Off-Loading Facilities (Ref. Paragraph 4-3.2).

a. Use an alternate receipt mode where ever practical. It is not required to have two methods of receipt.

b. Where possible, do not locate tank truck or tank car receiving facilities closer than 50 feet (15m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines, and 25 feet (7.6m) from the installation interior fence surrounding the fuel farm. Where tank truck or tank car receiving facilities need to be closer than the prescribed distances, determine potential ignition risks and install other means of fire protection to mitigate the risk. The mitigation measure must be approved by the Service Headquarters Subject Matter Expert. Receiving facilities should maintain as much distance as possible if they are unable to meet the recommended stand-off distances.

c. Provide a spill containment system in accordance with 4-3.2.1 if possible. Alternate methods of containment must be approved by the Service Headquarters Subject Matter Expert on a case-by-case basis.

d. For off-loading tank trucks, arrange the flow of traffic to permit continuous forward movement of tank trucks. If space does not permit this, the tank truck off-loading area will be limited to two truck positions per lane, with space behind the second truck to back up.

e. Provide access for adequate response of emergency vehicles. This is to be determined by the site layout and in conjunction with representatives of the emergency vehicle community.

f. For tank truck and tank car off-loading facilities, follow the required system components. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-4.3 Dispensing Facilities (Ref. Chapter 4-4).

16-4.3.1 Refueler Truck Fillstands (Ref. Chapter 4-4.1).

a. Mission and turn-around times will establish the number of fill positions. There are no minimum number of positions.

b. Where possible, do not locate the refueler loading facility closer than 50 feet (15m) from buildings, roads, overhead power lines, pad-mounted transformers, and installation property lines, and 25 feet (7.6m) from the installation interior fence surrounding the fuel farm. Where tank truck or tank car receiving facilities need to be closer than the prescribed distances, determine potential ignition risks and install other means of fire protection to mitigate the risk. The mitigation measure must be approved by the Service Headquarters Subject Matter Expert. Receiving facilities should maintain as much distance as possible if they are unable to meet the recommended stand-off distances. Do not locate closer than allowed per NFPA.

c. Provide a spill containment system in accordance with 4-4.1.1 if possible. Alternate methods of containment must be approved by the Service Headquarters Subject Matter Expert on a case-by-case basis.

d. Provide access for adequate response of emergency vehicles. This is to be determined by the site layout and in conjunction with representatives of the emergency vehicle community.

e. For refueler truck fillstands, follow the required system components. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-4.3.2 Aircraft Direct Fueling Systems (Ref. Chapter 4-4.2).

a. Aircraft Direct Fueling Systems in austere environments are based on the Type III, IV and V hydrant systems. Systems in austere environments may be simplified versions of the highly controlled standard systems. Additionally, modifications can be made to improve reliability but may sacrifice some operational capability as long as it is acceptable to the

Mission Owner and the Fuels Operators. An example of this is using commercial pits, which improve reliability but eliminate the ability to defuel the aircraft through the hydrant system.

b. For dual pressure control, a single device can be used. The single device must be a combination of the HSV and a pressure control coupler when commercial pits are used. Hose end couplers provide pressure control but do not have surge features.

16-4.4 Description of System Components (Ref. Chapter 4-6).

For dispensing facilities, follow the required system components. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-4.5 Controls (Ref. Paragraph 4-7).

Controls for these type of systems must be simplified versions. Use the control scheme that provides the greatest reliability and the lowest maintenance for the mission of the location.

16-4.6 Aviation Turbine Fuel Receipt Filtration Table (Ref Table 4-1).

Use Table 4-1 as a guide. The designer will need to analyze the particular situation and determine the most appropriate fuel cleaning methodology.

16-5 MARINE RECEIVING AND DISPENSING FACILITIES (REF. CHAPTER 5).

16-5.1 Controls (Ref Paragraph 5-9).

Controls for these type of systems may be simplified versions, for example Programmable Logic Controller (PLC), electro-mechanical relay or manual operation. Use the control scheme that provides the greatest reliability and the lowest maintenance for the mission of the location.

16-6 INTERTERMINAL AND INSTALLATION PIPELINES (REF. CHAPTER 6).

16-6.1 Controls (Ref Paragraph 6-6).

Controls for these type of systems may be simplified versions, for example Programmable Logic Controller (PLC), electro-mechanical relay or manual operation. Use the control scheme that provides the greatest reliability and the lowest maintenance for the mission of the location.

16-7 GROUND PRODUCTS FUELING FACILITIES (REF. CHAPTER 7).

16-7.1 Stand-off Distances (Ref. throughout Chapter 7).

Where possible, follow the prescribed stand-off distances prescribed in Chapter 7. Where facilities need to be closer than the prescribed distances, determine potential ignition risks and install other means of fire protection to mitigate the risk. The mitigation measure must be approved by the Service Headquarters Subject Matter Expert. Ground Products Fueling Facilities should maintain as much distance as possible if they are unable to meet the recommended stand-off distances. At a minimum, federal, state, and local regulations must be followed.

16-7.2 Spill Containment (Ref. Paragraph 7-3.12).

Provide a spill containment system in accordance with Chapter 7 if possible. Alternate methods of containment must be approved by the Service Headquarters Subject Matter Expert on a case-by-case basis.

16-7.3 Controls (Ref. Paragraph 7-6).

Controls for these type of systems may be simplified versions. Use the control scheme that provides the greatest reliability and the lowest maintenance for the mission of the location.

16-8 ATMOSPHERIC STORAGE TANKS (REF. CHAPTER 8).

16-8.1 General Criteria (Ref. Chapter 8-3).

a. Any deviation to tank materials must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

b. Provide a minimum of two tanks for each type of fuel to ensure the tanks can be maintained appropriately. A single tank option may be used if the mission supports it.

c. Follow tank spacing, as prescribed in paragraph 8-3.5, as much as possible. In austere locations, cost and available land may force the tanks to be placed closer together. In these circumstances, the tank spacing must not be less than the spacing requirements stated in NFPA 30. Where facilities need to be closer than the prescribed distances, determine potential ignition risks and install other means of fire protection to mitigate the risks. The mitigation measure must be approved by the Service Headquarters Subject Matter Expert. Tanks should maintain as much distance as possible if they are unable to meet the recommended stand-off distances. At a minimum, federal, state and local regulations must be followed.

16-8.2 Horizontal Aboveground Tanks (Double Wall Steel) (Ref. Chapter 8-5).

Tank dimensions and capacity may be exceeded. However, the tanks must be UL listed or equivalent. Tanks larger than those prescribed in paragraph 8-5 may be difficult to transport. Logistical challenges must be accounted for. At a minimum, host nation, federal, state, and local regulations must be followed.

16-8.3 Aboveground Vertical Storage Tanks (Ref. Chapter 8-8).

a. If use of sand beneath the tank bottom is impractical, alternative methods may be considered. The mitigation measure must be approved by the Service Headquarters Subject Matter Expert.

b. Alternatives to hydrostatic testing may be required for austere environments. If deviating from a standard practice, the revised procedures must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-8.4 Underground Horizontal Storage Tanks (Ref. Chapter 8-9).

Tank dimensions and capacity may be exceeded. However, the tanks must be UL listed or equivalent. Tanks larger than those prescribed in paragraph 8-5 may be difficult to transport. Logistical challenges must be accounted for. At a minimum, host nation, federal, state, and local regulations must be followed.

16-8.5 Appurtenances (Ref Chapter 8-11).

For tanks, follow the appurtenances as outlined in Table 8-1. Any requested changes must be submitted to the Service Headquarters Subject Matter Expert for review and approval.

16-8.6 Aboveground Tank Spill Containment Systems (Ref. Chapter 8-14).

Use Chapter 8-14 as a guide to design containment systems for aboveground tanks. For austere systems, alternative methods of containment may be considered. This includes alternative tank dike, remote impoundment, and remote containment design. Key considerations for designing the tank containments are safety of operators who may be in the tank containment area, fire prevention, and the ability to contain a fuel spill.

16-9 PIPING SYSTEMS (REF. CHAPTER 9).

(Reserved)

16-10 ALTERNATE POL FACILITIES (REF. CHAPTER 10).

(Reserved)

16-11 SUPPORT FACILITIES (REF. CHAPTER 11).

(Reserved)

16-12 MAJOR REHABILITATION (REF. CHAPTER 12).

(Reserved)

16-13 FUELING FACILITY TEMPORARY DEACTIVATION (REF. CHAPTER 13).

(Reserved)

16-14 FUELING FACILITY CLOSURE (REF. CHAPTER 14).

(Reserved)

16-15 FUEL SYSTEM COMPONENTS (REF. CHAPTER 15).

(Reserved)

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APPENDIX A MANUAL SURGE CALCULATIONS FOR SIMPLE PIPING SYSTEMS

1. Determine the critical time of the system. This is defined as the time it takes for the first increment of the pressure wave to travel upstream, reflect, and return to the valve. Use the following equation:

EQUATION (1):

$$T_c = \frac{2L}{a}$$

Where:
T_c = critical closure time of system(s)
L = length of pipe (ft or m)
a = surge pressure wave velocity (fps or m/s)

Values for "a" for liquid petroleum in schedule 40 steel pipe are as follows. These values are based on hydrocarbons with a specific gravity of 0.8 at a temperature of 68 degrees F (20 degrees C):

Nominal Pipe Size inches (mm)	Surge Pressure Wave Velocity, "a" ft/s (m/s)
2 (50)	3,771 (1149.4)
3 (75)	3,763 (1147.0)
4 (100)	3,736 (1138.7)
6 (150)	3,692 (1125.3)
8 (200)	3,663 (1116.5)
10 (250)	3,639 (1109.2)
12 (300)	3,599 (1097.0)

2. If valve closure time (T) is less than Tc, it is equivalent to instantaneous closure and will result in maximum surge pressure. The equation used to calculate surge pressure rise for this situation is:

EQUATION (2):

$$P_1 - P = (V_1 - V_0)(\rho)(a)$$ ***(Metric Units)***

$$P_1 - P = [(V_1 - V_0)(\rho)(a)] / [(C)(g_c)]$$ ***(English Units)***

Where:
P_1 = maximum pressure (psig or Pa)
P = pump shutoff pressure (psig or Pa) (equal to system static pressure)
V_1 = initial velocity (fps or m/s)
V_0 = final velocity (fps or m/s)
ρ = density of the fluid (lbm/ft^3 or kg/m^3)
a = surge pressure wave velocity (fps or m/s)

C = unit conversion factor (144 in^2/ft^2)
g_c = gravitational unit conversion constant (32.17 ft · lbmass / (lbforce · sec^2))
Metric units require no conversion. 1 Pa = 1 N / m^2 = 1 kg / (m · sec^2)

3. For example, a fuel storage facility has a truck loading rack located 2,000 feet (610 m) away. The load rack is fed by a 600 gpm (38 L/s) pump located at the storage facility. The load rack is equipped with a deadman apparatus which is tied to a hydraulically operated diaphragm control valve at the rack. The valve has a closure time of 1.0 seconds. The pipe is 6-inch (150 mm) diameter carbon steel, Schedule 40, with Class 150 flanges. The pump shutoff pressure is 60 psig (410 kPa). Find the critical time of the system if the loading rack control valve closes.

$$T_c = 2L/a = 2 \times 2{,}000/3{,}692 = 1.08\, seconds$$

From the table of values for "a", the surge pressure wave velocity (a) is 3,692 fps (1125.3 m/s). The maximum pressure in any pipeline occurs when the total discharge is stopped in a period of time equal to or less than the critical time. Since the valve will theoretically close prior to this, Equation (2) should be used to determine the pressure rise. In this case, the final velocity (V_o) will be assumed to be zero because the critical time is greater than the valve closure time.

$$P_1 - P = [(V_1)(\rho)(a)] / [(144)(g_c)]$$

$$= [(6.81 \times 51.5 \times 3{,}692)] / [(144 \times 32.2)] = 279\, psig\ (1925\, kPa)$$

$$P_1 = P + 273 = 60 + 279 = 339\, psi\ (2337\, kPa)$$

Initial velocity (V_1) was found by dividing the given flow rate of 600 gpm (38 L/s) by the cross sectional area of the 6-inch (150 mm) diameter, Schedule 40 pipe. Considerations will have to be made for this system to deal with the maximum predicted pressure.

4. When the valve closure time is longer than the critical time, the surge will be less than predicted by Equation (2). The equation used to calculate surge pressure rise for this situation is:

EQUATION (3):

$$P_1 - P = [2(L)(\rho)(V_1 - V_c)] / [1.3\,(T)] \qquad \textit{(Metric Units)}$$

$$P_1 - P = [2(L)(\rho)(V_1 - V_c)] / [1.3\,(C)(g_c)(T)] \qquad \textit{(English Units)}$$

Where:
P_1 = maximum pressure (psig or Pa)
P = pump shutoff pressure (psig or Pa) (equal to system static pressure)
V_1 = initial velocity (fps or m/s)
V_0 = final velocity (fps or m/s)

ρ = density of the fluid (lbm/ft^3 or kg/m^3)
a = surge pressure wave velocity (fps or m/s)
C = unit conversion factor (144 in^2/ft^2)
g_c = gravitational unit conversion constant (32.17 ft · lbmass / (lbforce · sec^2))
Metric units require no conversion. 1 Pa = 1 N / m^2 = 1 kg / (m · sec^2)

Determination of V_c is too complex for simple calculation. Therefore, for the conditions where $T > T_c$, use a computer modeling program.

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APPENDIX B CHARTER OF DOD FUELS DISCIPLINE WORKING GROUP (FDWG)

B-1 INTRODUCTION.

To benefit from Department of Defense (DoD) wide petroleum, oils, and lubricants (POL) expertise and apply it to fuel facilities issues facing the DoD, the Engineering Senior Executive Panel (ESEP) approved (2018) the establishment of the Fuels Discipline Working Group, previously known as the Fuels Facility Engineering Panel (FFEP). The FDWG consists of recognized POL experts, primarily from the engineering community, to establish the criteria for the DoD community on ways to provide safe, operationally effective, and economic fuel facilities systems to meet the mission requirements. The FDWG will examine, develop, recommend and provide design features for the standardization of facilities and equipment, and procedures used in fuel handling systems for storage, distribution, maintenance and dispensing of aircraft, marine, and ground fuels. The FDWG will evaluate facility component parts on DoD installations and will serve as a pool of expertise to assist in resolving systemic fuel handling facility problems. FDWG meetings will also serve as a forum to update members on new equipment, DoD or service-specific programs, and changes affecting the fuels facility maintenance, repair and construction community.

B-2 COMPOSITION.

B-2.1 FDWG Members.

a. Air Force Fuels Facility Subject Matter Expert (AFCEC/COSM)

b. NAVFAC Fuels Facility Subject Matter Expert (NAVFAC EXWC)

c. HQ Army Corps of Engineers Technical POC, POL Facility Criteria (CECW-EC)

B-2.2 Associate member:

a. Defense Logistics Agency Installation Support for Energy – Facilities Engineer (DLA-DF-FEI)

B-2.3 Coordinating members.

a. Defense Logistics Agency (Installation Management; Installation Operations)

b. Defense Logistics Agency Energy (SRM; Quality)

c. Defense Fuel Region Facility Managers

d. AF MAJCOM Fuels Engineers

e. AF Petroleum Agency Fuels Facilities Team

f. NAVPETOFF Fuels Facility Engineers

g. NAVAIR Fuels Engineers

h. NAVFACENGCOM, Fuels Facility Engineers

i. Army Petroleum Center Fuel Facility Team Members

j. Army Corps of Engineers, Omaha District, POL Mandatory Center of Expertise (POL-MCX)

k. Space and Naval Warfare Systems Center Atlantic (SPAWAR Atlantic)

B-3 TASKS.

Tasks of the FDWG include but are not limited to:

1. Develop and maintain standardized designs for receipt, storage, and dispensing fuel facilities and fuel systems.
2. Periodically review and update UFC 3-460-01 and UFC 3-460-03, including referenced DoD fuel handling facility criteria, and fuel system maintenance and repair criteria, and fuel facility assessment criteria (FUELER).
3. Perform technical review and provide approval of new or proposed design standards or concepts.
4. Review fuel system operational challenges, including system components and materials, and recommend corrections.
5. Cross-feed information such as problems and solutions, new missions and equipment, needed modifications to equipment, and new DoD or Service-wide programs and periodically communicate this information in a newsletter.
6. Provide a means of communication among the Air Force, Army, Navy, and DLA Energy to reduce duplication and institutionalize DoD-wide Standardization for fuel facilities.
7. Evaluate changes to fuel facilities that enhance training and efficient use of operation and maintenance personnel.
8. Provide information to fueling operations personnel to assure proper operation of equipment.
9. Assess the impact of mission demand, environmental, health and fire safety, energy, economic, and other drivers on fuel facilities design, and develop criteria that will address these impacts.

B-4 MEETINGS.

1. The Chairperson will be rotated biennially among the FDWG and Associate members.

2. The FDWG will meet at the call of the Chairperson but not less than once per year. FDWG members may request a meeting at any time. A quorum consists of not less than three FDWG/Associate members, and no more than one Proxy.

3. Decisions of the FDWG will be by consensus among the FDWG/Associate members.

4. When a FDWG/Associate member cannot attend a meeting, the member shall appoint a proxy for meeting attendance. The FDWG must be advised of the proxy prior to the meeting.

B-5 CHARTER REVIEW.

1. The FDWG will review the Charter at least once per year, and update as required.

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APPENDIX C PLATES

Note: This appendix contains information for technical guidance only. -

Plate 022 – Thermal Relief Piping Systems Truck Offload Stations and Fillstands

Plate 023 – Thermal Relief Piping Systems Storage Tanks

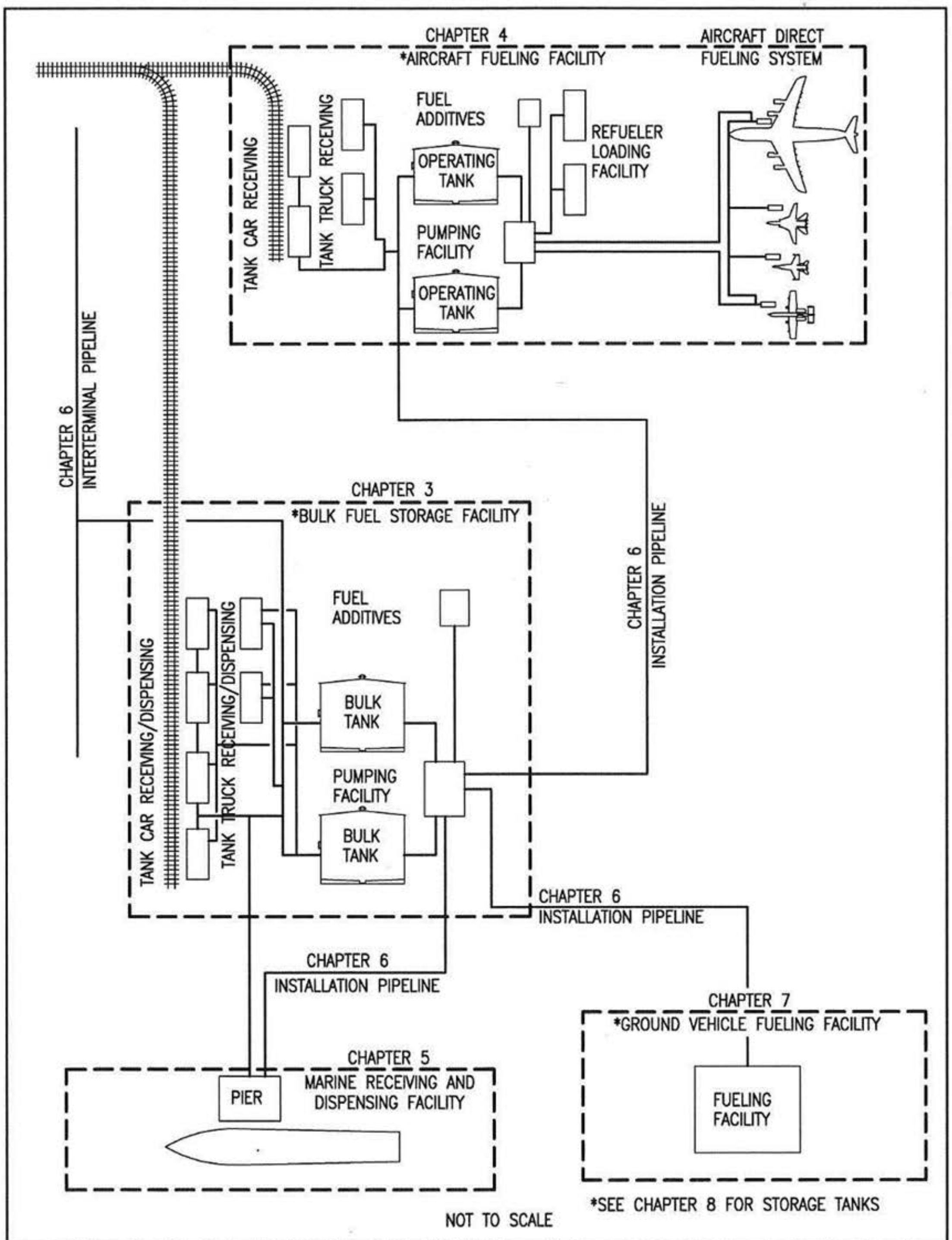
Plate 024 – Liquefied Petroleum Gas Facilities Small Volume Facility for Trucks and Cylinders

Plate 025 – Liquefied Petroleum Gas Facilities Large Volume Facility for Tank Cars and Water Vessels

Plate 026 – Liquefied Petroleum Gas Facilities Tank Spacing Requirements

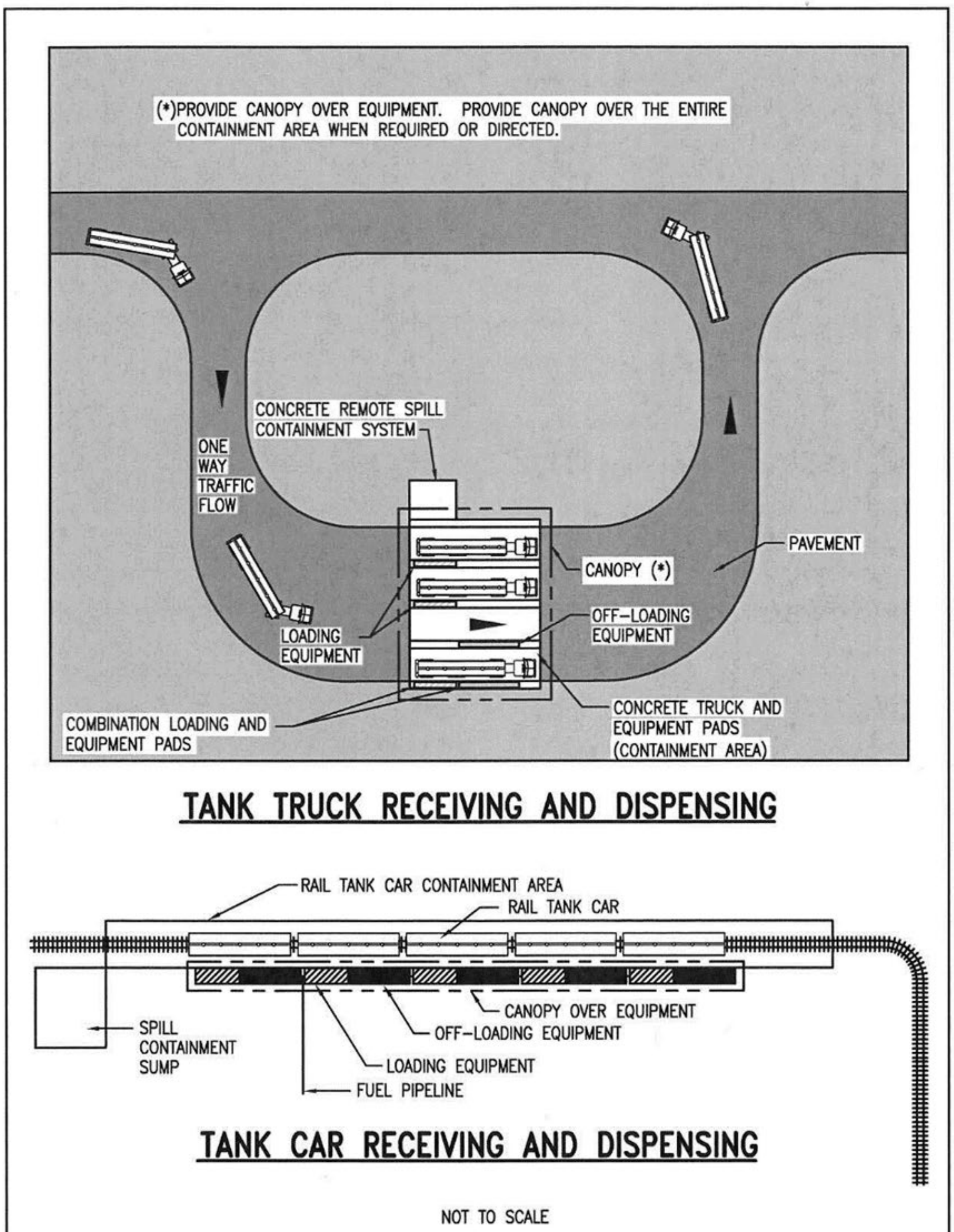
Plate 027 – Liquefied Petroleum Gas Facilities Tank Spacing Requirements

Plate 001 – UFC Chapter Identification Plan



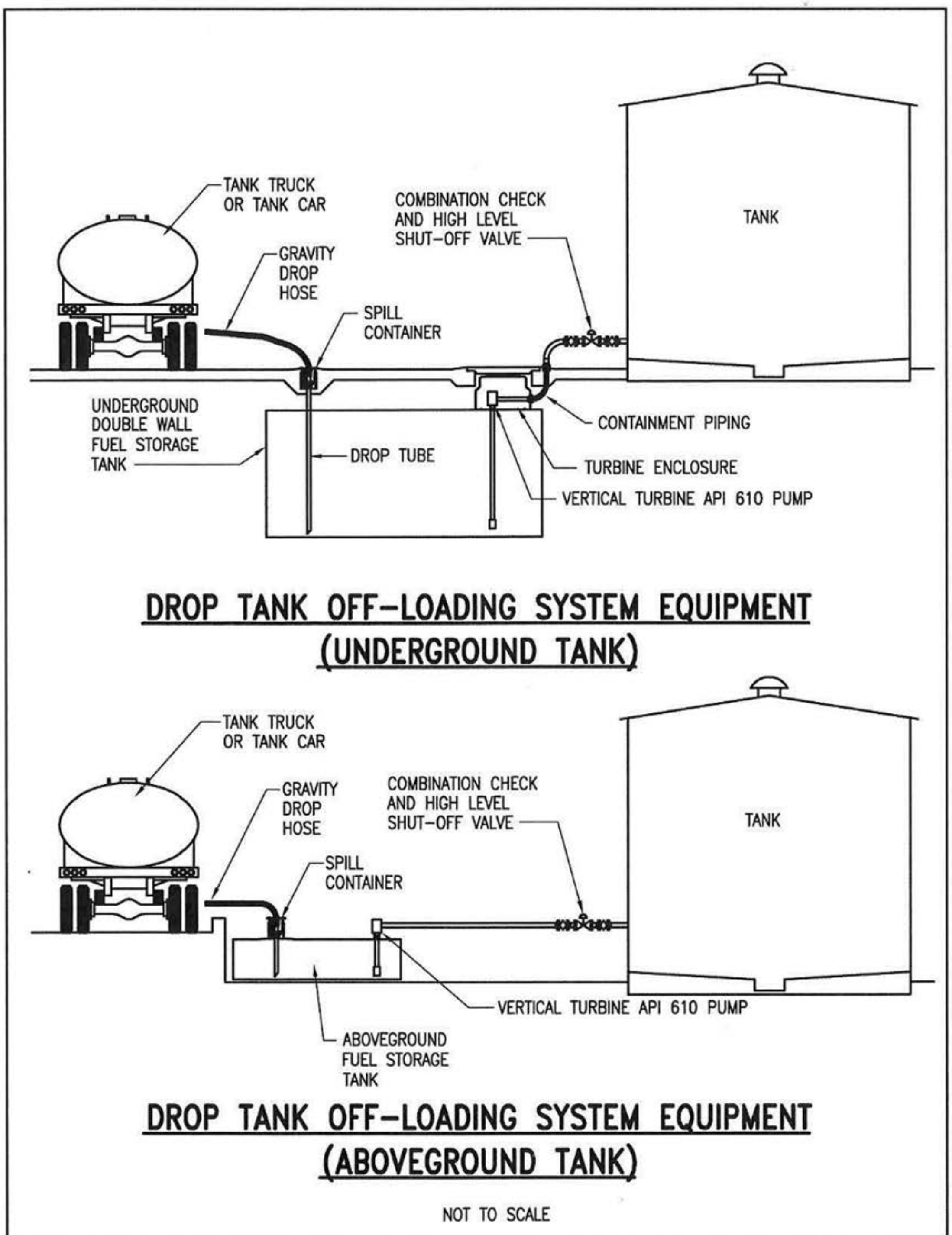
TITLE UFC 3-460-01 Chapter Identification Plan	DATE 07/08	FACILITY PLATE 001

Plate 002 – Tank Truck and Tank Car Receiving and Dispensing Facilities



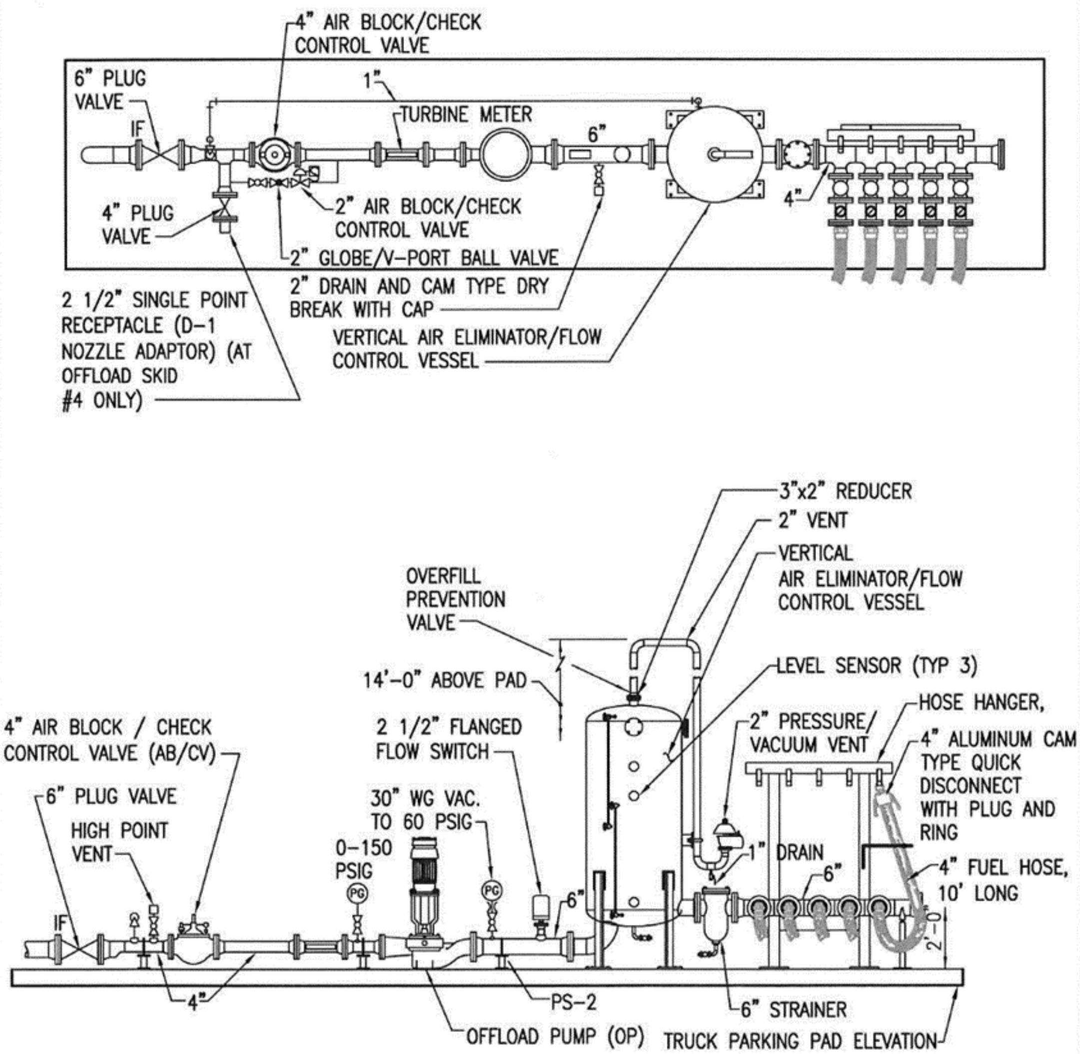
TITLE	DATE	FACILITY PLATE
Tank Truck and Tank Car Receiving and Dispensing Facilities	03/18	002

Plate 003 – Tank Truck and Tank Car Off-Loading Drop Tank System



TITLE	DATE	FACILITY PLATE
Tank Truck And Tank Car Off-Loading Drop Tank System	03/18	003

004 – Tank Truck and Tank Car Packaged Off-Loading System

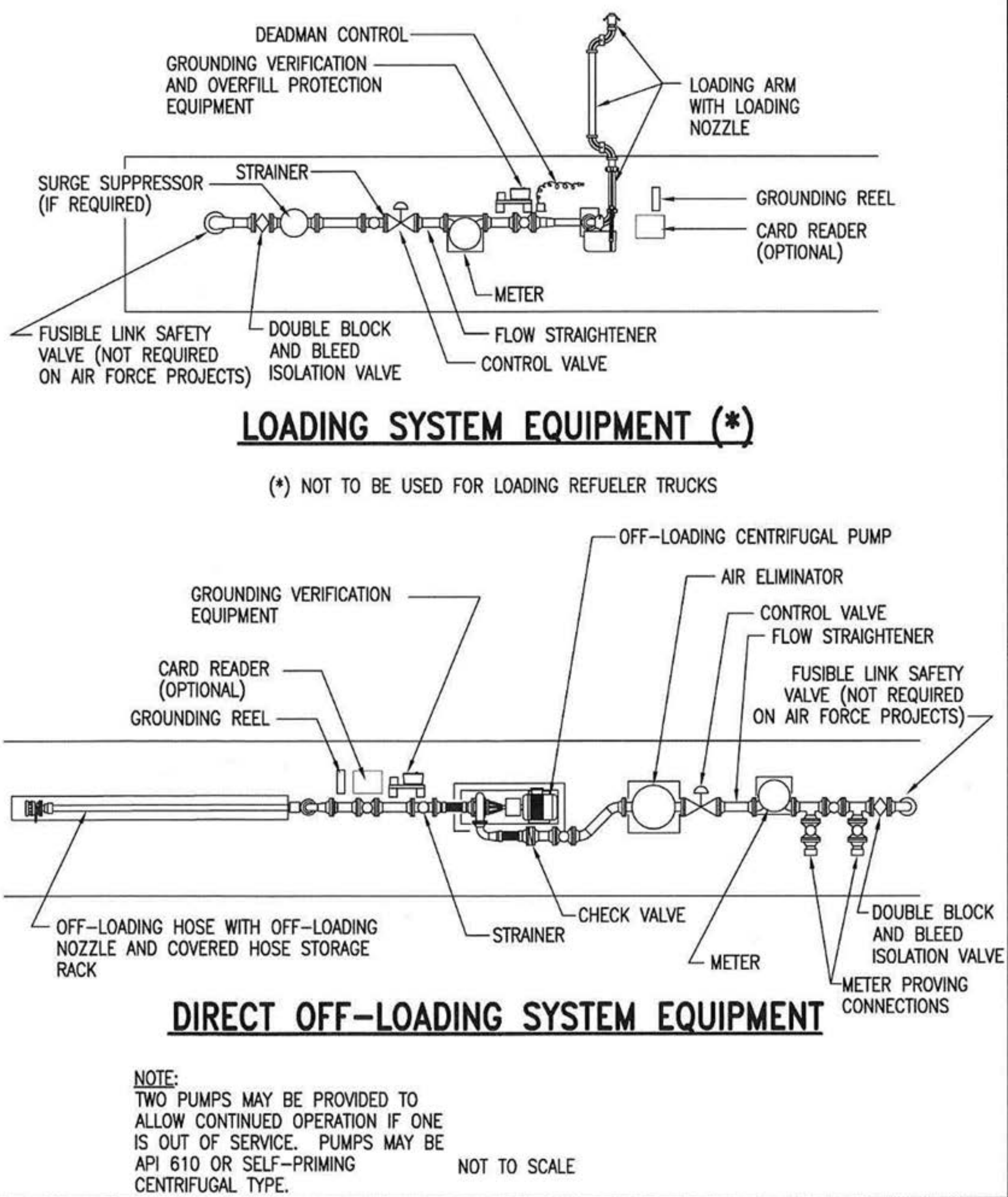


PACKAGED OFF-LOADING SYSTEM EQUIPMENT

NOT TO SCALE

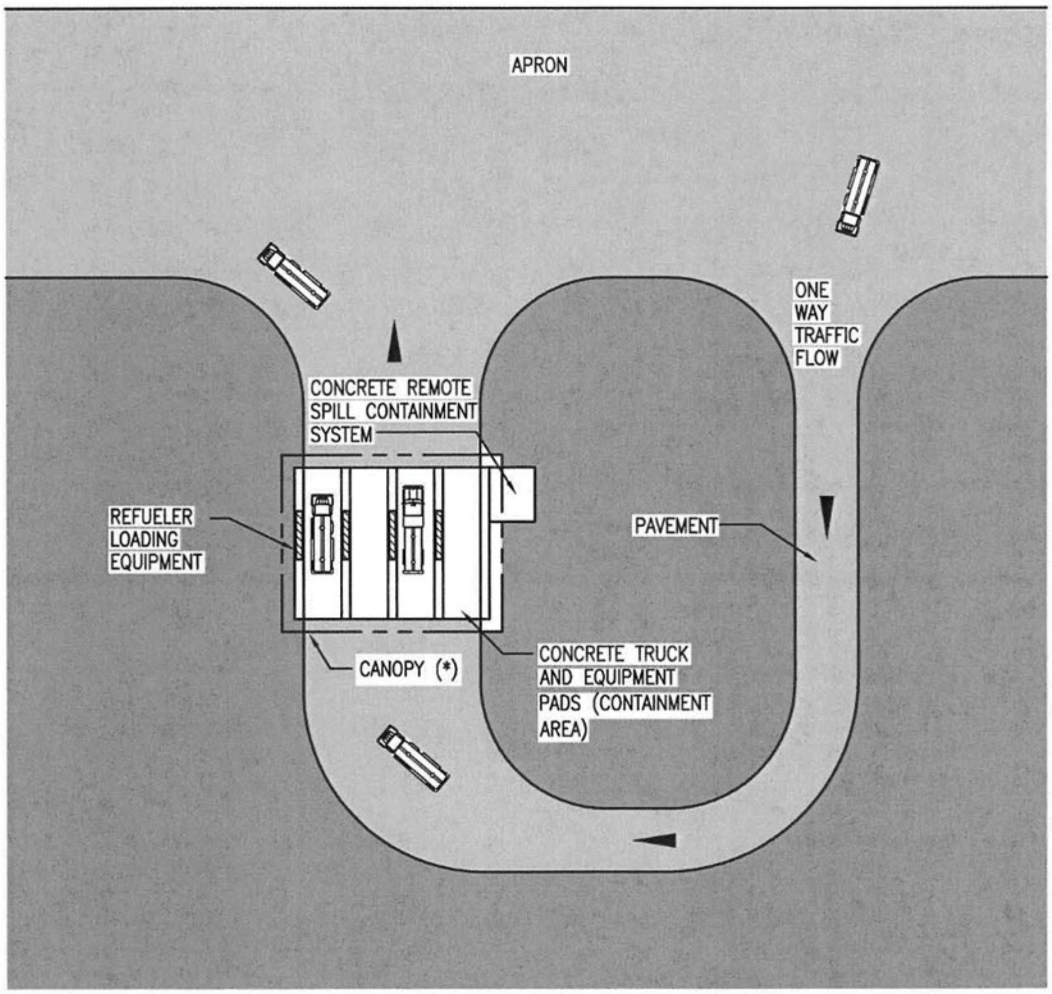
TITLE	DATE	FACILITY PLATE
Packaged Tank Truck and Tank Car Off-loading System	03/18	004

Plate 005 – Tank Truck and Tank Car Loading System and Direct Off-Loading System



TITLE	DATE	FACILITY PLATE
Tank Truck and Tank Car Loading System and Direct Off-Loading System	03/18	005

Plate 006 – Refueler Truck Facilities Layout Plan



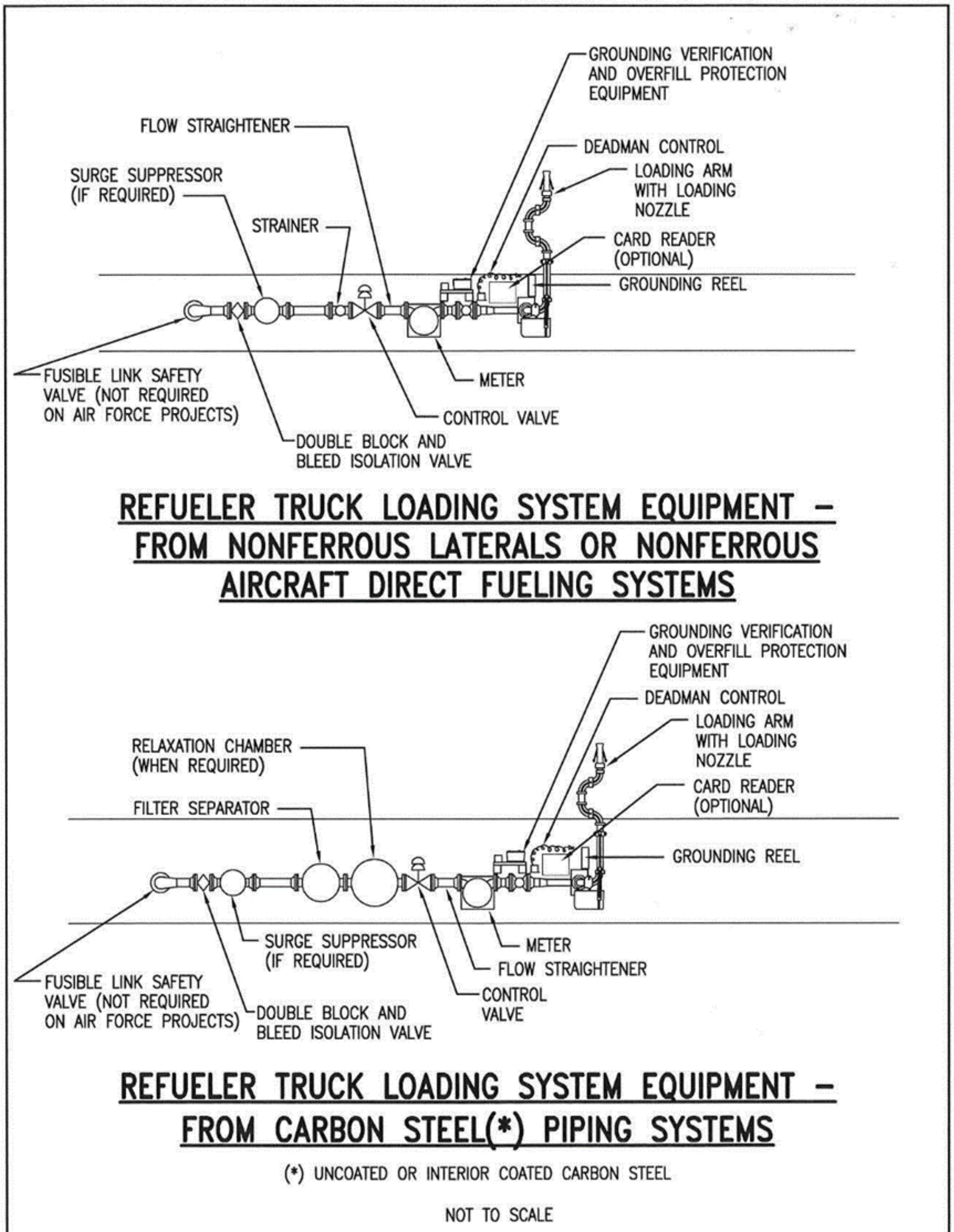
REFUELER TRUCK LOADING LAYOUT PLAN

(*) PROVIDE CANOPY OVER CONCRETE EQUIPMENT PAD. PROVIDE CANOPY OVER THE ENTIRE CONTAINMENT AREA WHEN REQUIRED OR DIRECTED.

NOT TO SCALE

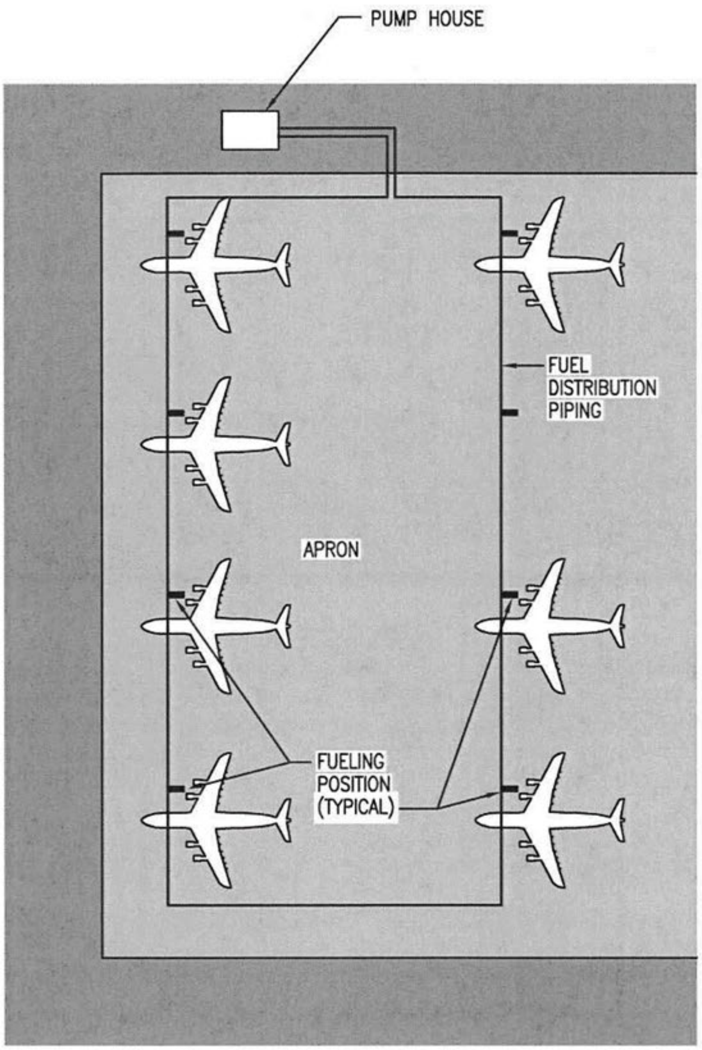
TITLE	DATE	FACILITY PLATE
Refueler Truck Facilities Layout Plan	03/18	006

Plate 007 – Refueler Truck Loading Systems



TITLE	DATE	FACILITY PLATE
Refueler Truck Loading Systems	03/18	007

Plate 008 - Aircraft Direct Fueling Systems Large Frame Aircraft On-Apron Fueling Positions



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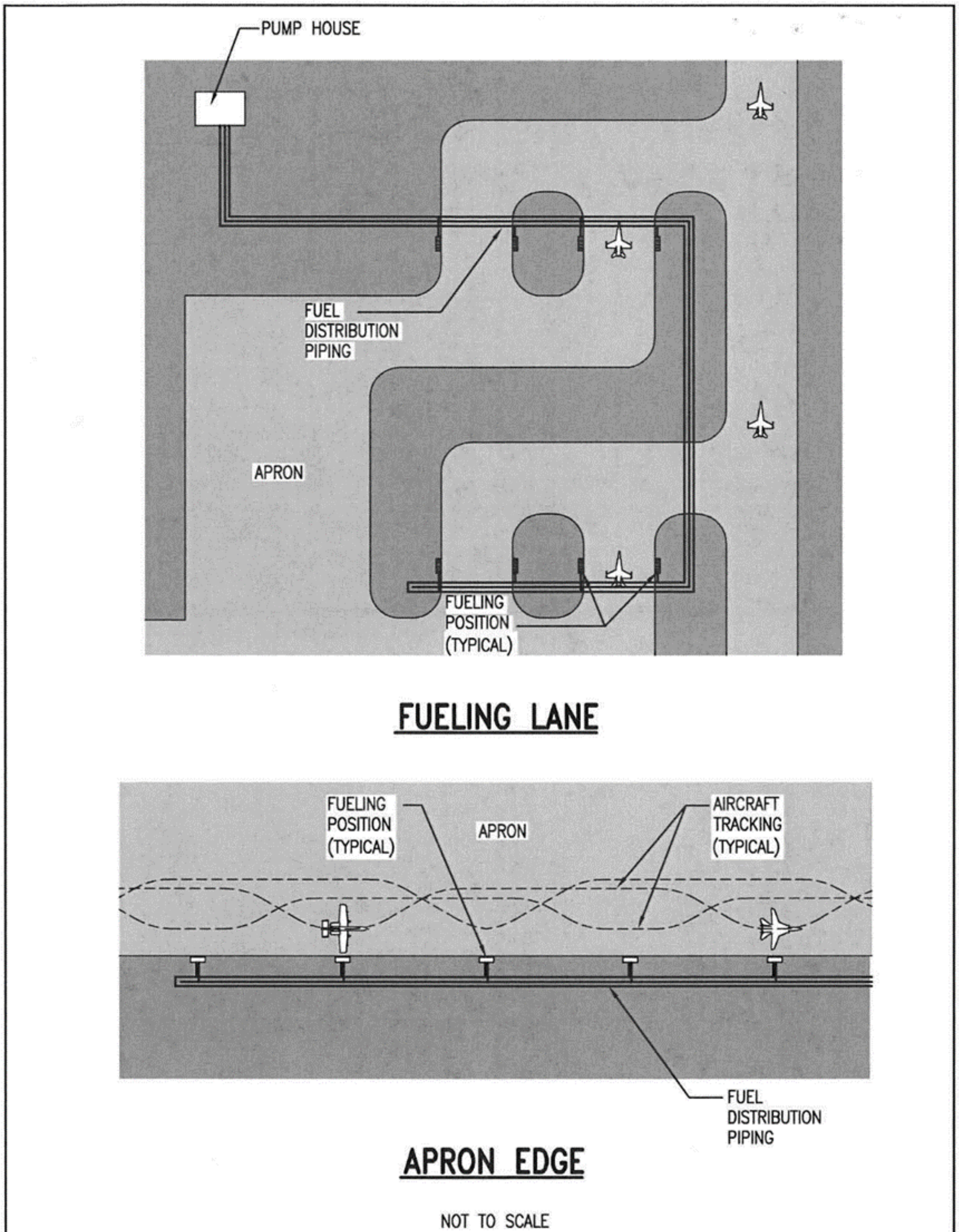
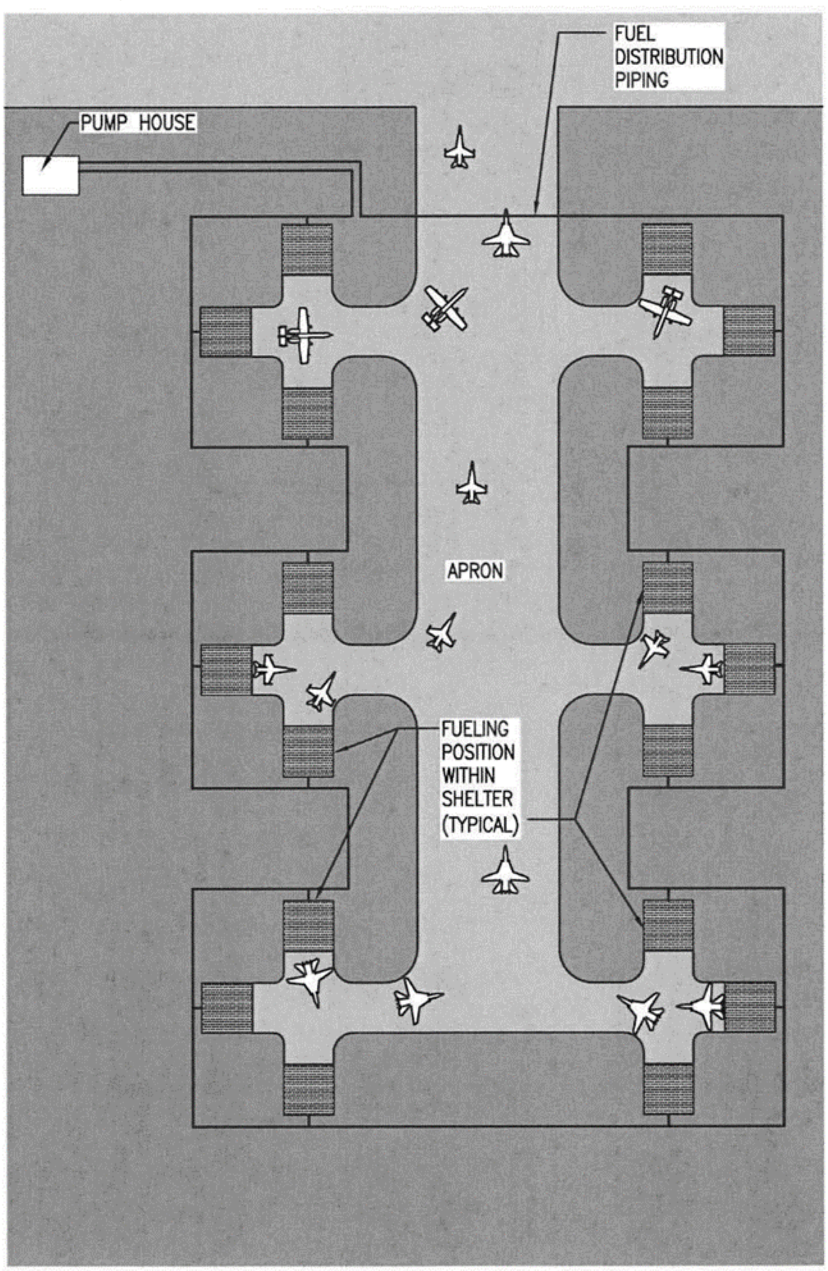
TITLE Aircraft Direct Fueling Systems Large Frame Aircraft On–Apron Fueling Positions	DATE 03/18	FACILITY PLATE 008

Plate 009 – Aircraft Direct Fueling Systems Small Frame Aircraft Fueling Lane and Apron Edge



TITLE Aircraft Direct Fueling Systems Small Frame Aircraft Fueling Lane And Apron Edge	DATE 03/18	FACILITY PLATE 009

Plate 010 - Aircraft Direct Fueling Systems Small Frame Aircraft In-Shelter Fueling Positions



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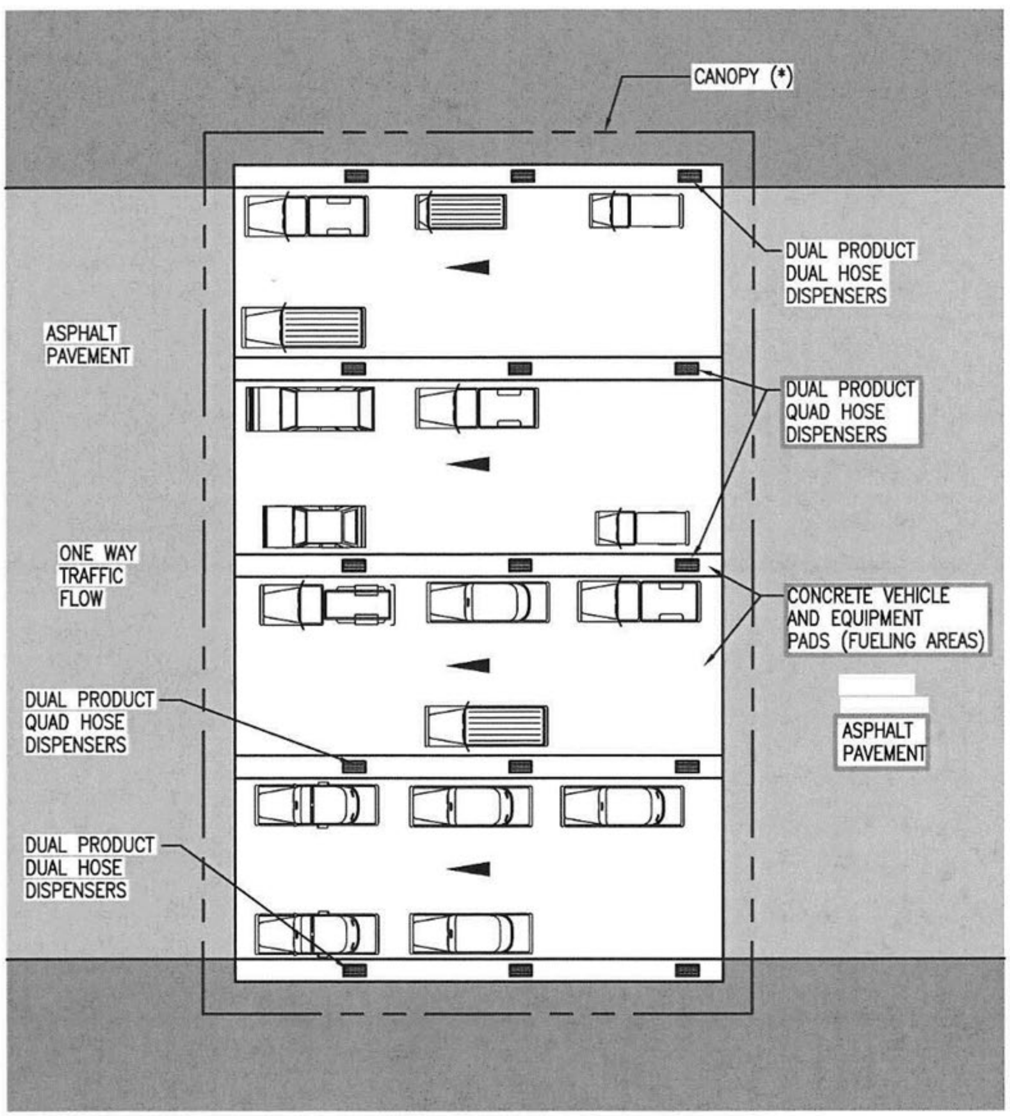
TITLE	DATE	FACILITY PLATE
Aircraft Direct Fueling Systems Small Frame Aircraft In-Shelter Fueling Positions	03/18	010

Plate 011 – GOV Vehicle Motive Fuel Filling Station Plan



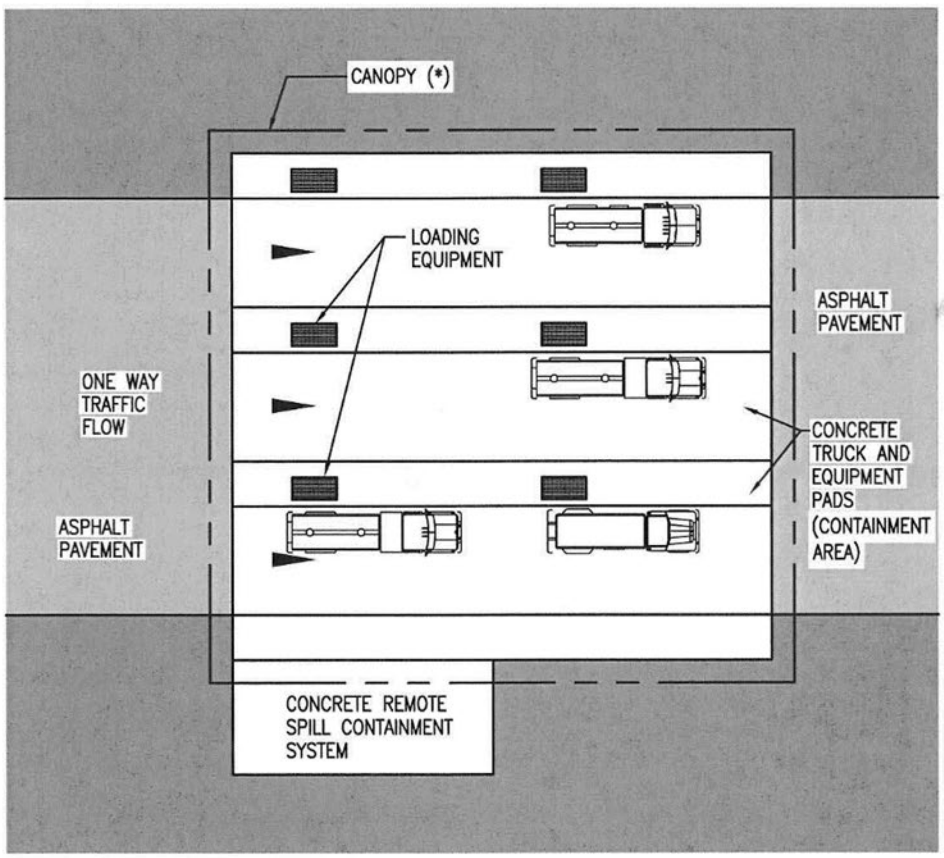
GOV VEHICLE MOTIVE FUEL FILLING STATION PLAN

(*) PROVIDE CANOPY OVER CONCRETE EQUIPMENT PADS. PROVIDE CANOPY OVER THE ENTIRE FUELING AREA WHEN REQUIRED OR DIRECTED.

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
GOV Vehicle Motive Fuel Filling Station Plan	03/18	011

Plate 012 – Tactical Refueler Ground Product Truck Loading Facility Plan



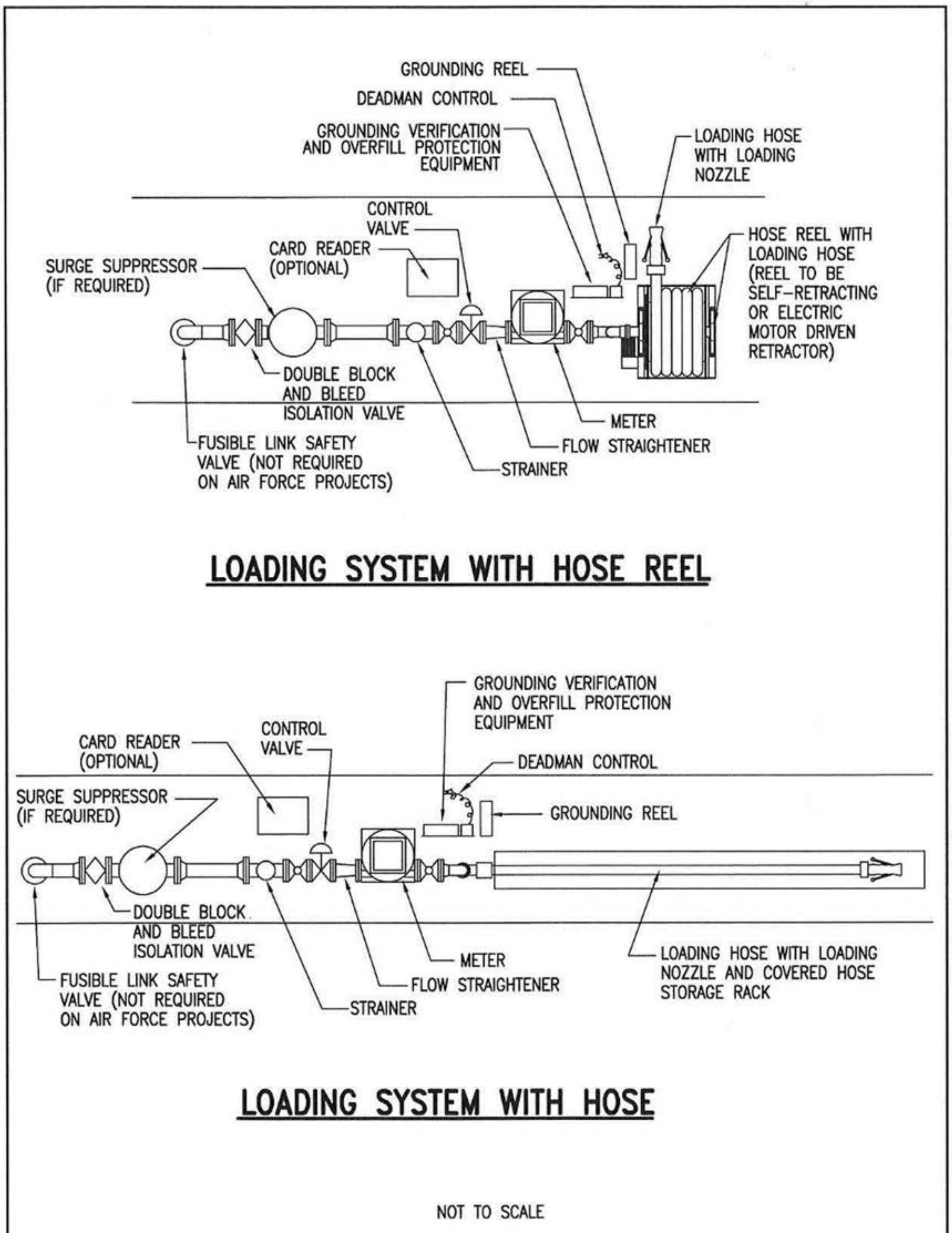
TACTICAL REFUELER GROUND PRODUCT TRUCK LOADING FACILITY PLAN

(*) PROVIDE CANOPY OVER CONCRETE EQUIPMENT PAD. PROVIDE CANOPY OVER THE ENTIRE CONTAINMENT AREA WHEN REQUIRED OR DIRECTED.

NOT TO SCALE

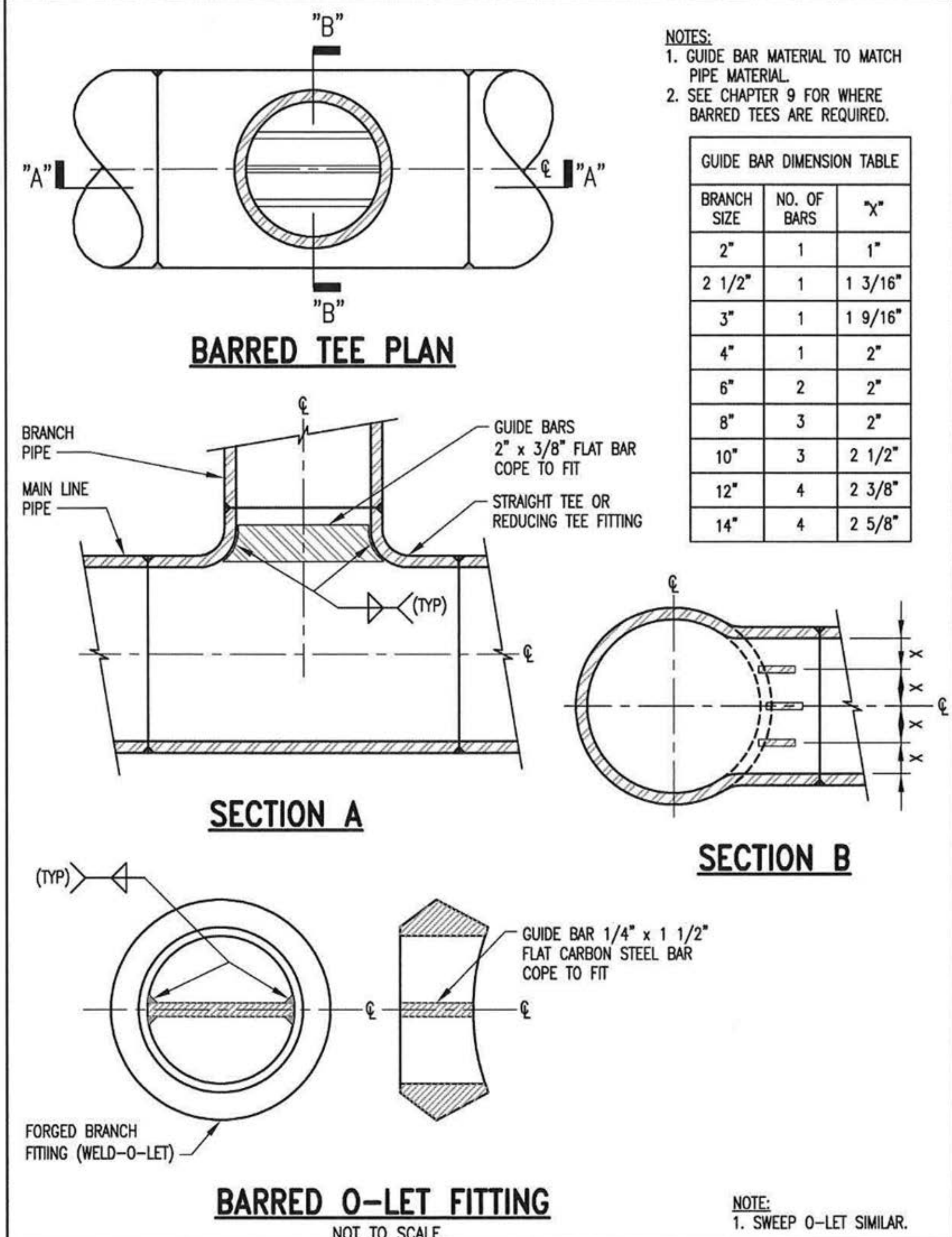
TITLE	DATE	FACILITY PLATE
Tactical Refueler Ground Product Truck Loading Facility Plan	03/18	012

Plate 013 – Tactical Refueler Ground Product Truck Loading Systems



TITLE	DATE	FACILITY PLATE
Tactical Refueler Ground Product Truck Loading Systems	03/18	013

Plate 014 – Piping Systems Barred Tee



NOTES:

1. GUIDE BAR MATERIAL TO MATCH PIPE MATERIAL.
2. SEE CHAPTER 9 FOR WHERE BARRED TEES ARE REQUIRED.

GUIDE BAR DIMENSION TABLE

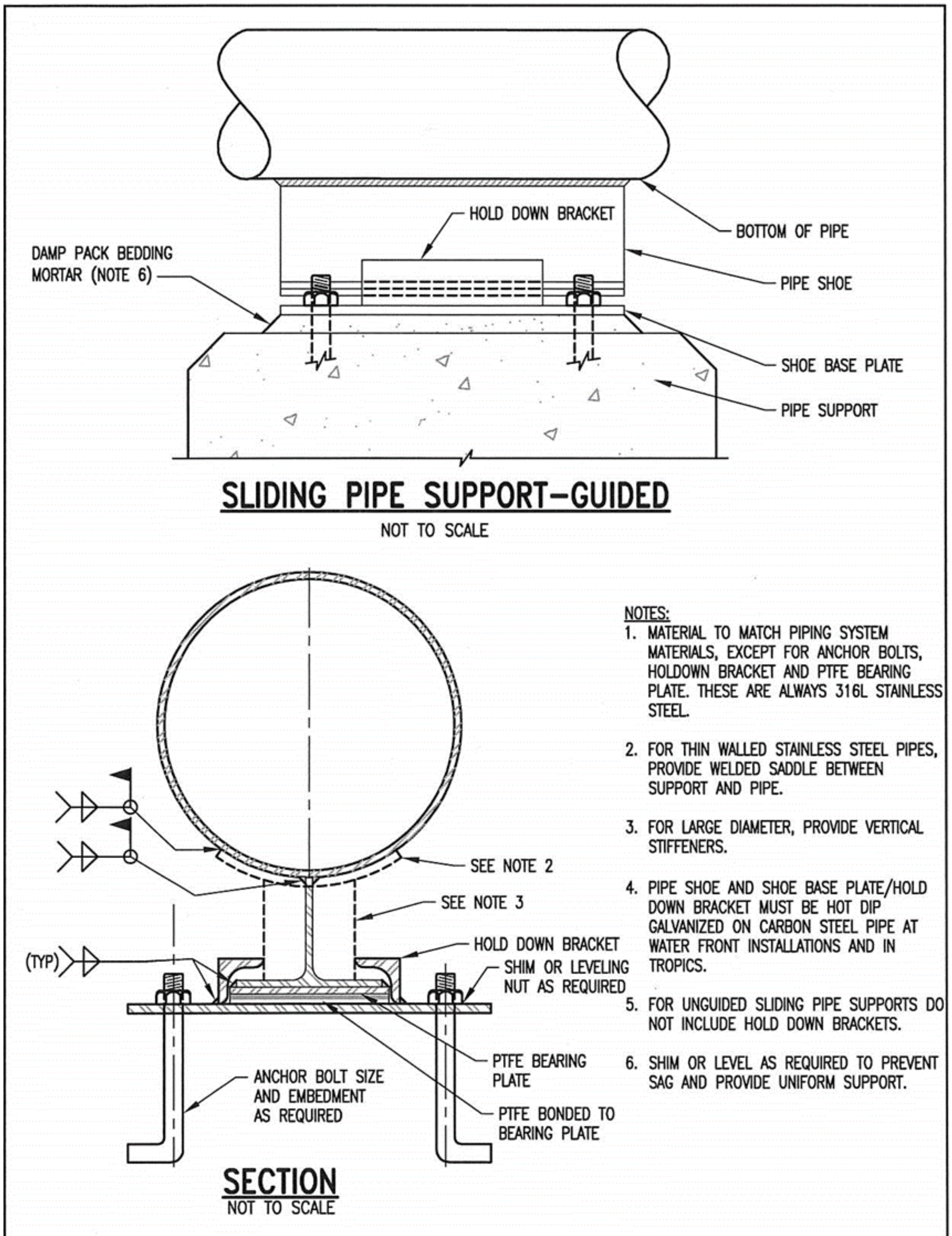
BRANCH SIZE	NO. OF BARS	"X"
2"	1	1"
2 1/2"	1	1 3/16"
3"	1	1 9/16"
4"	1	2"
6"	2	2"
8"	3	2"
10"	3	2 1/2"
12"	4	2 3/8"
14"	4	2 5/8"

NOTE:

1. SWEEP O-LET SIMILAR.

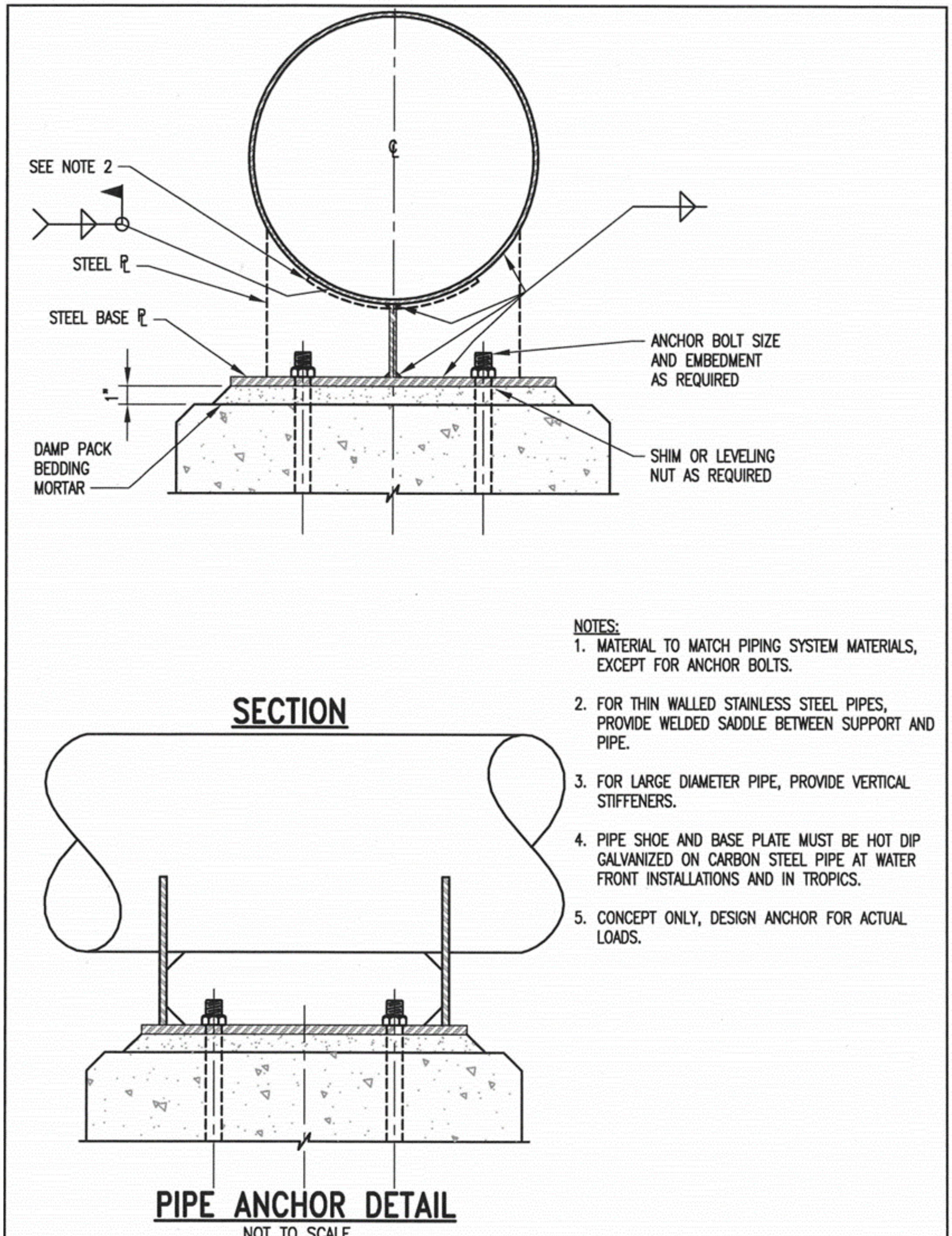
TITLE	DATE	FACILITY PLATE
PIPING SYSTEMS BARRED TEE	03/18	014

Plate 015 – Piping Systems Sliding Pipe Support – Guided



TITLE	DATE	FACILITY PLATE
PIPING SYSTEMS SLIDING PIPE SUPPORT – GUIDED	06/18	015

Plate 016 – Piping Systems Anchor Pipe Support



TITLE PIPING SYSTEMS ANCHOR PIPE SUPPORT	DATE 06/18	FACILITY PLATE 016

Plate 017 – Piping Systems U-Bolt Pipe Supports

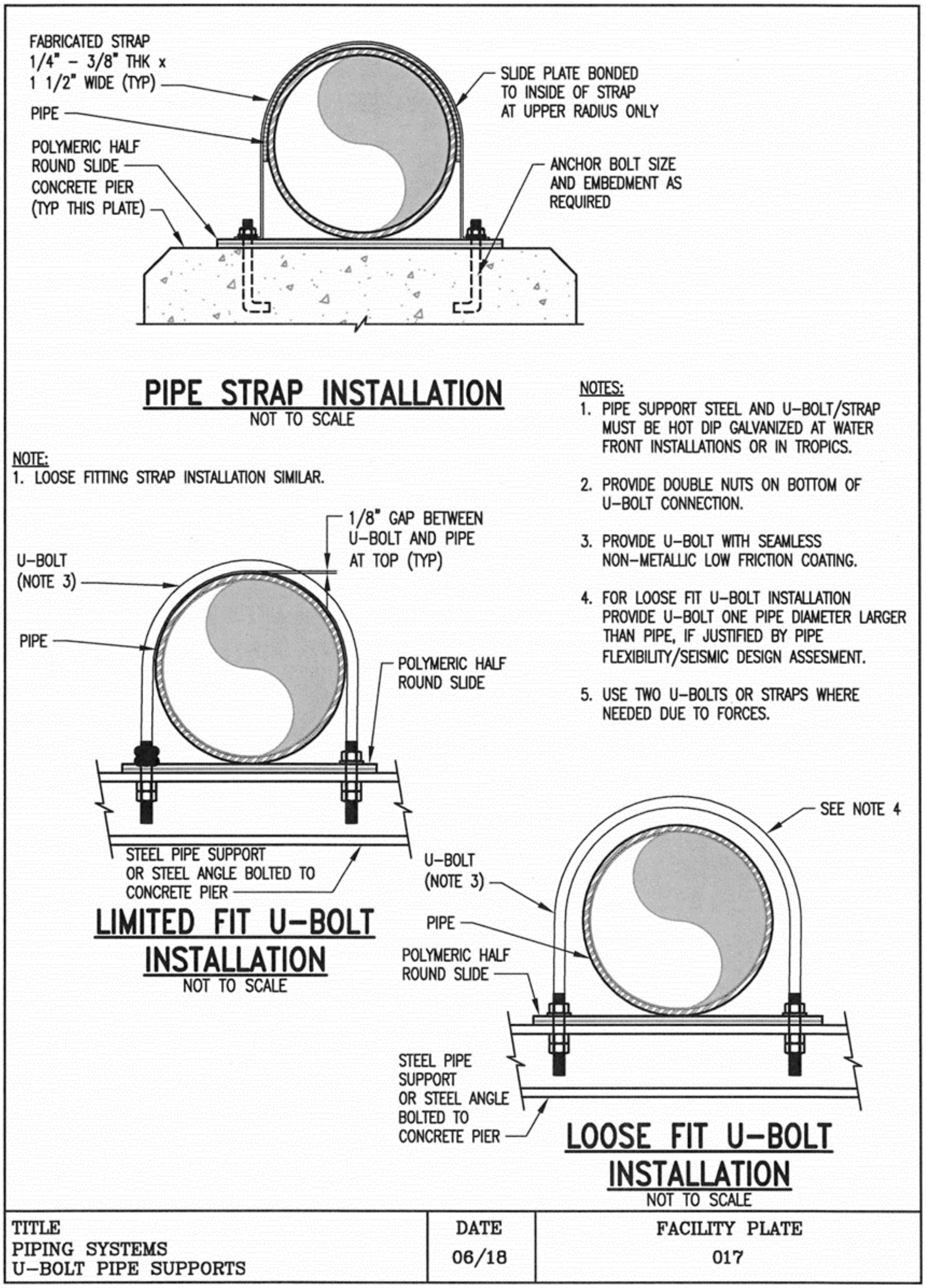
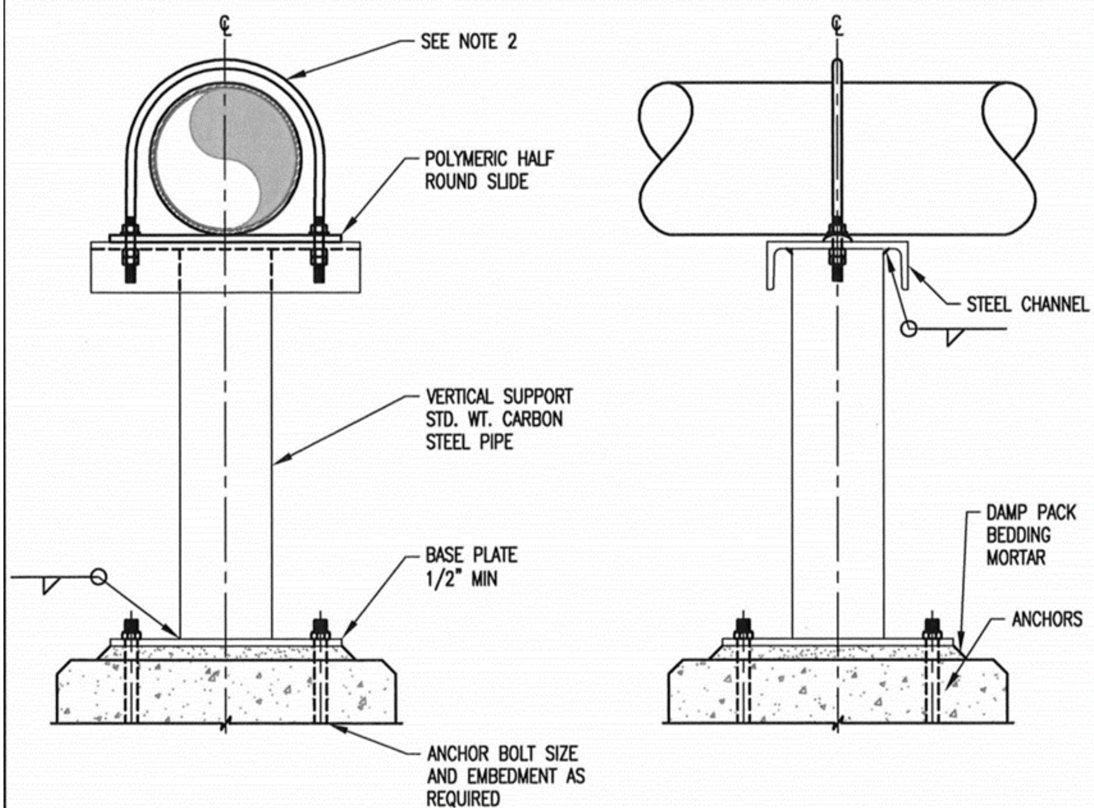


Plate 018 – Piping Systems U-Bolt Small Pipe Support



U–BOLT SMALL PIPE SUPPORT

NOT TO SCALE

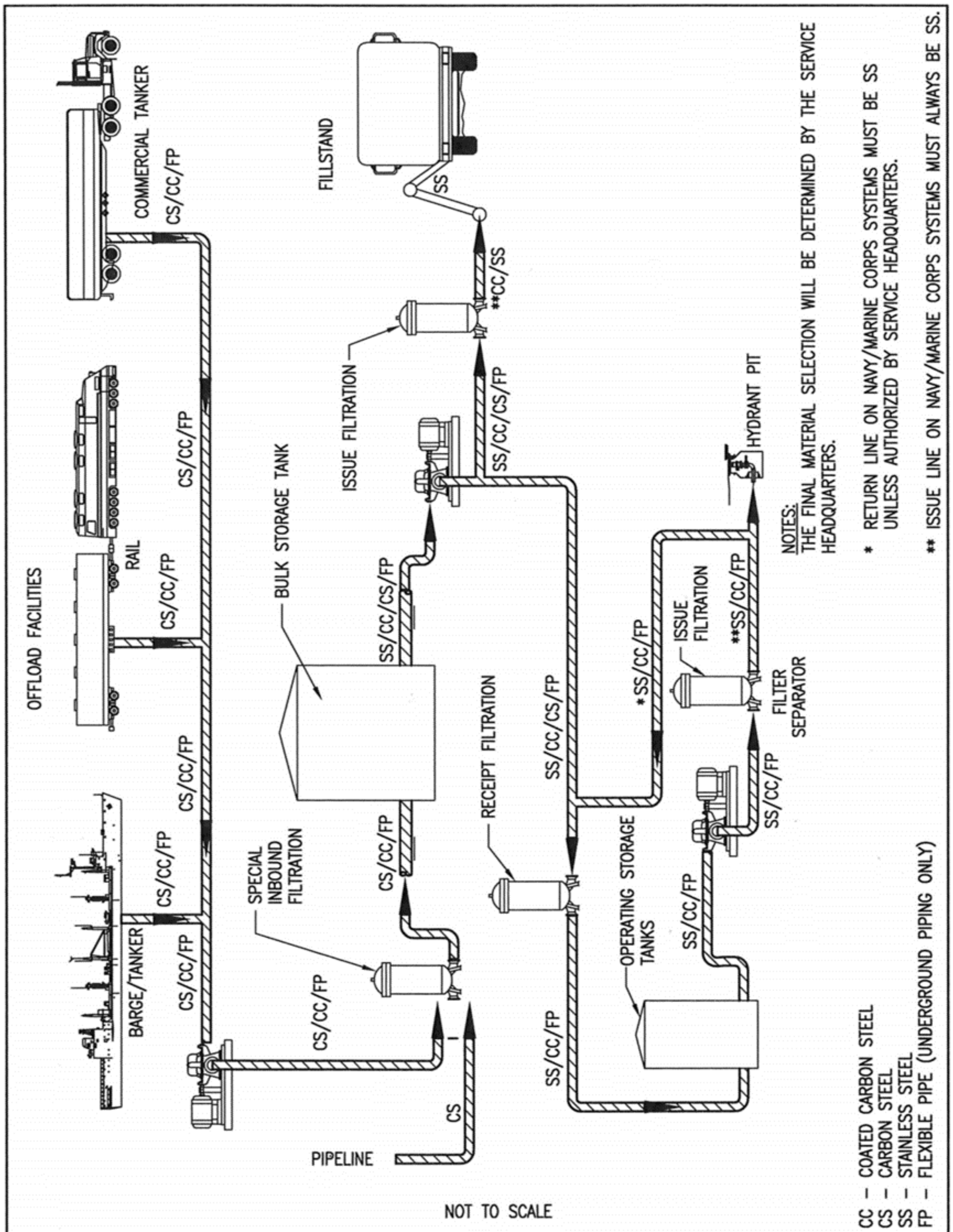
DIMENSION TABLE		
PIPE SIZE	VERTICAL SUPPORT SIZE	m
3", 4"	3"	C6
< 3"	2"	C4

NOTES:

1. ACCEPTABLE FOR USE UP TO 4–INCH.
2. U–BOLT MUST BE LOOSE–FIT OR SNUG PER FACILITY PLATE 017.
3. SUPPORT MUST BE HOT DIPPED GALVANIZED AT WATERFRONT INSTALLATIONS OR IN TROPICS.

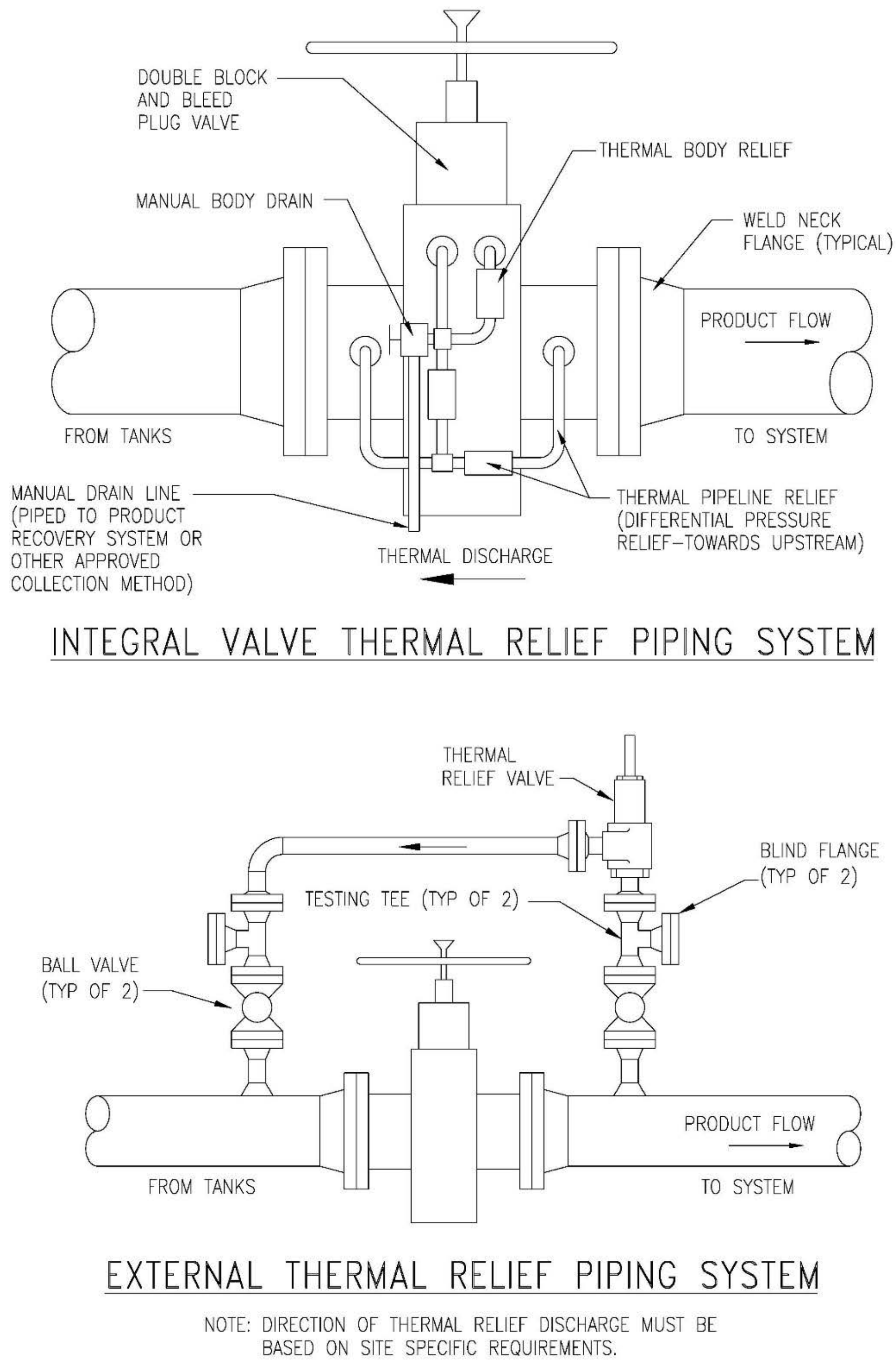
TITLE	DATE	FACILITY PLATE
PIPING SYSTEMS U–BOLT SMALL PIPING SUPPORT	03/18	018

Plate 019 – Aviation System Piping Materials Standards



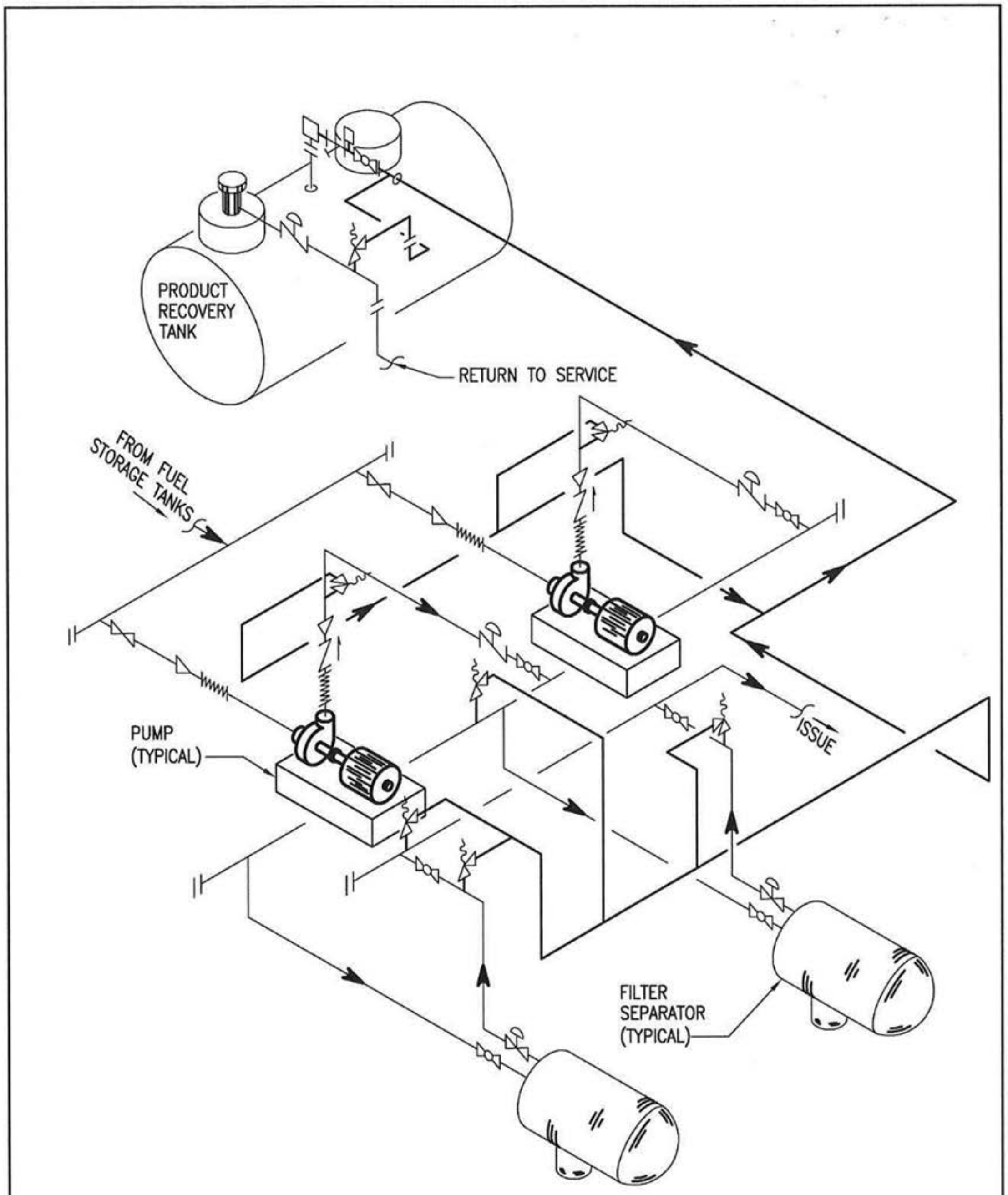
TITLE	DATE	FACILITY PLATE
Aviation System Piping Materials Standards	03/18	019

Plate 020 – Thermal Relief Piping Systems Integral Valve and External\2



TITLE	DATE	FACILITY PLATE
Thermal Relief Piping Systems Integral Valve And External	08/21	020

/2/ Plate 021 – Thermal Relief Piping Systems Equipment Pump House or Pads

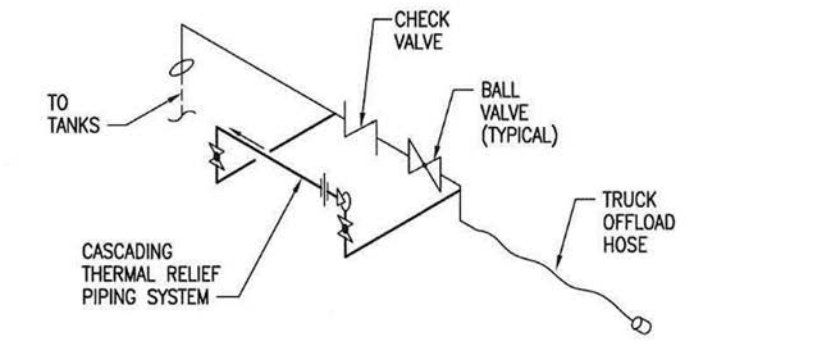


EQUIPMENT PUMPHOUSE OR PADS

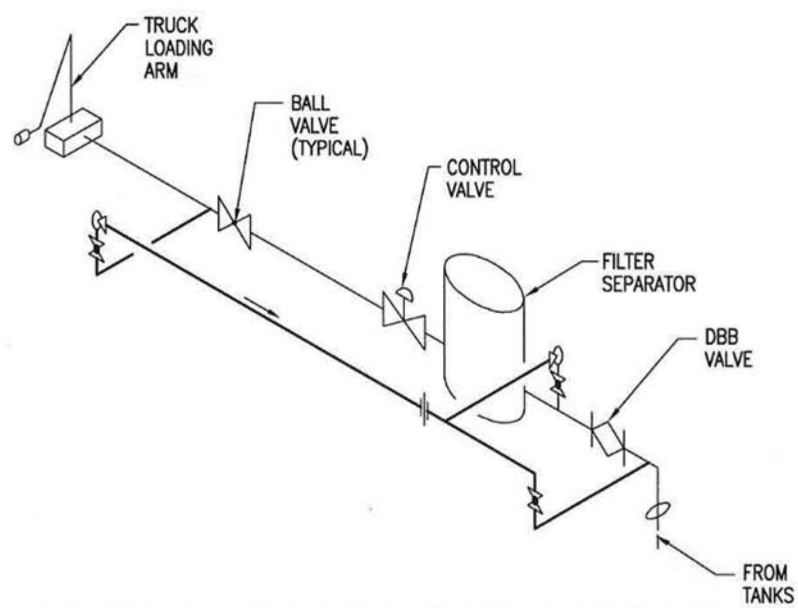
NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Thermal Relief Piping Systems Equipment Pumphouse Or Pads	03/18	021

Plate 022 – Thermal Relief Piping Systems Truck Offload Stations and Fillstands



THERMAL RELIEF FOR TRUCK OFFLOAD STATION

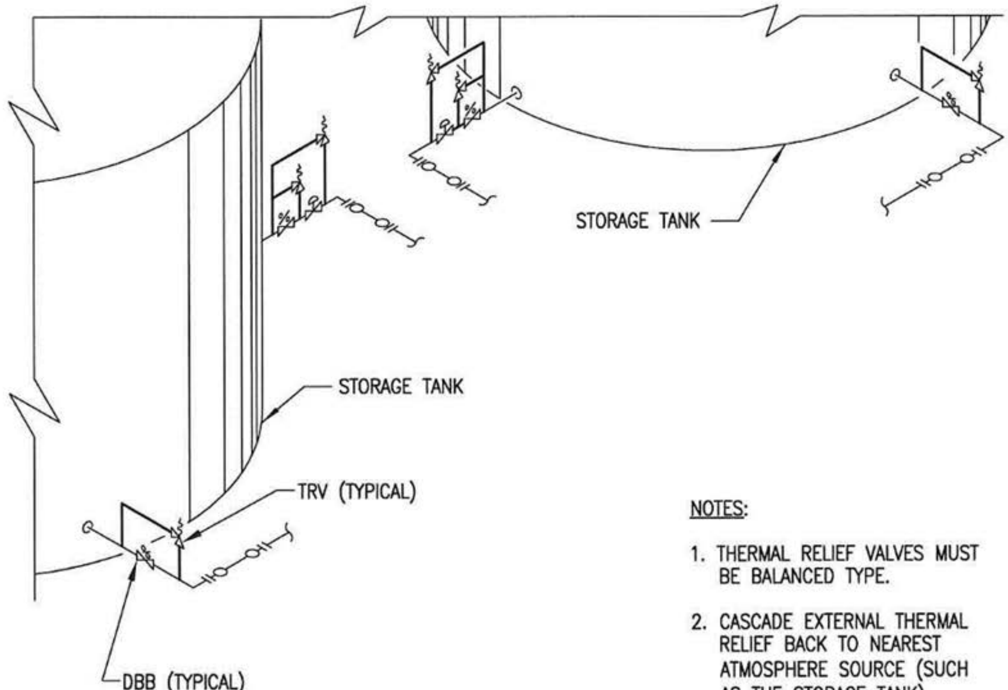


THERMAL RELIEF FOR TRUCK FILLSTAND

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Thermal Relief Piping Systems Truck Offload Stations and Fillstands	02/18	022

Plate 023 – Thermal Relief Piping Systems Storage Tanks



NOTES:

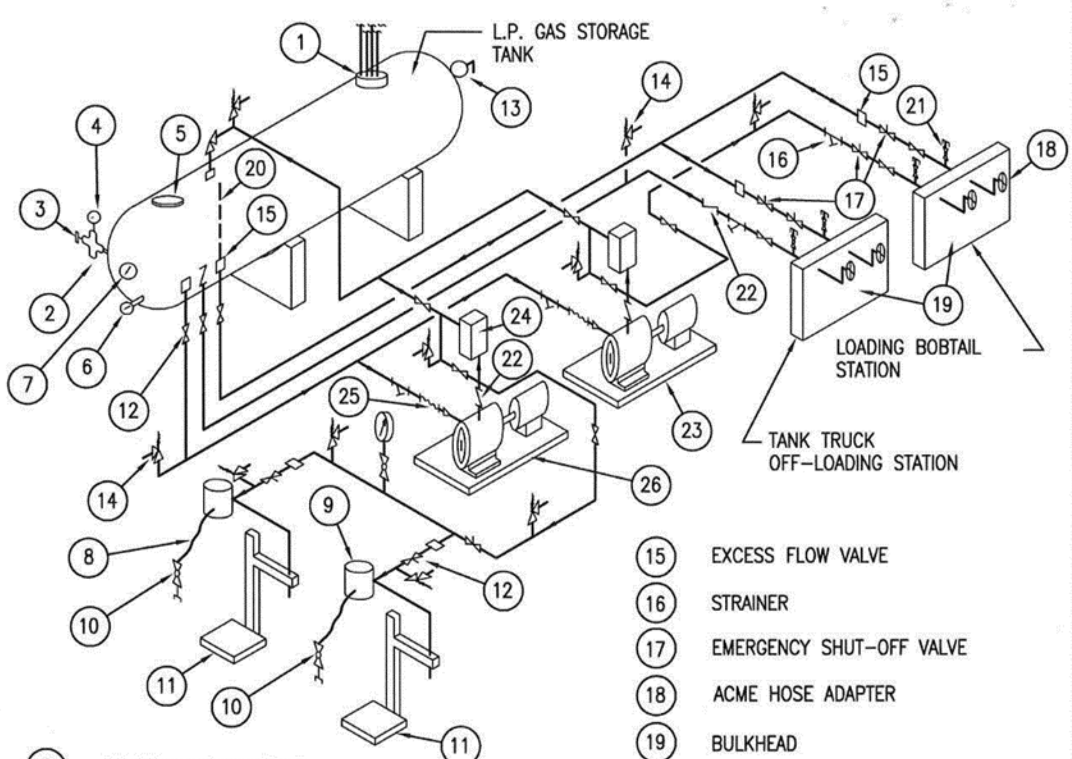
1. THERMAL RELIEF VALVES MUST BE BALANCED TYPE.
2. CASCADE EXTERNAL THERMAL RELIEF BACK TO NEAREST ATMOSPHERE SOURCE (SUCH AS THE STORAGE TANK).

STORAGE TANK THERMAL RELIEF PIPING SYSTEM

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Thermal Relief Piping Systems Storage Tanks	03/18	023

Plate 024 – Liquefied Petroleum Gas Facilities Small Volume Facility for Trucks and Cylinders



(1) RELIEF VALVE MANIFOLD
(2) 85% MAXIMUM FILL LEVEL SPIT GAUGE
(3) COMBINATION VALVE
(4) PRESSURE GAUGE
(5) MANHOLE
(6) THERMOMETER
(7) MAGNETIC LIQUID LEVEL GAUGE
(8) HOSE
(9) AUTOMATIC CYLINDER FILLING VALVE
(10) QUICK ACTING VALVE
(11) CYLINDER FILLING SCALE
(12) SHUT–OFF VALVE
(13) ROTO GAUGE
(14) RELIEF VALVE
(15) EXCESS FLOW VALVE
(16) STRAINER
(17) EMERGENCY SHUT–OFF VALVE
(18) ACME HOSE ADAPTER
(19) BULKHEAD
(20) INTERNAL RISER PIPE
(21) VENT VALVE
(22) CHECK VALVE
(23) BOBTAIL FILL PUMP WITH EXPLOSION PROOF MOTOR
(24) DIFFERENTIAL BYPASS VALVE
(25) FLEXIBLE CONNECTOR
(26) CYLINDER FILLING PUMP WITH EXPLOSION PROOF MOTOR

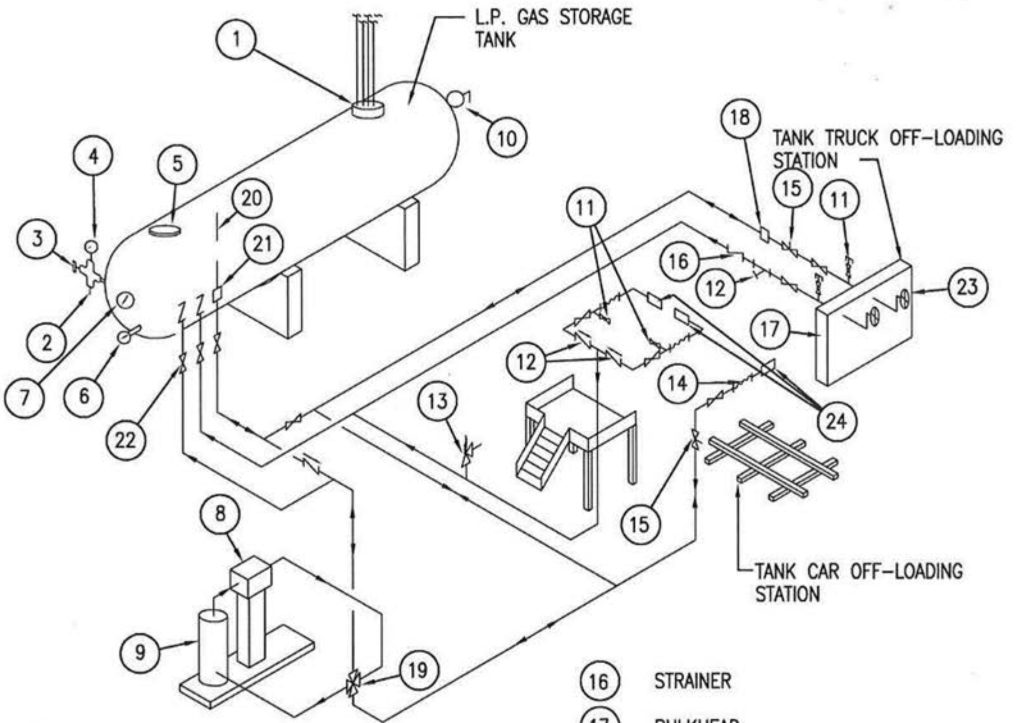
NOTES:

1. PIPES TO BE ANCHORED TO BULKHEAD.
2. EMERGENCY SHUT–OFF VALVES ARE TO LOCALLY AND REMOTELY OPERATE AND TO BE RECEIVED WITH THERMAL ACTUATOR.
3. BULKHEADS FOR TRANSPORT OFF–LOADING AND BOBTAIL FILLINGS ARE TO BE ISOLATED FROM EACH OTHER.

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Liquefied Petroleum Gas Facilities Small Volume Facility For Trucks And Cylinders	03/18	024

Plate 025 – Liquefied Petroleum Gas Facilities Large Volume Facility for Tank Cars and Water Vessels



1. RELIEF VALVE MANIFOLD
2. 65% MAXIMUM FILL LEVEL SPIT GAUGE
3. COMBINATION VALVE
4. PRESSURE GAUGE
5. MANHOLE
6. THERMOMETER
7. MAGNETIC LIQUID LEVEL GAUGE
8. VAPOR COMPRESSOR
9. LIQUID TRAP
10. ROTO GAUGE
11. VENT VALVE
12. CHECK VALVE
13. RELIEF VALVE
14. HOSE
15. EMERGENCY SHUT-OFF VALVE
16. STRAINER
17. BULKHEAD
18. EXPRESS FLOW VALVE
19. 4-WAY VALVE
20. INTERNAL RISER PIPE
21. EXCESS FLOW VALVE
22. SHUT-OFF VALVE
23. ACME HOSE ADAPTER
24. COMBINATION RAILCAR ADAPTER/EMERGENCY SHUT-OFF VALVE

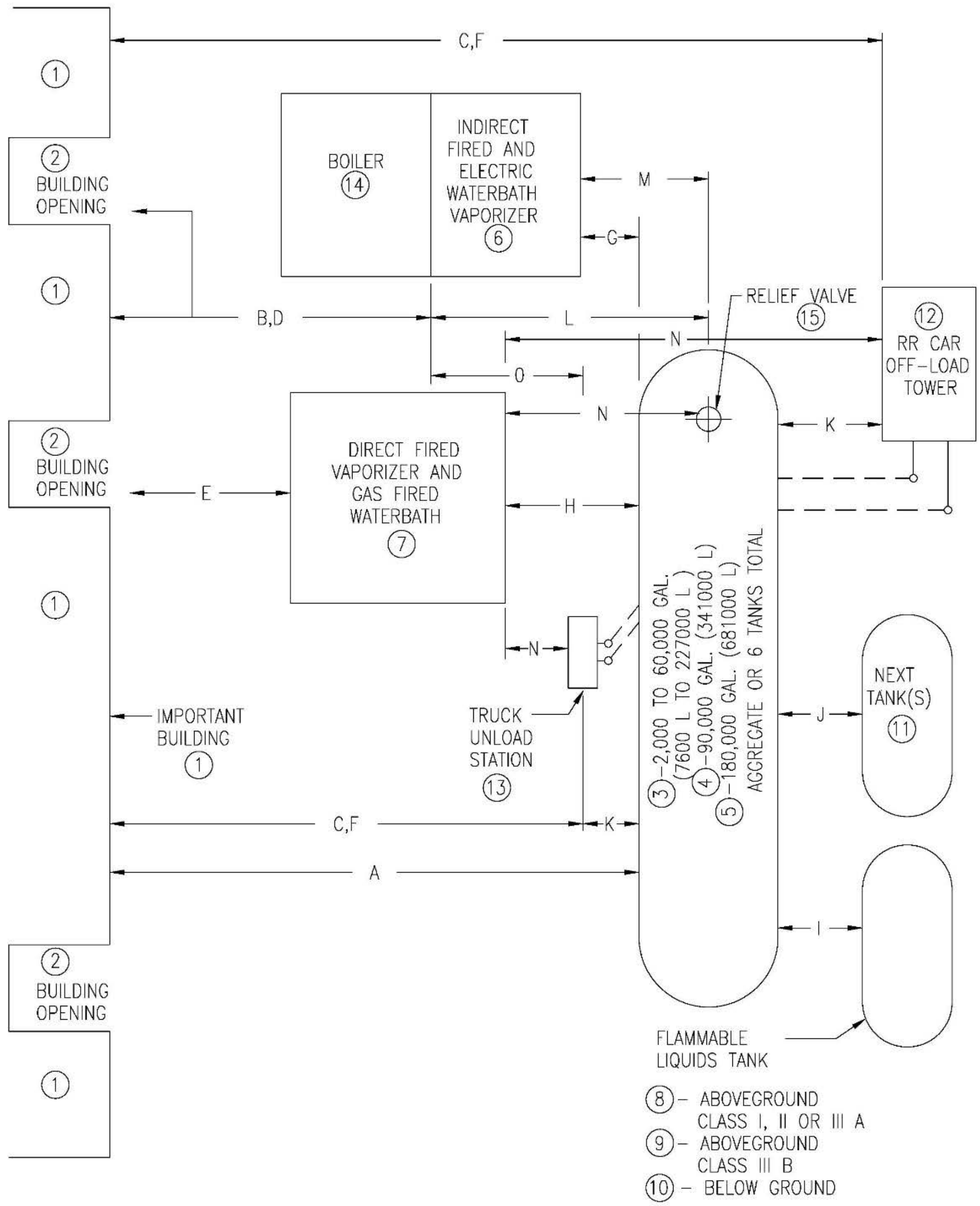
NOTES:

1. PIPES TO BE ANCHORED TO BULKHEAD.
2. EMERGENCY SHUT-OFF VALVES ARE TO LOCALLY AND REMOTELY OPERATE AND TO BE RECEIVED WITH THERMAL ACTUATOR.

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Liquefied Petroleum Gas Facilities Large Volume Facility For Tank Cars And Water Vessels	03/18	025

Plate 026 – Liquefied Petroleum Gas Facilities Tank Spacing Requirements\2



FOR RECOMMENDED MINIMUM SPACING BETWEEN LP–GAS STORAGE TANKS, OFF–LOADING STATION, FLAMMABLE LIQUID STORAGE TANKS, VAPORIZER HOUSE, AND IMPORTANT BUILDINGS SEE FACILITY PLATE 027.

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Liquefied Petroleum Gas Facilities Tank Spacing Requirements	03/18	026

/2/ Plate 027 – Liquefied Petroleum Gas Facilities Tank Spacing Requirements

MINIMUM RECOMMENDED DISTANCE			
DIMENSION	POINT TO POINT	DISTANCE, FT.	DISTANCE, M
A	1 TO 3 [A]	75	23
	4 [A]	150	46
	5 [B]	200	60
	5 [C]	350	105
B	6	20	6
C	12	200	60
	13	50	15
D	2 TO 6	20	6
E	7	50	15
F	12	200	60
	13	75	23
G	3,4,5 TO 6	5	1.5
H	7	15	4.5
I	8	100	30
	9	50	15
	10	20	6
J	11 [D]	75	23
K	12	75	23
	13	50	15
L	14	75	23
M	6 TO 15	50	15
N	7 TO 12,13,15 [E]	75	23
O	13 TO 14	75	23

NOTES:

A. FOR SINGLE TANKS ONLY. TREAT MULTIPLE TANKS AS NO. 5.
B. FOR BUILDINGS WITH HYDRANT PROTECTION.
C. FOR BUILDINGS WITHOUT HYDRANT PROTECTION.
D. 5 FT. (1.5M) FOR TANKS WITHIN A GROUP.
E. FOR TANKS SMALLER THAN 2,000 GAL. (7600 L), 25 FT. (7.6M).

NOT TO SCALE

TITLE	DATE	FACILITY PLATE
Liquefied Petroleum Gas Facilities Tank Spacing Requirements	03/18	027

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APPENDIX D GLOSSARY

D-1 ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AFCEC	Air Force Civil Engineer Center
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AIS	Automated Information System
ANSI	American National Standards Institute
AOE	US Navy Hull Classification Symbol; Fast Combat Support Ship
APC	Army Petroleum Center
API	American Petroleum Institute
ASCII	American Standard Code for Information Interchange
ASME	American Society of Mechanical Engineers
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
ATG	Automatic Tank Gauging
BSM-ERP	Business System Modernization – Enterprise Resource Programs
Btu	British Thermal Unit
CFR	Code of Federal Regulations
CI	Corrosion Inhibitor
CNG	Compressed Natural Gas
CONUS	Continental United States
COTS	Commercial-off-the-shelf
D	Diameter
DFM	Diesel Fuel Marine

DFSP	Defense Fuel Support Point
DIEGME	Diethylene Glycol Monomethyl Ether
DLA	Defense Logistics Agency
DoD	Department of Defense
DOT	Department of Transportation
EFSO	Emergency Fuel Shut-off
EMAT	Electromagnetic Acoustic Transducer
EPU	Emergency Power Unit
F-A	Fire Resistant Aboveground Storage Tank
FDV	Fuel Delivery Vehicle
FRP	Fiberglass Reinforced Plastic
FSII	Fuel System Icing Inhibitor
H-A	Horizontal Aboveground Storage Tank
HDPE	High-density Polyethylene
HTH	Calcium Hypochlorite
H-U	Horizontal Underground Storage Tank
ICC	International Code Council
IESNA	Illuminating Engineering Society of North America
JPTS	Jet Propellant Thermally Stable Fuel
LPG	Liquefied Petroleum Gas; Propane, Butane
MFL	Magnetic Flux Leakage
MIL	A unit of length equal to one thousandth of an inch, especially used to measure the thickness of paints and coatings
Mogas	Common contraction of Motor Gasoline, referring to fuel for land vehicles

NACE	National Association of Corrosion Engineers
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NBBI	National Board of Boiler and Pressure Vessel Inspectors
NBIC	National Board Inspection Code
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NAVFAC EXWC, OC	Naval Facilities Engineering and Expeditionary Warfare Center, Oceans Technical Department
NFPA	National Fire Protection Association
NPDES	National Pollutant Discharge Elimination System
OCONUS	Outside of the Continental United States
OMSI	Operation and Maintenance Support Information
OSHA	Occupational Safety and Health Act of 1970
OVP	Over-Voltage Protection
P-A	Protected Aboveground Storage Tank
PDP	Pressure Dew Point
pH	A number assigned to indicate whether a substance is acidic or alkaline (pH 7 is considered neutral, less than 7 is acidic and more than 7 is alkaline)
PLC	Programmable Logic Controller
POL	A commonly used abbreviation which broadly refers to all Petroleum, Oils, and Lubricants
PSI or PSIG	Pounds per Square Inch, the unit of pressure measurement; gauge pressure above atmospheric
PSIA	Pounds per Square Inch absolute; pressure above an absolute vacuum
PVC	Polyvinyl Chloride

RDBMS	Relational Database Management System
SAE	Society of Automotive Engineers, used in conjunction with specification for viscosity of lubricating oils
SPCC	Spill Prevention Control and Countermeasure
SPR	Single Point Receptacle
STANAG	Standardization Agreement (NATO term)
UFGS	Unified Facilities Guide Specifications
ULSD	Ultra Low Sulfur Diesel
UPV	Unfired Pressure Vessel
UST	Underground Storage Tank
USAFE	United States Air Forces in Europe
V-A	Vertical Aboveground Storage Tank
VOC	Volatile Organic Compound
V-U	Vertical Underground Storage Tank

D-2 DEFINITION OF TERMS

Additive. Chemical added in minor proportions to fuels or lubricants to create, enhance or inhibit selected properties; example, fuel system icing inhibitor (FSII).

Aircraft Direct Fueling System. Method used to refuel aircraft by issuing fuel directly to the aircraft from the tank farm without first transferring the fuel to a refueler truck. Also known as a hydrant system.

Aircraft Refueling Adapter. A device, mounted on an aircraft, that combines with a pressure refueling nozzle mounted on a refueling vehicle or station to form a quick disconnect connection for the purpose of refueling or defueling aircraft. It can also be used for refueling and defueling refuelers.

Ambient. Encompassing on all sides, as temperature.

Anode. The positively charged electrode of an electrolytic cell.

API Gravity. Petroleum industry scale for measuring the density of oils.

ASME Type Thermal Relief Valve. Thermal relief valve that is labeled in accordance with ASME BPVC SEC VIII D1.

Atmospheric Pressure. The pressure exerted by the earth's atmosphere, when measured at sea level under standard conditions is equal to 14.7 pounds per square inch (101 kPa).

Atmospheric Tank. Storage tank which operates at or near atmospheric pressure (14.7 psi (101 kPa) at sea level).

Balanced Type Thermal Relief Valve. Thermal relief valve that is a fully balanced (back pressure will not affect relief pressure) regulator-type valve.

Ballast Water. Water carried in ship's fuel tanks or cargo tanks to improve the vessel's stability when empty of petroleum.

Barrel. Measure of volume as used in the petroleum industry, equivalent of 42 U.S. gallons (0.16 m^3).

Blind Flange. Piping flange with no passage through the center.

Boiler Fuel Oil. Fuel oil that is burned in furnaces to create steam or hot water, also called fuel oil.

Boiling Point. The temperature at which the vapor pressure of a liquid is equal to the pressure of the vapor above the liquid, usually atmospheric pressure. The temperature increases as the atmospheric pressure increases.

Bollard. A heavy solid post used to protect equipment from an impact. Also used on docks and ships for mooring.

Bond. Electrical connection between two objects which equalizes their potential.

Boom. Flexible floating barrier consisting of linked segments designed to contain free oil on the surface of a body of water.

Bottom Loading. Method of filling tank trucks or tank cars through a tight connection at the bottom.

Breakaway Coupling. Coupling designed to part easily with a moderate pull with a dry-break from both directions.

Bulk Storage Tank. Storage tank for fuel normally received by pipeline, tank truck, or tank car. For aviation turbine fuel, configure tank to supply fuel to operating storage tanks, either directly tank-to-tank, or indirectly by issuing fuel to tank trucks, tank cars, barges, ships, or pipelines.

Bunkers. Common expression referring to heavy residual boiler fuel.

Calibration. Adjustment of the scale of a graduated device to meet an established standard, especially applicable to the adjustment of meter registers to indicate true volume as determined by a standard measure.

Cathodic Protection. A method for preventing the corrosion of metals by electrolysis.

Centistokes. A centistoke (cSt) is equal to 1 millimeter squared per second.

Centrifugal Pump. A rotating device which moves liquids and develops liquid pressure by imparting centrifugal force.

Clean Product. Refined light petroleum products such as gasoline or distillates, as differentiated from residuals or black oils.

Coalescer. A porous substance through which a liquid is passed to remove unwanted water from fuel by causing very small drops of water to form larger drops (coalesce) which will separate from fuel by gravity.

Coalescer Vessel. A pre-filtration vessel designed to remove gross amounts of water and, to a lesser degree, particulate water. Types include Haypack coalescers.

Combustible Liquid. Any liquid having a flash point at or above 100 °F (38 °C).

Contaminated Fuel. Petroleum fuel containing suspended or emulsified water, cleaning chemicals; or other foreign matter such as iron scale, dust, or other solid particles; or containing an unacceptable percentage of noncompatible fuel or other liquids; or containing more than one, or all of these classes of contaminants.

Contamination. The accidental addition to a petroleum fuel of some foreign material (contaminant) such as dirt, rust, water, or accidental mixing with another grade of petroleum.

Corrosion. The process of dissolving, especially of metals due to exposure to electrolytes.

Crude Oil. Petroleum in its natural state prior to refining.

Cut and Cover. Refers to underground vertical storage tanks.

Cyclonic Filter. A filter used to remove gross amount of particulate matter using the principle of centrifugal force to separate solid particles from a liquid.

Deadman Control. A control device, such as a switch or valve, designed to interrupt flow if the operator leaves his station.

Density. The mass per unit volume of a substance.

Dike. An embankment or wall, usually of earth or concrete, surrounding a storage tank to impound the contents in case of a spill.

Distillate. Common term for any of a number of fuels obtained directly from distillation of crude petroleum, usually includes kerosene, JP-5, light diesel, and light burner fuels. Does not include any grades of gasoline.

Double Block and Bleed Valve. A valve with two seats with a cavity in between them which can be drained while the valve is closed to prove the valve is not leaking.

Downgrade. To use a fuel for a lesser purpose than originally specified, often because of contamination.

Effluent. Stream flowing; discharge.

Electrode. Electrical conductor through which an electric current enters or leaves an electrolyte.

Electrolysis. Chemical change, especially decomposition, produced in an electrolyte by an electric current.

Electrolyte. A substance capable of forming solutions with other substances which produce ions and thereby permit the flow of electric currents.

Electrical Conductor. A substance which permits the flow of electric currents without permanent physical or chemical change; copper, aluminum.

Element. Term used to describe the ‘disposable’ part of a filter vessel such as a filter-separator, micronic filter, or Haypack coalescer. Also referred to as a cartridge.

Emulsion. A suspension of small globules of one liquid in a second liquid with which the first will not mix.

Epoxy Coating. A coating of thermosetting resins having strong adhesion to the parent structure, toughness, and high corrosion and chemical resistance, also used as an adhesive.

Explosion-proof. Classification of electrical enclosures for use in hazardous areas designed to prevent the passage of internal arcs, sparks or flames.

Fender. Part of a pier structure designed to absorb the impact of a moving vessel.

Fiberglass. Composite material consisting of glass fibers in a matrix of resin such as epoxy.

Filling Station. A facility designed to fill vehicles with gasoline or diesel as motive fuel.

Filter. A porous substance through which a liquid is passed to remove unwanted particles of solid matter. Types include cyclonic filters and micronic filters.

Filter/Coalescer Elements. A type of coalescer that removes water and particulate matter from fuel. Used as the first element in filter-separators. Also to as coalescer elements or coalescers.

Filter-separator. A filtration vessel consisting of two separate element types (also called stages). The first stage consists of filter/coalescer elements to remove fine particulate matter and to remove entrained water by coalescing it; the second stage consists of separator elements to prevent fine droplets of water (caused by the coalescing process) from reaching the vessel outlet. It removes dirt and free water down to the very low levels required for aircraft operations. Filter-separators are the only approved vessels for use in fine filtration; they are occasionally used for pre-filtration as well.

Fine Filtration. A term used to refer to filtration vessels used to remove dirt and free water down to the very low levels required for aircraft operations. Fine filtration vessels are always filter-separators.

Fire Resistant Tank. Aboveground storage tank that is listed in accordance with UL 2080, that consists of a primary tank that is protected or insulated from a 2-hour fire exposure.

Flammable Liquid. Any liquid having a flash point below 100 degrees F (38 degrees C) and a vapor pressure not exceeding 40 psia (275 kPa) at 100 degrees F (38 degrees C).

Flash Point. The lowest temperature at which a combustible or flammable liquid produces enough vapor to support combustion.

Floating Roof Tank. Petroleum storage tank with a roof that floats on the liquid surface and rises and falls with the liquid level.

Free Water. Undissolved water content in fuel.

Freeze Point. The temperature at which wax crystals form in distillate fuels and aviation turbine fuels.

Fuel Oil. See Boiler Fuel Oil.

Fuel Quality Monitor. A special type of filter designed to interrupt the flow of fuel when dirt r water content becomes too great.

Galvanizing. Rust inhibiting zinc coating applied to iron and steel.

Ground. An electrical connection to earth.

Haypack Coalescer. A type of coalescer that uses hay, straw, or excelsior as a medium to remove large slugs of water.

Hazardous Area. Electrical classification for areas where flammable or combustible liquids or vapors may be present.

Hot Refueling. Refueling of aircraft when one or more engines are running.

Housekeeping Pad. Concrete pad usually installed on concrete slabs or floors to elevate and anchor equipment. Housekeeping pads aid in maintenance and keep equipment clear of debris.

Hydrant System. Distribution and dispensing system for aviation turbine fuels consisting of a series of fixed flush type outlets or hydrants connected by piping. It issues fuel directly to the aircraft from the tank farm without first transferring the fuel to a refueler truck. Also known as an aircraft direct fueling system.

Hydrocarbon. A compound made up exclusively of hydrogen and carbon in various ratios and molecular arrangements.

Hydrostatic Head. Pressure caused by a column of liquid.

Hydrostatic Test. A test for leaks in a piping system using liquid under pressure as the test medium.

Hydrostatic Test Pressure. The pressure in the system while it is undergoing a hydrostatic leak test as defined by ASME B31.3. For the purpose of this document, set at 1.5 times the maximum allowable working pressure.

Ignition Temperature. The minimum temperature required to initiate or cause self-sustained combustion independent of any heating or heated element.

Impervious. Not easily penetrated. The property of a material that does not allow, or allows only with great difficulty, the movement or passage of a fluid. Also referred to as impermeable.

Impressed Current System. A cathodic protection system using an outside source of electric power.

Inert Material. Any solid, liquid, or gaseous substance not combustible or fire-producing when exposed to the atmosphere under ordinary climatic conditions; it includes common metals, packing materials, ceramic materials, construction materials such as concrete, mineral aggregates, and masonry.

Installation Pipelines. Pipelines which connect POL facilities within an installation such as a barge pier to a bulk facility and a bulk facility to an operating (ready-issue) tank. These pipelines do not cross property lines and, therefore, do not leave the government facility and control.

Interterminal Pipelines. Pipelines which connect two government installations such as a Defense Energy Supply Center depot to a military installation. These pipelines cross property lines and cross public and/or private properties, streets, highways, railroads, and utility rights-of-way.

Intrastate Interterminal Pipelines. Interterminal pipelines that do not cross state lines.

Interstate Interterminal Pipelines. Interterminal pipelines that cross state lines.

JP Fuel. Military designation applied to aviation turbine fuels (e.g., JP-4, JP-5, and JP-8).

Kerosene. A general term covering the class of refined petroleum which boils between 370 degrees F and 515 degrees F (188 degrees C and 268 degrees C). Mostly used in oil lamps and cooking stoves.

Kerosene Type Aviation Turbine Fuel. JP fuel derived from kerosene without the addition of naphthas; characterized by a flash point of 100 degrees F (38 degrees C) or more.

Kinematic Viscosity. The ratio of viscosity of a liquid to its specific gravity at the temperature at which the viscosity is measured.

Lead Hazard. Poisonous contamination of the atmosphere, sludge, or other surroundings, particularly in petroleum storage tanks caused by tetraethyl lead or its residues.

Line Blind. A solid flat plate used to obtain absolute shut-off of flow. Also, referred to as spectacle plates or flanges, blinding plate, figure eights and paddle blinds.

Lube Oil. Common contraction for lubrication oil; used to reduce friction and cool machinery.

Maximum Allowable Working Pressure. The maximum allowable pressure of a fuel system or component will see. For the purposes of this document, set at the pressure rating of a flanged joint per ASME B16.5.

Maximum Allowable Operating Pressure. The maximum pressure at which a system is to operate. For the purposes of this document set at 2/3 of the hydrostatic test pressure, not to exceed the maximum allowable working pressure.

Maximum Allowable Surge Pressure. The maximum pressure allowed during a surge event. For the purposes of this document, set the pressure at 133% of the qualified maximum allowable operating pressure.

Micron. A unit of length equal to one millionth of a meter, especially used as a measure of the size of very fine particles found as contaminants in fuel.

Micronic Filter. A type of pre-filter vessel equipped with paper filter elements, designed to remove particulate matter from a fuel stream. Will not remove water.

Military Specifications. Guides for determining the quality requirements for materials and equipment used by the military services.

Motive Fuel. Any fuel that is used to power vehicles, aircraft, or vessels.

Naphthas. Refined petroleum which boils at 800 degrees F (427 degrees C) to 4400 degrees F (2427 degrees C), used as a component of gasoline and solvents.

Nipple. Short length of pipe, usually used to make side branch connections.

Nondestructive Testing. A method of inspecting materials without cutting, drilling or otherwise destroying the material; usually used to examine steel plates, pipes, and welds.

Nozzle. A spout or connection, usually with a control valve through which fuel is discharged into a receiving container.

Octane Number. A numerical measure of the antiknock properties of automotive gasoline as measured against standard reference fuels, under controlled laboratory conditions. Iso-octane is a reference fuel whose octane number is given a value of 100.

Off-Specification. Usually referring to fuel which is contaminated or otherwise deficient in quality. Commonly used contraction for off-specification is “off-spec”.

Oil/water Separator. A device used to separate mixtures of oil and water, usually by the difference in specific gravity and usually to protect the environment from contamination by the oil.

Oily-water Mixture. Mixture in which water comprises more than half the total volume. Most such untreated mixtures contain less than 15 percent oil, some of which may be in emulsified form.

Operating Storage Tanks. Storage tank for aviation turbine fuel configured to issue fuel directly to an aircraft, hydrant system, or refueler. A tank configured to issue aviation turbine fuel to a refueler only in an emergency is considered a bulk storage tank.

Orifice Plate. A plate with a hole in the center held between two flanges in a pipeline, used to create a drop in pressure which is proportional to flow and can be used to measure the flow or to modulate control devices.

Pantograph. A series of pipes, joined by flexible joints, used to connect fueling equipment to aircraft.

Parallel Pumps. Two or more pumps having common suction and discharge connections.

Particulate Matter. Solid particles such as dirt, grit, and rust, which contaminate fuel.

Pigging. The use of internal pipe tools, called pigs, to clean the inside of the pipe, determine the geometry of the pipe, and determine the location and magnitude of any internal or external corrosion occurring on the pipe.

Pig Launcher. An arrangement of valves and closure devices to launch pigs at the beginning of their run through a pipeline.

Pig Receiver. An arrangement of valves and closure devices to trap pigs at the end of their run through a pipeline.

Pile Cluster. A group of pilings driven close together and usually wrapped with wire rope to act as fender or mooring for small vessels.

Pour Point. The lowest temperature at which an oil will pour or flow without disturbance.

Pontoon Roof. A type of floating roof for a storage tank having liquid-tight compartments for positive buoyancy.

Pre-filter. A term used to refer to any filtration vessel used immediately upstream of a fine filtration filter-separator in a fuel storage/delivery system. They are used to remove gross amounts of particulates and/or free water from a fuel stream in order to prolong the life of the elements used in the fine filtration filter-separator. Typically cyclonic or micronic filters are used as pre-filters although Haypack coalescers or even filter-separators may also be used in this role.

Pre-Filtration. Pre-filters or coalescers vessels placed ahead of additional, more sophisticated, fine filtration vessels for the gross removal of solids and/or free water.

Pressure Drop. The loss in pressure of a liquid flowing through a piping system caused by friction of pipe and fittings, velocity, and change in elevation.

Pressure Refueling Nozzle. A device, mounted on a refueling vehicle or station, that combines with an aircraft refueling adapter mounted on an aircraft to form a quick disconnect connection for the purpose of refueling or defueling aircraft. It can also be used for refueling and defueling refuelers.

Product Recovery Tank. Tank used to collect and store aviation turbine fuel that would otherwise become waste fuel. It is part of a closed system that, either manually or automatically, pumps the fuel back into the system through a hard piped connection. Tanks that do not have this hard piped connection are not product recovery tanks.

Protected Tank. Aboveground storage tank that is listed in accordance with UL 2085, that consists of a primary tank that is protected or insulated from a 2-hour fire exposure and protected from physical damage.

Pump Pad. A facility housing one or more pumps with no roof or canopy.

Pump Shelter. A facility housing one or more pumps with a roof, at least one wall completely open with adequate fire department access, and a total open wall area of 50 percent or more.

Pumphouse. A facility housing one or more pumps with a roof, and a total open wall area of less than 50 percent.

Radiograph. An image produced on radiosensitive film by invisible radiation such as X-ray, specifically the image produced by radiographic inspection of welds and plates.

Ready-Issue Tank. See operating storage tank.

Recoverable Fuel. That portion of the fuel which may be separated and collected from a given lot of contaminated fuel, by proper processing in the treating facility in question.

Recovered Oil. Used to denote untreated petroleum fuel removed from oil/water separators or picked up after being spilled on land or water. Also used to mean oil which has been separated from and collected from a given lot of contaminated fuel by processing in a treating facility.

Refueler. Except for tactical refuelers, tank truck vehicles used to resupply aircraft with fuel. Tactical refuelers may transport ground products (gasoline, diesel) or aviation turbine fuel.

Reid Vapor Pressure. Vapor pressure measured under controlled conditions with the liquid temperatures at 100 °F (38 °C).

Residual Fuel Oil. Topped crude petroleum from refinery operations. Commercial grades of Burner Fuel No. 5, No. 6, and bunker fuels are residual fuel oils.

Relaxation Tank. Small tank in a fuel dispensing piping system downstream of filter-separators designed to remove static electricity from the liquid stream before discharge into a receiving tank.

Rotary Pump. A positive displacement pump which operates in rotary fashion such as a vane, gear, bucket, lobe, or screw pump; not centrifugal, turbine, or propeller pumps.

Rust. Ferric oxide, a reddish-brown scaly or powdery deposit found on the surface of steel and iron as a result of oxidation of the iron.

Safety Relief Valves. Valves that are installed on pressurized vessels to relieve pressure in access of the maximum allowable working pressure of the vessel. Safety valves are provided to protect people, equipment, and property.

Scraper. A type of cleaning pig used in pipelines.

Secondary Containment-Type Tank. A tank that has an inner and outer wall with an interstitial space (annulus) between the walls and that has a means for monitoring the interstitial space for a leak.

Service Headquarters. Defined as follows: Army – Headquarters, U.S. Army Corps of Engineers Technical POC, POL Facility Criteria (CECW-CE); Air Force - The Air Force Fuels Facilities Subject Matter Expert (HQ AFCEC/COS); Navy/Marine Corps: NAVFAC POL Facility Subject Matter Expert (NAVFAC EXWC, SH25)

Service Provider. Defined as follows: Defense Logistics Agency (DLA) – DLA Facilities Engineer, DLA Installation Support for Energy (DLA DS-FEI)

Single Point Receptacle. Point at which fueling hose is attached to skin of aircraft during aircraft refueling operations.

Skimmer. A device used to collect thin layers of oil floating on a body of water.

Slop Oil. Oil or fuel which has become contaminated with other oils or substances, often requiring separation or treatment before it is fit for use.

Sludge. Heavy viscous oily mass found in the bottom of storage tanks and treatment vessels, often contains rust, scale, dirt, lead additives, wax, gum, or asphalt.

Specific Gravity. The ratio of the weight in air of a given volume of a substance to the weight in air of an equal volume of distilled water (62.4 lb/ft^3) (1000 kg/m^3), both taken at the same temperature, usually 39.2 °F (3.98 °C).

Static Electricity. Accumulation of electric charge on an insulated body; also the electrical discharge resulting from such accumulation.

Strapping. The process of determining the volume of a storage tank or cargo hold by measuring its linear dimensions.

Stripper Pump. A pump used to strip or remove the last bit of liquid from a tank or pipe.

Subdivision. A physical structure that divides a secondary containment area. Also known as intermediate curb.

Sump. A low area or depression which receives drainage.

Surge. Sudden increase in fluid pressure caused by sudden stopping of a moving stream as by a quick closing valve; hydraulic shock; also the sudden, brief increase in voltage or current in an electrical circuit.

Surge Arrestor. A protective device for limiting surge voltages by discharging or bypassing surge current, and it also prevents continued flow of follow current while remaining capable of repeating these functions. Designed primarily for connection between a conductor of an electrical system and ground to limit the magnitude of transient (surge) overvoltages on equipment. Also known as arrestor or arrester, surge arrester, lightning arrestor or arrester.

Surge Suppressor. Device designed to control or reduce surges; hydraulic shock absorber.

Thermal Relief Valves. Valves that are installed around isolation valves to relieve excessive pressure caused by thermal expansion of the fuel in the pipe.

Tolerance. An allowable variation from a specified standard of measurement, commonly applied to the accuracy of meters.

Top Loading. Method of filling tank cars and trucks through an opening in the top.

True Vapor Pressure. Vapor pressure measured at actual liquid temperature.

Vapor Lock. Malfunction of an engine fuel system or of a pumping system caused by vaporization of the fuel, usually associated with gasoline.

Vapor Pressure. Internal pressure of vapor in a liquid usually in pounds per square inch; an indication of volatility.

Viscosity. Measure of the internal resistance of a fluid to flow or movement, most commonly measured in centistokes.

Volatility. Measure of the tendency of a liquid to vaporize; vapor pressure.

Waste Oil. Oil from which the water and other contaminants cannot be removed by the available treating facilities, and hence is unfit for further use. This term is also loosely used for contaminated oil which may contain recoverable fuel collected at facilities having no treatment facility for fuel reclamation.

Water Bottom. Free water which has settled to the bottom of a storage tank.

Water Draw-off. A valve or similar device used to remove water from the bottom of a tank.

Water Slug Shutoff. A valve in the discharge piping from a filter-separator which closes automatically when the water in the unit rises above a set level.

Wax. Viscous or solid high molecular weight hydrocarbon substance; paraffin.

Weatherproof. Type of enclosure for electrical apparatus for outdoor service in nonhazardous areas.

Wharf. A landing place where vessels tie up to load or unload; pier.

APPENDIX E REFERENECES

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 350.4R-04, *Design Considerations for Environmental Engineering Concrete Structures.*

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

Industrial Ventilation: A Manual of Recommended Practice for Design

AMERICAN PETROLEUM INSTITUTE (API)

API 17J, *Specification for Unbonded Flexible Pipe*

API 570, *Piping Inspection Code: In-Service Inspection, Rating, Repair and Alteration of Piping Systems*

Bulletin D16, *Suggested Procedure for Development of Spill Prevention Control and Countermeasure Plans*

MPMS Chapter 2, *Tank Calibration*

MPMS Chapter 3, *Tank Gauging*

MPMS Chapter 5, *Metering*

Pub 2202*, Dismantling and Disposing of Steel from Tanks which have Contained Leaded Gasoline*

RP 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities – Classified as Class I, Division I and Division 2*

RP 540, Electrical Installations in Petroleum Processing Plants

RP 651*, Cathodic Protection of Aboveground Petroleum Storage Tanks*

RP 1004, *Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles*

RP 1102, *Steel Pipelines Crossing Railroads and Highways*

RP 1604, *Closure of Underground Petroleum Storage Tanks*

RP 1615, *Installation of Underground Petroleum Storage Systems*

RP 1637, *Using the API Color-Symbol System to Mark Equipment and Vehicles for Product Identification at Gasoline Dispensing Facilities and Distribution Terminals*

RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*

RP 2350, *Overfill Protection for Storage Tanks in Petroleum Facilities*

Spec 6D, *Specification for Pipeline*

Std 607, *Testing of Valves – Fire Type-Testing Requirements*

Std 608, *Metal Ball Valves – Flanged, Threaded and Butt-Welding Ends*

Std 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*

Std 650, *Welded Tanks for Oil Storage*

Std 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

Std 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*

Std 2015*, Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*

Std 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*

Std 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities*

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D396*, Standard Specification for Fuel Oils*

ASTM D910, *Standard Specification for Aviation Gasoline (Avgas)*

ASTM D975, *Standard Specification for Diesel Fuel Oils*

ASTM D1655, *Standard Specification for Aviation Turbine Fuels (DoD Adopted)*

ASTM D1835*, Standard Specification for Liquefied Petroleum (LP) Gases*

ASTM D3699*, Standard Specification for Kerosene*

ASTM D4814, *Standard Specification for Automotive Spark-Ignition Engine Fuel*

ASTM D5798, *Standard Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines*

ASTM D6751, *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels*

ASTM D7467, *Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME BPVC, *Boiler and Pressure Vessel Code*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

ASME B16.47, *Large Diameter Steel Flanges: NPS 26 through NPS 60*

ASME B31.3, *Process Piping*

ASME B31.4, *Pipeline Transportation Systems for Liquid Hydrocarbons and other liquids*

CODE OF FEDERAL REGULATIONS (CFR)

29 CFR Part 1910, *Occupational Safety and Health Standards*

29 CFR 1910.1200, *Hazardous Communication*

33 CFR Part 154*, Facilities Transferring Oil or Hazardous Material in Bulk*

40 CFR Part 60*, Standards of Performance for New Stationary Sources*

40 CFR Part 63, *National Emission Standards for Hazardous Air Pollutants for Source Categories*

40 CFR Part 112, *Oil Pollution Prevention*

40 CFR Part 122, *EPA Administered Permit Programs: The National Pollutant Discharge Elimination System (NPDES)*

40 CFR Part 280, *Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)*

4 CFR Part 281*, Approval of State Underground Storage Tank Programs*

49 CFR Part 195, *Transportation of Hazardous Liquids by Pipeline*

COMMERCIAL ITEM DESCRIPTION (CID)

CID A-A-52557*, Fuel Oil, Diesel; for Posts, Camps and Stations*

CID A-A-59693, *Diesel Fuel, Biodiesel Blend (B20)*

COMPRESSED GAS ASSOCIATION (CGA)

Pamphlet G-7.1, *Commodity Specification for Air*

COORDINATING RESEARCH COUNCIL, INC. (CRC)

Report No. 346*, Electrostatic Discharges in Aircraft Fuel Systems – Phase I*

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Report No. 635, *Handbook of Aviation Fuel Properties*

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DoD Standard Design AW 078-24-29, *Pressurized Hydrant Direct Fueling System, Type IV/V*

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HYDRAULIC INSTITUTE

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IEEE 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems

IEEE 1100, Recommended Practice for Powering and Grounding Electronic Equipment

IEEE C2, National Electrical Safety Code (NESC)

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NAVAIR 00-80T-109, *Aircraft Refueling NATOPS Manual*

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OPNAVINST 5100.23, *Navy Safety and Occupational Health (SOH) Manual*

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SAE AS5877, *Detailed Specification for Aircraft Pressure Refueling Nozzle*

SAE J1616, *Standard for Natural Gas Vehicle Fuel*

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STI R912, *Installation Instructions for Shop Fabricated Aboveground Tanks for Flammable, Combustible Liquids*

STI SP001, *Aboveground Tank System Inspector Training*

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UFC 3-580-01, *Telecommunications Building Cabling Systems Planning and Design*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*

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UFC 4-150-06, *Military Harbors and Coastal Facilities*

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\3 UFGS 33 56 21.17, *Single Wall Aboveground Fixed Roof Steel POL Storage Tank* **/3/**

\3 UFGS 33 56 21.18, *Single Wall POL Tank Undertank Interstitial Space* **/3/**

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MIL-STD-461, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*

MIL-STD MS 24484, *Adapter, Pressure Fuel Servicing, Nominal 2.5-inch Diameter*

MIL-STD-3007, *Department of Defense Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications*

UFC 3-460-03
10 November 2017
Change 2, 24 August 2023

UNIFIED FACILITIES CRITERIA (UFC)

PETROLEUM FUEL SYSTEMS MAINTENANCE

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-460-03
10 November 2017
Change 2, 24 August 2023

UNIFIED FACILITIES CRITERIA (UFC)

PETROLEUM FUEL SYSTEMS MAINTENANCE

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND **\1\/1/**

AIR FORCE CIVIL ENGINEER CENTER **\1** (Preparing Activity)**/1/**

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	29 April 2021	Chapter 1, 2, 3, 4, 5, 6, 7, 8, 11, Appendix A, Appendix, B, Appendix C, Appendix G, Appendix I, Appendix J. Changes incorporated CCR and administrative changes.
2	24 August 2023	Chapter 1, 2, 3, 6, Appendix A, Appendix, B, Appendix C, Appendix I, Appendix J. Changes incorporated CCR and administrative changes. Added Two-Person Rule in Chapter 2. Changed several maintenance tasks in Appendix C between OM and SM.

This UFC supersedes UFC 3-460-03, dated 21 January 2003.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), host nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source: Whole Building Design Guide website https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)

CHANGE SUMMARY SHEET

Document: UFC 3-460-03, *Petroleum Fuel Systems, Maintenance*

Superseding: UFC 3-460-03, dated 21 January 2003

Description: Unified Facilities Criteria (UFC) 3-460-03 contains general inspection and maintenance criteria for military land-based liquid petroleum fuel facilities. It also applies to facilities dispensing Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) for ground vehicle fueling. These criteria are applicable to all branches of the Department of Defense (DoD) and the Defense Logistics Agency (DLA).

Reasons for Document: UFC 3-460-03 was developed to harmonize requirements and guidance documents from the Army, Navy, U.S. Marine Corps, Air Force, industry guidelines, standards and codes. Creating a true unified criteria allows military services to define the required tasks for contractors and government personnel in maintaining petroleum fuel facilities.

Other military publications reviewed during the update to UFC 3-460-03 include United States Air Forces in Europe (USAFE) *Volume 1 General Description and Operation*; USAFE *Volume 2 Maintenance and Repair*; Standardization Agreement (STANAG) 3609 *Standards for Maintenance of Fixed Aviation Fuel Receipt, Storage and Dispensing Systems*; United States Air Force (USAF) Air Force Instruction (AFI) 23-204 *Organizational Fuel Tanks*; USAF Technical Order (TO) 37-1-1 *General Operation and Inspection of Installed Fuel Storage and Dispensing Systems*; and Unified Facilities Guide Specifications (UFGS).

Several industry standards, recommended practices, and codes have been incorporated into UFC 3-460-03 criteria including: American Petroleum Institute (API), Airlines for America (A4A), Energy Institute (EI), National Association of Corrosion Engineers (NACE) International, Petroleum Equipment Institute (PEI), Society of Automotive Engineers (SAE) International, and the Steel Tank Institute (STI).

Impact:

- Provides the requirements for tasks and frequencies for the inspection and maintenance of Petroleum Fuel Systems and components such as aircraft hydrant systems, tanks, and pipelines.
- Provides checklists for the inspection and maintenance of Petroleum Fuel Systems.
- Provides fuel quality, safety, environmental, fire protection guidance to follow during the inspection and maintenance of Petroleum Fuel Systems.

Unification Issues: The Army, Navy, U.S. Marine Corps, and Air Force could not unify on tank cleaning requirements listed in Section 8-7. The Air Force will require fuel tanks above 20,000 gallon in capacity to be cleaned on a 10 year cycle. The Army, Navy, and U.S. Marine Corps will require tanks to be cleaned during out of service inspections. The period of out of service inspections may vary depending on the type and condition of each tank.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

1-1.1 Introduction.

Clean, water-free fuel of the correct grade is essential to the safety of vehicles, ships and aircraft, and their operators and personnel. This manual emphasizes inspection and preventive maintenance to avoid system shutdowns, prevent fuel contamination, and decrease fire, safety, and health hazards. Periodic inspections and maintenance are essential to continue efficient safe operations and reduce major repairs.

1-1.2 Applicability.

UFC 3-460-03 applies to all real property facilities used for storing, distributing, and dispensing fuels for reciprocating and jet engine aircraft, automotive fuels, lubricating oils, and diesel fuel.

1-1.3 Scope.

This manual establishes the minimum inspection and maintenance standards for fueling systems and applies to all active installations. If the installation is in an inactive or surplus status, reduce maintenance standards to a point consistent with the anticipated mission.

1-1.4 Design Criteria.

This is not a design manual. Refer to UFC 3-460-01 for current design and construction standards.

1-2 ROLES AND RESPONSIBILITIES.

A role is a position or job defined by a set of responsibilities. A responsibility is a task or duty required of a designated party. Military services delegate tasks differently to military service-specific petroleum fuel personnel, contracted operations personnel, or maintenance contractors.

UFC 3-460-03 defines minimum maintenance tasks and their frequency. The criteria outlined within UFC 3-460-03 must be accomplished by DoD personnel (active duty/civilian) and/or DoD contractors.

The Command Authority (i.e., Army, Navy, U.S. Marine Corps, Air Force, and/or DLA) defines how tasks are divided among personnel at each facility. DoD 4140.25-M provides requirements applicable to all DoD fuel facilities.

1-2.1 Operational Tasks.

Operational tasks are actions taken to control and run the petroleum fuel system on a day-to-day basis. These tasks include monitoring control systems, bulk issue and receipt, and storage of petroleum fuel. Operating tasks help ensure the safety of personnel and the environment. Operating tasks often include specific measures to maintain petroleum fuel quality.

1-2.2 Maintenance Tasks

Maintenance tasks are recurring, daily, periodic, or scheduled work required to: preserve a facility, prevent deterioration, prevent component failure, prevent unscheduled outages, and identify components requiring replacement or repair. Maintenance tasks involve: routine inspection, testing of petroleum fuel systems, and identifying required repairs. Maintenance tasks help ensure product quality, safe working conditions, and environmental safety.

Maintenance tasks are separated into Operator Maintenance (OM) and Systems Maintenance (SM). OM is normally performed by facility operator personnel as part of normal use. SM is normally performed by trained personnel of base facility maintenance, facility operating contracts, or maintenance contracts for recurring maintenance and repair. Military services can delegate maintenance tasks between OM and SM differently. Appendix C includes a list of maintenance tasks included in this UFC and their associated designation as OM or SM for the Army, Navy and U.S. Marine Corps, and the Air Force.

1-3 DEPARTMENT OF DEFENSE FUELS \1\ DISCIPLINE WORKING GROUP /1/.

UFC 3-460-03 was updated by the DoD Fuels **1**\ Discipline Working Group (FDWG) /**1**/. For more information on the **1**\ FDWG /**1**/ refer to UFC 3-460-01, Appendix **1**\B/**1**/.

1-4 SERVICE HEADQUARTERS SUBJECT MATTER EXPERTS.

Policies, obligations, and responsibilities vary between DoD components. For interpretation of components required in petroleum fuel systems, consult the applicable Service Headquarters Subject Matter Expert (SME). For interpretation, the SME at the appropriate Service Headquarters is defined as follows:

- Army – Headquarters, US Army Corps of Engineers, POL Facilities Proponent (CECW-EC).
- Air Force – The Air Force Fuels Facilities Subject Matter Expert (**1**\/**1**/ AFCEC/COS) through the applicable **1**\ Regional Fuels Engineer (USAFE/PACAF) /**1**/.
- Navy/Marine Corps: NAVFAC POL Facility Subject Matter Expert (NAVFAC EXWC, CI11).

1-5 SERVICE CONTROL POINTS.

Service Control Points (SCP) have been established for each of the military services. SCPs serve as the central management function in coordinating requirements, technical issues, and supply actions with military units and DLA Energy. For interpretations on operation and maintenance requirements of fuel systems, consult the applicable SCP as defined in DoD 4140.25-M, Volume 1, Chapter 1, Section C1.3.1.5.

1-6 REGULATORY COMPLIANCE.

Inspection and maintenance activities must meet the most stringent of UFC and Military Specific requirements as well as applicable host nation, Federal, state, and local codes and regulations. For example, Ramstein Air Base must comply with the more stringent maintenance criteria of UFC 3-460-03, the applicable NATO STANAG, USAFE documents, or German law.

1-7 WAIVERS AND EXEMPTIONS.

Recommended UFC 3-460-03 language generated from recurring waivers and exemptions will be considered by the DoD **1**\ FDWG /**1**/ with supporting rationale for inclusion on **1**\ FDWG /**1**/ voting agendas. Recommended changes to UFC 3-460-03 are reviewed and approved by the voting members of the DoD **1**\ FDWG /**1**/, preferably in a normal recurring meeting.

1-7.1 Waivers.

Waivers are temporary deviations from the stated criteria within UFC 3-460-03. Waivers are valid for up to one year or as stated on the waiver and are submitted to the military service-specific SCP for review. Refer to Military Standard (MIL-STD)-3007G for the waiver process.

1-7.2 Exemptions.

In contrast to waivers, exemptions are permanent deviations from the stated criteria within UFC 3-460-03. Exemption requests must be submitted through the military service-specific SCP for review. Refer to Military Standard (MIL-STD)-3007G for the exemption process. The **1**\ FDWG /**1**/ must be advised when an exemption is granted.

1-8 REFERENCES.

Other sources for criteria related to petroleum fuel facilities are identified in **1**\ Appendix J. /**1**/ Any reference noted is the latest edition (as of the publication of this document) unless otherwise stated. Many of these documents are available within the public domain and can be found on the Internet; others require purchase. Before purchasing copies of referenced documents, contact the military service-specific SME to determine the need to have a complete copy of the referenced document versus obtaining the specific data needed from the referenced document from the SME.

1-9 CAPITALIZED FUEL SYSTEMS.

SM is normally eligible for DLA Energy funding at facilities that contain, handle, or distribute DLA Energy capitalized fuel under the Sustainment, Restoration, and Modernization (SRM) program. Proper coordination and scheduling with facility operators is necessary before conducting SM to ensure minimal mission impact.

DLA Energy also funds other inspection and maintenance programs at petroleum fuel facilities that contain, handle, or distribute DLA Energy capitalized fuel. See **1**\ Appendix A /**1**/ for a list of current maintenance and inspection programs that are funded by DLA Energy.

1-10 MAINTENANCE AND INSPECTION FREQUENCIES.

The maintenance and inspection frequencies provided in this UFC are strict guidelines and are based on regulatory requirements and commercial practices. The military service-specific SCP can authorize deviations and alternate equivalent methodologies for specific individual tasks and only as needed to support the mission requirements. For example, the military service-specific SCP can authorize deviations to delay or accelerate an out of service inspection of a fuel storage tank to coincide with other work to avoid reducing mission capabilities.

CHAPTER 2 GENERAL

2-1 GENERAL MAINTENANCE INFORMATION.

This chapter contains information general to all chapters of UFC 3-460-03. This chapter includes health and safety information, information related to fuel quality, and general practices and requirements.

2-2 HEALTH AND SAFETY.

Personnel must comply with the measures outlined in this chapter. Petroleum fuel products are hazardous because of their toxic and flammable nature. Health and safety precautions are required and must be strictly adhered to in order to prevent incidents and accidents to personnel and Government property. Before initiating maintenance work on petroleum fuel facilities, a hazard analysis must be completed and procedures must be established to assure recognized hazards have been controlled, items to be serviced are properly isolated and adequate light is available for the task. Only properly trained and authorized personnel are permitted to operate and perform maintenance on petroleum fuel system components. Breaches of safety standards may result in disciplinary action and possible injury or death. Safe efficient maintenance activities require cleanliness, neatness, and order. Each individual is expected to recognize and correct hazardous situations promptly, if qualified, and/or report them to supervisors.

2-2.1 Safety References.

Military service-specific health and safety procedures and information listed in USACE EM 385-1-1, **2**\ **1**\ DAFMAN 91-203 /**1**/ /**2**/, Navy Occupational Safety & Health (NAVOSH) and Occupational Safety and Health Administration (OSHA) regulations, NFPA 2112, NFPA 2113, and ASTM F1449 must be followed as applicable. Refer to Installation Safety Office for additional local and Installation specific safety requirements and procedures.

2-2.2 Personal Protective Equipment.

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a. The purpose of this section is to reduce the health and safety risks associated with the incorrect selection and use of personal protective equipment when personnel are potentially exposed to petroleum fuels and associated fire hazards. Each facility is responsible for performing a hazard analysis in accordance with NFPA 2113 to identify, eliminate, and control recognized and identified hazards. Personnel Protection Equipment (PPE) will be selected to provide the user with the appropriate personal protection. Personnel will be trained in the proper selection, use, care and maintenance of their PPE in accordance with the Installation’s written PPE program. Installations that determine there is the potential for a fire to exist from flammable vapors must utilize PPE that meets the minimal standards of NFPA 2112. Installations must reassess the hazard analysis at least every 5 years, or when a significant change is made to the work environment.

b. Any type of clothing may be worn as outer garments when working with high-flashpoint petroleum fuel (e.g., JP-5, JP-8, JP-10, Jet A, Jet A-1, additized Jet A (F-24) or diesel). However, personnel working with low-flashpoint petroleum fuel (e.g., JP-4, Jet B, aviation gasoline, or motor gasoline) must utilize PPE that meets the requirements of NFPA 2112 where the petroleum fuel facility hazard analysis has demonstrated that flammable materials or vapors are present in quantities that may result in a fire or endanger personnel. Wool socks, wool glove inserts, woolen caps, and underwear of nylon, silk, or polyester pose no significant hazard and are acceptable. Appropriate weather gear is allowed for personnel who are subject to outside work during inclement weather.

c. Conventional 50% polyester and 50% cotton-blend coveralls are adequate for routine maintenance work in petroleum fuel facilities that do not pose a fire hazard potential. When completing tasks in petroleum fuel facilities where petroleum fuel is present (e.g., tank cleaning), the use of disposable protective coveralls having a static-dissipating coating may be necessary. Disposable coveralls may be worn alone or over polyester/cotton-blend coveralls. Replace fuel-contaminated clothing.

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2-2.3 Health Hazards.

The following paragraphs describe health hazards of exposure to petroleum fuel vapors, liquid petroleum fuels, and solids. The paragraphs also provide guidance on administering appropriate types of first aid for personnel exhibiting symptoms resulting from petroleum fuel exposure. Review and become familiar with the health and exposure hazards listed on Safety Data Sheets (SDSs) for the types of fuel stored and handled in fuel systems to be maintained.

2-2.3.1 Petroleum Fuel Vapors.

Petroleum fuel vapors within a confined space, regardless of their toxicity and explosive potential, will displace oxygen and may cause suffocation. Petroleum fuel vapors can be harmful even at concentrations with a Lower Explosive Limit (LEL) of 0 (zero) unless the area has been completely freed of vapor. The Permissible Exposure Limit (PEL) of petroleum fuel vapors that can be safely inhaled is lower than the LEL. To reduce the potential for personnel exposure to hazardous petroleum fuel vapor concentrations, a facility industrial hygiene survey should be completed and safety controls implemented in accordance with applicable military service requirements as well as OSHA requirements and American Conference of Governmental Industrial Hygienists guidelines.

2-2.3.1.1 Petroleum Fuel Vapor Inhalation First Aid.

Safely remove all persons from the work area who exhibit adverse symptoms of exposure to petroleum fuel vapors to include dizziness, nausea, or headache. If a person is overcome by petroleum fuel vapors, first aid should be administered at once by someone trained in first aid, and the person exhibiting symptoms should get prompt medical attention. Recovery from initial exposure to vapors is usually prompt after exposure to fresh air. If breathing has stopped, Cardiopulmonary Resuscitation (CPR) should be administered by a person trained in CPR. Promptly report all incidents or accidents potentially resulting from petroleum fuel vapor inhalation to supervisors.

2-2.3.2 Liquid Petroleum Fuel.

Avoid getting liquid petroleum fuel on skin or clothing. Liquid petroleum fuel products remove protective oils from the skin, causing drying, chapping, and cracking. Swallowed liquid petroleum fuel products may cause central nervous system depression and pneumonia.

2-2.3.2.1 Liquid Petroleum Fuel Contact/Ingestion First Aid.

External Contact: Remove contaminated clothing at once and avoid any source of ignition. Remove liquid petroleum fuel products from the skin by washing with soap and water as soon as possible after contact. Remove liquid petroleum fuel that comes in contact with eyes immediately with an eyewash or other available means of flushing the eye with water. Obtain medical attention as soon as possible after exposure to liquid petroleum fuel. Do not expose a person to flame producing activities once they have been contaminated with liquid petroleum fuel.

Ingestion: Do not induce vomiting except as directed by physician, as uncontrolled vomiting may cause liquid petroleum fuel to go into the lungs. A person that has ingested liquid petroleum fuel should be taken to a medical facility at once. Be sure to inform medical administrators of the type and approximate amount of liquid petroleum fuel ingested.

2-2.3.3 Solids.

Dusts are formed by additives in petroleum fuel products remaining after the volatile liquids have evaporated. Solid particles in sludge may be dispersed as the sludge dries. Dust can also result from scale, sandblast, and rust particles removed from tank walls and strainers during cleaning operations. Consult the Installation Environmental Office for proper procedures for sludge and solid waste cleaning and disposal.

2-2.3.3.1 Solids Contact/Inhalation First Aid.

Solids will enter the body through inhalation of contaminated dust particles. Treat bodily contact with dust as you would with liquid petroleum fuels (Section 2-2.3.2.1) and inhalation of dust as you would with petroleum fuel vapors (Section 2-2.3.1.1). Seek immediate medical attention.

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2-2.4 Confined Spaces.

A confined space is a space large enough and configured so personnel can bodily enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous human occupancy. Examples include tanks, pits, manholes, etc.

2-2.4.1 Construction Activities.

Employees engaged in construction activities at a worksite with one or more confined spaces must comply with 29 CFR 1926, Subpart AA, state, local and installation requirements.

2-2.4.2 Hazards.

Personnel entering or working in confined spaces may encounter a number of potentially serious hazards. These hazards may include atmospheric hazards such as oxygen deficiency insufficient to support life, oxygen-enriched levels that increase the danger of fire or explosion, flammable or explosive atmospheres and materials, or toxic gases or materials. In addition, the confined space may include electrical, mechanical, engulfment or entrapment hazards that must be locked out, or controlled by other means of securing hazardous energy. Many of these hazards are not readily apparent, nor detectable by odor, or by sight, which may result in workers entering confined spaces without adequate consideration of potential dangers. Workers must consider that all confined spaces may contain unfavorable and unsafe conditions and must not enter or work in these spaces until tests, evaluation, and locally-developed procedures are performed to ensure safe conditions exist prior to entry and are maintained during the entire work period. **/1/**

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2-2.4.3 Two-Person Policy.

Ensure two people are present when entering confined spaces, performing maintenance on fuel systems and tanks, or in and around fuel facilities. /**2**/

2-3 ELECTRICAL SAFETY.

This section provides general information related to electrical safety with regard to maintenance operations, static electricity, stray electric currents, hazardous locations, and power generators. These hazards must be considered when handling and dispensing petroleum products. See National Fire Protection Association (NFPA) 70, National Electrical Code, for the practical safeguarding of persons and property from hazards arising from the use of electricity. See NFPA 70E, *Standard for Electrical*

Safety in the Workplace, for electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees in their pursuit of gainful employment. See NFPA 77, for additional guidance on static electricity hazards.

2-3.1 Lockout/Tagout.

An electrically safe work condition must be established while operating or performing maintenance on electrical equipment, regardless of whether the equipment is energized or de-energized. NFPA 70E includes detailed information on safety-related work practices, safety-related maintenance requirements, and installation safety requirements.

Establishing and following lockout/tagout procedures is essential for the safe execution of maintenance work on electrical equipment. While specific lockout/tagout procedures can differ from site to site, they must abide by the general principles outlined in NFPA 70E, Article 120, Section 120.2(B). In general, all sources of electrical energy must be controlled in such a way as to minimize personnel exposure to electrical hazards. NFPA 70E also includes Annex G, “Sample Lockout/Tagout Procedure,” which can be used as a basis for establishing a site specific procedure.

2-3.2 Static Charges.

Low-conductivity liquids, such as jet fuel and gasoline, become electrostatically charged while flowing through petroleum fuel systems and during transport in barges, tanker trucks, rail cars and other fuel transport systems. This can produce enough electrical energy to cause ignition, fire, or explosion of petroleum fuel vapor-air mixtures above the liquid petroleum fuel surface.

Grounding and bonding components of petroleum fuel facilities are important to prevent ignition, fire and explosion. All petroleum fuel system components must be bonded and grounded to dissipate static electric charges and stray electrical currents that can discharge in the form of an electric arc. Bonding across flanges is not required provided they are not electrically insulated. UFC 3-460-01, Section **\1** 2-11.3 **/1/,** includes information on grounding petroleum fuel system equipment in order to prevent the accumulation of static electricity.

2-3.2.1 Personnel Static Prevention Requirements.

Personnel must periodically ground themselves to pump house structures, tanks, and equipment by making firm contact with attached grounding bars or approved grounding points. Personnel must not put on or remove garments while conducting petroleum fuel handling operations.

Personnel must ground sampling devices to grounding bars or approved grounding points before collecting petroleum fuel samples.

2-3.3 Electrical Currents.

Electrical currents originate in generators, transmission systems, wiring, and electrical devices. They are more dangerous than static electric charges because of the continuous electric spark that can be created versus the brief electric spark created by a static electric discharge. Verify all electrical work on petroleum fuel storage and dispensing systems complies with NFPA 70, 501, Class I Locations to reduce electrical current hazards.

2-3.3.1 Stray Currents.

Stray currents flow through unintended paths or are extraneous current in the earth. Sources of stray currents include electric railways, electric power systems, electric welders, cathodic protection systems, and aircraft aeronautics electrical equipment malfunctions. Since many fixed petroleum fuel systems are in intimate earth contact, stray currents can take paths through the conducting parts of petroleum fuel systems. Stray currents can cause electric arcs that may ignite combustible petroleum fuel vapor-air mixtures.

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2-3.3.1.1 Fuel System Grounding Requirements.

Ground systems used to dissipate static electric charges also reduce stray electric current hazards. These systems provide a path to conduct stray electric currents into the earth without arcing.

2-3.3.1.2 Tank Car Loading and Unloading Requirements.

Railroad spurs used for loading and unloading tank cars should be insulated from the main line rails, ensuring isolation from stray currents that may flow in the main line rails.

2-3.3.1.3 Marine Terminal Requirements.

Stray currents from cathodic protection systems at marine terminals require special attention. These systems protect piping and steel piers and cause current flow in the water. Steel hull vessels act as a conductor of these currents. The ship-to-shore fuel-handling hose will act as a conductor and will complete a low-resistance circuit from the vessel to shore-side piping. Arcs may occur between the vessel and the hose when the hose is connected, disconnected, or brought into contact with the vessel's deck. Arcing can be prevented by connecting a bonding cable between shore-side piping and the vessel before operations begin. A switch on the shore side wired inline with the bonding cable must be closed after the cable connection is made and before the petroleum fuel handling hose is taken aboard the vessel.

2-3.3.1.4 Piping Requirements.

Stray current may flow through petroleum fuel piping systems because their electrical resistance is low compared to the surrounding earth. Removal of piping or components will interrupt the continuity of the petroleum fuel system. A bonding jumper wire must be installed prior to removal of piping or components and must remain in place until the items are replaced. Installing a jumper will prevent an arc when the piping or components are removed or replaced.
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2-3.4 Hazardous Location Classification.

NFPA 70 defines hazardous locations including areas where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, flammable liquid produced vapors, combustible liquids produced vapors, and combustible dust. Hazardous locations are classified in three ways: Type (Class), Condition (Division), and Nature (Group). Petroleum fuel facilities are Class 1 where flammable gases or vapors may be present in the air in sufficient quantities to be explosive or ignitable. Class 1 is divided into two divisions. Division 1 areas include environments where the hazard is to be expected under normal operating conditions, and Division 2 areas include environments where the hazard is not normally present in an explosive concentration or present only through accidental rupture, breakage or unusual faulty operation. The National Electrical Code (NEC) further defines the nature or “group” of the hazardous substance. Most petroleum fuel facilities will fall under Group D: hydrocarbons, fuels, solvents. Personnel must ensure that all electrical components and equipment installed, operated or replaced meet the required hazardous classification for the intended environment. Refer to UFC 3-460-01 for additional hazardous location information.

2-4 PETROLEUM FUEL QUALITY.

Every type and grade of petroleum fuel or lubricant has been specifically formulated to provide the most satisfactory and economic performance possible for a particular engine, under the operating conditions for which it was designed. Petroleum fuels or lubricants that have become contaminated or have degraded, can cause fires, explosions, injuries, loss of life, and loss of valuable machinery and equipment. Petroleum fuel product suspected of being contaminated must be reported to the military service-specific SCP.

2-4.1 Water Contamination.

Water contamination usually occurs during the transportation and storage of petroleum fuel. Water contamination is the most common form of contamination and may take one of the following three forms.

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2-4.1.1 Free Water.

Free water consists of relatively large drops of water which, if left undisturbed, will settle to the bottom of the container. In low density petroleum fuel products with low viscosity, free water settlement can be quite rapid, but in higher density or more viscous petroleum fuel products, settlement will take longer. Some petroleum fuels contain anti-corrosive or cleaning agents otherwise known as surfactants, which tend to prevent the settlement of free water.

2-4.1.2 Dissolved Water.

In this state, the water is invisible, and the petroleum fuel appears to be clear; but a drop in temperature may cause dissolved water to separate from the petroleum fuel in tiny droplets that remain suspended and give the petroleum fuel a cloudy appearance.

2-4.1.3 Emulsified Water.

Emulsions are mechanical dispersion of petroleum fuel and water having a frothy appearance. Emulsions can be very stable and hard to separate. Separation may require special mechanical and chemical treatments.
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2-4.2 Prevention and Removal of Water Contamination.

a. Operate sump drains on tanks, filter separators, and other vessels and equipment and check for free water on a daily basis when the systems are operated.

b. During petroleum fuel flow operations, observe filter separator differential pressure gauges and be sure units are functioning properly.

c. Ensure that operator and system maintenance is properly performed.

d. Newly received aviation petroleum fuels must be allowed to stand undisturbed in receiving tanks to permit settlement of free water before product is dispensed. Aviation petroleum fuel must be allowed to stand for 1 hour per 1 foot (0.31 m) of liquid level rise in storage tanks up to a maximum standing time of 24 hours or in accordance with undisturbed standing time allowed by military service-specific established procedure or policy. Ground vehicle petroleum fuels do not require settlement time before they are dispensed.

e. When field fabricated aboveground vertical tanks are available for entry, they must be inspected for unintended low spots and repaired as required to eliminate unintended low spots which could collect free water.

f. Tank roofs, seals, and fittings of all types must be maintained in good, weather-tight condition.

g. Testing and inspections required for tanks and underground piping must be followed and documented. If unexplained accumulation of water is detected, the underground petroleum fuel tank(s) suspected of leaking must be tested using a temperature-controlled, hydrostatic stand-pipe test. Underground petroleum fuel piping suspected of leaking must be isolated and subjected to the applicable underground piping annual test as described in Appendix G - Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.

2-4.3 Solid Matter Contamination.

Iron rust, scale, sand, and airborne dirt are examples of solid matter contamination most prevalent in petroleum fuel. The principal source of iron rust is corrosion in pipelines, storage tanks, or other inline steel components. Sand and dirt are particularly serious in extremely sandy or dusty areas where they may accumulate around tank gauge hatches, tank manways, or other openings and enter the tank when the covers are removed. The presence of large amounts of particulate matter in petroleum fuel results in restricting or clogging of filter separators, silting and plugging of fuel control components and nozzles, and wear and scoring of petroleum fuel system components by abrasion.

2-4.4 Prevention and Removal of Solids Contamination.

a. Brush away or remove accumulated dirt or sand around fill covers, manholes, and other covered openings before removing them.

b. Whenever petroleum fuel tanks, piping, or equipment are open for construction, repairs, or inspection, ensure they are protected against entry of dirt and foreign objects. Normally closed tank openings not required to be open for ventilation or access must remain closed. Open ends of piping and equipment such as pumps and meters must be sealed by temporary closures when they are not required to be open for inspection or repair.

c. Do not operate petroleum fuel handling equipment unless all filters, strainers, screens, and nozzle spout caps are properly installed.

d. Never remove filter, strainer basket, or strainer screens for any purpose, other than cleaning or maintenance. Filters, strainers baskets, and strainer screens must always be replaced immediately after cleaning or maintenance.

e. Observe water that is drained from filter separator sumps and report unusual accumulation of foreign matter to supervisors.

f. The inside of new petroleum fuel pipe must be carefully inspected for loose scale, dirt, or rust. Debris must be removed by brushes, swabs, plugs, or pigs before installation. New piping and pipeline systems must be thoroughly flushed according to UFGS 33 08 55. Temporary strainers installed at strategic points to remove trapped matter will assist with removal of solids.

g. When changing grades of petroleum fuel in a tank, piping or pipeline, the penetrating action of the new grade may loosen existing scale or rust. Prior to changing petroleum fuel grade, the tank, piping or pipeline may need to be thoroughly mechanically or chemically cleaned. Even if a good cleaning job is done, loosened scale or rust can continue to appear in the product for several weeks after starting the new operation. Extra precautions such as more frequent sampling, circulating of petroleum fuel product, temporary use of strainers, frequent cleaning of strainers, and use of cleaning pigs may need to be taken. See Section 2-5 Changes in Tank Product for additional information related to changing grades of petroleum fuel product in tanks.

h. Ensure replacement parts or equipment, such as hoses, packing, gaskets, O-rings, seals, and pipe compounds, are made from materials compatible with the petroleum fuel type and grade.

i. Do not allow petroleum fuel systems to lie unused for long periods of time. Inactive systems may accumulate water at low points and cause corrosion or biological activity leading to solids contamination.

2-4.5 Microbiological Contamination

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a. When water and petroleum fuels exist together, yeast, fungus, and, bacteria may be present at the interface of the two fluids or at the water-steel interface. These organisms live in water and feed on petroleum fuel. Only a small amount of water, such as a puddle in a tank bottom, is required to support large colonies of these organisms.

b. Microbiological contamination usually appears as a brown, black, or gray slime-like deposit that adheres to the inner surface of fuel tanks. This results in corrosion of fuel system components also known as Microbial Induced Corrosion (MIC), clogging of filters, and erratic operation of petroleum fuel quality indicating systems. Microbiological contamination is most severe in high temperature/high humidity environments and in alternative ground vehicle fuel products. Damage from microbiological induced corrosion is caused by hydrogen sulfide that is produced as waste by micro-organisms as they metabolize petroleum fuel in the absence of sufficient oxygen and can cause significant damage to tanks and piping and environmental problems in very short periods of time.

c. The presence of microbiological contamination in petroleum fuel is a reliable indication of failure of petroleum fuel filtration equipment, inadequate water stripping of petroleum fuel storage tanks and a need for more frequent cleaning of petroleum fuel storage tanks. **/1/**

2-4.5.1 Prevention of Microbiological Contamination.

To prevent microbiological contamination, remove water from petroleum fuel systems by the use of sumps on tanks, filter vessels and low point drains. The use of biocides in aviation fuels and F-76 is prohibited under current product specifications. Biocides are allowed on a case-by-case basis on rare occasions and require extensive justification and approval by the military service-specific SCP.

2-4.6 Other Product Contamination.

The properties of one type or grade of petroleum fuel can be greatly changed by mixing it with another grade or type of petroleum fuel. Some causes of cross contamination between petroleum fuels are leaky bulkheads between tanks, leaky valve manifolds separating product systems, use of multiproduct pipelines, delivery of improper petroleum fuel grade, and improper cleaning of a tank compartment or pipeline prior to changing petroleum fuel product service.

“Jelly” or “Apple Jelly” is a contaminant found in petroleum fuel systems, specifically filtration equipment, resulting from media migration. “Apple Jelly” occurs when free water particles in the petroleum fuel react with small quantities of super-adsorbent polymers that pass or migrate into the petroleum fuel as it flows through water adsorption media filter and/or monitors. The mixture creates an aggressive solvent that when mixed with other particulates and debris creates a thick “jelly-like” substance. Fuel System Icing Inhibitor (FSII – Diethylene Glycol Monomethyl Ether (DiEGME)) has been shown to increase the rate of media migration, and as a result, water adsorption media filters and/or monitors are no longer used in systems that handle petroleum fuel containing FSII.

2-4.6.1 Prevention of Other Petroleum Fuel Contamination.

Clear identification of petroleum fuel systems and equipment by product type and grade is essential to operational safety and product quality protection. Systems must be clearly identified in accordance with Section 2-7.

a. Be sure that system flow diagrams are available to all operators. Use arrows to indicate the direction of petroleum fuel flow within pipes. Include petroleum fuel product labeling on all petroleum fuel tanks, piping, and load and offload points.

b. Do not begin petroleum fuel transfer operations until markings of all needed petroleum fuel equipment has been checked and found to agree.

c. Ensure valves in valve manifolds are positively shut-off and locked out between petroleum fuel products. Do not depend solely on single valves to separate petroleum fuel products as they may leak. Install spectacle blinds, blind flanges, or use double block and bleed valves in manifolds where petroleum fuel product is to be separated.

d. Be sure that newly arrived petroleum fuel products were not contaminated during shipment. Take samples per military service-specific quality control directives or MIL-STD-3004, and if possible, do not ship or use a petroleum fuel product until test results are confirmed acceptable.

e. Use separate pipelines and equipment for each petroleum fuel product. Unless designed to act as a multi-product line, or required as an alternative capability in a contingency, pipelines should never be used for more than one type of petroleum fuel. Common piping systems must never be used for incompatible petroleum fuel products.

2-4.7 Special Considerations for Biodiesel Blend B20.

Biodiesel Blend B20 is 20 (±1) volume percent biodiesel conforming to specifications ASTM 6751 and 80 volume percent petroleum diesel fuel conforming to ASTM D975.

a. Biodiesel fuel is comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. Biodiesel is meant to be used in standard diesel engines and should not be confused with the vegetable and waste oils used to fuel converted diesel engines.

b. A B20 product must be pre-blended prior to delivery. It is not acceptable to attempt blending into a Government tank during the delivery.

c. DoD Components and Federal agencies must not order B20 where projected consumption and product storage duration exceeds three months, due to extended and unresolved product stability concerns.

d. B20 may be stored in tanks and handled with equipment used for diesel service. Nevertheless, Defense Energy Support Points (DFSPs) must comply with standard military service-specific procedures and directives regarding tank cleaning prior to converting existing storage tanks from diesel to B20 service.

e. A generally higher cloud point than standard diesel may occasionally affect B20 cold flow properties. DoD Components and Federal agency customers should order more frequent, smaller B20 quantities to achieve advantage of seasonal diesel cloud point adjustments that minimize potential vehicle and equipment cold weather operation problems.

f. DoD only allows the use of B20 biodiesel in non-tactical equipment.

2-4.8 Special Considerations for Fuel Ethanol Blend E85.

Fuel Ethanol Blend E85 is 75 to 85 volume percent fuel ethanol blended with 25 to 15 volume percent hydrocarbon fuel, usually unleaded gasoline. ASTM 5798 governs E85 procurement as fuel ethanol intended for use in ground vehicles with spark-ignition engines.

a. DoD Components and Federal agencies must ensure material compatibility with storage tanks and dispensing equipment prior to converting facilities to E85 service.

b. Special materials requirements are described in DOE's "Handbook for Handling, Storing, and Dispensing E85." Pre-1992 fiberglass tanks may not be suitable to convert to E85 service.

c. Three vapor pressure classes of fuel ethanol (Ed75 – Ed85) with ethanol content varying between 75 and 85 percent for different seasonal conditions and geographic regions serve to ensure proper vehicle operation throughout the year in all locations.

d. High E85 ethanol content may reduce lubricating properties as well as increase water tolerance. Decreased temperature and increased water content may reduce hydrocarbon fuel solubility in fuel ethanol.

e. Monitor and keep water content to a minimum, due to water's miscibility in fuel alcohol, to minimize performance degradation.

f. Ethanol is not compatible with aluminum, and all aluminum products must be removed from a gasoline dispensing system that will be used to dispense E85.

g. In accordance with EPA regulations, all commercial grades of gasoline must contain certain additives, detergents, and corrosion inhibitors. In a finished blend of E85, any additive that was found previously in gasoline is now contained in E85 (although at reduced levels). While adding detergent to the hydrocarbon component of E85 is necessary, it is not necessary to add detergent based on the alcohol portion of the product. Overuse of additives with E85 may result in poor vehicle operation.

2-5 CHANGES IN TANK PRODUCT.

Changes of petroleum fuel product in tank and piping systems must be conducted in accordance with the more stringent of military service-specific quality control directives and MIL-STD-3004.

2-6 ENVIRONMENTAL PROTECTION.

The DoD is actively committed to protecting quality of the environment by preventing and controlling pollution resulting from use and operation of petroleum fuel facilities. The DoD is required to comply with environmental laws and regulations. Individuals who violate environmental regulations may be subject to serious civil and criminal penalties, including fines and jail terms. Significant precautions as listed in UFC 3-460-01, such as petroleum fuel storage tank, load, and offload secondary containment systems, are used to prevent the discharge of petroleum fuel products to sanitary and storm sewer systems, ground water systems, local streams and waterways.

2-6.1 Spill Planning.

Facilities containing or handling petroleum fuel products are designed and constructed in a manner that should prevent spillage. Should a spill occur, the facilities should prevent the spill from leaving the property and/or entering a waterway or ground water table. Installations must have a Spill Prevention Control and Countermeasure (SPCC) plan or, for overseas sites, the spill response document required by the Overseas Environmental Baseline Guidance Document or Environmental Final Governing Standards, as applicable. Refer to UFC 3-460-01, and included references for SPCC requirements. Personnel should be familiar with SPCC requirements specific to the petroleum fuel facility where they are preforming inspections and maintenance.

While performing maintenance activities where a petroleum fuel release is imminent, a drip pan or other suitable means must be utilized to contain petroleum fuel that may be released from a system. Spill pads must also be readily available. Bonding the drip pan to the petroleum fuel system or a grounding rod will reduce the risk of a static electric discharge. Bonding points for drip pans should be provided where they are put into regular use.

2-6.1.1 Reference of UFC 3-460-03 in SPCC Plans.

Spill plans, response plans, operational plans, or other plans required by law should not include UFC 3-460-03 by title for complete inclusion. Only specific items from the document should be included when required.

2-6.2 Containment.

Secondary containment should be provided for petroleum fuel systems and components as required by UFC 3-460-01. These systems may include earthen berms, containment paving, spill kits, and/or liners.

2-6.3 Containment Drain Valves.

Containment areas must be drained as frequently as required to maintain them in a clean, dry, and accessible state. Debris caught in the drainage inlet grate must be removed after each draining. Containment drain valves must be maintained as outlined in Section 6.6 Valves. Coordinate containment area draining with operational personnel.

2-6.4 Waste Disposal.

To ensure waste is disposed of properly, check that adequate waste disposal containers are available and disposal procedures are identified. Coordinate waste disposal procedures with the Installation Environmental Office. Coordination must include strict adherence to the most stringent of host nation, Federal, state, or local hazardous waste regulations to include permitting.

2-7 SIGNAGE AND MARKINGS.

Signs and marking require periodic inspections and maintenances to ensure that important information is easily accessible.

2-7.1 Inspection and Maintenance - Signage and Markings.

a. Check permanent signs and markings for adequacy and readability. Repair or replace deteriorated or illegible signs and markings.
Frequency: Weekly

b. Inspect the location of Department of Transportation (DOT) regulated underground petroleum fuel pipelines and ensure they are marked in accordance with 49 Code of Federal Regulations (CFR) 195.410.
Frequency: Monthly

c. Check that petroleum fuel pipelines, tanks, valves, pumps, meters, and other equipment are marked in accordance with UFC 3-460-01 Section 2-**\1** 17 /**1**/. If markings are missing or insufficient, repair or add markings in accordance with UFC 3-460-01.
Frequency: Monthly

d. Ensure petroleum fuel system Emergency Fuel Shutoff (EFSO) pushbuttons are properly identified at each location. Ensure that signage is properly secured and that the lettering is legible from 25 feet (7.5 meters) away and not faded.
Frequency: Monthly

e. Verify enough movable or temporary signs are maintained in good condition to serve anticipated needs; for example: "DANGER," "CLOSED TO TRAFFIC," “KEEP FLAMES AWAY," "MEN WORKING,” "NO SMOKING,” "DANGER NO OPEN FLAME OR IGNITION SOURCE BEYOND THIS POINT.” Use bilingual signs when appropriate.
Frequency: Annually

2-8 FIRE PROTECTION.

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- Three simultaneous conditions are necessary to create petroleum fuel fires: the petroleum fuel product must be in the form of vapor; petroleum fuel vapor-air mixture must be present in correct proportions to support combustion or explosion; and the combustible mixture of petroleum fuel vapor and air must be raised to its ignition temperature or subjected to a source of ignition. The absence of any one of these conditions prevents occurrence of a fire.

- It is not practical to eliminate air completely or to control petroleum fuel vapor-air proportions where petroleum fuel is handled and dispensed, and temperatures cannot be controlled to the point where petroleum fuel vapors are not possible. Therefore, the elimination of sources of ignition is the primary controllable factor for the prevention of petroleum fuel fires.

- NFPA 10 details the number and types of portable fire extinguishers that should be located around petroleum fuel areas and storage locations.

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2-8.1 Petroleum Fuel Vapor Sources for Fires and Explosions.

Petroleum fuel vapors escaping to atmosphere are quickly diluted to within the flammable or explosive limit, and if ignited will cause fire. Eventually the petroleum fuel vapor concentration within a tank or vessel is diluted, creating an explosive hazard within the tank. Petroleum fuel vapors are heavier than air and can travel long distances before they dissipate into the atmosphere. Any source of ignition may ignite petroleum fuel vapors causing a fire or explosion.

2-8.2 Solid Sources for Fires and Explosions.

Sludge and other petroleum fuel saturated material (such as sediment, hollow roof supports, sidewall scale, foam pan seals, and oil-soaked wooden structures) emit petroleum vapors which can accumulate to the flammable or explosive limit.

2-8.3 Ignition Sources for Fires and Explosions.

Primary causes and sources of ignition are poor maintenance or defective electrical equipment, negligence, relaxed disciplinary action to violations of safety regulations, and static or stray electrical currents.

2-8.3.1 Maintenance Tools.

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- Non-sparking tools provide protection against fires and explosions in petroleum fuel product environments. Non-sparking tools should be used for operation and maintenance work on highly volatile petroleum fuels with flash points below 100 °F (38 °C) unless the environment has been certified to be vapor free. Common non-sparking tool materials are brass, bronze, copper-nickel alloy, copper-beryllium alloy and copper-aluminum alloy. Ensure non-sparking tools are kept clean of ferrous or other contaminants which have sparking properties.

- Electric tools must have a three-wire cord with a ground and be plugged into a grounded receptacle, be double insulated, or be powered by a low-voltage isolation transformer. Electric tools must be protected by a ground-fault circuit interrupter or an assured equipment-grounding conductor program. All electric power tools, battery or corded, and electrical extension cords must be intrinsically safe and Underwriters Laboratory (UL) listed for the intended hazardous location.

- Refer to OSHA Booklet 3080 *Hand and Power Tools* (based upon 29 CFR, Part 1910, Subpart P) or military service-specific directives for additional safety and guidance regarding the appropriate tools for work to be performed.

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2-8.3.2 Power Generators.

Diesel and gasoline engine-powered generators and other internal combustion powered tools (e.g. internal combustion engine driving pumps) must only be used in close proximity to petroleum fuel systems if equipped with spark arrestors. The equipment must be located outside of petroleum fuel tank containment areas and upwind of petroleum fuel tanks and at least 50 feet (15.2 meters) from the nearest petroleum fuel tank manhole or vent.

2-8.3.3 Smoking Clearances.

"No Smoking" signs must be placed conspicuously around petroleum fuel systems. Smoking must only be permitted in designated smoking areas outside of petroleum fuel vapor clearances.

2-8.4 Fire and Explosion Preventative Measures.

a. Provide proper ventilation for pump houses, pits, and other enclosed spaces where petroleum fuel vapors may accumulate.

b. Take precautions to prevent leakage or spillage of petroleum fuel products.

c. When spillage is expected from petroleum fuel pipes, hoses connections, or opened equipment, ventilate the area and eliminate sources of ignition. Direct the expected spillage to an approved container or a drip pan as applicable. Bonding the drip pan to the petroleum fuel system or a grounding rod will reduce the risk of a static electric discharge. Bonding points for drip pans should be provided where they are put into regular use.

d. If a small amount of petroleum fuel spills on the ground, asphalt or concrete, cover it with dry absorbent. Remove used absorbent once petroleum fuel has been absorbed.

e. Where major operations raise a possibility of sizeable petroleum fuel spills, call fire department authorities for possible standby.

f. Be familiar with local petroleum fuel spill contingency plans and the proper contact information for the local fire department.

g. Do not start or run a vehicle in an area where petroleum fuel has been spilled until all flammable or combustible liquid is removed and the area is freed of petroleum fuel vapors unless the vehicle is required to clean up the spill (e.g., vacuum truck or skimmer boat).

h. Do not weld, cut, rivet, do mechanical or other hot work on out of service petroleum fuel storage tanks, pipe, or other equipment that has contained flammable or combustible substances until the equipment has been properly ventilated and certified vapor free. In limited cases, hot work can be performed safely on in-service equipment with an approved plan. Always obtain a hot work permit before hot work is conducted on petroleum fuel systems.

i. Only allow personnel that meet the requirements of UFGS 33 52 90.00 20 to conduct welding on petroleum fuel tanks or vessels that have contained flammable or combustible liquids or petroleum fuel vapors.

j. Drain, purge, and ventilate petroleum fuel tanks or other equipment brought back to maintenance buildings for repair and keep them outside of buildings, well away from open flames and other sources of ignition.

k. Do not allow open flames near Class 1 hazardous areas as established in NFPA 70.

l. Artificial light and power tools must meet the requirements of Section 2-8.3.1, “Maintenance Tools.”

m. Immediately dispose of petroleum fuel soaked rags or waste, or place them in approved closed noncombustible containers. Refer to Section 2-6.4 Waste Disposal for waste disposal procedures.

2-9 EMERGENCY ACTION PLANS.

Agencies that operate and/or maintain petroleum fuel infrastructure must be knowledgeable of their applicable emergency action plans that include measures to address a variety of emergency responses including but not limited to natural disasters, terrorist threat conditions, and environmental protection.

2-10 SITE MAINTENANCE PROGRAM.

Facility maintainers (e.g., Base Civil Engineering, Department of Public Works, contractors, operators) have the primary responsibility for maintaining and repairing petroleum fuel infrastructure (e.g., petroleum fuel or lubricant receipt, issue and storage systems) under their stewardship. DoD petroleum fuel sites may have more than one facility maintainer depending on the type of mission, the facility owner, or other contractual relationship. Military services can delegate maintenance tasks between operator maintenance and system maintenance differently. See Section 1-2.2, “Maintenance Tasks,” for more information on the delegation of maintenance tasks.

Agencies responsible for infrastructure maintenance must develop site maintenance programs that include:

- List and details of petroleum fuel equipment requiring maintenance.
- Coordination requirements and points of contact for other agencies that may support or provide input on maintenance activities (e.g., cathodic protection, electrical, environmental, fire department, plumbing, and safety).
- Documentation and record retention procedures.
- Details for maintaining infrastructure as-built information.
- Details for developing and submitting projects to maintain, repair or upgrade existing infrastructure and details for coordination with agencies on requirements for new infrastructure.
- Quality assurance requirements for contractors working on petroleum fuel infrastructure.

2-10.1 Maintaining Petroleum Fuel Infrastructure.

Petroleum fuel facility maintainers should utilize recurring maintenance systems to track inspections, scheduled and unscheduled maintenance actions, and equipment serviceability.

Petroleum fuel facility maintainers and operators must coordinate requirements and schedule maintenance actions to minimize mission impact.

2-10.2 Documentation and Record Retention.

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a. Petroleum fuel system documentation and record retention must include maintenance records in sufficient detail to identify each real property or equipment item’s current maintenance status (e.g., tanks, pumps, valves, piping). These records must be maintained at the Installation and should be used to justify recommendations for repair, upgrade, and replacement.

b. Each Installation must develop and have site-specific maintenance manuals such as Operation and Maintenance Support Information (OMSI) or Operation, Maintenance, Environmental, and Safety Plan (OMES). These manuals must include manufacturer’s operation and maintenance information for the specific equipment and components installed. The Installation-specific OMSI or OMES manuals must be used in conjunction with the inspection and maintenance criteria of UFC 3-460-03.

c. Unless otherwise specified by military service-specific or contract requirements, maintenance agencies must retain petroleum fuel infrastructure records of tests and inspections (e.g., API Standard 570 and

API 653). Copies of these records must be issued to the Installation for official record retention.

d. Environmental regulations typically require retention of records for a minimum of three to five years. In some cases environmental regulations require record retention for the life of the system (e.g., tanks). Records must be maintained for a minimum of three years unless more stringent military service, Federal, state, host nation, or local requirements apply.

e. For agencies that are responsible for maintenance of DOT regulated petroleum fuel pipelines, additional inspection and repair information is required and must comply with 49 CFR 195.310, 195.404, 195.507 and 195.589.

f. For agencies that are responsible for maintenance of underground storage tanks inspection and repair recordkeeping must comply with 40 CFR 280.34.

g. For agencies that are responsible for maintenance of hose and pipelines near, over, or through navigation and navigable waters, inspection and repair recordkeeping must comply with 33 CFR 154.740.

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2-10.3 As-built Information.

Available as-built information for petroleum fuel systems must be preserved and protected. As-built information must be updated when projects that change the configuration of the system are executed at petroleum fuel facilities. An accurate process flow diagram of each petroleum fuel system is the minimum amount of documentation that must be maintained. Copies of as-built information must be maintained at the Installation's petroleum fuel facility operations building and permanent Installation files.

As-built information required for DOT regulated pipelines must comply with 49 CFR 195.404.

2-10.4 Operation and Maintenance Support Information.

Each Installation must maintain a current library or access to manufacturer's operation and maintenance manuals for all equipment that is associated with petroleum fuel infrastructure under the Installation's responsibility.

Operation and maintenance information required for DOT regulated pipelines must comply with 49 CFR 195, Section 402. Operation and maintenance information required for facilities that conduct petroleum fuel transfer to or from marine vessels must comply with 33 CFR Part 154 Sections 300 to 325.

2-10.5 Safety Reports.

All petroleum fuel facilities must follow military service or contract requirements when reporting safety and risk assessments on infrastructure.

Facilities regulated by DOT have additional reporting requirements that are governed by 49 CFR 195 Subpart B. The facility operators or maintainers must copy DLA Energy and/or military service commands when notifying the Pipeline and Hazardous Materials Safety Administration (PHMSA) of a regulated pipeline incident.

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CHAPTER 3 BULK TRANSFER FACILITIES

3-1 INTRODUCTION.

This chapter applies to permanent petroleum fuel infrastructure and is not intended for contingency or mobility equipment or temporary petroleum fuel receipt or issue systems.

3-2 TRUCK RECEIPT.

Major components of petroleum fuel truck offloading facilities include offloading hoses, piping, basket strainers, air eliminator tanks, pumps, meters, pre-filters, filter separators, grounding systems, ground verification systems and control panels.

a. Piping used to distribute petroleum fuel from truck offloading positions to petroleum fuel tanks may be installed underground, aboveground, or in a combination of aboveground and underground segments.

b. Sometimes these systems use drop tanks which can be underground, vaulted, or low-profile equipped with submerged turbine pumps.

c. Pumps are typically self-priming centrifugal or rotary vane positive displacement.

d. Underground or low-profile petroleum fuel tanks typically receive fuel by gravity offload.

3-2.1 Inspection and Maintenance - Truck Receipt.

a. Refer to Section 3-9.2, “Offloading Fuel Hoses,” for inspection and maintenance requirements of offloading hoses.

b. Refer to Section 6-1, “Pipe Testing And Inspections,” for inspection and maintenance requirements of pipelines and piping.

c. Refer to Section 3-6.4, “Basket Strainers, “for inspection and maintenance requirements of basket strainers.

d. Refer to Section 3-10.1, “Air Eliminator Tanks,” for inspection and maintenance requirements of air eliminator tanks.

e. Refer to Section 3-8, “Pumps,” for inspection and maintenance requirements of petroleum fuel pumps.

f. Refer to Section 3-7, “Meters,” for inspection and maintenance requirements of petroleum fuel meters.

g. Refer to Section 3-6.1, “Pre-Filters,” for inspection and maintenance requirements of pre-filters.

h. Refer to Section 3-6.2, “Filters Separators,” for inspection and maintenance requirements of filter separators.

i. Refer to Section 9-1.6, “Grounding Systems,” for inspection and maintenance requirements of grounding systems.

j. Refer to Section 9-5, “Ground Verification Systems,” for inspection and maintenance requirements of ground verification systems.

k. Refer to Section 9-1.9, “Electronic Equipment,” for inspection and maintenance requirements of control panels.

3-3 PIPELINE RECEIPT.

Fuel can be supplied to petroleum fuel storage tanks from on-base or off-base pipelines. These pipelines can be Government Owned/Government Operated (GOGO), Government Owned/Contractor Operated (GOCO), or Contractor Owned/Contractor Operated (COCO).

Major components of pipeline receipt systems include piping, basket strainers, automatic air vents, meters, pre-filters, filter separators, grounding systems, and control panels.

3-3.1 Inspection and Maintenance – Pipeline Receipt.

a. Refer to Section 6-1, “Pipe Testing and Inspections,” for inspection and maintenance requirements of pipelines and piping.

b. Refer to Section 3-6.4, “Basket Strainers,” for inspection and maintenance requirements of basket strainers.

c. Refer to Section 3-10.2, “Automatic Air Vents,” for inspection and maintenance requirements of automatic air vents.

d. Refer to Section 3-7, “Meters,” for inspection and maintenance requirements of petroleum fuel meters.

e. Refer to Section 3-6.1, “Pre-Filters,” for inspection and maintenance requirements of pre-filters.

f. Refer to Section 3-6.2, “Filter Separators,” for inspection and maintenance requirements of filter separators.

g. Refer to Section 9-1.6, “Grounding Systems,” for inspection and maintenance requirements of grounding systems.

h. Refer to Section 9-1.9, “Electrical Equipment,” for inspection and maintenance requirements of control panels.

3-4 RAIL RECEIPT.

Rail receipt systems use components that are similar to the components used for truck receipt. Refer to Section 3-2 Truck Receipt for a list of typical components that should be expected in a rail receipt system and associated maintenance requirements.

3-5 BULK ISSUE.

3-5.1 Truck Issue.

The preferred connection system for jet fuel issue is a metal, counterbalanced, swivel type pantograph constructed of aluminum or stainless steel; although an approved loading fuel hose is acceptable. Loading fuel hoses, if provided, must be stored away from direct sunlight.

Major components of petroleum fuel truck issue facilities include piping, basket strainers, pumps, filter separators, meters, Truck Fill Valve (TFV), loading fuel hoses, fixed pantographs, fueling nozzles, grounding systems, ground verification equipment, electronic overfill protection systems, and control panels.

3-5.1.1 Inspection and Maintenance – Truck Issue.

a. Refer to Section 6-1, “Pipe Testing and Inspections,” for inspection and maintenance requirements of pipelines and piping.

b. Refer to Section 3-6.4, “Basket Strainers,” for inspection and maintenance requirements of basket strainers.

c. Refer to Section 3-8, “Pumps,” for inspection and maintenance requirements of petroleum fuel pumps.

d. Refer to Section 3-6.2, “Filter Separators,” for inspection and maintenance requirements of filter separators.

e. Refer to Section 3-7, “Meters,” for inspection and maintenance requirements of petroleum fuel meters.

f. Refer to Section 6-6.5.1, “Truck Fill Valves,” for inspection and maintenance requirements of TFVs.

g. Refer to Section 3-9.1, “Loading Fuel Hoses,” for inspection and maintenance requirements of loading fuel hoses.

h. Refer to Section 4-7.1.1, “Fixed Pantographs,” for inspection and maintenance requirements of fixed pantographs.

i. Refer to Section 4-7.3, “Fueling Nozzles,” for inspection and maintenance requirements of fueling nozzles.

j. Refer to Section 9-1.6, “Grounding Systems,” for inspection and maintenance requirements of grounding systems.

k. Refer to Section 9-5, “Ground Verification Systems,” for inspection and maintenance requirements of ground verification systems.

l. Refer to Section 9-6, “Electronic Overfill Prevention Systems,” for inspection and maintenance requirements of electronic overfill prevention systems.

m. Refer to Section 9-1.9, “Electrical Equipment,” for inspection and maintenance requirements of control panels.

3-5.2 Pipeline Issue.

Major components of pipeline issue systems include piping, basket strainers, automatic air vents, pumps, filter separators, meters, grounding systems, and control panels.

3-5.2.1 Inspection and Maintenance – Pipeline Issue.

a. Refer to Section 6-1, “Pipe Testing and Inspections,” for inspection and maintenance requirements of pipelines and piping.

b. Refer to Section 3-6.4, “Basket Strainers,” for inspection and maintenance requirements of basket strainers.

c. Refer to Section 3-10.2, “Automatic Air Vents,” for inspection and maintenance requirements of automatic air vents.

d. Refer to Section 3-8, “Pumps,” for inspection and maintenance requirements of petroleum fuel pumps.

e. Refer to Section 3-6.2, “Filter Separators,” for inspection and maintenance requirements of filter separators.

f. Refer to Section 3-7, “Meters,” for inspection and maintenance requirements of petroleum fuel meters.

g. Refer to Section 9-1.6, “Grounding Systems,” for inspection and maintenance requirements of grounding systems.

h. Refer to Section 9-1.9, “Electrical Equipment,” for inspection and maintenance requirements of control panels.

3-5.3 Rail Issue.

Counterbalanced articulated (swivel-type) tank car loading pantographs or loading fuel hoses are used to load railcars.

Major components of rail issue facilities include piping, basket strainers, pumps, filter separators, meters, TFV, loading fuel hoses, fixed pantographs, fueling nozzles, grounding systems, ground verification systems, electronic overfill protection, and control panels.

3-5.3.1 Inspection and Maintenance – Rail Issue.

a. Refer to Section 6-1, “Pipe Testing and Inspections,” for inspection and maintenance requirements of pipelines and piping.

b. Refer to Section 3-6.4, “Basket Strainers,” for inspection and maintenance requirements of basket strainers.

c. Refer to Section 3-8, “Pumps,” for inspection and maintenance requirements of petroleum fuel pumps.

d. Refer to Section 3-6.2, “Filter Separators,” for inspection and maintenance requirements of filter separators.

e. Refer to Section 3-7, “Meters,” for inspection and maintenance requirements of fuel meters.

f. Refer to Section 6-6.5.1, “Truck Fill Valves,” for inspection and maintenance requirements of TFVs.

g. Refer to Section 3-9.1, “Loading Fuel Hoses,” for inspection and maintenance requirements of loading fuel hoses.

h. Refer to Section 4-7.1.1, “Fixed Pantographs,” for inspection and maintenance requirements of fixed pantographs.

i. Refer to Section 4-7.3, “Fueling Nozzles,” for inspection and maintenance requirements of fueling nozzles.

j. Refer to Section 9-1.6, “Grounding Systems,” for inspection and maintenance requirements of grounding systems.

k. Refer to Section 9-5, “Ground Verification Systems,” for inspection and maintenance requirements of ground verification systems.

l. Refer to Section 9-6, “Electronic Overfill Prevention Systems,” for inspection and maintenance requirements of electronic overfill prevention systems.

m. Refer to Section 9-1.9, “Electrical Equipment,” for inspection and maintenance requirements of control panels.

3-6 FILTRATION.

3-6.1 Pre-Filters.

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a. Micronic pre-filters meeting the requirements of UFGS 33 52 43.28 are sometimes installed upstream of filter separators to extend the life of coalescer cartridges in filter separators. Pre-filters remove particles that cause contamination. Petroleum fuel to be filtered enters the lower part of the housing and flows through the filter cartridges from outside to inside. Coarse dirt particles settle immediately; finer particles are absorbed by the pleated paper type filter cartridges.

b. An elevated differential pressure measurement indicates dirty filter cartridges. Investigate sudden drops or spikes in differential pressure measurement reading. A drop in the flow rate or an increase in pressure of a system may indicate filters cartridges are fouled with debris or contaminants. A sudden increase in flow rate or decrease in pressure may indicate that the filter cartridges are damaged or torn. Replacement filter cartridges must meet the filter cartridge requirements of UFGS 33 52 43.28.

c. The Installation must maintain an inventory of filter cartridges. The inventory must be sufficient to allow the Installation to change the filter cartridges of all pre-filters at an Installation once. The inventory must be kept in a temperature controlled environment in accordance with manufacturer recommendations.

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Figure 3-1 Pre-Filter

3-6.1.1 Inspection and Maintenance – Pre-Filters.

Stencil pre-filters in accordance with Section 3-6.1.3 Stenciling of Pre-Filters when filter cartridges are changed. Pre-filters require the following inspection and maintenance:

a. Open drains under flow conditions until clear fuel is observed from the drain valve.
Frequency: Daily

b. Monitor differential pressure in filter cartridges. Chart differential pressure measurements from readings taken during normal operations.
Frequency: Daily

c. Operate pre-filter isolation valves.
Frequency: Quarterly

d. Replace filter cartridges when the acceptable maximum differential pressure is reached, the maximum in-service duration has passed, or the fuel becomes visibly dirty or discolored. Acceptable maximum differential pressure for a specific pre-filter is dependent on the system flow rate. The military service-specific SCP may extend in-service duration filter cartridge replacement period based on differential pressure for high throughput systems. Check expiration date of replacement filter cartridges before installation.
Frequency: When differential pressure has reached the lower of manufacturer's recommendation or 20 psid (140 kPa), filter cartridge in-service period of 24 months has expired, or when fuel becomes visibly dirty or discolored.

e. Refer to Section 6-7.2, "Differential Pressure Gauges," for inspection and maintenance requirements of differential pressure gauges.

f. Refer to Section 3-10.2, "Automatic Air Vents," for inspection and maintenance requirements of automatic air vents.

g. Refer to Section 6-6.3, "Thermal and Pressure Relief Valves," for inspection and maintenance requirements of thermal and pressure relief valves.

h. Conduct inspections of code rated vessels in accordance with UFC 3-430-07.

3-6.1.2 Pre-Filter Waste Disposal.

Refer to Section 2-6.4 Waste Disposal for proper disposal of filtered waste and used filter cartridges.

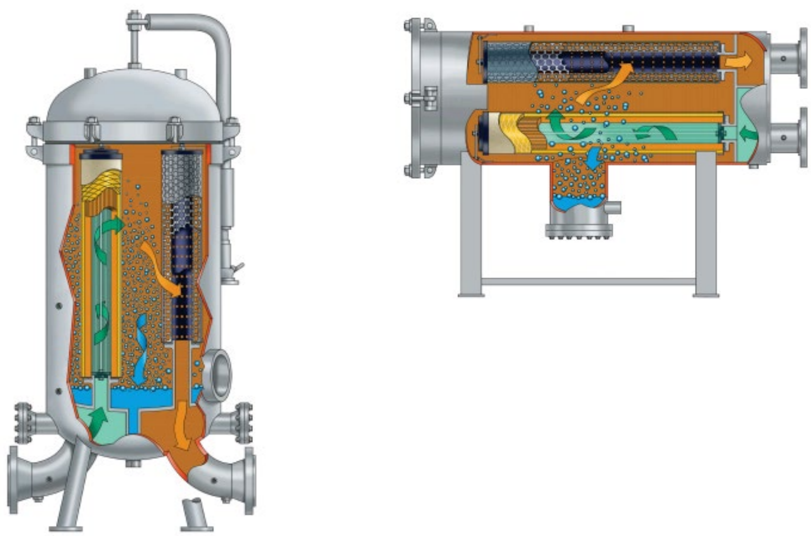
3-6.1.3 Stenciling of Pre-Filters.

Use stencils or embossing tape (0.75 to 1-inch (19 to 25 mm) letters) to permanently mark pre-filters when filter cartridges are changed with date changed, due date for next change, and maximum differential pressure.

3-6.2 Filter Separators.

Filter separators meeting which meet the requirements of UFGS 33 52 43.28 remove undissolved (free) water and solids from petroleum products. Very fine water particles pass through coalescer cartridges from inside to outside and grow in size (coalesce) into larger droplets that fall to the water collection sump.

Figure 3-2 Filter Separator



Second-stage Teflon or nylon coated screens or treated paper cartridges (separator) repels water droplets and prevents them from leaving the filter separator and cause them to fall to the water collection sump. The solids in the fuel are trapped in the coalescer cartridges and build up a differential pressure across the filter separator. Water accumulated in the water collection sump at the bottom of the filter separator is typically removed manually under flow conditions. Additional important notes for filter separators are as follows:

a. Filter separators must be equipped with coalescer and separator cartridges that meet the requirements of UFGS 33 52 43.28. Older units must be modified to accept these cartridges or must be replaced with modern units.

b. If installed, remove automatic water drain option from filter separators at the first opportunity, unless they are installed on a receipt system that must handle excessive water, or if waived by the military service-specific

SME. If automatic water drains are to remain they must be piped to a product recovery or drain tank.

c. Filter separators are equipped with differential pressure gauges to indicate when coalescer cartridges should be changed. The piston-type differential pressure gauge is preferred for petroleum fuel systems. Replace individual gauges with the piston-type as soon as practical.

d. Filter separators have a sampling port in the outlet pipe used to obtain petroleum fuel quality samples. Check the flow direction arrow on sample probes to ensure they are installed in the proper orientation.

e. The Installation must maintain an inventory of coalescer and separator cartridges. The inventory must allow the Installation to change the coalescer and separator cartridges of all filter separators at an Installation once. The inventory must be kept in a temperature controlled environment in accordance with manufacturer recommendations.

3-6.2.1 Inspection and Maintenance – Filter Separators.

Stencil filter separators in accordance with Section 3-6.2.4 Stenciling of Filter Separators when coalescer cartridges are changed. Filters separators require the following inspection and maintenance:

a. Open drain under flow conditions until clear fuel is observed from the drain valve.
Frequency: Daily

b. Monitor differential pressure of coalescer cartridges. The acceptable maximum differential pressure for a specific filter separator is dependent on the system flow rate. Monitor and chart differential pressure measurements of filter separators from readings taken during normal operations. Investigate sudden drops or spikes in differential pressure measurement readings.
Frequency: Daily

c. Operate filter separator isolation valves.
Frequency: Quarterly

d. Inspect components and check operation of water shutoff system.
Frequency: Quarterly

e. Change coalescer cartridges. Refer to Section 3-6.2.2 Replacement of Coalescer Cartridges for general instructions on replacement of coalescer cartridges. Military service-specific SCP may extend the coalescer cartridge replacement frequency based on differential pressure if filters separators are used on high throughput systems. Check expiration date of replacement coalescer cartridges before installation.
Frequency: Every 36 months or sooner if required by differential pressure.

f. Inspect and clean separator cartridges at time of coalescer cartridge change in accordance with Section 3-6.2.3 Separator Cleaning. Worn or damaged separator cartridges must be replaced.
Frequency: Every 36 months or sooner if required by differential pressure.

g. Refer to Section 6-7.2, "Differential Pressure Gauges," for inspection and maintenance requirements of differential pressure gauges.

h. Refer to Section 3-10.2, "Automatic Air Vents," for inspection and maintenance requirements of automatic air vents.

i. Refer to Section 6-6.3, "Thermal and Pressure Relief Valves," for inspection and maintenance requirements of thermal and pressure relief valves.

j. Refer to Section 4-4.2.2, "Filter Separator Control Valves," for inspection and maintenance requirements of filter separator control valves.

k. Conduct inspections of code rated vessels in accordance with UFC 3-430-07.

3-6.2.2 Replacement of Coalescer Cartridges.

General instructions for the replacement of filter separator coalescer cartridges are included in Appendix D. Refer to manufacturer's maintenance and operation manual for additional guidelines.

3-6.2.3 Separator Cleaning.

Separator cartridges, when new, operate in a satisfactory manner, but over time they gradually become less effective. Every time the coalescer cartridges are changed, the separator cartridges must be inspected and cleaned. Typical instructions for cleaning separator cartridges are included in Appendix D. Refer to manufacturer's operation and maintenance manual for additional guidelines.

3-6.2.4 Stenciling of Filter Separators.

Use stencils or embossing tape (0.75 to 1-inch (19 to 25 mm letters) to permanently mark filter separators when coalescer cartridges are changed with date changed, due date for next change, and maximum differential pressure.

3-6.2.5 Initial Filling of Filter Separators.

Internal flash fires have occurred within filter separators. In some cases, there were no audible sounds or immediate indications of a problem. These incidents are mainly due to electrostatic ignition of the petroleum fuel vapor-air mixture during the initial filling operation. Ignition inside filter separators is possible regardless of the type of petroleum fuel handled (e.g., JP-4, JP-5, JP-8, Jet A, additized Jet A (F-24)). Filling a filter separator must take a minimum of ten minutes to perform. Slow filling is the only authorized method of refilling an empty filter separator. This slows buildup of static electricity in fuel, reducing the possibility of a spark igniting the explosive atmosphere inside the vessel. In most cases, coalescer elements cannot be grounded or bonded to dissipate the static electric charge that is generated during filling.

3-6.3 Haypack Filters.

Haypack filters are typically only used for marine barge and tanker offloading where large amounts of water are expected to be present in the fuel.

3-6.3.1 Inspection and Maintenance – Haypack Filter.

Refer to manufacturer's operation and maintenance manual for inspection and maintenance requirements of haypack filters. Refer to Section 2-6.4 Waste Disposal for disposal of requirements.

3-6.4 Basket Strainers.

Basket strainers, which meet the requirements of UFGS 33 52 43.13, remove large particulate matter from petroleum fuel streams. Basket strainers are typically equipped with 60 mesh (0.25 mm sieve) wire strainer screens. In most cases basket strainers are equipped with differential pressure gauges that can be used to measure the differential pressure across the strainer. The maximum retaining capacity of rust and sediment in the basket strainer is reached when the acceptable maximum differential pressure is indicated across the strainer. The acceptable maximum differential pressure for a specific basket strainer is dependent on the size of the strainer and the system flow rate. Reference the manufacturer's data sheet for the maximum differential pressure of a particular basket strainer.

Dirty strainer screens can be washed (using air jets or pressurized liquid streams) and reused as long as they are not ruptured or otherwise damaged. Gum or tar can be removed by soaking strainer screens in a high flash point petroleum fuel, such as kerosene. In order to reduce shutdown time, it is advisable to have extra strainer screens on hand.

3-6.4.1 Inspection and Maintenance - Basket Strainers.

a. Monitor and chart differential pressure measurements of basket strainers from readings taken during normal operations. Investigate sudden drops or spikes in differential pressure measurement reading.
Frequency: Daily

b. Clean and inspect basket and strainer screen. Basket strainer isolation valves must be closed and the strainer body must be drained before removing the cover. After cleaning, the strainer screen must be inserted in the strainer body, and the head tightened and checked for leakage. If strainer is not equipped with means to measure differential pressure, unit must be opened monthly and inspected.

Frequency: Semi-annually if basket strainer is equipped with means to measure differential pressure; otherwise monthly.

c. Refer to Section 6-7.2, Differential Pressure Gauges, for inspection and maintenance requirements of differential pressure gauges.

3-6.5 Filter Separator Sump Heaters.

Heaters are used in sumps to prevent freezing of separated water during winter months in cold climates. Sump heaters are not approved for DoD systems. If heaters are installed contact the military service-specific SCP for guidance. Existing heaters installed in systems must be maintained.

3-6.5.1 Inspection and Maintenance – Filter Separator Sump Heaters.

a. Inspect filter separator sump and drain line heater elements for proper operation per manufacturer's operation and maintenance manual. Ensure heater elements meet manufacturer's requirements by measuring resistance of heater elements with an ohm meter.
Frequency: Semi-annually.

3-7 METERS.

3-7.1 Positive Displacement Meters.

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Positive displacement meters that meet the requirements of **\1** UFGS 33 57 55 **/1/** are used to record the amount of petroleum fuel received, transferred, or issued. Flow control devices and strainers are sometimes installed upstream of meters to help ensure accuracy and protect meter internals.

Truck and railcar loading meters may be equipped with a preset feature. This feature is used to slow the petroleum fuel flow to a predetermined rate when the preset petroleum fuel total is approached. Slower fill rates allow a more accurate final fill and reduce the likelihood of hydraulic shock to the system once flow of petroleum fuel is stopped. Meters installed at custody transfer points may be equipped with temperature compensation. This feature allows the meter to adjust the measurement of the flow rate to a standard temperature.

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Figure 3-3 Positive Displacement Meter

3-7.1.1 Inspection and Maintenance – Positive Displacement Meters.

Component wear and accumulation of solids make periodic calibration necessary. Certified master meters or volumetric prover tanks are used for calibration. Master meters must have been certified within a year of calibration operations. Master meters are tested at a predetermined flow rate. Master meters must be calibrated within ±10% of the normal operating flow rate through the inline positive displacement meter. Volumetric prover tanks must have been certified within the last five (5) years of calibration operations.

a. Inspect counter head for unusual noises and smooth operation.
Frequency: Monthly

b. Positive displacement meters must be inspected and calibrated semi-annually or when improper performance is suspected; when unusual sounds or register actions develop; or after repairs have been made which may affect performance. Positive displacement meters are satisfactory when the measurement error in the normal flow direction is within ±0.3% of actual quantity delivered (e.g., ±1.8 gallons for a 600-gallon test (±6.8 liters for a 2275-liter test)). Adjustment of the meter's register will be in accordance with manufacturer's instructions. Identify the next calibration date on meters (example: Mar 14 for March 2014). Use weather resistant label that will remain legible and affixed for at least one year.
Frequency: Semi-annually or as required

c. **\2** Positive displacement meters with temperature compensator feature must be inspected and calibrated semi-annually. Calibration procedures will be followed according to manufacturer's recommendation.
Frequency: Semi-annually /2/

d. Inspect temperature element operation of meters equipped with temperature compensation feature per manufacturer’s operation and maintenance manual.
Frequency: Semi-annually

3-7.2 Turbine Flow Meters

Turbine flow meters that meet the requirements of UFGS 33 52 43.11 utilize an axially aligned rotor to measure fluid flow. Clearances between the rotor and housing allow some slippage which can reduce the accuracy of the flow meter.

Figure 3-4 Turbine Flow Meter

3-7.2.1 Inspection and Maintenance- Turbine Flow Meters.

Component wear makes periodic calibration necessary. Certified master meters or volumetric prover tanks are used for calibration of turbine flow meters in accordance with API *Manual of Petroleum Measurement Standards*. Master meters must have been certified within a year of calibration operations. Master meters are tested at a predetermined flow rate. Master meters must be calibrated within ±10% of the normal operating flow rate through the turbine meter. Volumetric prover tanks must have been certified within the last five (5) years of calibration operations. Refer to the manufacturer’s operation and maintenance manual for turbine flow meter-specific calibration procedures.

a. **\2** Turbine flow meters must be inspected and calibrated semi-annually or when improper performance is suspected, when unusual sounds or register actions develop, or after repairs have been made which may affect performance. /**2**/ Turbine flow meters are satisfactory when the measurement error in the normal flow direction is within ±0.5% of actual quantity delivered (e.g., ±3 gallons for a 600-gallon test (±11 liters for a 2275-liter test)). Adjustment of the meter's register will be in accordance with the manufacturer's instructions. Identify the next calibration date on meters (example: Mar 14 for March 2014). Use weather resistant label that will remain legible and affixed for at least one year.
Frequency: Semi-annually or as required

b. **\2** Turbine flow meters with temperature compensator feature must be inspected and calibrated semi-annually. Calibration procedures will be followed according to manufacturer's recommendation
Frequency: Semi-annually /2/

c. Inspect temperature element operation of meters equipped with temperature compensation feature per manufacturer's operation and maintenance manual.
Frequency: Semi-annually

3-7.3 Orifice Flow Meters.

Orifice flow meters that meet the requirements of UFGS 33 52 43.11 typically do not require calibration. Orifice flow meters are customized to a specific flow rate and are only accurate over a small range.

3-7.3.1 Inspection and Maintenance - Orifice Flow Meters.

Refer to manufacturer's operation and maintenance manual for unit-specific maintenance requirements.

a. Refer to Section 6-7.2, Differential Pressure Gauges, for inspection and maintenance requirements of differential pressure gauges.

b. Refer to Section 6-7.4, Differential Pressure Transmitters, for inspection and maintenance requirements of differential pressure transmitters.

3-8 PUMPS.

3-8.1 Centrifugal Pumps.

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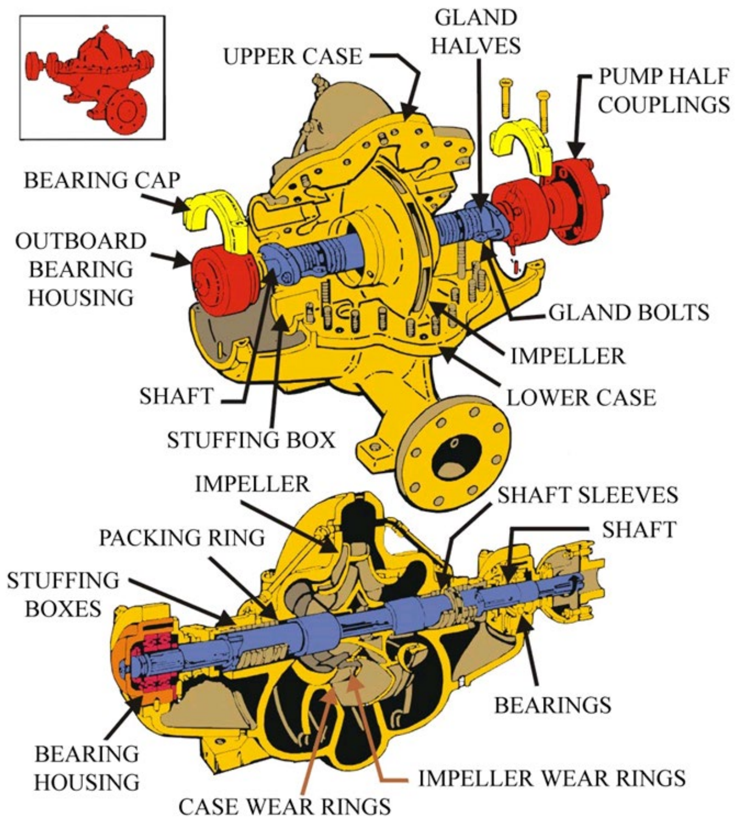
a. Centrifugal pumps work best if the impeller is completely immersed in liquid. It is important to prevent air pockets from delivery trucks and hoses from entering pumps. If air gets into a pump the performance can be drastically reduced. Air eliminator tanks and automatic air vents are used to release air from the suction lines of pumps. In some cases air eliminators are attached directly to the housing of pumps.

b. Centrifugal pumps must have proper shaft alignment with the motors. The pumps must also be properly shimmed and mounted securely. Both inlet and outlet pipe connections should be made with vibration dampeners. The bearings must be adequately lubricated and the mechanical seals should show no signs of leaks.

c. Mechanical seals require maintenance, but they provide reliable service if properly installed on a true shaft. Frequent trouble is usually caused by shaft vibration, wear, or improper installation. It is most important to protect seal faces from contact with skin, grease, or metal particles, which can contaminate the seal and cause premature seal failure./**1**/

Figure 3-5 Split-Case Centrifugal Pump



3-8.1.1 Inspection and Maintenance - Centrifugal Pumps.

Refer to manufacturer’s operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of pump. Follow applicable general maintenance and safety requirements listed in the manufacturer’s operation and maintenance manual.

a. Check for proper operations while pump is in use. Check suction and discharge pressure gauges for abnormal readings.
Frequency: Quarterly

b. Check for unusual noise, vibration, and overheating of bearings or case.
Frequency: Quarterly

c. If equipped with lubricating oil charge, check oil level and adjust as necessary.
Frequency: Quarterly

d. Tighten or replace loose, missing or damaged nuts, bolts, or screws.
Frequency: Quarterly

e. Inspect suction and discharge isolation dampeners for misalignment and wear.
Frequency: Quarterly

f. Inspect mechanical seals, if possible, for proper operating temperature, drips, leaks and dirt.
Frequency: Quarterly

g. Check for alignment, clearances, and rotation of shaft and coupler (requires removal of coupler shroud or cover).
Frequency: Annually

h. Lubricate pump bearings.
Frequency: Annually

i. If equipped with lubricating oil charge, drain old oil, and fill with new oil to full mark on sight indicator (also fill bulb).
Frequency: Annually

j. Refer to Section 9-1.7, “Electric Motors,” for inspection and maintenance requirements of electric motors.

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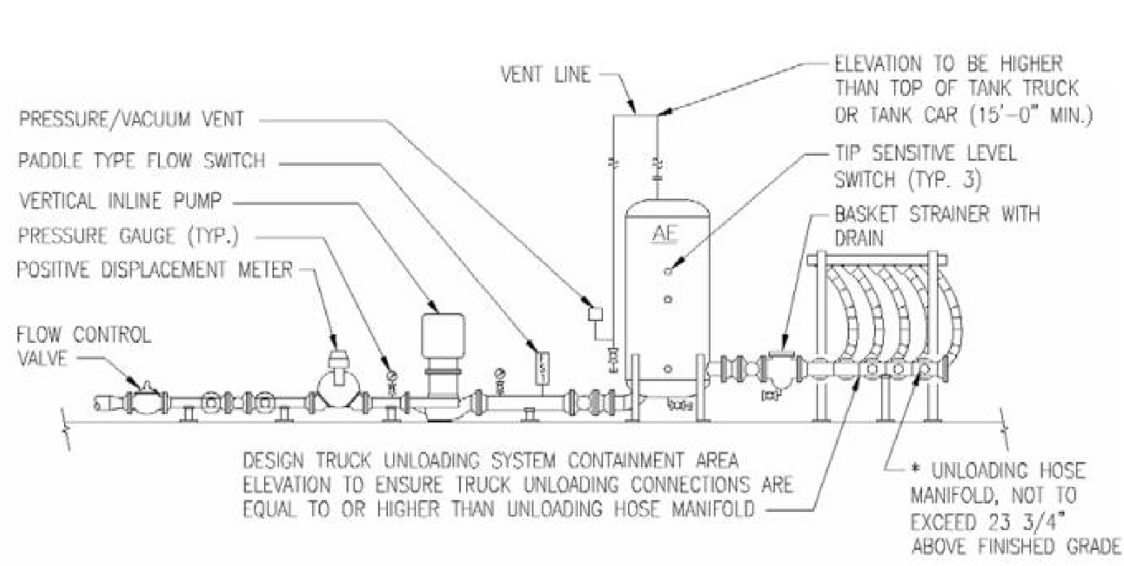
3-8.2 /1/ Vertical Inline Pumps.

Vertical inline pumps should meet the requirements of **1**\ UFGS 33 52 43.23 /**1**/. Off-loading pump can operate at lower liquid levels than similarly sized end suction pumps due to the geometry of the impeller location and are used frequently in petroleum fuel offloading applications. Vertical inline pumps must be properly supported to prevent unnecessary stress on inlet and outlet piping.

Figure 3-6 Vertical Inline Pump



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3-8.2.1 /1/ Inspection and Maintenance – Vertical Inline Pumps.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of pump. Follow applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.

a. Check for proper operations while pump is in use. Check suction and discharge pressure gauges for abnormal readings.
Frequency: Quarterly

b. Check for unusual noise, vibration, and overheating of bearings.
Frequency: Quarterly

c. Tighten or replace loose, missing or damaged nuts, bolts, or screws.
Frequency: Quarterly

d. Inspect suction and discharge isolation dampeners for misalignment and wear.
Frequency: **Quarterly**

e. Inspect mechanical seals, if possible, for proper operating temperature, drips, leaks and dirt.
Frequency: Quarterly

f. Check for alignment, clearances, and rotation of shaft and coupler (requires removal of coupler shroud or cover).
Frequency: Annually

g. Lubricate pump bearings.
Frequency: Annually

h. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.

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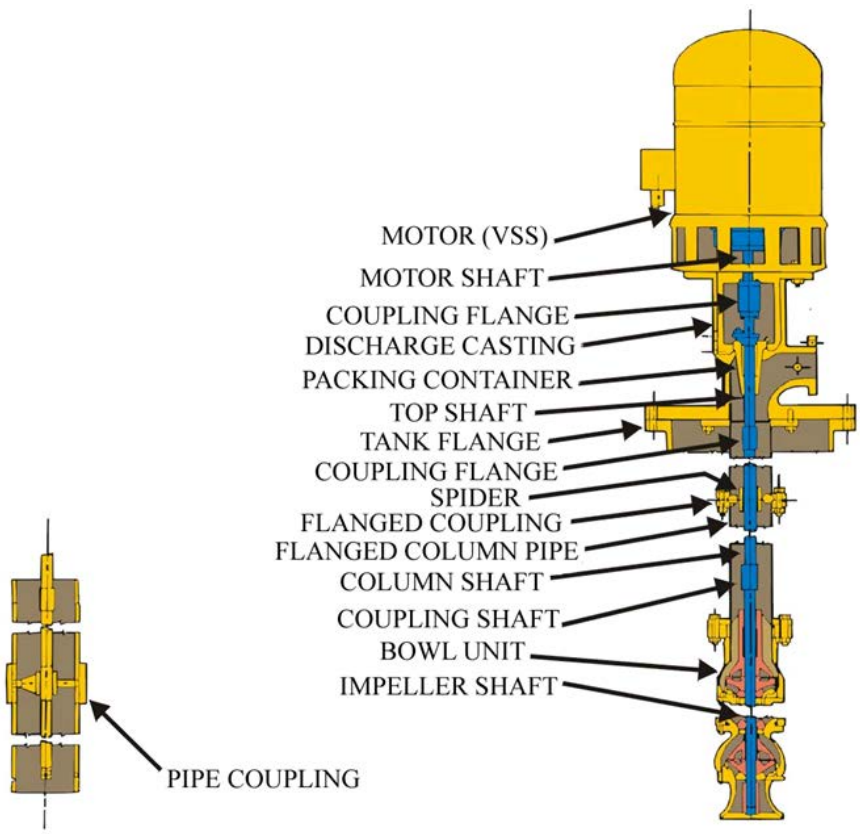
3-8.3 /1/ Vertical Turbine/Submerged Turbine Pumps.

Submerged turbine pumps that meet the requirements of UFGS 33 52 43.23 are used to pump from aboveground, underground, and cut and cover tanks. This type of pump is also used to transfer fuel from drop tanks used in some petroleum fuel truck offloading systems. A "can" pump is another type of vertical turbine pump.

Submerged turbine pumps are sometimes used in military service station applications to supply fuel to vehicle fuel dispensers and petroleum fuel truck loading positions. Refer to manufacturer's operation and maintenance manual for more information on each type of pump.

Figure 3-7 Vertical Turbine Pump



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3-8.3.1 /1/ Inspection and Maintenance – Vertical Turbine/Submerged Turbine Pumps.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of pump. Follow applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.

a. Check for proper operation while pump is in use. Check discharge pressure gauge for abnormal readings.
Frequency: Quarterly

b. Check for unusual noise, vibration, and overheating of bearings or case.
Frequency: Quarterly

c. If equipped with lubricating oil charge, check oil level and adjust as necessary.
Frequency: Quarterly

d. Tighten or replace loose, missing or damaged nuts, bolts, or screws.
Frequency: Quarterly

e. Inspect mechanical seals, if possible, for proper operating temperature, drips, leaks and dirt.
Frequency: Quarterly

f. Inspect anti-rotation device for proper operation.
Frequency: Semi-annually

g. Check for alignment, clearances, and rotation of shaft and coupler (requires removal of coupler shroud or cover).
Frequency: Annually

h. Lubricate pump bearings.
Frequency: Annually

i. If equipped with lubricating oil charge, drain old oil, and fill with new oil to full mark on sight indicator (also fill bulb).
Frequency: Annually

j. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.

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3-8.4 /1/ Positive Displacement Pumps.

Positive displacement pumps have an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The pumped volume is constant given each cycle of operation.

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3-8.5 /1/ Sliding Vane Pumps.

Sliding vane pumps (sometimes referred to as rotary vane pumps) are self-priming positive displacement pumps used where suction lifts are high or where the pump may frequently lose prime such as petroleum fuel truck offload systems. These pumps must have internal or downstream pressure relief.

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3-8.5.1 /1/ Inspection and Maintenance – Sliding Vane Pumps.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of pump. Follow applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.

a. Inspect pump for unusual noise, vibrations, and overheating of bearings and case.
Frequency: Quarterly

b. Inspect mechanical seals, if possible, for drips or leaks and dirt.
Frequency: Quarterly

c. Lubricate pump bearings.
Frequency: Quarterly

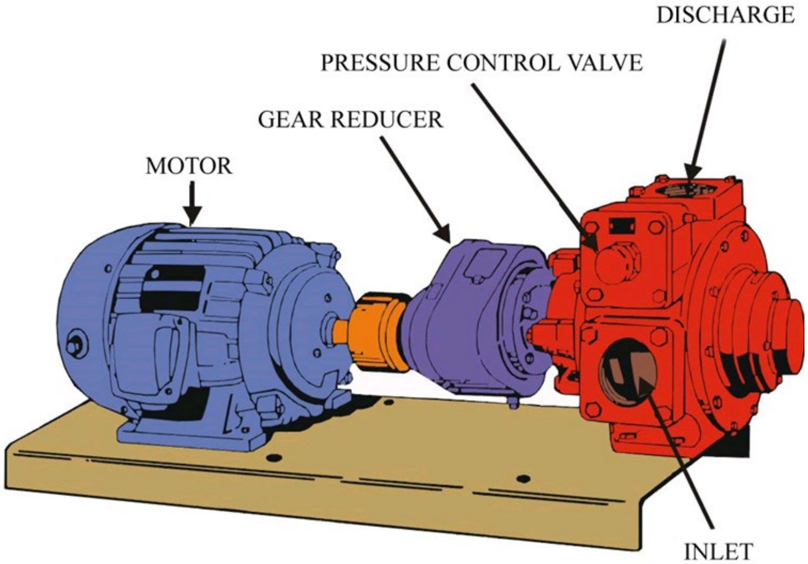
d. Inspect pump and motor coupling for proper alignment.
Frequency: Annually

e. Refer to manufacturer's operation and maintenance manual for internal pressure relief testing and calibration procedures.
Frequency: Annually

f. Refer to Section 3-8.4 Gearboxes for inspection and maintenance of reduction gearboxes.

g. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.

Figure 3-8 Rotary Vane Pump



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3-8.6 /1/ Gear Pumps.

Gear pumps may be used to transfer petroleum fuel at moderate flow rates and can operate at high pressures.

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3-8.6.1 /1/ Inspection and Maintenance – Gear Pumps.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of pump. Follow applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.

a. Inspect pump for unusual noise, vibrations, and overheating of bearings and case.
Frequency: Quarterly

b. Inspect mechanical seals, if possible, for drips or leaks and dirt.
Frequency: Quarterly

c. Lubricate pump bearings.
Frequency: Quarterly

d. Inspect pump and motor coupling for proper alignment.
Frequency: Annually

e. Refer to Section 3-8.4 Gearboxes for inspection and maintenance of reduction gearboxes.

f. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.

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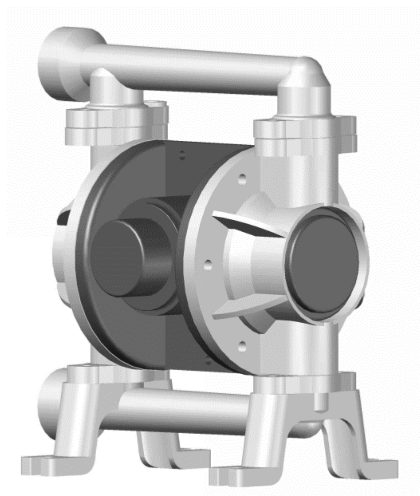
3-8.7 /1/ Diaphragm Pumps.

Diaphragm pumps are relatively low maintenance pumps that provide good performance for transferring high viscosity liquids such as petroleum sludge left in a tank.

Figure 3-9 Diaphragm Pump



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3-8.7.1.2 /1/ Inspection and Maintenance – Diaphragm Pumps

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of pump. Follow applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual. Ensure pump, hoses, and fittings are kept clean and are stored in a protected area out of the elements when is not in use.

a. Inspect hoses for cracks or dry rot.
Frequency: Quarterly

b. Inspect compressed air connections and hose couplings for signs of leaks.
Frequency: Quarterly

c. Inspect compressed air hose coupling safety pins or safety wires for wear and damage. Replace damaged components.
Frequency: Quarterly

d. Diaphragm pumps should have the internal diaphragm replaced if the pump shows decreased performance. Also check operation of actuator valve and ensure ball checks seat properly.
Frequency: As required

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3-8.8 /1/ Internal Combustion Drives.

Internal combustion drives are used where equipment is needed on a temporary or portable basis such as temporary pumps or power generators. Internal combustion drives are also used to operate permanent power generators when standard power is interrupted such as emergency backup generators, and where large power feeds for large equipment is not available or cost effective to install such as petroleum fuel transfer pumps installed in remote locations.

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3-8.8.1 /1/ Inspection and Maintenance – Internal Combustion Drives.

a. Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of internal combustion drive. Follow all applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.
Frequency: As required

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3-8.9 /1/ Gearboxes.

Gearboxes transmit power from motors to pumps and other rotating equipment. Gearboxes must be monitored for proper alignment and oil level. Do not overfill gearboxes during maintenance.

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3-8.9.1 /1/ Inspection and Maintenance – Gearboxes.

When replacing lubricating oil, verify metal shaving content is within manufacturer's recommendations. Refer to manufacturer's operation and maintenance manual for oil testing procedures, proper oil levels, and proper type of oil which should be used. Refer to the applicable manufacturer's operation and maintenance manual for specific maintenance procedures and schedules, and follow applicable general maintenance and safety requirements.

a. Inspect gearboxes for signs of smoke near shaft connections or discoloration of the gearbox from overheating.
Frequency: Quarterly

b. Verify that the oil in the sight glass is not dark or appears to have foam. Adjust oil level if required.
Frequency: Quarterly

c. Lubricate bearings per manufacturer's recommendations.
Frequency: Semi-annually

d. Check motor and gear box and gear box and pump couplers for wear and alignment.
Frequency: Semi-annually

e. Inspect gear alignment within gearbox.
Frequency: Annually

f. Replace lubricant oil in accordance with manufacturer's specifications and recommendations.
Frequency: Annually

3-9 HOSES.

3-9.1 Loading Fuel Hoses.

Loading fuel hoses must meet the requirements of aviation fueling hoses listed in **\1** UFGS 33 57 55 **/1/**. General requirements for loading fuel hose use are as follows:

a. Hoses must be stored away from direct exposure to sun and extreme weather such as rain and snow in a hinged enclosure when not in use.

b. Dust covers or other protective devices must be used to keep out dirt and water.

d. Hoses must be installed within 2 years of the date of the hose's manufacture, and have a maximum service life of 10 years from the date of manufacture.

3-9.1.1 Inspection and Maintenance – Loading Fuel Hoses.

a. Visually inspect hoses for loose covers, cracks, brittle surface coatings, exposed wire braids, exposed reinforcement, flattening, kinks, and bulges or soft spots which might indicate broken or displaced reinforcement.
Frequency: Monthly

b. Pressurize hose to normal working pressure. Check flanged and threaded connections for leaks and inspect hose couplers for fluid seepage by pushing at the base of the coupling with thumbs. A hose softened by petroleum fluid seepage must be replaced.
Frequency: Monthly

c. Check for coupling slippage. Replace hose that shows signs of coupling slippage.
Frequency Quarterly

d. **\1\ /1/**

e. Conduct test of petroleum fuel hose electrical resistivity using an electrostatic meter in accordance with NFPA 77 and API 2003.
Frequency: Annually

3-9.2 Offloading Fuel Hoses.

Offloading petroleum fuel hoses meeting the requirements of UFGS 33 52 43.11 are used for offloading operations. Offloading petroleum fuel hoses must be stored away from direct sunlight in a hinged enclosure when not in use or must be purchased with ultraviolet (UV) light protection.

3-9.2.1 Inspection and Maintenance - Offloading Fuel Hoses.

a. Visually inspect hoses for cracks, brittle surface coatings, exposed wire braids, exposed reinforcement, flattening, kinks, and bulges or soft spots which might indicate broken or displaced reinforcement.
Frequency: Monthly

b. Check flanged and threaded connections for leaks and inspect hose couplers for fluid seepage by pushing at the base of the coupling with thumbs. A hose softened by petroleum fluid seepage must be replaced. Damaged or leaking hoses must be replaced immediately or isolated and taken out of service. **Frequency: Quarterly**

c. Conduct test of offloading petroleum fuel hose electrical resistivity as directed in NFPA 77 and API 2003.
Frequency: Annually

3-10 AIR ELIMINATORS.

Air eliminators are used to remove non-condensing gases such as air from petroleum fuel systems.

3-10.1 Air Eliminator Tanks.

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a. Air eliminator tanks meeting the requirements of UFGS 33 52 43.11 are used to remove air from petroleum fuel offloading systems. Air eliminator tanks should include a sight gauge, float vent valve, level sensors, and a pressure/vacuum vent.

b. A float vent valve is installed at the top of air eliminator tanks in an extractor fitting at the base of the vent pipe. The float and body of the valve are suspended from the extractor fitting inside the air eliminator tank. The float of the valve is buoyant in petroleum fuel and rises to close the float vent valve and block off the vent pipe when the air eliminator tank is full of petroleum fuel. When the level of petroleum fuel in the air eliminator tank drops, the float of the float vent valve drops and opens the vent pipe.

c. A pressure/vacuum vent is installed at the end of the vent pipe. The pressure/vacuum vent allows air to vent from the tank when a small positive pressure is developed in the air eliminator tank and allows air to enter the vent line when a small negative pressure is developed inside the air eliminator tank.

d. Level sensing probes are installed at two or three locations in the air eliminator tank. The level probes are used by the offloading control system to control the operation of the offloading pump.

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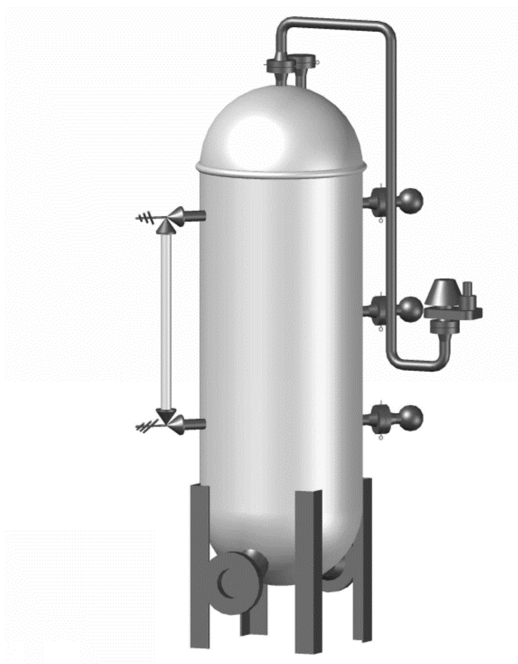
Figure 3-10 Air Eliminator Tank



3-10.1.1 Inspection and Maintenance - Air Eliminator Tanks.

a. Inspect operation of petroleum fuel level probes. Ensure probes operate correctly when the level of petroleum fuel in the tank rises to the level of the probe sensing unit.
Frequency: Annually

b. Remove the float vent valve from the air eliminator tank. Clean and inspect the sealing surfaces of the float vent valve. Ensure the float is buoyant in petroleum fuel and test the valve to ensure it closes properly.
Frequency Annually

c. Refer to Section 8-9.3 Tank Pressure/Vacuum Vents for inspection and maintenance requirements of pressure vacuum vents.

3-10.2 Automatic Air Vents.

Automatic air vents meeting the requirements of UFGS 33 52 43.13 automatically vent air under pressure and prevent a vacuum when pressure drops below positive pressure. The vents are operated by a float ball that is buoyant in petroleum fuel. When air is present the float will drop allowing air to escape, and when petroleum fuel is present the ball will float and seal the vent opening. In most cases, automatic air vents are piped to a tank such as a product recovery tank.

Figure 3-11 Automatic Air Vent

3-10.2.1 Inspection and Maintenance - Automatic Air Vents.

a. Check for proper operation of the automatic air vent. Ensure the vent opens to allow air to escape and ensure the float of the vent is buoyant in petroleum fuel and rises to close the vent when the float is suspended in petroleum fuel.
Frequency: Annually

3-11 FUEL ADDITIVE INJECTORS.

Fuel additive injectors are used to inject additives into fuel to change its grade such as a change from Jet A to F-24.

3-11.1 Inspection and Maintenance – Fuel Additive Injectors.

Refer to the manufacturer's operation and maintenance manual for specific calibration and maintenance procedures and schedules and follow all applicable general maintenance and safety requirements.

a. Inspect injectors to ensure they are operating properly.
Frequency: When system has flow through it, inspect injectors weekly. When system is idle, inspect injectors monthly.

b. Calibrate injector to ensure proper additive to fuel ratio.
Frequency: Annually

3-12 CODED VESSELS.

Coded vessels such as filter separators, filters, and relaxation tanks are used when spaces larger than standard piping is required to conduct operations such as filtering or static dissipation in petroleum fuel systems.

3-12.1 Inspection and Maintenance – Coded Vessels.

Pressure vessels used in petroleum fuel system are built to applicable pressure vessel codes and stamped with plates that provide information on the coded vessel. These vessels must follow inspection and maintenance requirements included in UFC 3-430-07.

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CHAPTER 4 AIRCRAFT FUELING FACILITIES

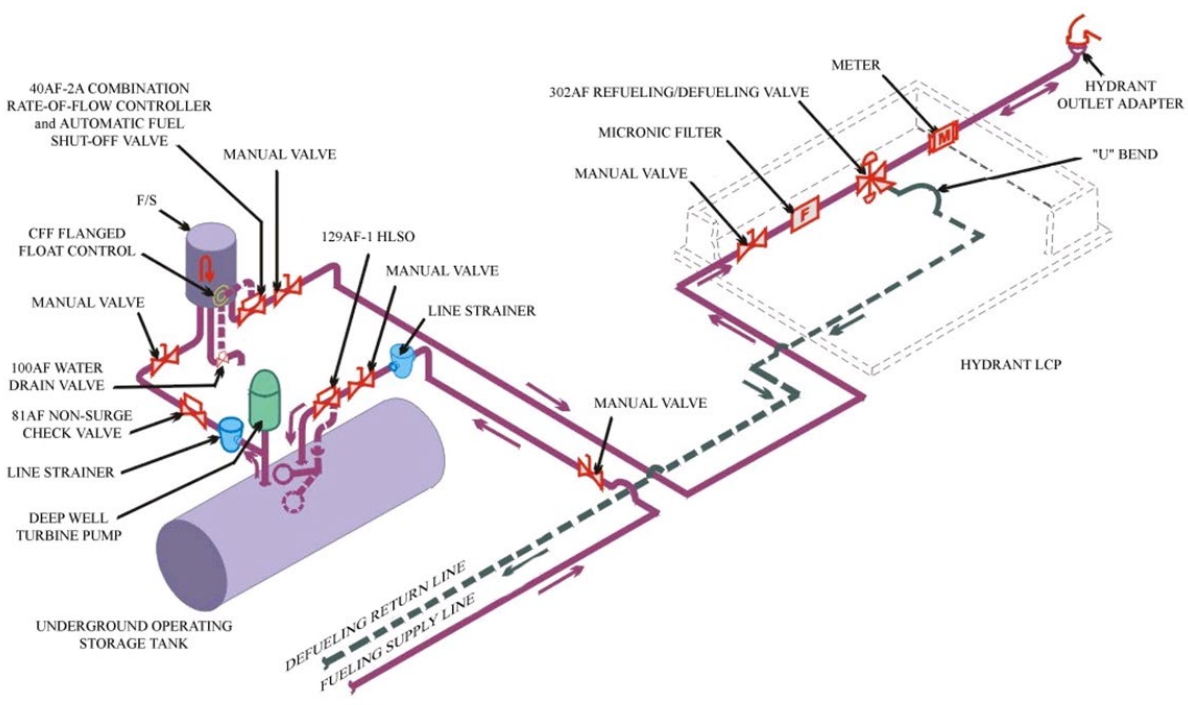
4-1 INTRODUCTION.

This chapter contains a brief operational description of each type of hydrant system and the major components included in each system. Hydrant systems are site-specific. The settings provided within this manual are derived from standard designs and may vary due to configuration, climate, and location of an installed system. Before systems or components are calibrated or maintained, personnel should consult as-built and start up data and must be familiar with proper settings of the specific system.

4-2 HYDRANT SYSTEM – TYPE I.

Type I hydrant systems are known as Panero systems. Panero systems were built in the 1940's and 50's, and were the first hydrant system used by the DoD. Panero systems have been superseded by more modern hydrant systems, but a limited number are still in use. Panero systems pump petroleum fuel to refueling outlets, and aircraft are moved to outlets to conduct refueling operations. These systems typically use vertical turbine pumps and underground horizontal storage tanks. Original Panero systems had automatic control valves on the issue and defuel lines in filter/meter pits. Major modifications to the original Panero created the Modified Panero system. The Modified Panero system uses one automatic control valve to perform both issue and defuel operations and uses MH-2 hose carts instead of filter/meter pits. With these systems defuel operations are conducted by gravity to a dedicated defuel tank.

Figure 4-1 Modified Panero, Type I Hydrant System



4-3 HYDRANT SYSTEM – TYPE II.

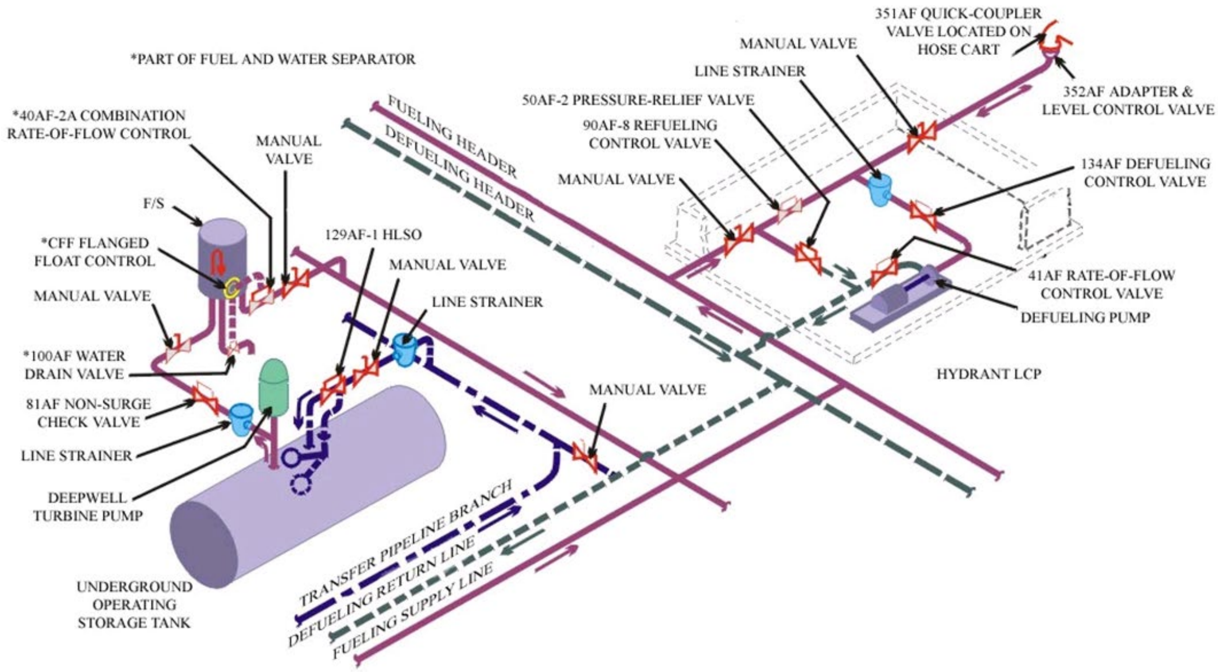
4-3.1 General Description.

Type II hydrant systems are known as Pritchard systems. Pritchard systems were developed in 1955 to improve hydrant refueling operating characteristics. These systems employ Lateral Control Pits (LCPs) and typically use vertical turbine pumps and underground horizontal storage tanks. Pritchard systems can service multiple hydrant outlets per LCP. This system allows flexibility in hydrant outlet locations and enables aircraft to be refueled at parking positions. The Type II Pritchard pumphouse is similar to the Type I, but the Type II Pritchard pumphouse does not include a separate defuel tank. Instead, one of the system operating tanks is designated as the defuel tank on a rotational basis. LCPs include a defueling pump and automatic valves. The MH-2 hose cart equipped with a filter separator, meter, and hoses is used for connecting hydrant outlets to aircraft, and as a result, filtration or meters are not required in LCPs. The following is a simplified description of operation:

a. Fuel Issue: When fuel is required at a hydrant outlet, the operator places a magnet on the refueling magnetic control assembly. This causes a preselected pump in the pumphouse to start and energizes a solenoid on the refueling control valve in the LCP that supplies the activated hydrant outlet. Fuel moves from the pumphouse into the fueling manifold and to the LCP. Fuel enters the refueling control valve and causes it to open. The refueling control valve provides pressure reduction, non-surge, pressure relief, excess flow shutoff, and emergency shutoff capabilities. Fuel flows through the hydrant outlet adapter and to the MH-2 hose cart and into the aircraft. During fuel issue operations, the defueling valve solenoid is de-energized and the defuel valve is held closed. The pressure relief valve relieves excess pressure from the upstream side of the refueling control valve into the defuel line if required.

b. Defueling: When a defuel operation is required the operator places the magnet on the defuel refueling magnetic control assembly switch. This causes a solenoid on the defueling valve connected to the hydrant pit to energize and the associated defuel pump to start. When the defuel solenoid energizes the defuel valve opens and fuel is drawn through the defuel pump and forced through the rate-of-flow control valve into the defuel line at a rate of 200 gallons per minute (gpm) (12.5 Liters per Second (lps)). Fuel flows to the operating tank designated to receive defuel product.

Figure 4-2 Pritchard, Type II Hydrant System



4-3.2 System Specific Control Valves.

4-3.2.1 General System Control Valves.

Petroleum fuel system control valves use hydraulic pressure from the upstream side of petroleum fuel piping connected to the valve to open or close the valve. The valves are equipped with flexible diaphragms and control pilots that are used to operate the valves. The valves can be used to perform many functions. The functionality of the valve is dependent on the type of control pilot that is installed on the valve and the orientation of flow through the valve.

4-3.2.1.1 Inspection and Maintenance - General System Control Valves.

a. Verify operating settings of valve. Valve adjustment must be in accordance with manufacturer's operation and maintenance manuals and final start-up and commissioning set points. Use of DoD standard set points should only be used as a reference starting point as pipe size and other hydraulic factors influence final system settings.
Frequency: Quarterly

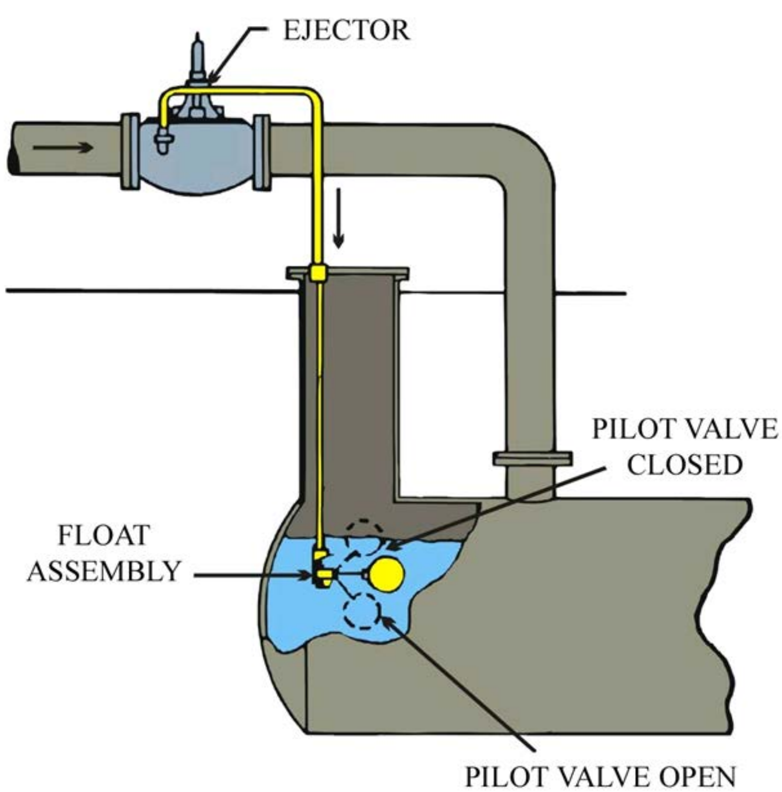
b. Remove and clean strainer installed in the petroleum fuel supply line to the pilot and main valve diaphragm. This strainer is provided to prevent clogging of the orifice in the supply line. Clogging of the screen will cause malfunctioning of the valve.
Frequency: Annually for unfiltered systems and as required for filtered systems.

c. Diaphragms must be removed and inspected for deterioration and breaks at the flexing joint. Damage is often caused by pipe scale, pipe tape, and thread sealant compound that collect above the diaphragm and become lodged between the diaphragm and bonnet of the valve. Damage may also be caused by a change of operational petroleum fuel type or grade (such as a change from JP-4 to JP-8).
Frequency: Every 10 years

4-3.2.2 High Level Shut-off Valve.

For information on the operation and maintenance of a High Level Shut-Off (HLSO) valves, refer to Section 8-9.6 High Level Shut-off Valve (HLSO).

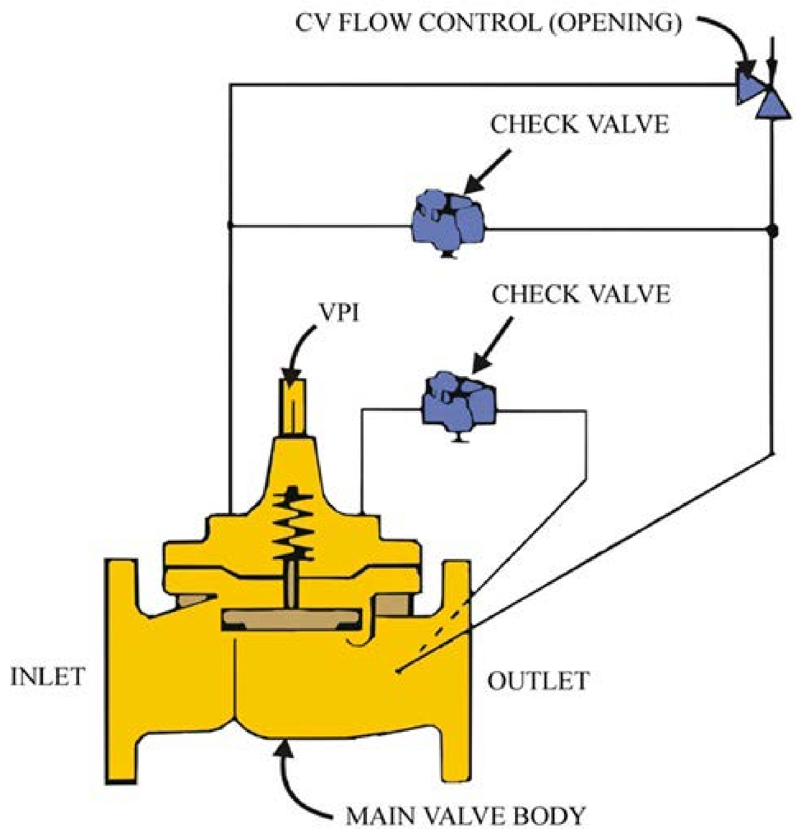
Figure 4-3 High Level Shut-off Valve (Type II)



4-3.2.3 Non-Surge Check Valves.

Type II system non-surge check valves are similar in design and operation to Type III non-surge check valves. Refer to Section 4-4.2.1 Non-Surge Check Valves for information on inspection and maintenance of non-surge check valves.

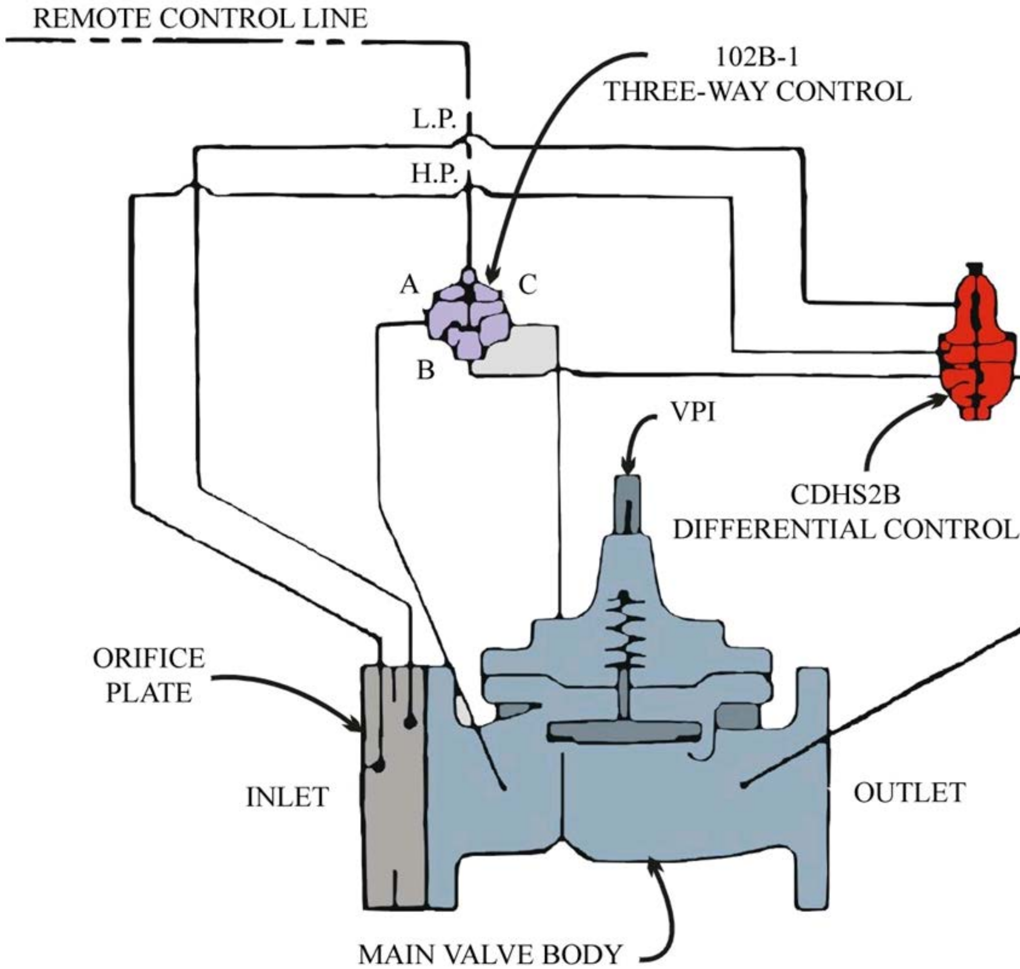
Figure 4-4 Non-Surge Check Valve (Type II)



4-3.2.4 Filter Separator Control Valves.

Type II system filter separator control valves are similar in design and operation to Type III filter separator control valves. Refer to Section 4-4.2.2 Filter Separator Control Valves for information on inspection and maintenance of filter separator control valves.

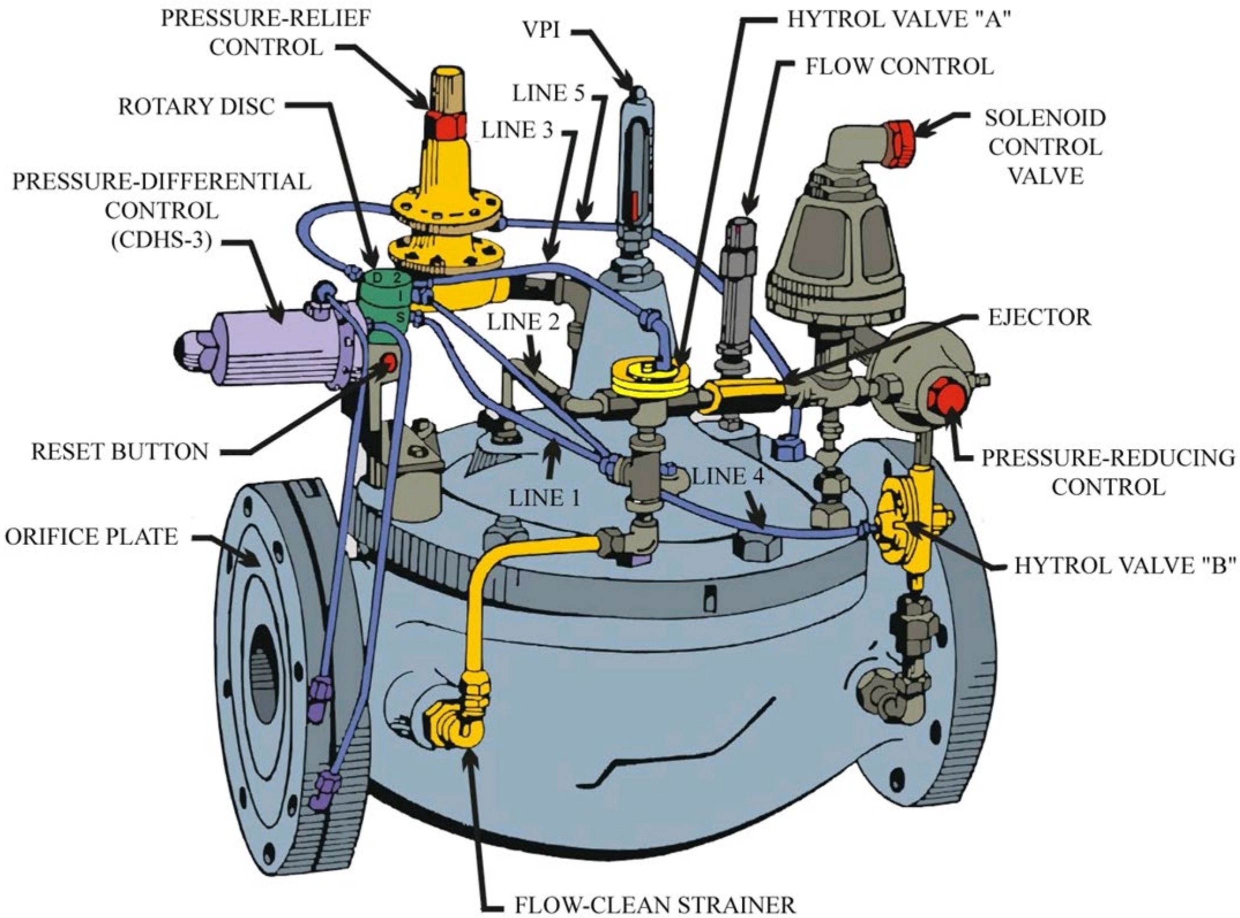
Figure 4-5 Filter Separator Control Valve (Type II)



4-3.2.5 Refuel Control Valves.

The diaphragm actuated refuel control valve provides five functions: pressure reduction; non-surge; pressure relief; excess flow shutoff; and emergency shutoff for Type II systems.

Figure 4-6 Refueling Control Valve (Type II)



4-3.2.5.1 Inspection and Maintenance – Refuel Control Valves.

a. Verify refuel control valve is set to maintain 100 psig (690 kPa) (typical operating pressure) as measured at the furthest hydrant outlet.
Frequency: Quarterly

b. Verify pressure-reducing control will open at 5 psig (35 kPa) above normal operating pressure (typically 105 psig (725 kPa) as measured at the farthest hydrant outlet).
Frequency: Quarterly

c. Verify refueling control valve opening rate is set between 15 and 20 seconds. The valve should open as quickly as possible without tripping the pressure differential control shut-off.
Frequency: Quarterly

d. Verify operation of excess flow shutoff function.
Frequency: Quarterly

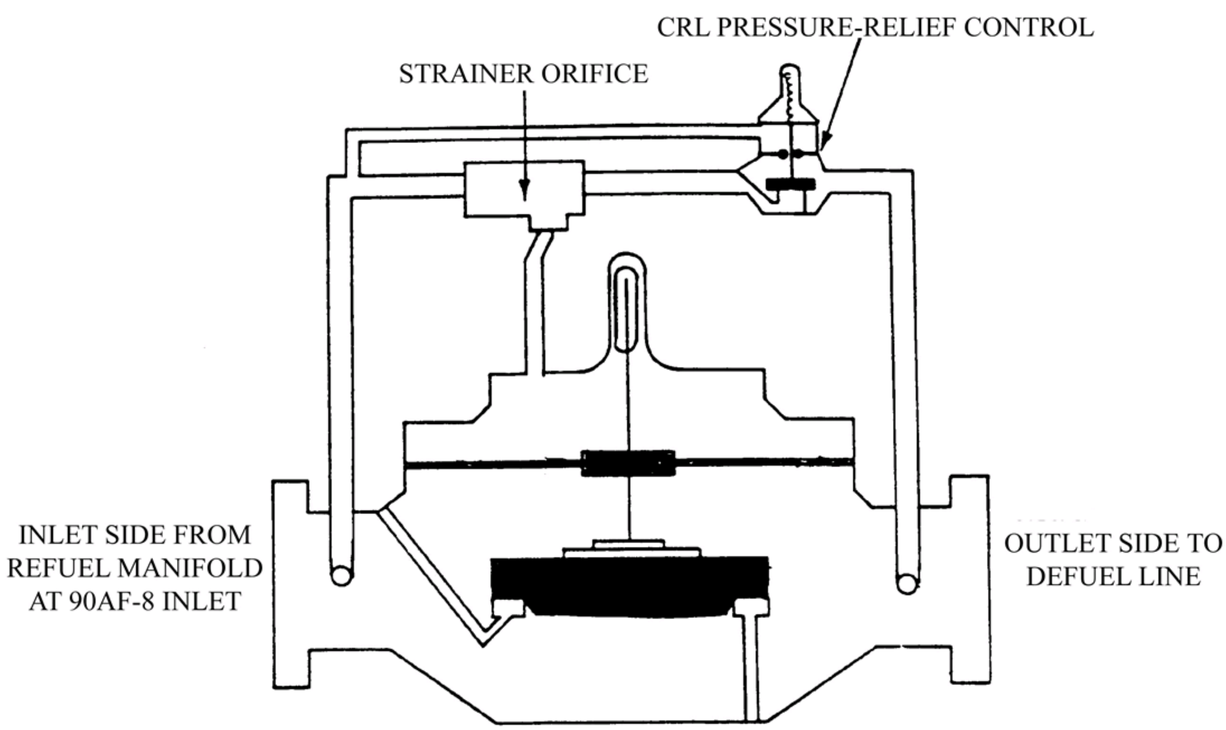
e. Verify operation of solenoid.
Frequency: Quarterly

f. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-3.2.6 Pressure Relief Valves.

The pressure relief valve is installed in the LCP between the fuel issue line and the defueling line. Pressure relief valves are provided to relieve excessive pressure caused by closing a downstream valve or thermal expansion in a closed section of pipeline. This valve is designed for petroleum fuel to flow under the seat disc inside the valve so that it "fails safe" in the open position if the main valve diaphragm fails.

Figure 4-7 Pressure Relief Valve (Type II)



4-3.2.6.1 Inspection and Maintenance – Pressure Relief Valves.

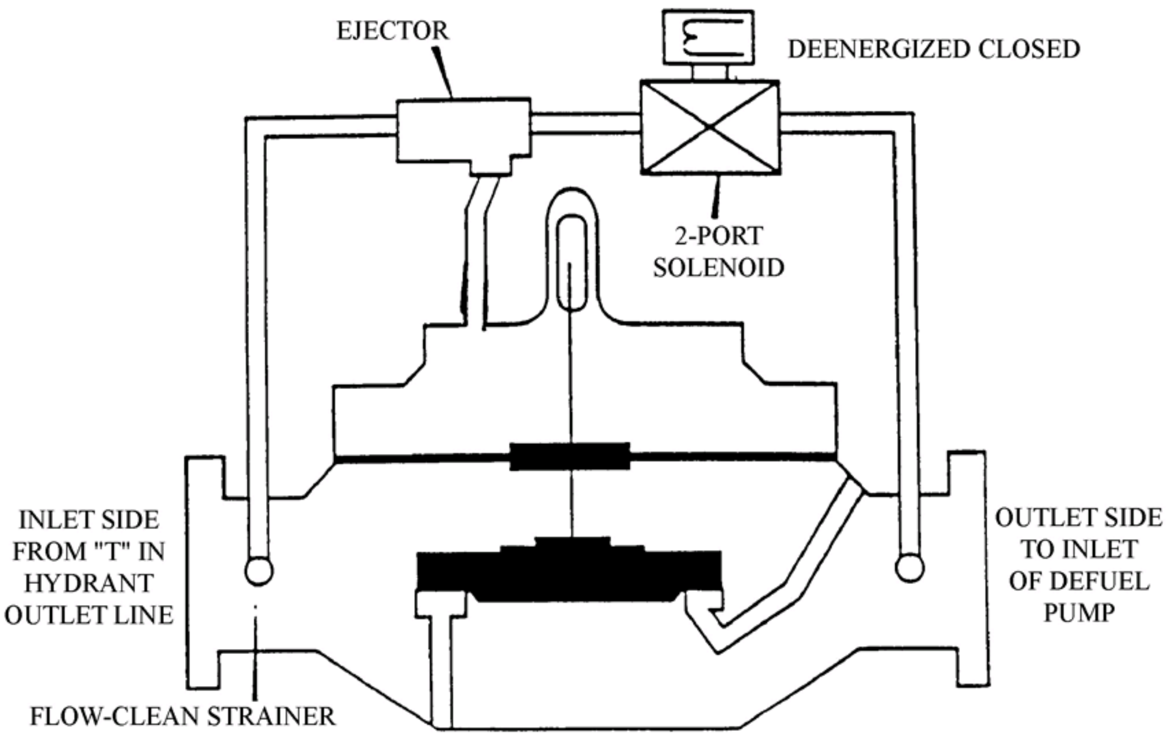
a. Verify pressure relief valve will open at 10 psig (69 kPa) above normal inlet pressure to the refuel control valve.
Frequency: Semi-annually

b. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-3.2.7 Defuel Control Valve.

The defueling control valve is a diaphragm-actuated solenoid shutoff valve. This valve and the defueling pump energize simultaneously. When the solenoid valve on the defuel control valve is energized, it allows the defuel control valve to open and permit defueling through the system.

Figure 4-8 Defuel Control Valve (Type II)



4-3.2.7.1 Inspection and Maintenance – Defuel Control Valves.

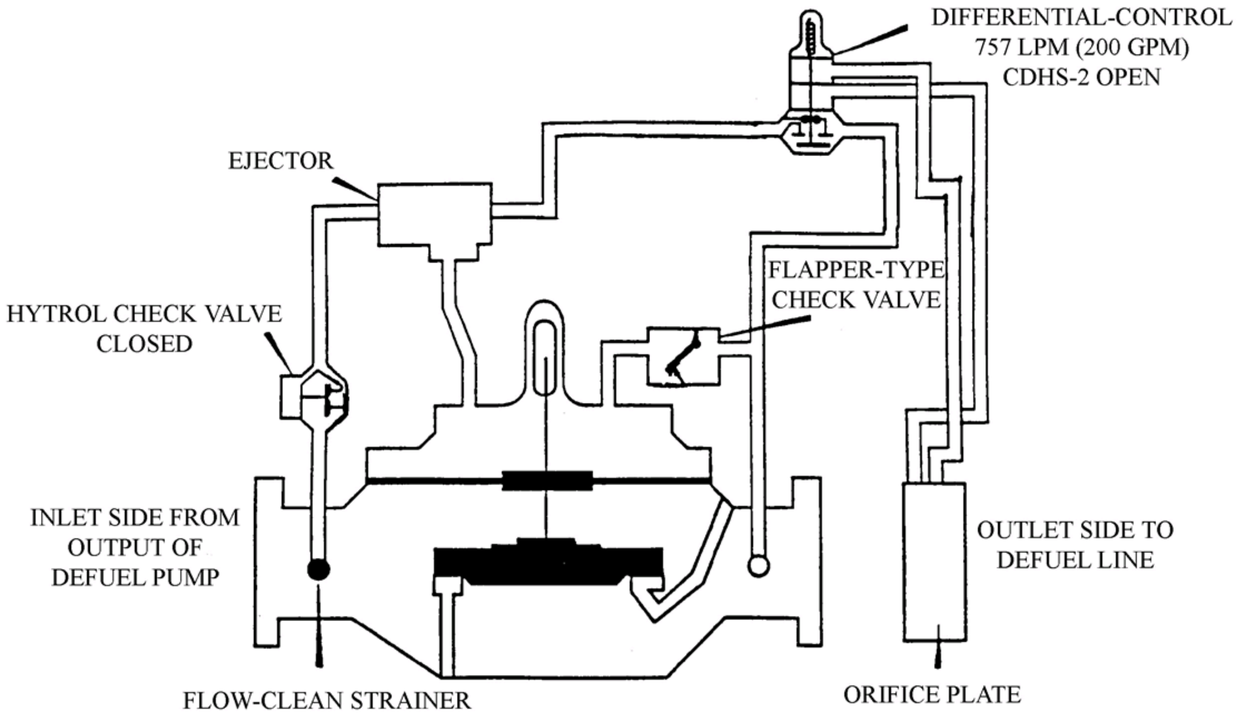
a. Verify the defuel control valve opens when the solenoid on the defuel control valve is energized.
Frequency: Quarterly

b. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-3.2.8 Dual Rate-of-Flow Control Valves.

The dual rate-of-flow control valve is a combination rate-of-flow control valve and fast closing, hydraulically operated check valve that closes the main valve against reverse flow. It performs two distinct functions: maintaining a preset flow rate (typically set at 200 gpm (12.5 lps)), and acting as a check valve to prevent reverse flow.

Figure 4-9 Dual Rate-of-Flow Control Valve (Type II)



4-3.2.8.1 Inspection and Maintenance – Dual Rate-of-Flow Control Valves.

a. Verify dual rate-of-flow control valve is set to maintain a flow rate of 200 gpm (12.5 lps).
Frequency: Quarterly

b. Verify operation of check valve feature.
Frequency: Quarterly

c. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

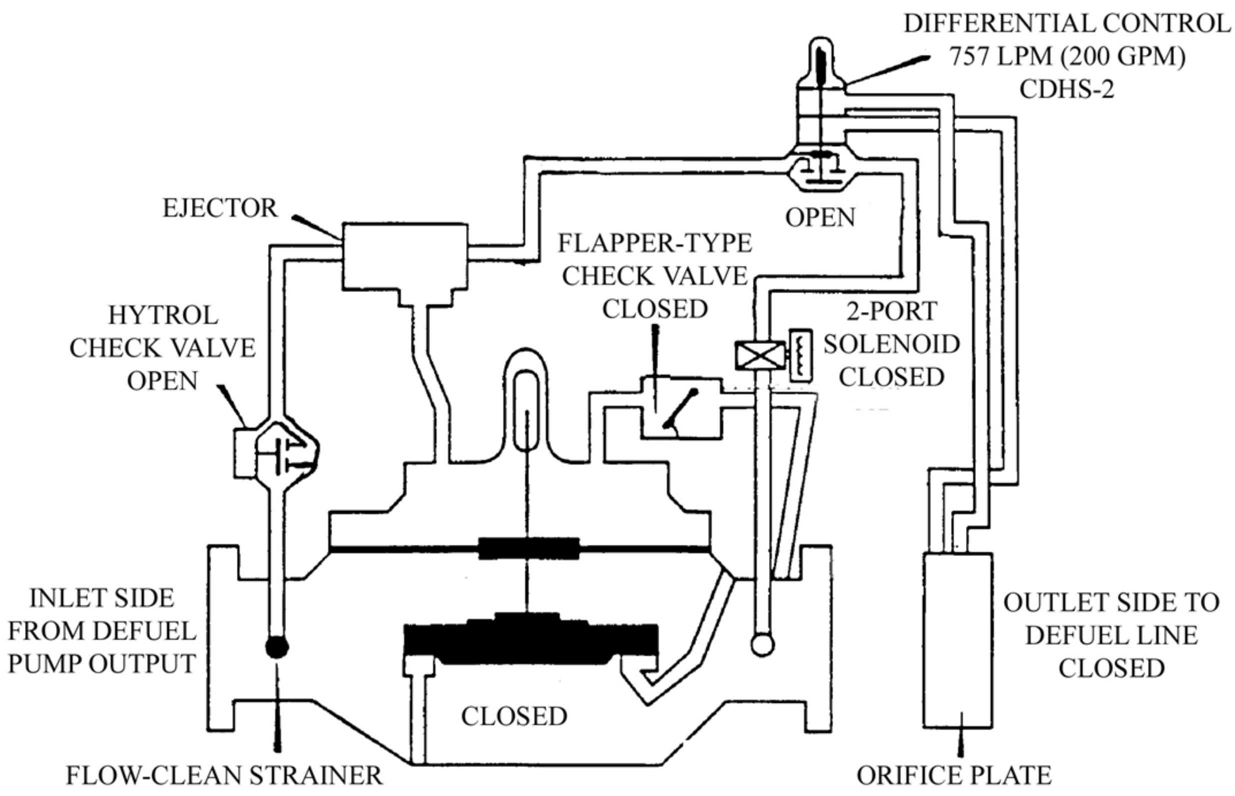
4-3.3 Type II Modified Control Valves (Rapid Flow).

The rapid flow modification was done on some Type II systems to increase defuel rates from 200 to 300 gpm (12.5 to 19 lps). A pump on the aircraft is used to transfer petroleum fuel from the aircraft through the LCP and into the designated defuel tank. The defueling pump in the LCP is only used to evacuate the hose cart after the aircraft pump is de-energized. Two modified control valves are used in the rapid flow system (combination dual rate-of-flow control valve and solenoid valve and dual pressure relief, solenoid shutoff, and check valve).

4-3.3.1 Combination Dual Rate-of-Flow Control and Solenoid Valves.

Combination dual rate-of-flow control and solenoid valves operate like the standard dual rate-of-flow control valves, with the addition of a solenoid for remote-control operations. All settings and functions are the same as the standard dual rate-of-flow control valve.

Figure 4-10 Combination Dual Rate-of-Flow Control and Solenoid Valve (Type II)



4-3.3.1.1 Inspection and Maintenance – Combination Dual Rate-of-Flow Control and Solenoid Valves.

a. Verify valve is set to maintain a flow rate of 300 gpm (19 lps).
Frequency: Quarterly

b. Verify operation of check valve feature.
Frequency: Quarterly

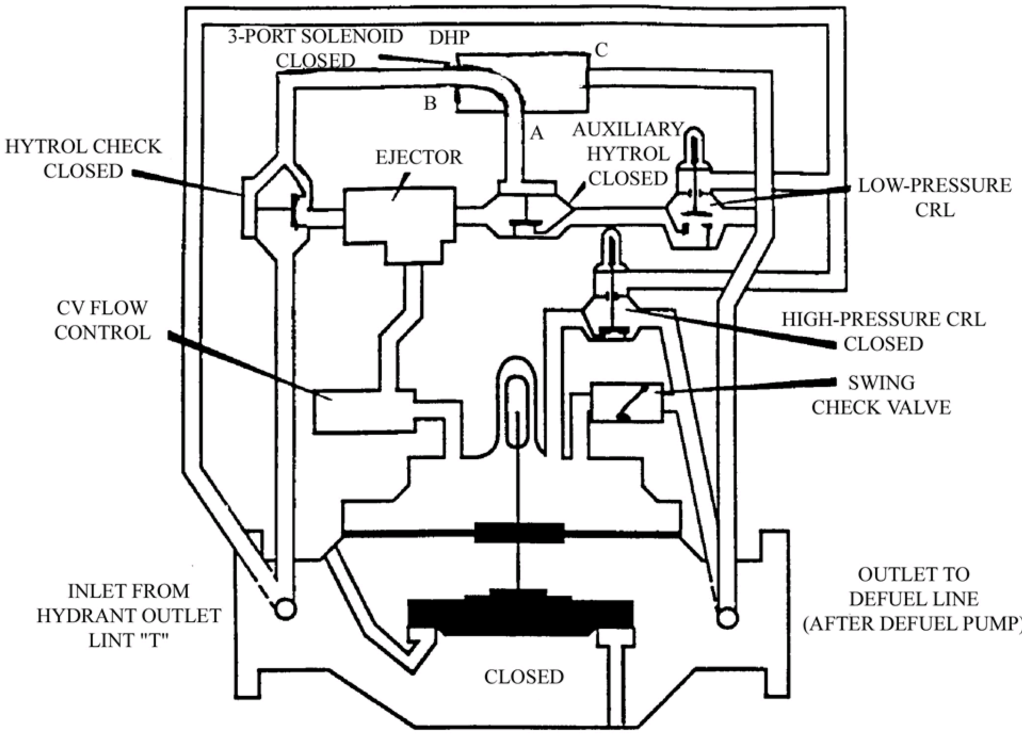
c. Verify solenoid operation.
Frequency: Quarterly

d. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-3.3.2 Dual Pressure Relief, Solenoid Shutoff, and Check Valves.

The dual pressure relief, solenoid shutoff, and check valve is installed in the modified hydrant lateral control pit downstream of the refueling control valve between the issue and defuel line. This relief valve performs two functions: relieves excess pressure in the issue line caused by quick-closing valves during the refueling operation; and maintains a minimum pressure of 5 psig (35 kPa) on the issue line piping when the refueling pumps are not in operation. This valve also has a flow control used to slowly close the valve during rapid defuel operations.

Figure 4-11 Dual Pressure Relief, Solenoid Shutoff, and Check Valve (Type II)



4-3.3.2.1 Inspection and Maintenance – Dual Pressure Relief, Solenoid Shutoff, and Check Valves.

a. Verify high pressure relief control will open at 5 psig (35 kPa) above the refuel control valve pressure relief control set point (typically set at 110 psig (760 kPa)).
Frequency: Quarterly

b. Verify low pressure relief control will open at 5 psig (35 kPa) when refueling pumps are stopped.
Frequency: Quarterly

c. Verify closing speed provides a smooth; pulsation free operation.
Frequency: Quarterly

d. Verify operation of solenoid valve.
Frequency: Quarterly

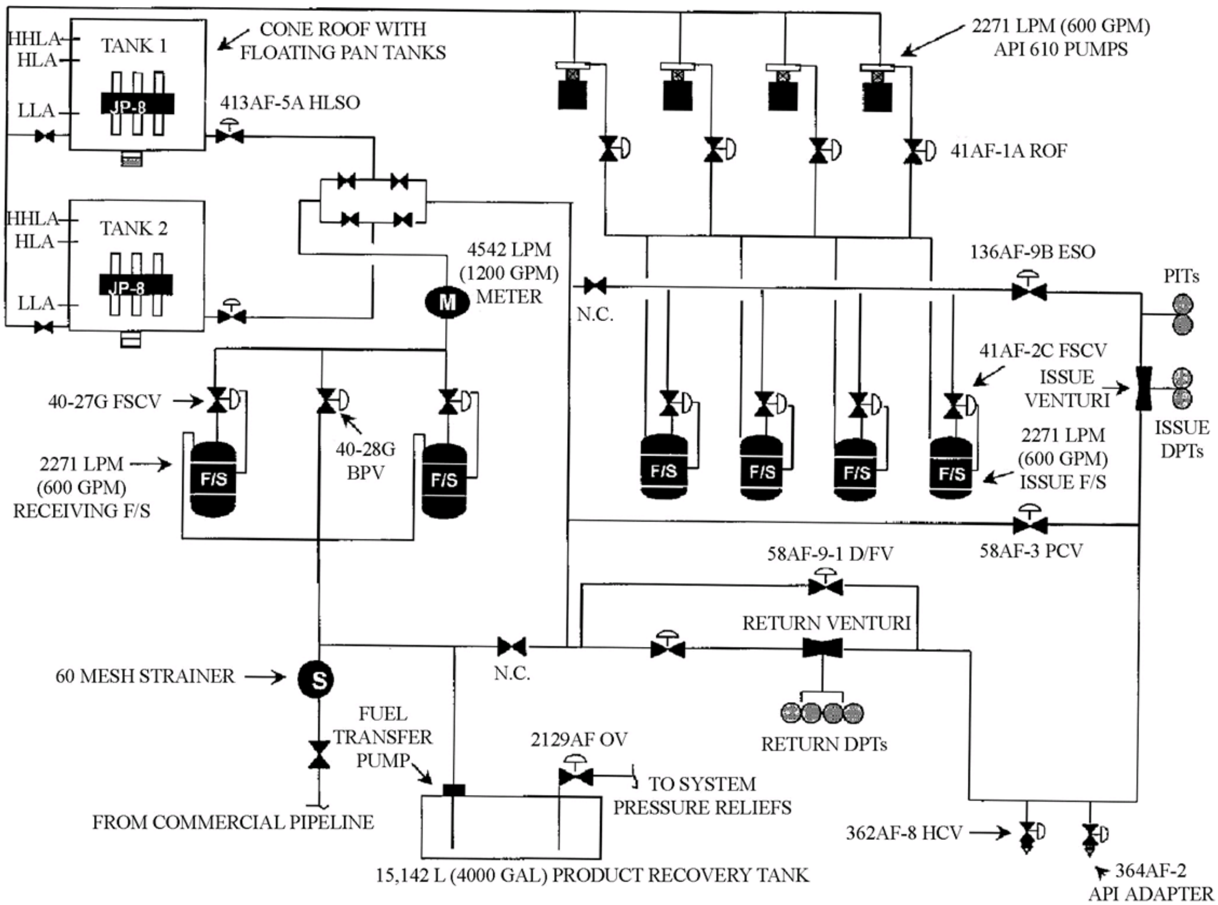
e. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4 HYDRANT SYSTEM – TYPE III.

4-4.1 General Description.

The DoD large-frame aircraft direct fueling system is referred to as the Type III pressurized fueling system. This system is generally comprised of two operating storage tanks, a pumphouse, a hydrant loop, and hydrant outlets at aircraft parking positions. Two redundant Program Logic Controllers (PLCs) are used to control the operation of the system including the pumps and control valves. The system is constantly pressurized when operating. Petroleum fuel is pumped from the tanks, through filter separators and an issue venturi into the hydrant loop. The petroleum fuel flows through the appropriate hydrant valve, through a hydrant servicing vehicle or mobile pantograph and into the aircraft. A backpressure control valve keeps the hydrant loop at a pre-set pressure and a return venturi measures flow back to the storage tank. Working in conjunction with the return venturi, pumps are turned on and off depending on petroleum fuel issue requirements. Systems are generally sized in 600 gpm (38 lps) increments up to 2,400 gpm (152 lps). Issue pumps are sized to provide a minimum of 100 psig (690 kPa) at the furthest hydrant outlet. Each hydrant pit control valve is equipped with a pressure control and surge shutdown pilot and newer systems also include a differential pilot. (See UFGS 33 52 43.14 for more information). The pilot controls are set at 45 psig (310 kPa) and 50 psig (345 kPa), respectively. Hydrant control valves allow flow rates up to 900 gpm (57 lps) using 4-inch (DN100) valve bodies. Hydrant control valves are typically set to 600 gpm (38 lps). Flow rates of up to 1,200 gpm (76 lps) are possible using 6-inch (DN150) hydrant control valve bodies.

Figure 4-12 Type III Hydrant System Diagram

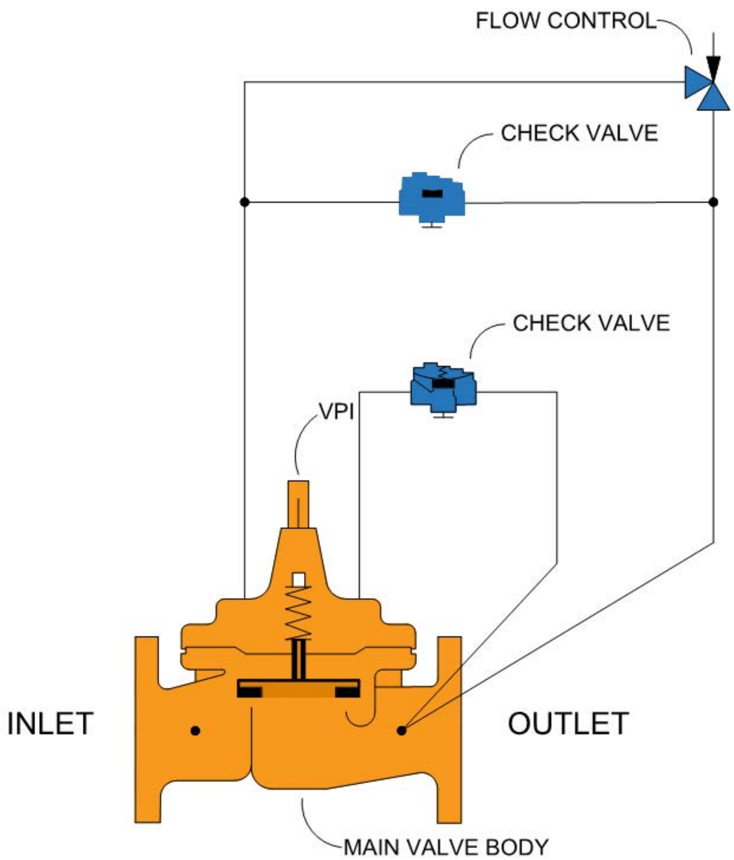


4-4.2 System-Specific Control Valves.

4-4.2.1 Non-Surge Check Valves.

Diaphragm non-surge check valves that meet the requirements of UFGS 33 52 43.14 are used as a flow control feature on the discharge of pumps. A non-surge check valve is used to prevent a pump from running out of its curve when petroleum fuel is flowing through multiple filter separators and to prevent backflow through the pump.

Figure 4-13 Non-Surge Check Valve



4-4.2.1.1 Inspection and Maintenance – Non-Surge Check Valves.

For more information on features, valve settings, and replacement, refer to commissioning documents, as-builts, and manufacturer's operation and maintenance manuals.

a. Verify main valve opening speed (typically 20 seconds). Adjust if required.
Frequency: Semi-annually

b. Verify valve maintains 650 gpm (41 lps) flow rate (some instances 950 gpm (60 lps) flow rate). Adjust if required.
Frequency: Semi-annually

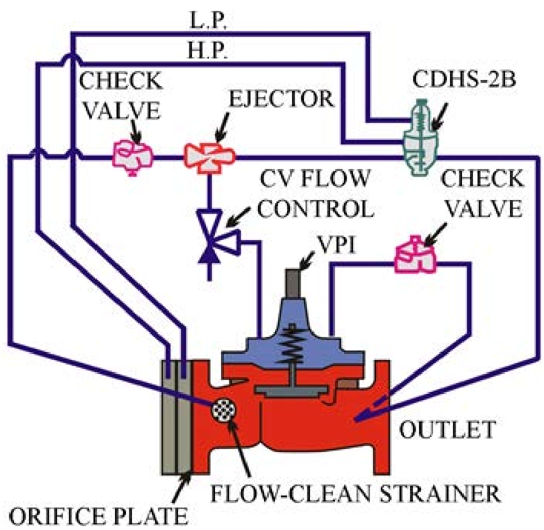
c. Ensure the check valve function is operating properly.
Frequency: Semi-annually

d. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4.2.2 Filter Separator Control Valves.

Filter Separator Control Valves (FSCVs) that meet the requirements of UFGS 33 52 43.14 are used to control the rate of flow through filter separators, prevent reverse flow, prevent water discharge when the water level float control reaches the high position, and act as an emergency shutoff valve when equipped with an emergency stop solenoid valve. Most FSCVs operate at 600, 900 or 1,200 gpm (38, 57 or 76 lps) based on the rated flow capacity of the filter separator.

Figure 4-14 Filter Separator Control Valve (Type III)



4-4.2.2.1 Inspection and Maintenance – Filter Separator Control Valves.

a. Test FSCV emergency shut off solenoid under flow conditions and ensure that valve closes within 10 seconds of EFSO button activation. Coordinate with overall EFSO test listed in Section 9-1.2.1 Inspection and Maintenance - Electrical Equipment.
Frequency: Quarterly

b. Operate test button (if installed) to ensure the FSCV closes at high water level. Physically press the test button, while recirculating fuel, and ensure the FSCV closes. Note: closing speed is a function of the number of open filters separators and the number of pumps operating. With all filters open and only one pump operating, the valve will close very slowly.
Frequency: Quarterly

c. Verify valve maintains flow rate (typically 600 gpm (38 lps), operating range based on commissioning documentation). Adjust flow rate if required. Flow rate is determined by filter separator vessel gpm (lps) rating, or element flow rate, whichever is less. Use return venturi to measure and confirm flow rate during valve testing and adjustment.
Frequency: Annually

d. Ensure the check valve function is operating properly.
Frequency: Annually

e. Test buoyancy of water level float. Remove the ball or float assembly and place it in a bucket of water. Correctly operating ball or float will float at the top of the water's surface.
Frequency: When coalescer cartridges are changed

f. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4.2.3 Defuel/Flush Valves.

\1

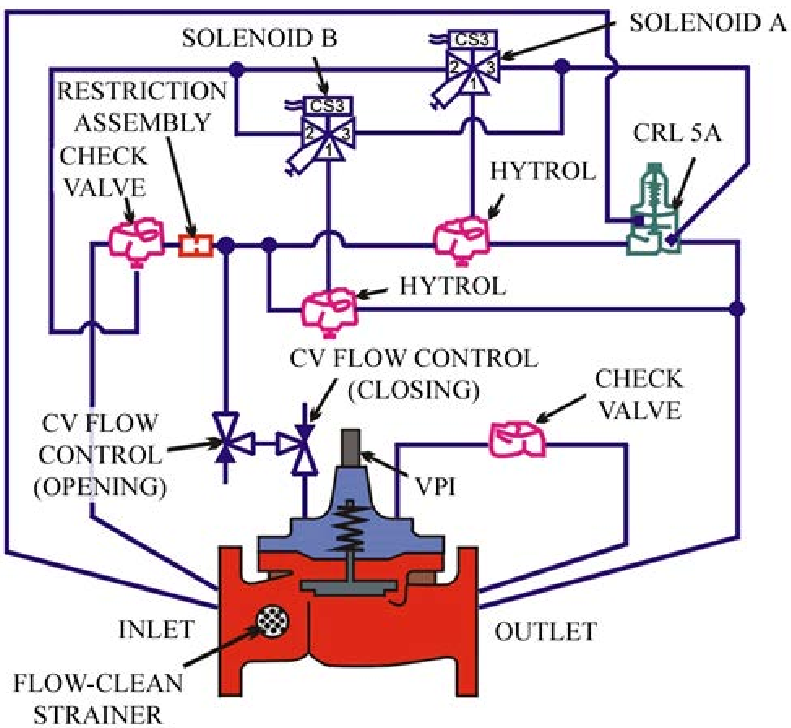
a. Defuel/Flush Valves (D/FV) that meet the requirements of UFGS 33 52 43.14 are controlled by two different solenoids. Solenoid A controls the defuel portion of the main valve and holds the valve closed any time a fuel pump is running. Solenoid B controls the flush portion of the main valve and functions only when the system is placed in flush mode. When the lead pump de-energizes, solenoid A energizes, allowing the valve to open and drop the system pressure to 80 psig (550 kPa) (typical set pressure). While the system is in the idle position, the valve will open to allow defueling when the hydrant loop pressure rises above 80 psig (550 kPa) (typical set pressure).

b. Defueling can be conducted using a Hydrant Hose Truck (HHT) to pump fuel off aircraft and force fuel into the hydrant loop. The HHT pump will overcome the 80 psig (550 kPa) setting of the D/FV and open the valve.

c. Solenoid B energizes only when the system is placed in flush mode. Flush mode is used to move fuel through the system in order to clean the loop. Flushing procedures vary based on system design and should be approved by the military service-specific SME.

/1/

Figure 4-15 Defuel/Flush Valve (Type III)



4-4.2.3.1 Inspection and Maintenance – Defuel/Flush Valves.

For more information on features, settings, and replacement, refer to commissioning documents, as-builts, and manufacturer's operation and maintenance manuals.

a. Ensure Solenoids A and B are de-energized with system in automatic mode and lead pump operating.
Frequency: Quarterly

b. Ensure Solenoid A is energized and Solenoid B is de-energized to allow main valve to open and drop system pressure to 80 psig (550 kPa) (typical set pressure) with system in automatic mode and lead pump off.
Frequency: Quarterly

c. Ensure Solenoid A is de-energized and Solenoid B is energized when system is in flush mode.
Frequency: Quarterly

d. Ensure Solenoids A and B are de-energized when system is in tightness test mode.
Frequency: Quarterly

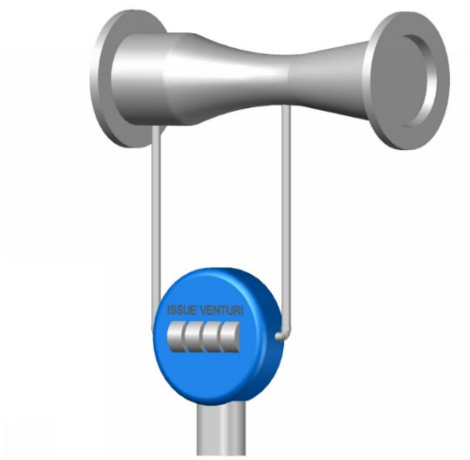
e. Check opening and closing speed. Speed should be as fast as possible while still maintaining smooth operation.
Frequency: Quarterly

f. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4.2.4 Issue Venturi.

The issue venturi is downstream of the issue filter separator manifold and is typically rated at 2,400 gpm (151 lps). The venturi has upstream and downstream sensing line connections for two redundant Differential Pressure Transmitters (DPTs). The control PLCs determines the flow rate using electronic signals from the DPTs.

Figure 4-16 Issue Venturi



4-4.2.4.1 Inspection and Maintenance - Issue Venturi.

a. Ensure issue venturi DPTs are reading the same value within ± 2% full scale.
Frequency: Semi-annually

b. Refer to Section 6-7.4 Differential Pressure Transmitters for inspection and maintenance requirements of DPTs.

4-4.2.5 Return Venturi.

The return venturi is located upstream of the Back-Pressure Control Valve (BPCV). It is similar to the issue venturi but is typically rated at 800 gpm (50 lps).

4-4.2.5.1 Inspection and Maintenance - Return Venturi.

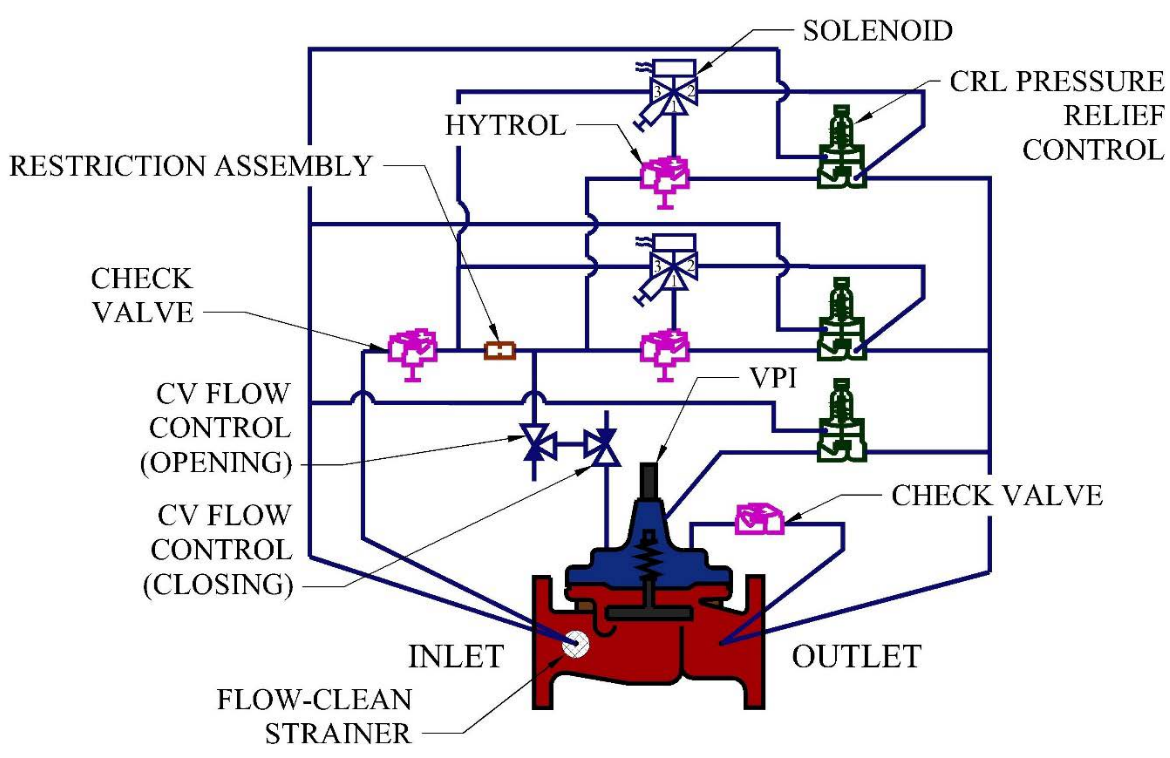
a. Ensure return venturi DPTs are reading the same value within ±2% full scale.
Frequency: Semi-annually

b. Refer to Section 6-7.4 Differential Pressure Transmitters for inspection and maintenance requirements of DPTs.

4-4.2.6 Back Pressure Control Valves.

Back Pressure Control Valves (BPCVs) that meet the requirements of UFGS 33 52 43.14 are used to maintain a constant hydrant loop pressure. The valve is typically 6-inch (DN 150), and the valve is typically set to maintain 100 psig (690 kPa) fuel pressure at the furthest hydrant outlet.

Figure 4-17 Back Pressure Control Valve (Type III)



4-4.2.6.1 Inspection and Maintenance – Back Pressure Control Valves.

For more information on features, valve settings, and replacement, refer to commissioning documents, as-builts, and manufacturer's operation and maintenance manuals.

a. Verify constant upstream pressure is maintained at the set point established and listed in the system commissioning documents. Adjust setting of BPCV as necessary.
Frequency: Quarterly

b. Ensure Solenoid A is energized and Solenoid B is de-energized while lead pump is operating in automatic mode.
Frequency: Quarterly

c. Ensure Solenoids A and B are de-energized prior to lead pump shutdown and system going to stand-by.
Frequency: Quarterly

d. Ensure Solenoids A and B are de-energized while system is in flush mode.
Frequency: Quarterly

e. Ensure that Solenoid A is de-energized and Solenoid B is energized while system is in tightness test mode.
Frequency: Quarterly

f. Verify closing speed control. Valve should close as fast as possible while still maintaining smooth operation.
Frequency: Quarterly

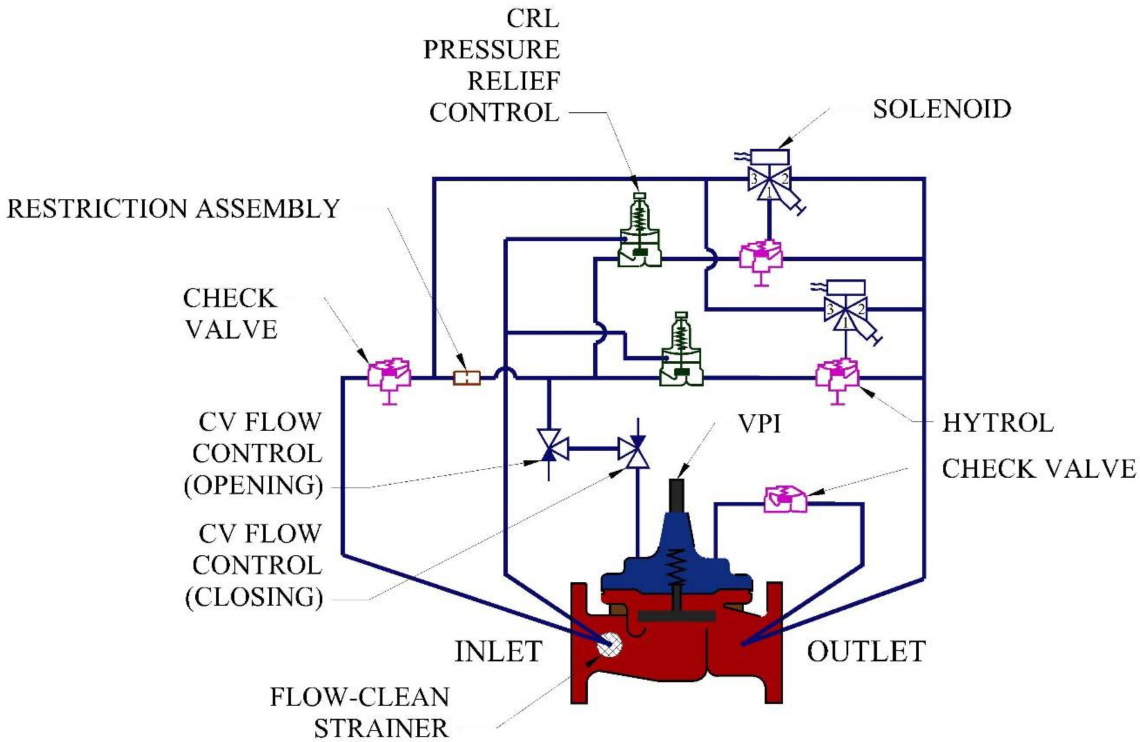
g. Check solenoid EFSO feature when equipped. Coordinate test with overall EFSO test listed in Section 9-1.2.1 Inspection and Maintenance - Electrical Equipment.
Frequency: Quarterly

h. Refer to Section 4-4.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4.2.7 Pressure Control Valves.

Pressure Control Valves (PCV) meeting the requirements of UFGS 33 52 43.14 reduce system pressure down to 75 psig (515 kPa) during system shutdown process and provide thermal relief during idle periods. The valves are typically 2-inch (DN50). A solenoid installed on the valve energizes to close the valve when the lead pump is operating and de-energizes when the lead pump stops. When the solenoid is de-energized, the valve opens to reduce the system pressure to 75 psig (515 kPa) and the thermal relief function is operable. If the pressure rises above 75 psig (515 kPa), the valve opens and excess pressure flows to the operating storage tank. The valve opening and closing speed controls are typically set at three (3) seconds. In some cases, to prevent valve chattering, the PCV pressure-sensing line is connected to the large defuel/flush line.

Figure 4-18 Pressure Control Valve (Type III)



4-4.2.7.1 Inspection and Maintenance – Pressure Control Valves.

For more information on features, valve settings, and replacement refer, to commissioning documents, as-builts, and manufacturer’s operation and maintenance manuals.

a. Ensure Solenoid A is energized and Solenoid B is de-energized while system is in automatic mode and lead pump is operating.
Frequency: Quarterly

b. Ensure Solenoids A and B are de-energized while system is in automatic mode and lead pump is off. Verify valve opens to maintain system pressure at 75 psig (515 kPa).
Frequency: Quarterly

c. Ensure Solenoid A is energized and Solenoid B is de-energized while system is in flush mode and lead pump is operating.
Frequency: Quarterly

d. Ensure Solenoids A and B are de-energized while system is in flush mode and pumps are off.
Frequency: Quarterly

e. Ensure Solenoids A and B are energized while system is in tightness test mode.
Frequency: Quarterly

f. Verify closing speed control. Valve should close as fast as possible while still maintaining smooth operation.
Frequency: Quarterly

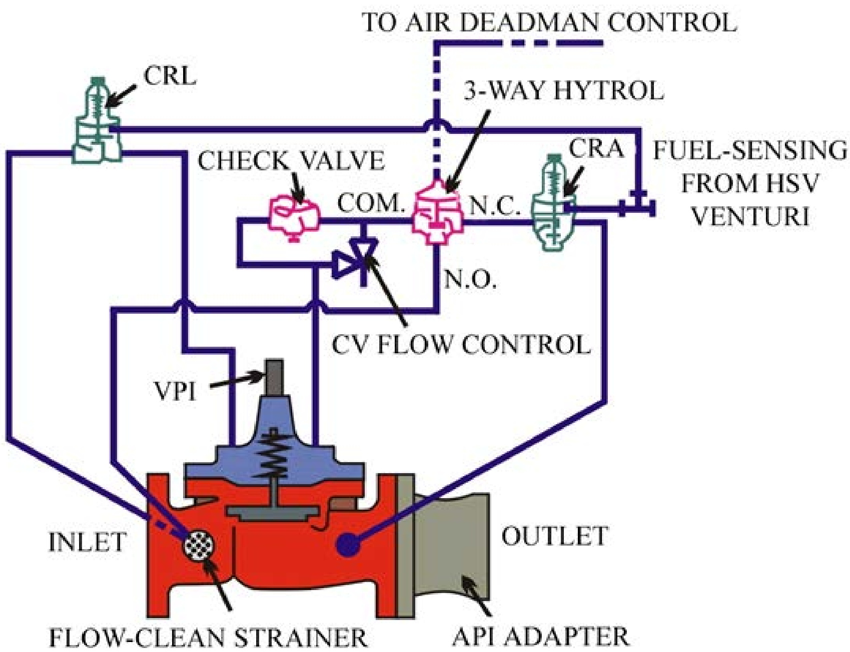
g. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4.2.8 Hydrant Control Valves.

Hydrant Control Valves (HCV) meeting the requirements of UFGS 33 52 43.14 provide constant nozzle pressure and relieve excess pressure. An air-sensing line is connected from the HHT to the HCV three-way hydraulically operated/diaphragm actuated globe valve. When the HHT's pneumatic deadman is depressed, air is supplied to the three-way valve, allowing the valve to open. A fuel-sensing line is connected from the HHT venturi to the Pressure-Reducing Control (CRA) and the Pressure-Relief Control (CRL) on the HCV. The venturi is calibrated to provide the same pressure as the actual nozzle pressure at the skin of the aircraft. The CRA maintains 45 psig (310 kPa) at the nozzle. The HCV is designed to close rapidly when the nozzle pressure exceeds the 50 psig (345 kPa) setting of the CRL. It reopens when the pressure drops below the 50 psig (345 kPa) set point.

Some Type III systems use towable pantographs instead of HHTs. The operation of a towable pantograph with a HCV is similar to the operation with a HHT.

Figure 4-19 Hydrant Control Valve (Type III)



4-4.2.8.1 Inspection and Maintenance – Hydrant Control Valves.

For more information on features, valve settings, and replacement, refer to commissioning documents, as-builts, and manufacturer's operation and maintenance manuals.

a. Verify HCV maintains 45 psig (310 kPa) nozzle pressure at a flow of 50 to 600 gpm (3 to 38 lps).
Frequency: Quarterly

b. Verify HCV closes when nozzle pressure exceeds 50 psig (345 kPa).
Frequency: Quarterly

c. Verify HCV opening speed is set at a minimum of 20 seconds.
Frequency: Quarterly

d. Verify HCV opens when the deadman control lever is pressed.
Frequency: Quarterly

e. Verify HCV closes within two to five seconds after the deadman lever is released.
Frequency: Quarterly

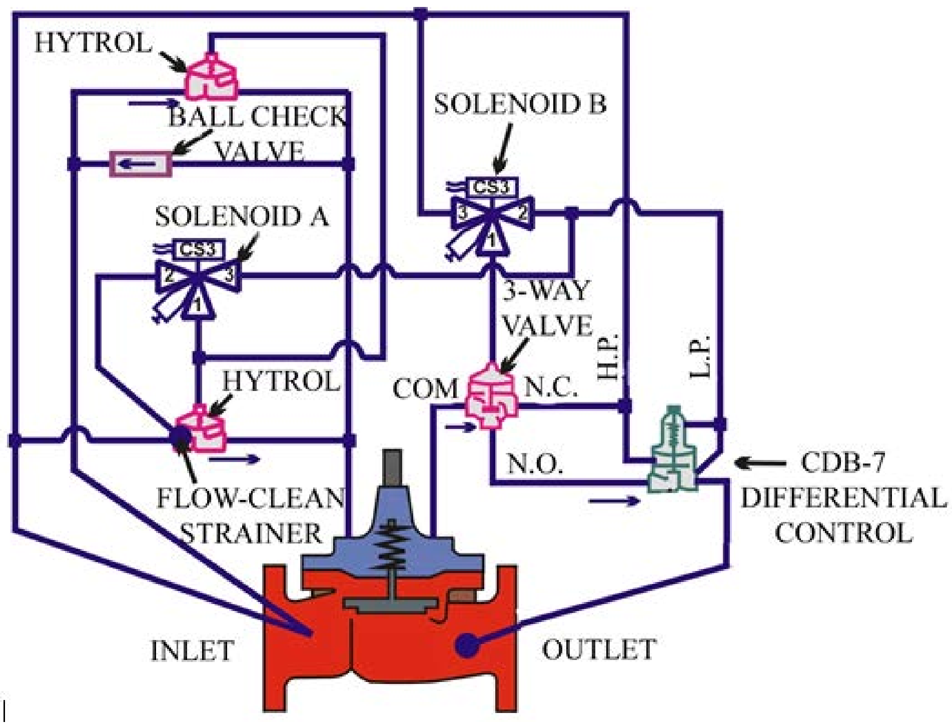
f. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-4.2.9 Emergency Shut-off Valves.

This valve has been removed from the standard Type III design, but it still exists in some systems. New Type III systems achieve the same function as the emergency shut-off valve by including a similar function on the FSCVs.

Emergency Shut-Off (ESO) valves that meet the requirements of UFGS 33 52 43.14 have two solenoids that are energized when power is on, enabling the main valve to open when fuel is flowing. Should power fail or an emergency stop button be pushed, the solenoids will de-energize and the main valve will close within 10 seconds. The valve also has a thermal relief feature that relieves excess cover chamber pressure back to the valve inlet, and a differential control is used to maintain a relatively constant differential pressure between the inlet and outlet of the main valve.

Figure 4-20 Emergency Shut-Off Valve (Type III)



4-4.2.9.1 Inspection and Maintenance – Emergency Shut-off Valves.

For more information on features, valve settings, and replacement, refer to commissioning documents, as-builts, and manufacturer's operation and maintenance manuals.

a. Ensure Solenoids A and B are energized under normal operations.
Frequency: Quarterly

b. Ensure Solenoids A and B are de-energized during emergency stop conditions.
Frequency: Quarterly

c. Test emergency stop function of the valve under flow conditions. Ensure the valve closes within 10 seconds of EFSO button activation. Coordinate test with overall EFSO test listed in Section 9-1.2.1 Inspection and Maintenance - Electrical Equipment.
Frequency: Quarterly

d. Verify differential control maintains a constant seven psig (48 kPa) differential pressure between the inlet and outlet of the valve.
Frequency: Quarterly

e. Ensure thermal relief function (ball check valve) relieves excess pressure when cover chamber pressure exceeds inlet pressure. **Frequency: Quarterly**

f. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-5 HYDRANT SYSTEM – TYPE IV.

4-5.1 General Description.

Type IV hydrant systems are similar in function to the Type III systems except that the Type IV system uses fixed pantographs, designed for fixed-wing, small frame aircraft direct fueling stations. Type IV systems are often designed to support hot refueling operations.

4-5.2 System-Specific Control Valves.

4-5.2.1 High Level Shut-off Valve (HLSO).

Refer to Section 8-9.6 High Level Shut-off Valves (HLSO) for inspection and maintenance requirements of Type IV HLSOs.

4-5.2.2 Non-Surge Check Valves.

Refer to Section 4-4.2.1 Non-Surge Check Valves for inspection and maintenance requirements of non-surge check valves.

4-5.2.3 Filter Separator Control Valve (FSCV).

Refer to Section 4-4.2.2 Filter Separator Control Valves for inspection and maintenance requirements of Type IV FSCVs.

4-5.2.4 Defuel/Flush Valve (D/FV).

Refer to Section 4-4.2.3 Defuel/Flush Valves for inspection and maintenance requirements of Type IV D/FV. Ignore the maintenance and inspection requirements for Type IV systems that are not equipped with a defuel/flush valve.

4-5.2.5 Flush Valves.

Refer to Section 4-4.2.3 Defuel/Flush Valves for inspection and maintenance requirements of Type IV flush valve. Ignore the maintenance and inspection requirements for Type IV systems that are not equipped with a flush valve.

4-5.2.6 Issue Venturi.

Refer to Section 4-4.2.4 Issue Venturi for inspection and maintenance requirements of issue venturi.

4-5.2.7 Return Venturi.

Refer to Section 4-4.2.5 Return Venturi for inspection and maintenance requirements of return venturi.

4-5.2.8 Back Pressure Control Valves.

Refer to Section 4-4.2.6 Back Pressure Control Valves for inspection and maintenance requirements of back pressure control valves.

4-5.2.9 Pressure Control Valves.

Refer to Section 4-4.2.7 Pressure Control Valves for inspection and maintenance requirements of pressure control valves.

4-5.2.10 Hydrant Control Valve (HCV).

Refer to Section 4-4.2.8 Hydrant Control Valves for inspection and maintenance requirements of Type IV HCVs.

4-5.2.11 Emergency Shut-off Valve (ESO).

Refer to Section 4-4.2.9 Emergency Shut-off Valves for inspection and maintenance requirements of Type IV ESOs.

4-5.2.12 Pantograph Control Valves.

The Pantograph Control Valve (PTCV) is used to control flow and pressure of fuel through the pantograph. The unit operates in conjunction with a pantograph venturi installed downstream of the PTCV. The valve is equipped with a deadman control lever.

4-5.2.12.1 Inspection and Maintenance – Pantograph Control Valves.

a. Verify PTCV maintains 55 psig (380 kPa) nozzle pressure at a flow of 50 to 600 gpm (3 to 38 lps).
Frequency: Quarterly

b. Verify PTCV opens when the deadman control lever is pressed.
Frequency: Quarterly

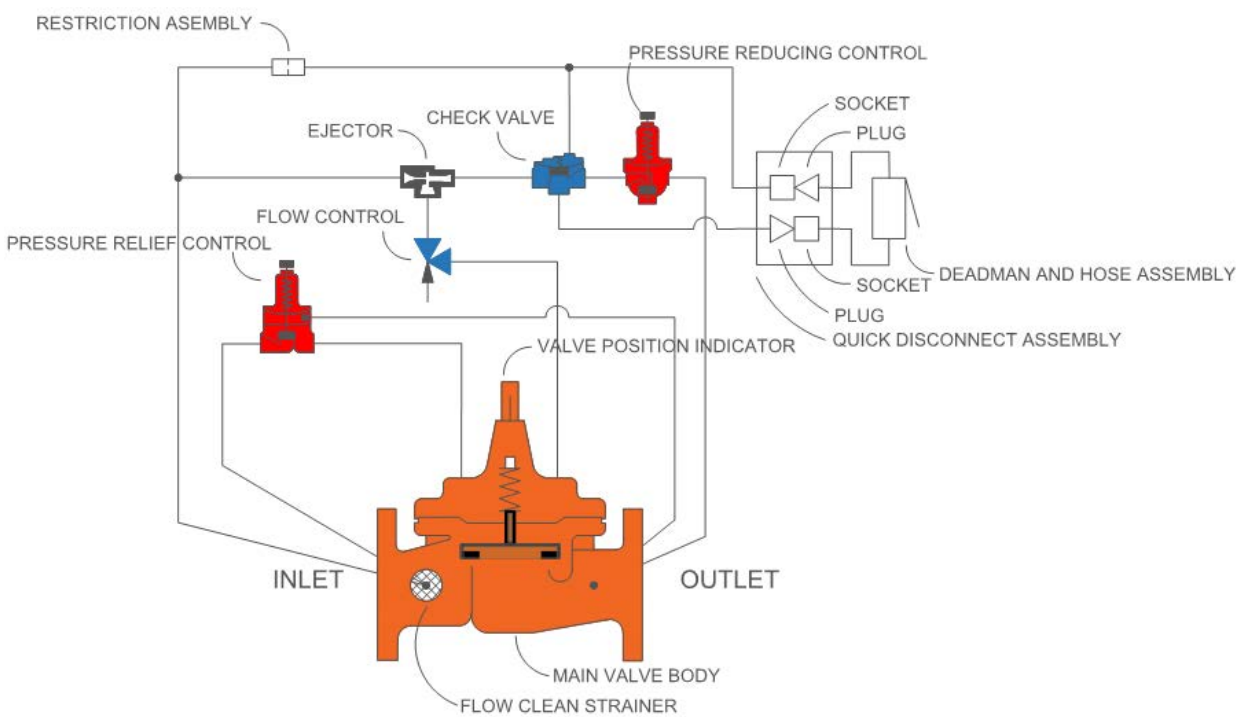
c. Verify PTCV closes in a maximum of 10 seconds after deadman lever is released.
Frequency: Quarterly

d. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

4-5.2.13 Pantograph Pressure Control Valves.

The Pantograph Pressure Control Valve (PPCV) relieves pressure from the pantograph downstream of the PTCV. The PPCV is set to open at 75 psig (515 kPa) and prevents excessive pressure from reaching the aircraft fuel tank.

Figure 4-21 Pantograph Pressure Control Valve



4-5.2.13.1 Inspection and Maintenance – Pantograph Pressure Control Valves.

a. Verify PPCV opens at 75 psig (515 kPa).
Frequency: Quarterly

b. Verify PPCV opening and closing speed are three seconds maximum.
Frequency: Quarterly

4-6 HYDRANT SYSTEM – TYPE V.

4-6.1 General Description.

Type V hydrant systems are similar to the Type IV systems except that the refueling points are located in hardened aircraft shelters.

4-7 HYDRANT SYSTEM GENERAL EQUIPMENT.

4-7.1 Pantographs.

Pantographs that meet the requirements of UFGS 33 52 43.12 are used in aircraft fueling facilities. Pantographs can be fixed at a single location or mounted on a towable frame to make them mobile. Pantographs have a number of swivel joints. The focus of a pantograph's maintenance centers on the care of the joints. Most pantographs have a sufficient number of swivel joints to prevent excessive strain. The movable joints require periodic lubrication when equipped with lubricated swivels and replacement of packings, seals, or O-rings. Once existing lubricated swivels show signs of leaks and failure, they should be replace with stainless steel non-lubricated type swivels.

Care must be taken to ensure that grounding or bonding wire is not damaged during maintenance or allowed to deteriorate. Pantographs are treated roughly during refueling operations. Personnel who perform preventive maintenance must be alert for leaks, wet spots, and erratic mechanical operation.

4-7.1.1 Fixed Pantographs.

Fixed pantographs are connected to piping at a single location and are not relocated.

4-7.1.1.1 Inspection and Maintenance – Fixed Pantographs.

a. Place entire pantograph under static pump head pressure and check for leaks, ease of movement, and damaged grounding or bonding wire.
Frequency: Monthly

b. Inspect wheels (if equipped) for warping, cracking, and uneven wear.
Frequency: Quarterly

c. Inspect exposed piping and components for corrosion.
Frequency: Quarterly

d. Refer to Section 4-7.3 Fueling Nozzles for inspection and maintenance requirements of fueling nozzle.

Figure 4-22 Fixed Pantograph

4-7.1.2 \1\ Detachable /1/ Pantographs.

Mobile pantographs are used in locations that are not equipped with fixed pantographs or hydrant hose trucks. These pantographs are mounted on wheels and can be towed to the use point. Each pantograph is equipped with a hydrant adaptor used to connect to a HCV and a fueling nozzle used to connect to the aircraft receiving fuel.

4-7.1.2.1 Inspection and Maintenance – \1\ Detachable/ 1/ Pantographs.

a. Place pantograph under static pump head pressure and check for leaks, ease of movement, and damaged grounding or bonding wire.
Frequency: Monthly

b. Inspect exposed piping and components for corrosion.
Frequency: Quarterly

c. Lubricate wheels.
Frequency: Quarterly

d. Inspect wheels for warping, cracking, and uneven wear.
Frequency: Quarterly

e. Refer to Section 4-7.2 Hydrant Adapters for inspection and maintenance requirements of pantograph hydrant adapters.

f. Refer to Section 4-7.3 Fueling Nozzles for inspection and maintenance requirements of fueling nozzles.

4-7.2 Hydrant Adapters.

Hydrant adaptors are used to connect to hydrant control valves. Hydrant adaptors are installed on hydrant hose trucks and mobile pantographs.

4-7.2.1 Inspection and Maintenance – Hydrant Adapters.

a. Inspect hydrant adapter for proper operation, damage, and wear.
Frequency: Quarterly

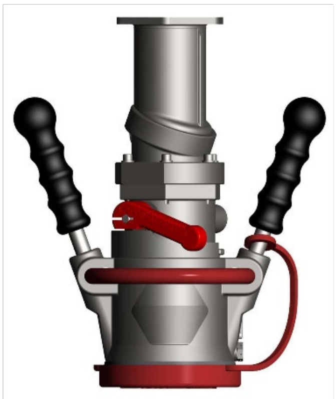
b. Test operation of dry break system.
Frequency: Quarterly

Figure 4-23 Hydrant Adapter

4-7.3 Fueling Nozzles.

Fueling nozzles are used to connect issue systems to refueler trucks and aircraft. They are installed on fuel issue hoses, pantographs, R-11 refuelers, R-12 hydrant hose trucks, and other systems that issue fuel. The fueling nozzle is equipped with 60-100 wire mesh screen (0.25-0.15 mm sieve) to trap particulates from the issue system.

Figure 4-24 Fueling Nozzle



4-7.3.1 Inspection and Maintenance – Fueling Nozzles.

a. Inspect the condition of the dust cap at the aircraft adapter end and ensure it is in good working order. Dust caps must be attached to nozzles when they are not is use.
Frequency: Monthly

b. Test leak resistance of poppet valve against full pump pressure. Unusual conditions found during this test indicate that repair is necessary and the nozzle must be removed from service.
Frequency: Monthly

c. Inspect storage racks for moisture or dirt accumulation. Correct conditions that may be attributing to accumulation of moisture or dirt in the storage racks.
Frequency: Monthly

d. Remove nozzle for inspection of content impinged upon the mesh screen. Clean and dry screens before nozzles are returned to service. If a strainer ball valve is installed upstream of the nozzle only the strainer in the strainer ball valve needs to be check. Nozzles should not be used while strainers are removed from upstream strainer ball valves.
Frequency: Monthly

e. Tests nozzle interlocks. Ensure interlocks prevent release of fuel when the fueling nozzle is not properly connected. Adjust the seating of the poppet valve if required.
Frequency: Monthly

f. Check the operation of the manual valve crank assembly for smooth and positive motion on a special test stand.
Frequency: Monthly

4-7.4 Surge Suppressors.

If the flow of liquid in a pipeline is suddenly stopped, a high pressure wave can be created as kinetic energy of flow is converted to pressure. The resulting pressure spike can cause leaks and damage to connected equipment. A common device designed to decrease pressure spikes in pipelines is a surge suppressor. Surge suppressors can reduce pressure spikes but will not eliminate them entirely.

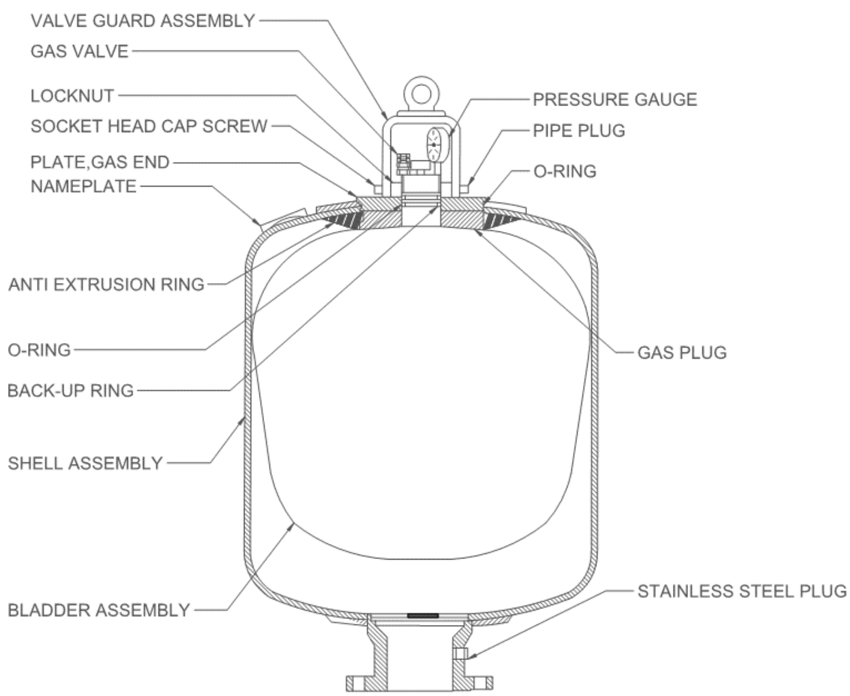
Surge suppressors can be constructed with diaphragms or bladders. Surge suppressors are equipped with a top-mounted pressure gauge, isolation valve, limited bleed-back check valve, and drains.

4-7.4.1 Inspection and Maintenance - Surge Suppressors.

a. Inspect for nitrogen leaks.
Frequency: Quarterly

b. Bladder pressure inside surge suppressors must be validated and recharged as needed with nitrogen. Some surge suppressors are also equipped with needle valves. Settings established in the startup and commissioning documents should be maintained. Adjust nitrogen charge per manufacturer’s recommendations.
Frequency: Quarterly

Figure 4-25 Surge Suppressor



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4-7.5 Aircraft Fueling Hoses.

Fuel issue hoses must meet the requirements of aviation fueling hoses listed in UFGS 33 52 43.12.

4-7.5.1 Inspection and Maintenance - Fuel Issue Hoses.

a. Visually inspect hoses for loose covers, cracks, brittle surface coatings, exposed wire braids, exposed reinforcement, flattening, kinks, and bulges or soft spots which might indicate broken or displaced reinforcement.
Frequency: Monthly

b. Pressurize hose to normal working pressure. Check flanged and threaded connections for leaks and inspect hose couplers for fluid seepage by pushing at the base of the coupling with thumbs. A hose softened by petroleum fluid seepage must be replaced.
Frequency: Monthly

c. Check for coupling slippage. Replace hose that shows signs of coupling slippage.
Frequency Quarterly

d. For hot pit refueling hoses only, refer to Appendix D, Section D-2.1 Loading Hose Hydrostatic Test for loading hose hydrostatic testing requirements and procedures.
Frequency: Annually

e. Conduct test of petroleum fuel hose electrical resistivity using an electrostatic meter in accordance with NFPA 77 and API 2003.
Frequency: Annually /1/

4-8 HYDRANT SYSTEM PRODUCT RECOVERY.

This system stores fuel from drain lines, filter separator drains, thermal relief valves and other components. It permits fuel and water to separate, the water to be drained off, and fuel to be returned to storage tanks.

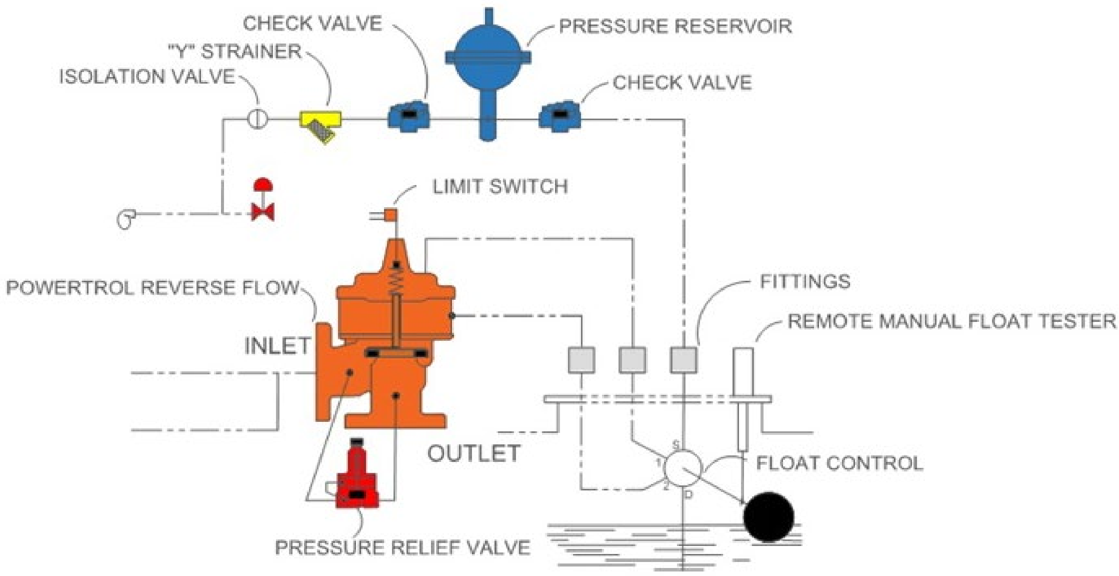
4-8.1 Overfill Valve for Product Recovery Tanks.

Overfill Valves (OVs) that meet the requirements of UFGS 33 52 43.14 are installed on product recovery tanks. Overfill valves are used to stop flow of fuel into product recovery tanks when the product recovery tanks reach a high level condition. A high-level alarm is activated at 85% full capacity, a high-high level alarm is activated at 90% full capacity, and the OV closes at 95% full capacity.

The valve is equipped with a pressure reservoir which supplies hydraulic pressure required to operate the valve. Reservoir pressure is supplied by the Fuel Transfer

Pump (FTP) installed on the product recovery tank. When the FTP operates, pressurized fuel is supplied to the reservoir. The reservoir utilizes a check valve to isolate the pressure in the reservoir. Automatic opening and closing of the OV is controlled by a float installed in the product recovery tank. The OV will close upon loss of reservoir pressure.

Figure 4-26 Overfill Valve for Product Recovery Tank



4-8.1.1 Inspection and Maintenance - Overfill Valve for Product Recovery Tanks.

For more information on features, valve settings, and replacement, refer to commissioning documents, as-builts, and manufacturer's operation and maintenance manuals.

a. Verify that a green light is illuminated on the pump control panel graphic display when OV is open.
Frequency: Semi-annually

b. Ensure pressure reservoir bladder is charged with 13 to 15 psig (90 to 103 kPa) of nitrogen and that the reservoir holds fuel pressure.
Frequency: Semi-annually

c. Verify that the OV closes when the control float is lifted (normally 95% full). Use the manual tester to lift the float. NOTE: When the float in the product recovery tank rises and the OV closes, the pressure in the pressure reservoir tank will decrease.
Frequency: Semi-annually

d. Verify that a red light is illuminated and that an alarm is activated on the pump control panel graphic display when OV is closed. Alarm is activated by a limit switch installed on the OV.
Frequency: Semi-annually

e. Ensure the pressure reservoir tank holds FTP deadhead pressure when the pump is deactivated.
Frequency: Semi-annually

f. Open and clean reservoir inlet strainer.
Frequency: Semi-annually

g. Refer to Section 6-6.3 Thermal and Pressure Relief Valves for inspection and maintenance requirements of thermal and pressure relief valves.

4-8.2 Product Recovery Tank Release Detection.

Underground double-walled product recovery tanks are provided with release detection in the annular space between the inside and outside walls of the underground tank.

4-8.2.1 Inspection and Maintenance - Product Recovery Tank Release Detection.

Refer to Section 8-9.13 Release Detection Monitoring for inspection and maintenance requirements of product recovery tank release detection systems.

4-8.3 Product Recovery Tank Automatic Tank Gauges.

Underground product recovery tanks are typically equipped with automatic tank gauges that are similar to underground storage tanks equipped with automatic tank gauges.

4-8.3.1 Inspection and Maintenance - Product Recovery Tank Automatic Tank Gauges.

Refer to Section 8-9.8 Automatic Tank Gauges for inspection and maintenance requirements of product recovery tank automatic tank gauges.

4-8.4 Product Recovery Tank Fuel Transfer Pump.

Product recovery tanks are equipped with transfer pumps that are used to transfer recovered fuel back to store tanks for use.

4-8.4.1 Inspection and Maintenance - Product Recovery Tank Fuel Transfer Pump.

Refer to Section 3-8.1.3 Vertical Turbine/Submerged Turbine Pumps for inspection and maintenance requirements of product recovery tank fuel transfer pumps.

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CHAPTER 5 MARINE RECEIVING AND DISPENSING FACILITIES

5-1 PIERS AND WHARVES.

A pier is a deck structure supported above the water on piles (open type), a solid fill structure retained by bulkheads (closed type with apron), or a combination of the two. It extends outward from the shore into a harbor or other navigable waters to permit berthing along one or both sides of its length.

A wharf is a deck structure supported above the water on piles (open type), a solid-fill structure retained by bulkheads (closed), or a combination of the two. It runs parallel to the shore and is connected to it at more than one point (usually continuously) to provide berthing along one side.

5-1.1 Inspection and Maintenance – Piers and Wharves.

Refer to UFC 4-150-07 for inspection and maintenance requirements of piers and wharves.

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5-1.2 Inspection and Maintenance – Fuel Containment Systems

a. Containment systems on piers and wharves degrade and will collect debris, which can clog drainage inlets or prevent drain valves from sealing properly. Hydrostatically test the secondary containment and associated drainage systems to include containment concrete/sealant, drain inlets, drain lines and containment drain valves to ensure containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of the 60 minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer to Appendix B for testing procedures and to document the testing.
Frequency: Every 3 Years

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5-2 MARINE RECEIPT.

These facilities include piers or wharves equipped with petroleum fuel transfer piping. Major components of marine receipt systems include marine hoses, marine loading arms, piping, strainers, fuel meters, stripper pumps, and grounding systems.

5-2.1 Inspection and Maintenance – Marine Receipt.

a. Conduct a shore side inspection of the pier or wharf for signs of damage as soon as marine barge or tanker disembarks.
Frequency: After each use

b. Inspect the ground switch used between the marine barge or tanker and the petroleum fuel receipt piping.
Frequency: Monthly

c. Inspect mooring lines, cleats, bollards, bitts, pulley blocks, steel wire ropes, and winches. Use UFC 4-150-08 as a guide when conducting inspections. Repair or replace damaged components as required.
Frequency: Monthly

d. Refer to Section 6-1 Pipe Testing and Inspections for inspection and maintenance requirements of petroleum fuel pipelines installed above water surfaces. These pipelines are regulated under 33 CFR 154 and 156. Any additional requirements listed under 33 CFR 154 and 156 must also be followed.

e. Refer to Section 5-1.1 Marine Transfer Hoses for inspection and maintenance requirements of petroleum fuel marine hoses.

f. Refer to Section 5-4 Marine Loading Arms for inspection and maintenance requirements of petroleum fuel marine loading arms.

g. Refer to Section 3-6.4 Basket Strainers for inspection and maintenance requirements of basket strainers.

h. Refer to Section 3-7 Meters for inspection and maintenance requirements of petroleum fuel meters.

i. Refer to Section 3-8.2 Positive Displacement Pumps for inspection and maintenance requirements of stripper pumps.

j. Refer to Section 9-1.6 Grounding Systems for inspection and maintenance requirements of grounding systems.

5-3 MARINE ISSUE.

Marine petroleum fuel issue systems are used to transfer petroleum fuel from shore storage systems to marine barges and tankers.

5-3.1 Inspection and Maintenance – Marine Issue.

Major components of marine petroleum fuel issue systems include piping, basket strainers, pumps, meters, marine hoses, marine loading arms, stripper pumps, and grounding systems.

a. Inspect pier or wharf for signs of damage as soon as marine barge or tanker disembarks.
Frequency: After each use

b. Inspect the ground switch used between the marine barge or tanker and the petroleum fuel issue piping.
Frequency: Monthly

c. Inspect mooring lines, cleats, bollards, bitts, pulley blocks, steel wire ropes, and winches. Use UFC 4-150-08 as a guide when conducting inspections. Repair or replace damaged components as required.
Frequency: Monthly

d. Refer to Section 6-1 Pipe Testing and Inspections for inspection and maintenance requirements of petroleum fuel pipelines installed above water surfaces. These pipelines are regulated under 33 CFR 154 and 156. Any additional requirements listed under 33 CFR 154 and 156 must also be followed.

e. Refer to Section 3-6.4 Basket Strainers for inspection and maintenance requirements of basket strainers.

f. Refer to Section 3-8 Pumps for inspection and maintenance requirements of marine loading and stripper pumps.

g. Refer to Section 3-7 Meters for inspection and maintenance requirements of petroleum fuel meters.

h. Refer to Section 5-5.1 Marine Transfer Hoses for inspection and maintenance requirements of petroleum fuel marine hoses.

i. Refer to Section 5-4 Marine Loading Arms for inspection and maintenance requirements of petroleum fuel marine loading arms.

j. Refer to Section 9-1.6 Grounding Systems for inspection and maintenance requirements of grounding systems.

5-4 MARINE LOADING ARMS.

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a. Marine loading arms are used to connect shore based petroleum fuel receipt and issues systems to marine barges and tankers.

b. The swivel, or swing joint attaching the arm to supply piping can be a source of leaks, especially if the arm is subject to stress when attached to the vessel. A program of periodic lubrication and inspection will ensure longer swivel life. If seals leak in spite of lubrication and seal replacement, complete refurbishment of the swivel may be required and the reason for the recurring failures should be identified. Non-lubricated swivels should not be lubricated.

c. A common cause of failure is inadequate support for the arm. Fully stocked kits are available to complete seal or joint renewal. Non-lubricated type swivels must be refurbished or replaced by the original equipment manufacturer.

d. Additional information pertinent to loading arms can be found in UFC 3-460-01 Section 5-8.a.

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5-4.1 Inspection and Maintenance – Marine Loading Arms.

Signs of leaking lubricant or grease contaminated with fuel are clear signs of swivel joint failure. Refer to the manufacturer's operation and maintenance manual for specific maintenance procedures and schedules and follow applicable general maintenance requirements.

a. Check swivel for smooth operation. Check seals for signs of wear and discoloration which may indicate a seal or ball bearing failure.
Frequency: Quarterly

b. Inspect ball bearings when accessible. Rough and/or uneven wear on the surface are indications of swivel joint failure.
Frequency: Annually

c. Conduct pressure test of marine loading arms in accordance with 33 CFR 156.170 *Equipment Tests and Inspections*, Section (f)(1).
Frequency: Annually

5-5 MARINE AND UNDERWATER HOSES.

5-5.1 Marine Transfer Hoses.

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a. Many fueling operations are completed between piers and smaller vessels with non-buoyant hoses because the distance between the vessel and pier is minimal, and because the fuel hose will never touch the water during these fueling operations. Hose sizes can range from 2 to 6 inches (50 to 150 mm) in diameter and range in length from 25 to 100 feet (7.5 to 30.5 meters). These hoses are used to issue and receive petroleum products. The hoses must meet the requirements of 33 CFR 154.500.

b. In some cases floating hoses are used to attach between shore-based facilities and marine barges and tankers. Floatation buoyancy is typically built into the petroleum fuel hose string components, but it can also be externally attached. Hose strings are made up of 30 to 40-foot (9 to 12 m) long sections of individual hose lengths bolted together by steel flanges built into the ends of each floating hose. Each hose connection should have a drain connection on the marine barge or tanker side of the block valve.

c. Floating petroleum fuel hose diameters are standardized, in accordance with Oil Companies International Marine Forum (OCIMF) best practices, and range from 6-inch (DN150) to a maximum of 24-inch (DN600) internal diameter. The hose string length is determined by mooring equipment, marine barge or tanker size, and manifold location. Floating petroleum fuel hose strings will typically end in a blind flange that must be removed by the marine barge or tanker crew before the petroleum fuel hose can be connected to the marine barge or tanker. Floating petroleum fuel hose strings include a pick-up line which is attached to the marine barge or tanker end of the petroleum fuel hose. This pick-up line is used to bring the petroleum fuel hose onto the marine barge or tanker and is connected to a marker buoy which makes the free end of the petroleum fuel hose pick-up line easier to locate.

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5-5.1.1 Inspection and Maintenance – Marine Transfer Hoses.

a. Visually inspect petroleum fuel marine transfer hoses. Transfer hoses must have no loose covers, kinks, bulges, soft spots, and no gouges, cuts or slashes that penetrate the hose reinforcement. Hoses must also have no external deterioration.
Frequency: Before each use

b. Visually survey petroleum fuel marine hoses. Observe the general condition and look for fluid puddles, fine mists, physical damage such as jacket abrasion or deformation, and deteriorated joints. Use sense of smell to detect petroleum vapor. Look for improper hose handling that may overstress the hose by stretching, relative movement, or kinking.
Frequency: During each use

c. Refer to Appendix D, Section D-2.2 Marine and Underwater Transfer Hose Hydrostatic Test for marine transfer hose hydrostatic testing requirements and procedures.
Frequency: Annually or not less than 30 days prior to the first transfer conducted past one year from the date of the last test and inspection.

5-5.2 Underwater Hoses.

Underwater petroleum fuel hoses are similar in construction to petroleum fuel marine transfer hoses but may have additional chafing gear covering some sections. External reinforcements may also be added to prevent kinking due to tidal motion when they are used in petroleum fuel transfer service in offshore moorings. Experience has shown that some sections of the underwater hose consistently wear more than others. Hose life can be extended by periodically changing the position of individual sections in the hose string. Ensure that the proper stainless steel bolts and Monel nuts are used to reassemble the string.

5-5.2.1 Inspection and Maintenance – Underwater Hoses.

It is recommended that, when equipment is available to lift buoys, anchors, chains, and other offshore mooring equipment, an effort be made to schedule hose inspection and testing concurrently, regardless of the duration since the last test. Work on the mooring systems can cause additional strain and wear on hoses.

a. Refer to Appendix D, Section D-2.2 Marine and Underwater Transfer Hose Hydrostatic Test for underwater hose hydrostatic testing requirements and procedures.
Frequency: Annually or not less than 30 days prior to the first transfer conducted past one year from the date of the last test and inspection.

5-6 DISPENSERS.

Dispenser systems located at marine facilities are similar to military service station type dispensers and typically include hose reels to refuel various types of watercraft. Hoses are routinely pulled across concrete and other abrasive surfaces that can cause damage to hoses. Automatic nozzle shut-off clips must be removed from marine fuel dispensing nozzles.

5-6.1 Inspection and Maintenance – Dispensers.

a. Refer to Section 7-2 Dispenser Nozzles for inspections and maintenance of requirements of dispenser nozzles.

b. Refer to Section 7-3 Dispenser Hoses for inspections and maintenance requirements of dispenser hoses.

c. Refer to Section 7-4 Breakaways for inspections and maintenance requirements of dispenser hose breakaways.

d. Refer to Section 7-5 Swivels for inspections and maintenance requirements of dispenser hose swivels.

e. Refer to Section 7-8 Dispenser Meters for inspections and maintenance requirements of dispenser meters.

f. Refer to Section 7-9 Dispenser Filters for inspections and maintenance requirements of dispenser filters.

g. Refer to Section 7-10 Dispenser Strainers for inspections and maintenance requirements of dispenser strainers.

h. Refer to Section 7-12 Emergency Shutoff Valves for inspections and maintenance requirements of emergency shutoff valves installed in the petroleum fuel supply line at the base of dispensers.

i. Refer to Section 7-15 Dispenser Pumps for inspections and maintenance requirements of dispenser pumps.

5-7 OFFSHORE MOORING SYSTEMS.

Offshore moorings designed in accordance with UFC 4-159-03 are located out of navigable shipping lanes with necessary anchorage suitable for holding specific capacity marine tankers. Typically a single steel pipeline connected to the shore petroleum fuel storage system extends underwater from the shore to the area of the mooring. This pipeline is used to handle all petroleum fuel products. Underwater petroleum fuel hose, flanged to the underwater pipeline provides a flexible connection to marine tankers. The mooring anchors installed for marine tankers are marked with buoys. The underwater petroleum fuel hose is equipped with a spool piece and a chain at the marine tanker end. The chain is connected to a marker buoy and is used to lift the petroleum fuel hose from the sea bottom for connection to the marine tanker.

Inspection and maintenance of offshore mooring systems focuses on buoy coatings, anchors, and chains. Cathodic protection systems are used to protect the anchors and chains and require routine inspection and replacement of sacrificial anodes.

5-7.1 Single Point Mooring Systems.

Single point moorings (monobuoys) consist of a single buoy. The buoy is attached to marine tankers by means of bow lines or anchor chain. The ship is free to swing 360 degrees around the buoy as it responds to environmental loading conditions (weather vane). This type of mooring may use either a riser or non-riser buoy system.

A diesel engine-driven air compressor is located in the interior of the buoy; its purpose is to provide compressed air displacement for the float/sink hoses. The product hoses are packed at all times, either with petroleum product or water, depending on the operational requirements.

5-7.1.1 Inspection and Maintenance – Single Point Mooring Systems.

2\ Refer to UFC 4-159-03 for frequencies of inspection and additional maintenance required for mooring systems. /**2**/ Required underwater inspections and testing must be performed by experienced professional divers.

a. Inspect and, if necessary, repair or replace all mooring hawsers or lines, deck hose, chain, chair stoppers, flange adaptors, gaskets or other gear used in mooring the marine tanker and in connecting hoses.
Frequency: Monthly

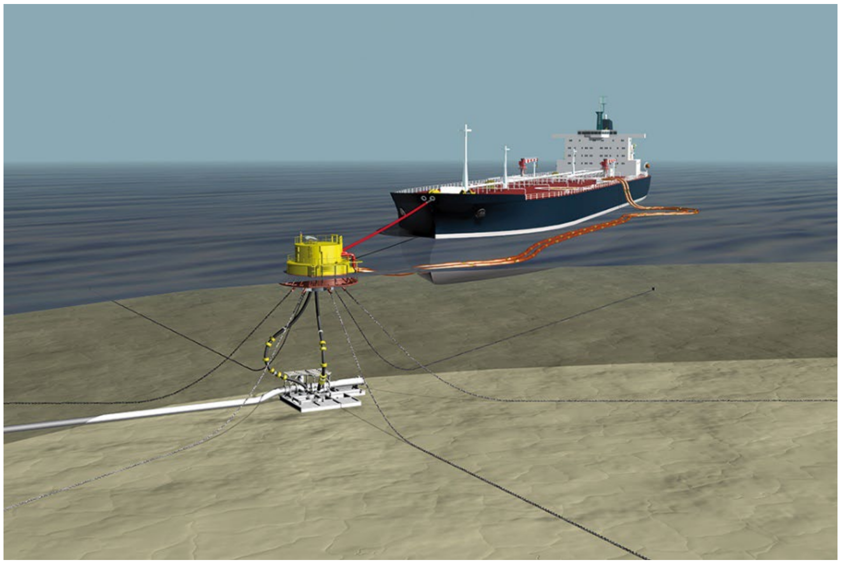
b. Inspect air-compressor for proper operation.
Frequency: Annually

c. **2**\\ Inspect navigation aids and mooring buoys in accordance with UFC 4-159-03 for evidence of damage and possible movement or dragging by marine tankers, current or winds. /**2**/
Frequency: Annually

d. Divers must conduct underwater inspections of mooring chains, shackles and anchors attaching buoys to bay/harbor floors.
Frequency: Annually

e. Conduct overhaul of single point mooring buoys every 3 to 5 years. Single point mooring buoys must be brought ashore for repair in these instances.
Frequency: Every 5 years

Figure 5-1 Single Point Mooring System



5-7.2 Multi-point Mooring Systems.

Multi-point moorings are designed for use by a single ship secured by its bow and stern lines to buoy systems. This mooring is normally installed near a shoreline, parallel to the direction of water current, and outside the normal navigational channel. Riser buoy systems are normally used in this type of mooring.

5-7.2.1 Inspection and Maintenance – Multi-point Mooring Systems.

2\\ Refer to UFC 4-159-03 for frequencies of inspection and additional maintenance required for mooring systems. /**2**/ Required underwater inspections and testing must be performed by experienced professional divers.

a. Inspect and, if necessary, repair or replace all mooring hawsers or lines, deck hose, chain, chair stoppers, flange adaptors, gaskets or other deck gear used in mooring the marine tanker and in connecting underwater hoses.
Frequency: Monthly

b. Inspect navigation aids and mooring buoys, in accordance with NAVFAC MO- for evidence of damage and possible movement or dragging by marine tanker, current or winds.
Frequency: Annually

c. Divers must conduct underwater inspections of mooring chains, shackles and anchors attaching buoys to bay/harbor floors.
Frequency: Annually

5-8 SUBMERGED PIPING SYSTEMS.

Submerged piping is used to connect shore based petroleum fuel systems to mooring locations of marine tankers. A hose is typically installed to connect the submerged piping to the moored marine tanker.

5-8.1 Inspection and Maintenance – Submerged Pipelines.

Required underwater inspections and testing must be performed by experienced professional divers.

a. Inspect water above submerged pipelines and their seaward end for tell-tale petroleum fuel slicks indicating leakage from pipes or underwater hoses.
Frequency: Weekly

b. If equipped, electrically check the cathodic protection rectifier for proper performance.
Frequency: Six times each calendar year with intervals not exceeding 2½ months.

c. Divers must inspect submerged pipe and hoses for signs of incipient failure or indications of rapid wear of parts subject to wave motion or abrasion on the ocean floor.
Frequency: Semi-annually

d. Conduct annual pipe test as specified in Appendix G – Petroleum Fuel Pipeline Pressure testing Guidelines and Criteria. Testing requirements of marine pipelines are regulated under 33 CFR 154 and 156, particularly 33 CFR 156 Section 170.
Frequency: Annually

e. Conduct cathodic protection tests on the protected pipeline as specified in Section 9.2.1 Cathodic Protection at least once each calendar year with

intervals not exceeding 15 months between tests from consecutive years.
Frequency: Annually

5-9 BOOM REELS.

Boom reels are hydraulic or manually operated. They are used to store floating spill containment booms that are used to surround marine barges and tankers and contain spills.

5-9.1 Inspection and Maintenance – Boom Reels.

a. Visually inspect hydraulic drives and hose connections for leaks.
Frequency: Quarterly

b. Grease bearings.
Frequency: Quarterly

c. Inspected boom reel for signs of corrosion. Inspect breaking system and ensure it is in good working order.
Frequency: Quarterly

d. Inspect boom for wear, rips, and tears. Repair or replace as required to ensure containment of petroleum fuel in the event of a spill.
Frequency: Annually

CHAPTER 6 PIPING SYSTEMS

6-1 PIPE TESTING AND INSPECTIONS.

This chapter includes information on testing and inspection requirements of pipelines and piping.

6-1.1 On-Base Pipelines.

On-base pipelines are routed exclusively within an Installation's property and do not pass outside of Installation boundaries. The pipelines are not regulated by the Department of Transportation (DOT). Where more than one type of petroleum fuel is transferred, separate pipelines are typically provided for each type of petroleum fuel. These pipelines include transfer lines between petroleum fuel truck and rail offloading and storage tanks, pump houses and petroleum fuel truck and rail loading systems, transfer lines between storage areas, and hydrant supply and return lines.

6-1.1.1 Inspection and Maintenance – On-Base Pipelines.

a. Conduct petroleum fuel pipeline visual Inspection of aboveground piping in accordance with Section 6-1.5 Pipeline Visual Inspection.
Frequency: Monthly

b. Conduct line walk in areas of petroleum fuel piping in accordance with Section 6-1.6 Line Walk.
Frequency: Conduct during transfer operations, or monthly, at a minimum.

c. Conduct annual test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.
Frequency: Annually

d. Conduct cathodic protection tests as specified in Section 9.2.1 Cathodic Protection on protected petroleum fuel pipelines at least once each calendar year, but with intervals not exceeding 15 months.
Frequency: Annually

e. Conduct five year test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.
Frequency: Every 5 years

f. Conduct petroleum fuel pipeline API 570 inspection in accordance with Section 6-1.9 API 570 Inspections.
Frequency: Every 5 or 10 years depending on API class piping or in accordance with Pipeline Integrity Management Plan (PIMP).

g. Conduct petroleum fuel pipeline cleaning in accordance with Section 6-2 General Pipeline Cleaning.
Frequency: As required to ensure fuel quality.

6-1.2 Inter-Terminal Pipelines.

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a. Inter-terminal petroleum fuel pipelines which cross outside of an Installation's property for more than one mile and are operated by non-government personnel are regulated by the DOT. Operation and maintenance of DOT regulated pipelines must comply with 49 CFR 195. Inter-terminal pipelines which cross outside of an Installation's property for more than one mile and are operated by government personnel are currently exempt from 49 CFR 195 requirements. Although government operated pipelines are not subject to DOT regulations, certain states may regulate or force an activity to adhere to a standard such as 49 CFR 195.

b. Inter-terminal pipelines supplying petroleum fuels to DoD petroleum fuel facilities may be dedicated to serving a single facility or may handle several types or grades of petroleum fuel for more than one user. These pipelines may be owned, operated, and maintained by DoD or commercial agencies; however, only those operated by contractors or non-government entities are potentially DOT regulated.

c. Inter-terminal pipelines owned, operated, and maintained by commercial agencies delivering petroleum fuel to DoD petroleum fuel facilities may be constructed on DoD property in order for the inter-terminal pipelines to reach the DoD petroleum fuel facilities located on DoD property. Responsibility of commercial agencies for maintaining inter-terminal pipelines owned and operated by commercial agencies usually terminates at the custody transfer point located on the DoD Installation. The custody transfer point is typically located close to the location where the commercial inter-terminal pipeline crosses into the Installation and is usually demarcated by a custody transfer valve.

d. In some cases supplier and operator contracts allow the responsible Installation activity to perform emergency maintenance on on-base segments of commercial inter-terminal pipelines, if necessary, to protect against environmental damage to public property or meet emergency wartime mission requirements.

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6-1.2.1 Inspection and Maintenance – Non-DOT Regulated Inter-Terminal Pipelines (Operated by DoD).

a. Conduct petroleum fuel pipeline volume check in accordance with Section 6-1.8 Volume Check.
Frequency: Monthly

b. Conduct line patrol in areas of underground petroleum fuel pipeline in accordance with Section 6-1.7 Line Patrol.
Frequency: Annually

c. Government operated inter-terminal petroleum fuel pipelines must follow the maintenance requirements listed in Section 6-1.1.1 On-Base Pipelines.

6-1.2.2 Inspection and Maintenance – DOT Regulated Inter-Terminal Pipelines.

DOT regulated petroleum fuel pipelines must be maintained and operated in accordance with the provisions of 49 CFR 195. This includes but is not limited to O&M Plans, Integrity Management Plans, and Operator Qualification Plans, which are outside the scope of this document.

6-1.3 Aboveground Piping.

Aboveground piping includes visible piping installed outside and inside of buildings. This piping is supported on aboveground pipe supports or in open trenches or trenches with removable covers.

6-1.3.1 Inspection and Maintenance – Aboveground Piping.

a. Conduct petroleum fuel piping visual Inspection in accordance with Section 6-1.5 Pipeline Visual Inspection.
Frequency: Weekly

b. Conduct petroleum fuel piping annual test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.
Frequency: Annually

c. Conduct petroleum fuel piping API 570 inspection in accordance with Section 6-1.9 API 570 Inspections.
Frequency: Every 5 or 10 years depending on API class piping or in accordance with Pipeline Integrity Management Plan (PIMP).

d. Conduct cleaning of petroleum fuel piping in accordance with Section 6-2 General Pipeline Cleaning.
Frequency: As required to ensure fuel quality.

6-1.4 Double-Wall Piping.

Double-wall piping is required by some states or host nations. In the event that the carrier pipe develops a leak, there are techniques for detecting the presence of fuel in the interstitial space of the double-wall piping. See Section 6-13.1 General Inspection of Release Detection Systems for more information on systems used for monitoring the interstitial space.

6-1.4.1 Inspection and Maintenance – Double-Wall Piping.

a. Conduct petroleum fuel pipeline visual Inspection of aboveground piping in accordance with Section 6-1.5 Pipeline Visual Inspection.
Frequency: Monthly

b. Conduct line walk in areas of petroleum fuel piping in accordance with Section 6-1.6 Line Walk.
Frequency: Conduct during transfer operations, or monthly, at a minimum.

c. Conduct annual carrier pipe test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.
Frequency: Annually

d. Conduct cathodic protection tests as specified in Section 9.2.1 Cathodic Protection on protected petroleum fuel pipelines at least once each calendar year, but with intervals not exceeding 15 months.
Frequency: Annually

e. Conduct containment pipe test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.
Frequency: Every three years

f. Conduct petroleum fuel pipeline API 570 inspection in accordance with Section 6-1.9 API 570 Inspections.
Frequency: Every 5 or 10 years depending on API class piping or in accordance with Pipeline Integrity Management Plan (PIMP).

g. Conduct petroleum fuel pipeline cleaning in accordance with Section 6-2 General Pipeline Cleaning.
Frequency: As required to ensure fuel quality.

6-1.5 Pipe Visual Inspection.

Visually inspect aboveground petroleum fuel piping for leaks (e.g., drips, mist spray). Repair identified leaks. Some leaks can be repaired by replacing or repairing mechanical components. Other leaks will require welding of the pipe for permanent repair. Approval through local work management processes is required before beginning welding or hot work in connection with repairs. The following list is a baseline for petroleum fuel pipeline operability:

a. Visually inspect piping and coatings for signs of corrosion or damage. Schedule maintenance or repair as necessary.

b. Inspect flanges and gaskets.

c. Inspect pipe supports to ensure pipe is properly supported without binding, misalignment, or tipping. Ensure insulating or sliding material between the supports and piping is securely fastened and not missing or deteriorated. Ensure contact points between support and pipe are not corroded.

d. Inspect pipe support anchor bolts and grout for signs of cracking, corrosion, or missing fasteners. Repair as required.

e. Visually inspect expansion bellows for cracks, tears, leaks, or misalignments. Expansion bellows cannot be repaired and must be replaced if damaged.

f. Inspect braided hoses and vibration dampeners for wear and damage to braiding. Also check for compression or tension that could indicate improper loading on the hose or dampener.

g. Visually inspect grounding wires and connection points between pipes and grounding rods.

6-1.6 Line Walk.

Line walkers or vehicle patrols must make detailed inspections of area conditions around aboveground petroleum fuel piping and above underground petroleum fuel piping. Inspections must include general condition of the right-of-way, valves in remote areas, and conditions that may indicate a leak. Leaks in underground pipelines can be detected by fuel surfacing on the ground, fuel runoff in storm drainage systems, fuel in underground pits or manholes, dead vegetation, or the continuous odor of fuel in a particular area. Investigate suspicious circumstances.

Inspections of DOT regulated petroleum fuel pipelines must be in accordance with 49 CFR 195, Subpart F, Section 195.402 , which requires inspections of right-of-way conditions at intervals not exceeding 3 weeks, but at least 26 times each calendar year.

6-1.7 Line Patrol.

Line patrols should occur on sections of petroleum fuel pipelines not easily accessible by vehicle or foot. Line patrols are conducted by observations from aircraft. Line patrols should be flown at an elevation of less than 500 feet (152 meters) from the ground and at speeds from 65 to 80 miles per hour (105 to 130 kilometers per hour). Petroleum fuel pipelines must be marked with posts or signs at 1 mile (1.6 kilometer) intervals and at bends. During line patrols the pilot acts as an observer who checks for unnatural changes in vegetation color and oil slicks on lakes and streams, which are evidence of leaking petroleum fuel pipelines; area construction work (e.g., roads, sewers) that could cross and possibly damage the petroleum fuel pipeline; and the overall condition of the right-of-way.

6-1.8 Volume Check.

Compare records kept on volume and temperature of petroleum fuel that has passed through each pumping station. Differences in meter readings not accounted for by temperature corrections between two stations may indicate a leak, but could also indicate theft, out-of-calibration meters, faulty temperature sensors, or human error.

6-1.9 API 570 Inspections.

Periodic inspections by an API 570 certified inspector must provide documentation of remaining pipeline life; recommended repairs; and/or need for replacement. Intervals for inspection are based on the class of piping and corrosion rate of the piping.

- Class 1: Over water – 5 years maximum.
- Class 2: Natural Gas – 10 years maximum.
- Class 3: Aboveground and underground petroleum fuel piping – 10 years maximum.

6-2 GENERAL PIPELINE CLEANING.

Petroleum fuel pipelines designed as suitable for pigging may be cleaned using various cleaning pigs. Intervals between cleanings are based on site conditions and the type of petroleum fuel. A drop in the flow rate; the continual presence of dirt, rust, or particulate in basket strainers; and/or shortened filter life may indicate a need for cleaning.

6-2.1 Cleaning Operations.

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a. Decide on the cleaning tool best suited for the pipe system and operation. For most petroleum fuel applications, a foam pig may be sufficient. For heavier petroleum fuel applications, or extensive cleaning requirements, brush and magnet pigs may be required. Verify operational specifications to be sure the pig will pass through all valves and bends.

b. Keep accurate time records of run start and quantity of petroleum fuel pumped to trace pig progress and determine its arrival at the receiving station. Meters must be bypassed during cleaning operations to avoid fouling. Cleaning pigs must be run at the manufacturer's suggested minimum velocity with no shutdowns while the pig is in the line. Shutdowns cause debris to settle in front of the pig and may cause it to become stuck.

c. Pigging operations may produce debris in the pipe system and extensive flushing and filtering should be performed once a pigging operation is completed. Flushing and filtering should be continued until all debris is removed from the pipe system.

6-3 PIPE SYSTEM REPAIRS.

a. Temporary repairs are defined as repairs made to piping systems that restore sufficient integrity to continue safe operation until permanent repairs can be scheduled and accomplished. The military service-specific SCP must be notified of temporary repairs and must have jurisdiction on how long a temporary repair may stay in place. The military service-specific SCP may require increased inspection while temporary repairs are in place.

b. Permanent repairs generally require planning and potentially welding or patching of the pipeline. Approvals through local work management processes are required before beginning welding or hot work in connection with repairs. All welding pipe repairs must meet the requirements of UFGS **\1**33 52 23.15**/1/** including documentation of welding procedures and welder qualifications before welding repairs are conducted.

c. Pipeline failures can create a welding safety hazard due to fuel-soaked soil in the area of the leak. Temporary pipeline repairs can be accomplished by clamping a steel plate of the same curvature as the pipe over the damaged area (i.e., clockspring repair) and using petroleum-resistant rubber, epoxy compounds, or gaskets for a seal. Once a temporary repair is in place, the area should be cleared of hazards. Permanent repairs may require replacement of failed sections.

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6-3.1 Pits and Small Leaks.

Pitting on pipeline exterior surface is caused by corrosion and can lead to pipeline failure. Pitting can be repaired in a number of ways, but severe pitting must be repaired by either a patch plate or pipe replacement. In some cases, a full encirclement sleeve should be considered. All pipeline welded repairs must meet the requirements of UFGS **\1** 33 52 23.15 **/1/** including documentation of welding procedures and welder qualifications before welding repairs are conducted.

6-4 PIPELINE INTEGRITY MANAGEMENT PLAN.

Each petroleum fuel pipeline facility should have a Pipeline Integrity Management Plan (PIMP) to assist with and guide pipeline integrity maintenance. PIMPs improve the integrity management of piping systems and help prevent leaks or pipeline failures. The plans are developed based on the principles of API Standard 570 Federal, state, host nation, and local codes and regulations.

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6-4.1 Certified Pipeline Inventory.

DLA-E requires that a fuel system volume be calculated using as-constructed pipe lengths, internal diameters, fittings, and components of a system; i.e., all items containing fuel with the exception of tanks. If the inventory does not exist, record and provide a detailed list with sizes, lengths, quantity, and volumes for each of the systems inspected or repaired. **/1/**

6-5 FLANGE GASKETS.

When installing a gasket, measure the gap between the flanges to ensure consistent dimensions around the circumference of the connection. The faces of each flange must be inspected for scratches, burs, or other signs of damage before gaskets are installed. Pipe can expand and contract during temperature changes and gaskets should be replaced during consistent temperature conditions.

6-6 VALVES.

6-6.1 Valve Tagging.

\1 Mark valves, pumps, meters, and other system components with easily discernible painted numbers or numbered corrosion-resistant metal or plastic tags attached with a suitable fastener. Ensure numbers correspond to those on the schematic flow diagrams and other drawings for the installation. **/1/**

6-6.2 Manual Valves.

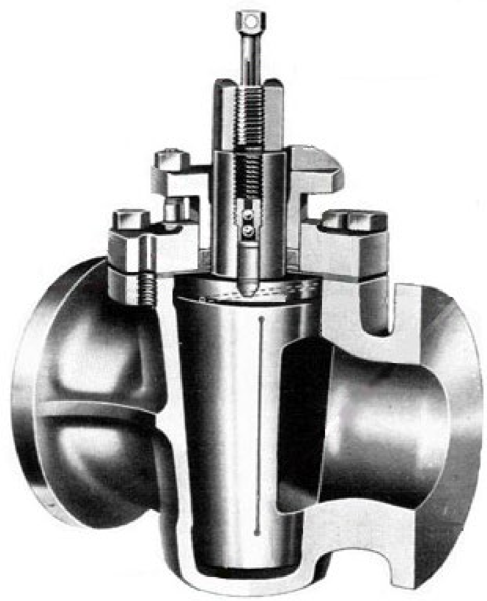
Manual valves are used to isolate portions of fuel systems and equipment, to control flow, or to direct the flow of fuel to a desired location.

6-6.2.1 Plug Valves – Lubricated.

Lubricated plug valves are not allowed in aircraft petroleum fuel systems and must be replaced. If lubricated plug valves are installed in other systems and cannot be replaced, they must be inspected regularly for proper operation.

Lubricated plug valves require lubrication and occasional flushing to keep them working properly. The valves require lubrication through a grease fitting on top of the valve that forces grease into feed channels within the valve plug. The plug is lubricated so that it passes freely over the seats without binding.

Figure 6-1 Lubricated Plug Valve



6-6.2.1.1 Inspection and Maintenance – Plug Valves – Lubricated.

a. Open and close valve to check for ease of operation.
Frequency Quarterly

b. Lubricate valve operator stems and grease fittings.
Frequency: Semi-annually

c. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Semi-annually

6-6.2.2 Plug Valves – Non-lubricated.

Non-lubricated plug valves use cylindrical or conically shaped plugs that are rotated within the valve body. They are used as block valves, or where shut-off is required in various parts of the system. Plug valves can be either reduced port or full port depending on the location.

6-6.2.2.1 Inspection and Maintenance – Plug Valves – Non-Lubricated.

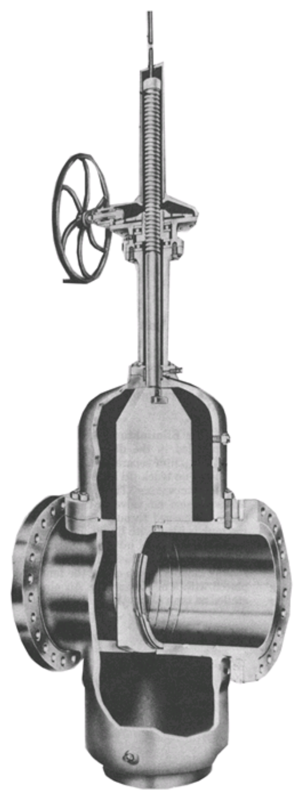
a. Open and close valve to check for ease of operation. Adjust or replace packing as needed.
Frequency Quarterly

b. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Semi-annually

6-6.2.3 Gate Valves.

A gate valve is equipped with a round or rectangular wedge that is lifted out of the path of fluid to allow flow, and lowered back to its seat to block flow. Gate valves are not designed for throttling. They are designed to be either fully open or fully closed. Gate valves are either of the rising stem type, to visually see that the gate is opening or closing as the stem rises and falls; or of the non-rising stem type, where the hand wheel is fixed and the stem threads are internal to the valve. Rising stem gate valves are preferred in order to keep the stem threads out of the fluid. Gate valves should be equipped with a stem position indicator to indicate the open or closed position. Gate valves are equipped with a bonnet to ensure leak-proof closure of the valve body and are equipped with a valve stem packing tightening mechanism.

Figure 6-2 Gate Valve



6-6.2.3.1 Inspection and Maintenance – Gate Valves.

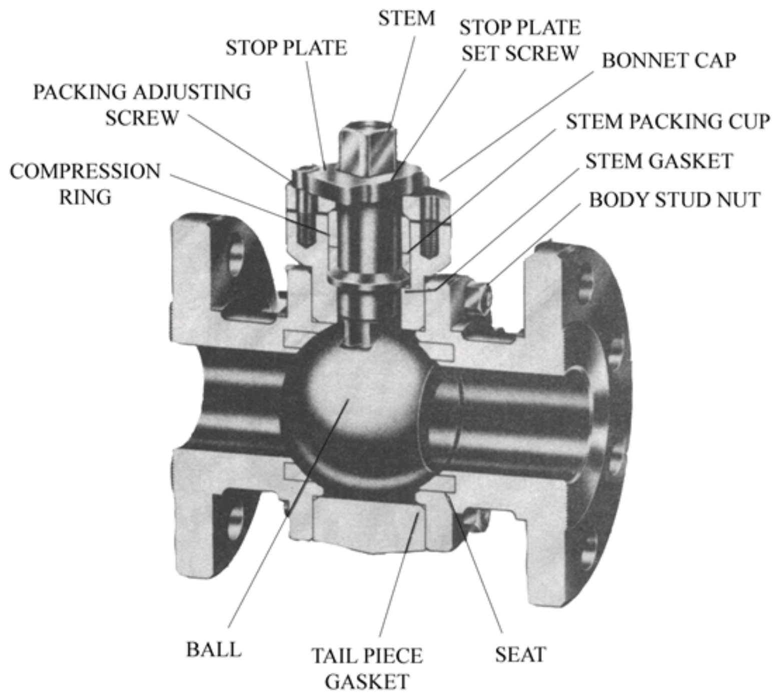
a. Open and close valve to check for ease of operation. Adjust or replace packing as needed.
Frequency Quarterly

b. Lubricate valve operator stem.
Frequency: Semi-annually

c. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Semi-annually

6-6.2.4 Ball Valves.

Figure 6-3 Ball Valve



Ball valves are used as quick shut-off (block) valves in applications such as piping to hydrant outlets, between pumps and headers, and between pumps and filter separators. They are quarter turn, 0 to 90 degree, open to close type valves consisting of a solid metal ball with either reduced or full port, usually of stainless steel, and tetraflouroethylene (TFE) or fluoroelastetomer (FKM, commonly referred to as Viton) seats, body seals and stem seals. When the valve ball is in its open position (0 degrees) flow is through the open port. When the valve is in its closed position the port is 90 degrees perpendicular to the flow, allowing no flow through the valve. The valves are lever operated or gear operated, depending on the size.

6-6.2.4.1 Inspection and Maintenance – Ball Valves.

a. Open and close valve to check for ease of operation.
Frequency Quarterly

b. Lubricate overhead valve chain operator gears.
Frequency: Quarterly

c. Adjust packing per manufacturer's specifications as needed.
Frequency: Quarterly

d. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Quarterly

e. Refer to Section 6-6.2.10 Manual Valve Gear Operators for inspection and maintenance of gear operators if equipped.

6-6.2.5 Double Block and Bleed Valves.

Double block and bleed (DBB) valves provide positive shutoff that can be verified by opening the cavity between the two blocks. They are used as positive isolation valves around tanks and in piping runs. They comply with API Specification 6D. Refer to UFC 3-460-01 for recommended locations.

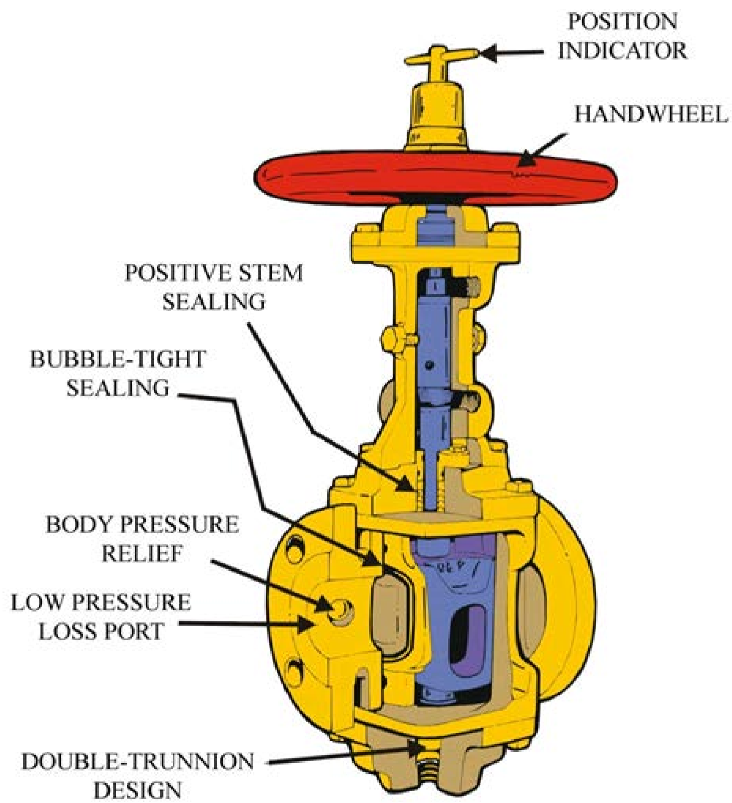
DBB valves can be plug, ball, or gate type, and reduced or full port depending on the location. Typically reduced port plug type DBB valves are used around tanks and in piping systems that do not require periodic pigging. Full port ball DBB valves are required in pipelines that require pigging.

a. Plug type DBB valves are equipped with non-lubricated, resilient, double-seated, trunnion-mounted, tapered lift plugs capable of two-way shutoff. The tapered plug is usually of ductile iron with chrome or nickel plating with the plug supported on upper and lower trunnions. Sealing slips are usually of steel or ductile iron with Viton seals which are held in place by dovetail connections. The sealing slips are removable and replaceable from the bottom of the valve while the valve is mounted in the pipeline in the open position. The valve hand wheel operates the valve from fully closed to fully open by first lifting the plug off the seats and then turning the plug so that the valve is in the fully open position.

b. Ball type DBB valves are equipped with non-lubricated, trunnion-mounted independent spring and hydraulically actuated, floating, single piston effect, self-relieving seat rings with bi-directional sealing. The ball is solid with a flow through conduit opening, suitable for the passage of pipeline pigs. The stems are anti-static, blow-out-proof design with O-ring seals and are provided with an emergency sealant injection fitting. The valves are 3-piece, bolted body design with flanged connections and are equipped with body drain, bleed valve and vent fitting.

c. Gate type DBB valves, when applicable per UFC 3-460-01 are non-lubricated with a bolted bonnet using an expanding gate which does not require pressure to produce a proper two-way seal. These valves are intended for fully open or fully closed operation and must not be used to throttle. The gate segments are usually of ductile iron with chrome or nickel plating. The hand wheel operates the valve from fully open to fully closed by moving the expanding gate into position then wedging the segments against the seats. The valves use flanged connections and are equipped with a body drain, bleed valve and vent fitting.

Figure 6-4 Double Block and Bleed Plug Valve



6-6.2.5.1 Inspection and Maintenance – DBB Valves.

Refer to valve manufacturer's operation and maintenance manual for disassembly, parts, additional maintenance for specific models, reassembly parts, and repair of DBB valves.

a. Open and close valve to check for ease of operation.
Frequency Quarterly

b. Lubricate overhead valve chain operator gears if equipped.
Frequency: Quarterly

c. Adjust packing per manufacturer's specifications as needed.
Frequency: Quarterly

d. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Quarterly

e. Operate the body cavity drain when the valve is in the closed position to ensure that the valve is closing properly.
Frequency: Quarterly

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f. Keep the valve operator housing full of lubricant to displace and prevent moisture from accumulating and freezing, in accordance with manufacturer's recommendations.
Frequency: Semi-annually

g. Remove bottom drain plug and drain valve.
Frequency: Annually

h. Refer to Section 6-6.2.10 Manual Valve Gear Operators for inspection and maintenance of gear operators if equipped.

i. Some double block and bleed valves are equipped with integrated pressure/thermal relief valves. Refer to Section 6-6.3 Thermal and Pressure Relief Valves for inspection and maintenance requirements of pressure/thermal relief valves

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6-6.2.6 Butterfly Valves.

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a. UFC 3-460-01 does not allow butterfly valves to be used as isolation valves in the construction of new petroleum fuel systems, as they are not considered positive shut-off valves. However, UFC 3-460-01 does specify that high-performance wafer trunnion butterfly type valves with synthetic seating material and a metal-to-metal seat that comply with API Std 607, equipped with a self-closing mechanism and a fusible link, must be used in two locations on Army and Navy projects. These locations are the inlet to truck fillstands, and on supply and return risers at aircraft direct fueling stations.

b. A butterfly valve is a short face to face valve incorporating a trunnion mounted flat disc that when closed is held tight against a synthetic seating material. Butterfly valves meeting the requirements of API Std 607 include a metal-to-metal seat as a back-up to the synthetic seat which enables the valve to continue to block flow in the closed position if the synthetic seat is burned out in a fire.

c. Butterfly valves are available in flanged, wafer, and lug style configurations. The wafer configuration does not include flanges on the valve body and fits between mating flanges installed in piping. A wafer style valve is centered inside the flange bolts of mating flanges when installed. Lug style valves include threaded lug bolts holes on the body of the valve. A lug style valve can be bolted to mating flanges from either side. For example, a lug style butterfly valve can be used at the end of a pipeline on a single mating pipe flange with the other end open, such as on a drain line.

d. Existing butterfly valves installed in petroleum fuel systems must be inspected and maintained.

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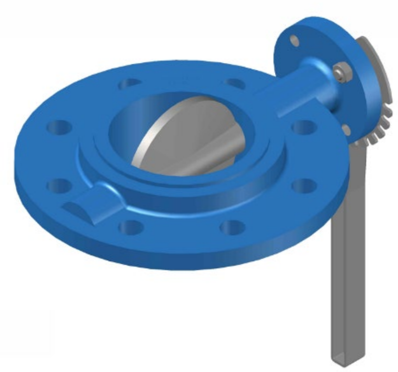
6-6.2.6.1 Inspection and Maintenance – Butterfly Valves.

a. Open and close valve to check for ease of operation. Ensure that lever operators and locking mechanisms are in place and working properly.
Frequency Quarterly

b. Adjust packing per manufacturer's specifications as needed. If butterfly valves are leaking or not shutting off flow, tightening the gland flange to tighten the stem packing or remove the valve from service and replace the seats as necessary.
Frequency: Quarterly

c. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Quarterly

Figure 6-5 Butterfly Valve



6-6.2.7 Globe Valves.

Globe valves are used for isolation and throttling purposes. Hand wheel operated globe valves consist of a disc that is tightened via the hand wheel against a seat. These valves are equipped with a gland seal mechanism to seal the packing against the valve stem. The valve stem packing is accessible through a gland seal on top of the valve, and the valve seat is typically accessible through the valve bonnet.

Figure 6-6 Globe Valve

6-6.2.7.1 Inspection and Maintenance – Globe Valves.

a. Open and close valve to check for ease of operation.
Frequency Quarterly

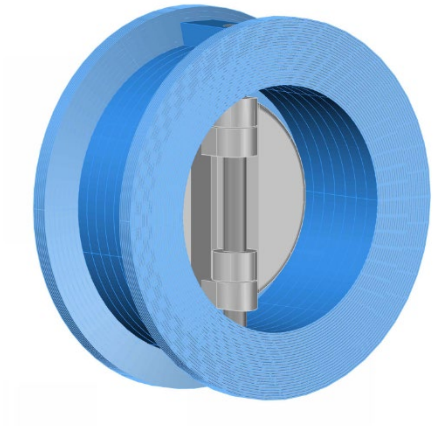
b. Adjust packing per manufacturer's specifications as needed.
Frequency: Quarterly

c. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Quarterly

6-6.2.8 Check Valves.

Check valves are used to prevent backflow through pumps, branch lines, meters, or other locations where reverse flow must be prevented. Check valves may be of the swing disk, globe, dual plate hinged disk, spring-loaded poppet, ball, or diaphragm-actuated types. Check valves require upstream pressure in order for the check valve mechanism to close. Check valves must conform to API Specification 6D.

Figure 6-7 Check Valve



6-6.2.8.1 Inspection and Maintenance – Check Valves.

Refer to the particular check valve manufacturer's operation and maintenance manual for additional maintenance and parts.

a. Use external test lever to make sure the valve is not sticking if equipped. If a check valve is suspected of not checking and cannot be serviced in place, it must be removed from the piping system and serviced in a shop.
Frequency: Quarterly

b. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.
Frequency: Quarterly

6-6.2.9 Line Blanks, Ring Spacers, and Spectacle Blinds.

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a. A line blank is a flat plate designed to fit between two flanges as an isolation device. They are designed to fit between flanges inside the bolt circle with gaskets on either side. For example, blanks may be used at tank connections to isolate a tank from an active system while the tank is being cleaned or inspected. Line blanks are equipped with a handle that protrudes between flange bolts and is visible when it is installed. The handle should be stamped with information about the design of the blank. These are often referred to as blinds or skillets.

b. A ring spacer is a metal ring with gasket seating surfaces with an inner open hole matching the inner diameter of the pipe flanges where it is installed. Ring spacers are used to allow flow in a location where a blank may be installed to block flow. The ring spacer and the associated blank should have the same take-out dimensions and both should fit in the gap installed between the associated pipe flanges. Ring spacers should be equipped with a handle that protrudes between flange bolts and is visible when it is installed. The handle should be stamped with information about the design of the ring spacer.

c. Spectacle blinds include a blank and a ring spacer in one unit. They look like a pair of round eye glasses with one side open to flow and one side blanked off to prevent flow. These allow a line to be drained and the spectacle blind to be flipped to allow flow or provide isolation.

/1/

Figure 6-8 Line Blank

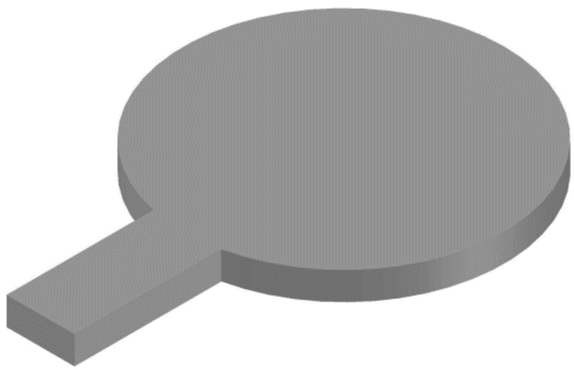


Figure 6-9 Ring Spacer

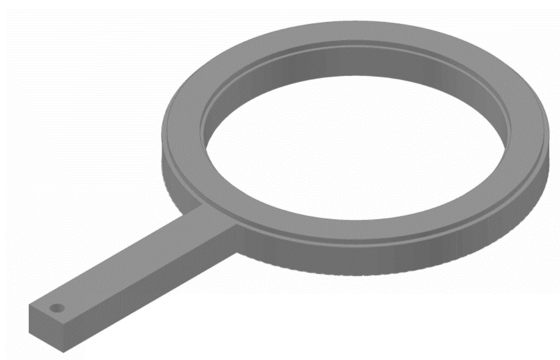
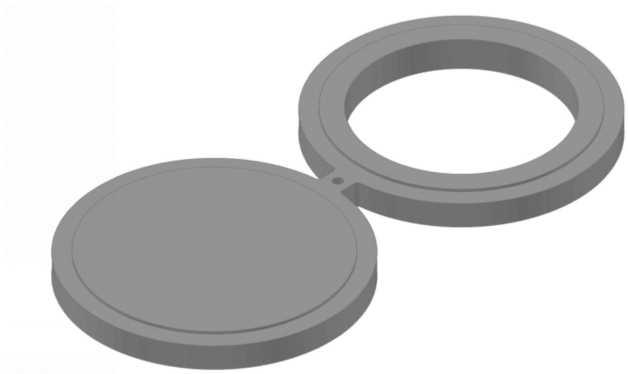


Figure 6-10 Spectacle Blind



6-6.2.9.1 Inspection and Maintenance – Line Blanks, Ring Spacers, and Spectacle Blinds.

a. Inspect exposed side of spectacle blinds. The exposed side must be kept clean and free of corrosion.
Frequency: Quarterly

b. Spectacle blinds should be inspected to ensure they are installed with the correct orientation for the desired flow or no-flow condition.
Frequency: Quarterly

6-6.2.10 Manual Valve Gear Operators.

Gear operators are used to open and close large valves. Gear operators can be installed on most types of large valves.

6-6.2.10.1 Inspection and Maintenance – Manual Valve Gear Operators.

a. Lubricate gear driven operators and check for smooth operation.
Frequency: Quarterly

6-6.3 Thermal and Pressure Relief Valves.

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a. Thermal and pressure relief valves are used to relieve high pressures in piping and system components. Thermal and pressure relief valves are factory set to relieve at a specified pressure and are furnished with certified test paperwork. Pressure relief valves are typically sized for an operating pressure and a flow rate. The flow rate required for a pressure relief valve will be dependent on the system that it is used to protect and may be based on vessel size, vessel surface area, pump operating capacity, or piping flow rate. Thermal relief valves are typically only sized for operating pressure and the flow rate is not specified.

b. Thermal relief valves are used to relieve relatively small volumes of fluid from static or blocked-off systems that may develop high pressures do to thermal heating of the petroleum fuel isolated in piping or a pressure vessel. The coefficient of expansion of liquid petroleum fuel at 60 °F (16 °C) is 0.0005 gallon per gallon per degree F (0.0009 L per L per degree C). The total volume generated in most cases is very small, but the pressure increase resulting from this expansion can equate to as much as 75 psi (515 kPa) for every degree rise in the fuel temperature if not relieved. Therefore, it is absolutely essential that all closed systems have a pressure relief bypass system (thermal release by-pass valve and or check valve). Relieved fuel should be directed to a tank vented to atmosphere.

c. There are two primary types of thermal and pressure relief valves: conventional and balanced type. Conventional spring-loaded relief valves are affected by back pressure. For these valves an increase in downstream back pressure is applied to the seating mechanism and increases the valve opening relief pressure setting. Balanced relief valves are designed so that the downstream back pressure is not applied to the valve seating mechanism and the opening relief pressure setting is not impacted by the back pressure.

d. Thermal and pressure relief valves must be replaced with models that match the type, size, flow rate, and function of valves they are replacing.

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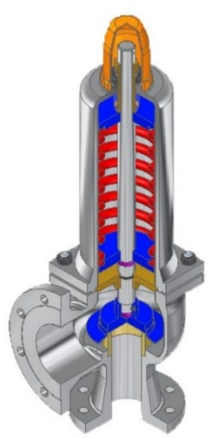
Figure 6-11 Thermal and Pressure Relief Valve



6-6.3.1 Inspection and Maintenance – Thermal and Pressure Relief Valves.

a. Thermal and pressure relief valves must be inspected for signs of leak-by. Inspect relief valves for leaks by visually inspecting downstream flow indicators (if installed) for flow. If no flow indicators are installed listen for

possible leaks. If suspect: isolate and test the relief valve; check opening pressure; and verify re-seating. Malfunctioning valves must be repaired or replaced.
Frequency: Monthly

b. Ensure manual isolation valves installed upstream and downstream of thermal and pressure relief valves are open with valve handles removed, wired open or locked.
Frequency: Monthly

c. Inspect exterior of thermal and pressure relief valves for corrosion. Repaint as required. Information plates attached to thermal and pressure relief valves must not be painted over.
Frequency: Quarterly

d. **\2** Visually inspect and verify thermal and pressure relief valve setting by consulting as-built and historical data. **/2/**
Frequency: Annually

e. Thermal and pressure relief valves must be validated for proper calibration by isolating the valve and using the test connection provided on the piping in conjunction with a hand pump and portable reservoir. The operating pressure must be checked against the set pressure listed on the stamped information plate attached to the valve. The operating pressure must be adjusted to the stamped set pressure if necessary. **\1** If there is no test connection provided, isolate the relief valve and remove the valve to test. If there is no valve isolation or test connection, consider adding these to simplify future testing. **/1/**
Frequency: \2\ Test every five years /2/

6-6.4 Semi-Automatic Valves.

6-6.4.1 Fire Valves.

Fire valves are spring loaded to close in case of a fire to prevent fuel flow. The valves usually incorporate a fusible link that holds the valve open until it melts at 165 °F (74 °C) and allows the valve to close. Fusible link check valves are installed at some locations to close against the flow of fuel when the fusible link melts.

Fire-safe ball valves are sometimes used with a fusible link and a spring actuated closing mechanism.

6-6.4.1.1 Inspection and Maintenance – Fire Valves.

a. Ensure the fusible link mechanism is attached properly to actuate in case of a fire and that it has not been by-passed, blocked, or damaged in any manner. Ensure the fusible link is not filled with debris or paint which could impact operation. **\1** Maintain fusible links per manufacturer's

recommendation. /**1**/
Frequency: Quarterly

b. Check the closing mechanism to ensure that it closes the valve properly.
Frequency: Annually

6-6.4.2 Fusible Link Butterfly Valves.

Fusible link butterfly valves must be fire rated for use on petroleum fuel systems.

6-6.4.2.1 Inspection and Maintenance - Fusible Link Butterfly Valves.

Fusible links are designed to yield under heat generated by a nearby fire. Once the fusible link breaks a spring operated actuator closes the butterfly valve.

a. Ensure the fusible link mechanism is attached properly to actuate in case of a fire and that it has not been by-passed, blocked, or damaged in any manner. Ensure the fusible link is not filled with debris or paint which could impact operation. **1**\ Maintain fusible links per manufacturer's recommendation. /**1**/
Frequency: Quarterly

b. Test the operation of spring closure unit. Ensure that the spring actuator closes the valve and that the valve closes securely against the seat.
Frequency: Annually

c. Refer to Section 6-6.2.6 Butterfly Valves for additional inspection and maintenance requirements of butterfly valves.

6-6.5 Automatic Control Valves.

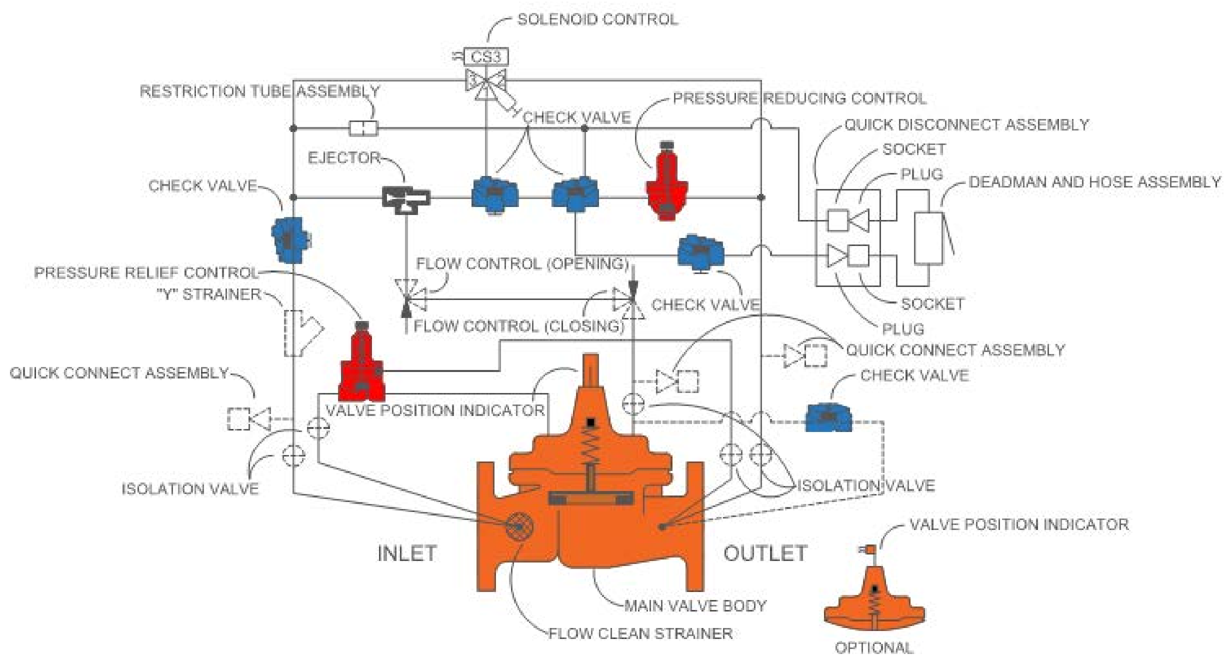
Automatic valves that meet the requirements of UFGS 33 52 43.14 are found throughout fuel systems and are typically of the diaphragm actuated globe type design. Flow through the valve can be either up and over the seat or under the seat and out, depending on the configuration and function of the control valve. The diaphragm is actuated by hydraulic pressure that forces the valve disc against the seat to close the valve or to open or throttle the valve for flow control purposes. An orifice plate is installed with the valve in some instances to control flow based on pressure differential. In other cases a separate float mechanism is installed to actuate the valve, such as in high-level shutoff valves. Almost all fuel control valves are installed in a fail-safe position (i.e., if the main valve diaphragm ruptures the valve will close or open to a safe operating position). Automatic valves can be installed in either a Normally Open (NO) or Normally Closed (NC) position.

Due to the many types of diaphragm-operated automatic valves in service, it is best to consult the particular valves schematic flow diagram and related parts list to understand the parts involved and to maintain and troubleshoot the valve if service is needed.

6-6.5.1 Truck Fill Valves.

Truck fill valves (TFV) meeting the requirements of UFGS 33 52 43.14 are used for petroleum fuel truck loading. TFVs include a deadman feature that is used to start and stop flow through the valve.

Figure 6-12 Truck Fill Valve



6-6.5.1.1 Inspection and Maintenance - Truck Fill Valves.

Deadman control is used to open and close TFVs on fillstands. Deadman controls may be hydraulic or electric. If deadman control fails functional check, remove deadman control from service and repair.

a. Verify TFV maintains 35 psig (240 kPa) nozzle pressure at a flow range of 50 to 600 gpm (3 to 38 lps).
Frequency: Quarterly

b. Verify TFV closes rapidly when outlet pressure exceeds control set point.
Frequency: Quarterly

c. Verify TFV opens when the deadman control lever is pressed.
Frequency: Quarterly

d. Verify TFV closes after the deadman control lever is released.
Frequency: Quarterly

e. If equipped, verify operation of solenoid connected to grounding verification system. Ground verification system should energize solenoid when an acceptable ground is detected by the ground verification unit.
Frequency: Quarterly

f. Systems that have overflow protection systems must be inspected and maintained concurrently with the inspection and maintenance of TFVs.
Frequency: Quarterly

g. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.

6-6.6 Motor Operators.

Motor operators provide electrical actuation of valves for open or closed service.

6-6.6.1 Inspection and Maintenance – Motor Operators.

Refer to the motor operator manufacturer's operation and maintenance manual for particular repair instructions and additional maintenance and parts.

a. Visually inspect motor operators to ensure smooth movement during opening and closing operation and adjust, if necessary, to ensure that they are opening and closing fully. Listen for and investigate unusual noises during operation.
Frequency: Quarterly

b. Lubricate mechanical overrides (if equipped).
Frequency: Quarterly

c. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.

6-7 PRESSURE AND VACUUM INSTRUMENTATION.

6-7.1 Pressure and Pressure/Vacuum Gauges.

Round scale type pressure gauges are used to directly indicate line pressure. In some cases these gauges are liquid filled with a silicon based oil.

6-7.1.1 Inspection and Maintenance – Pressure and Pressure/Vacuum Gauges.

Refer to the manufacturer's operation and maintenance manual for specific calibration procedures.

a. Check operation of gauge. Ensure gauge is indicating pressure of the system.
Frequency: Monthly

b. Clean outside of gauge glass.
Frequency: Quarterly

c. Inspect liquid filled gauges for leakage, refill or replace as needed.
Frequency: Semi-annually

d. Conduct calibration check by comparing readings of the process gauge with the readings of a certified master calibration gauge which has been calibrated within the last year. The process gauge and the master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of gauge is within ±2% of full scale. Calibrate gauge if required.
Frequency: Annually

6-7.2 Differential Pressure Gauges.

Differential pressure gauges are used to measure the difference in pressure between two sensing points.

6-7.2.1 Inspection and Maintenance - Differential Pressure Gauges.

Refer to the manufacturer's operation and maintenance manual for specific calibration procedures.

a. Verify proper operation of differential gauge in accordance with gauge manufacturer's procedures.
Frequency: Monthly

b. Clean outside of gauge glass.
Frequency: Quarterly

c. Conduct calibration check by comparing readings of the differential process gauge with the readings of a certified differential master calibration gauge which has been calibrated within the last year. The differential process gauge and the differential master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of gauge is within ±2% of full scale. Calibrate if required.
Frequency: Annually

d. Some differential pressure gauges have a small gauge protection filter located at the high pressure inlet of the gauge that must be checked and replaced as needed. Filters need to be replaced if the indicator is moving slow or sluggishly inside the sight glass or if the sight glass is dirty. Refer to manufacturer's operation and maintenance manual for filter replacement procedures.
Frequency: Annually for inspections and maximum 5 years of service between filter replacements.

6-7.3 Pressure Transmitters.

Pressure transmitters are used to measure pressure at sensing points. These units transmit a 4 to 20 mA (common in US installations) or 0 to 20 mA (common in European installations) electrical signal to a display or a PLC to indicate pressure.

6-7.3.1 Inspection and Maintenance - Pressure Transmitters.

a. Inspect the exterior of the transmitter enclosure for accumulated oil, dust, and dirt. Clean if required.
Frequency: Quarterly

b. Check that both enclosure caps are fully threaded onto the enclosure, compressing the O-ring between the cap and the enclosure. The O-ring must not be cracked, broken, or otherwise damaged.
Frequency: Quarterly

c. Inspect the display viewing glass for cleanliness and damage. Replace the enclosure cap assembly if the glass is damaged or missing. No accumulation of dust, dirt, or water (condensate) should be present inside the enclosure.
Frequency: Quarterly

d. Inspect transmitter and mounting bracket hardware for tightness. Tighten loose hardware as necessary.
Frequency: Quarterly

e. Inspect for loose, bent, or cracked sensing lines. Replace damaged sensing lines.
Frequency: Quarterly

f. Check operation of transmitter. Ensure transmitter is indicating accurate pressure of the system.
Frequency: Quarterly

g. Bleed sensing lines between the transmitter and the main line to ensure they are clean and free of suspended solids and air.
Frequency: Semi-annually

h. Check that all wire connections inside enclosure are tight.
Frequency: Annually

i. Pressure transmitters (PTs) and pressure indicating transmitters (PITs) must be calibrated mechanically and electrically with test equipment and adjusted if applicable. The presence of air in the sensing line of a pressure transmitter is a common cause for failure. Conduct calibration check by comparing readings of the PT or PIT with the readings of a certified master calibration gauge which has been calibrated within the last year. The PT or PIT and the master calibration gauge must be connected

to the same pressure source for testing. Verify accuracy of PT or PIT gauge is within ±2% of full scale. Calibrate in accordance with manufacturer's operation and maintenance manual if required.
Frequency: Annually

6-7.4 Differential Pressure Transmitters.

Differential pressure transmitters (DPT) are used to measure the difference in pressure between two sensing points. These units transmit a 4 to 20 mA (common in US installations) or 0 to 20mA (common in European installations) electrical signal to a display or a PLC to indicate differential pressure. These same signals can also be used to determine flow rate measurements using a function that correlates pressure differential to flow.

6-7.4.1 Inspection and Maintenance - Differential Pressure Transmitters.

a. Inspect the exterior of the transmitter enclosure for accumulated oil, dust, and dirt. Clean as required.
Frequency: Quarterly

b. Check that both enclosure caps are fully threaded onto the enclosure, compressing the O-ring between the cap and the enclosure. The O-ring must not be cracked, broken, or otherwise damaged.
Frequency: Quarterly

c. Inspect the display viewing glass for cleanliness and damage. Replace the enclosure cap assembly if the glass is damaged or missing. No accumulation of dust, dirt, or water (condensate) should be present inside the enclosure.
Frequency: Quarterly

d. Inspect transmitter and mounting bracket hardware for tightness. Tighten loose hardware as necessary.
Frequency: Quarterly

e. Inspect for loose, bent, or cracked sensing lines. Replace damaged sensing lines.
Frequency: Quarterly

f. Check operation of transmitter. Ensure transmitter is indicating accurate differential pressure measurement.
Frequency: Quarterly

g. Bleed sensing lines between the transmitter and the main line to ensure they are clean and free of suspended solids and air.
Frequency: Semi-annually

h. Check that all wire connections inside enclosure are tight.
Frequency: Annually

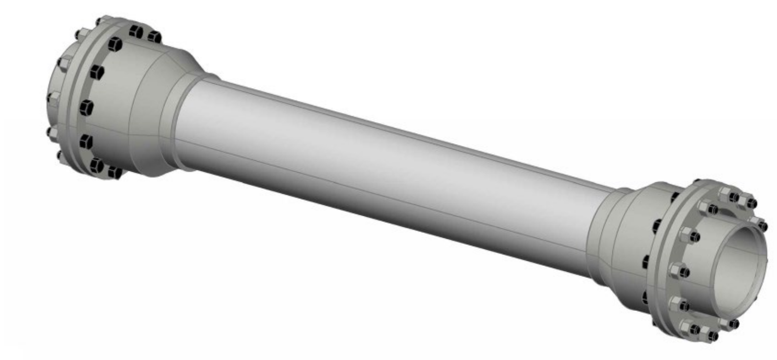
i. DPTs must be calibrated mechanically and electrically with test equipment and adjusted, if applicable. The presence of air in sensing lines of differential pressure transmitters is a common cause for failure. Conduct calibration check by comparing readings of the DPT with the readings of a certified differential master calibration gauge which has been calibrated within the last year. The DPT and the differential master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of DPT is within ±2% of full scale. Calibrate in accordance with manufacturer's operation and maintenance manual if required.
Frequency: Annually

6-8 FLEXIBLE BALL JOINTS.

6-8.1 Flexible Ball Joints.

Flexible ball joints are used to provide flexibility in connections between petroleum fuel tanks and pipelines. These joints may also be used in other areas where flexibility is required.

Figure 6-13 Flexible Ball Joint



6-8.1.2 Inspection and Maintenance – Flexible Ball Joints.

Flexible ball joints can be a source of leaks, especially if the piping is subject to stress when it mates to a tank or coupling adapter. A program of periodic lubrication and inspection will ensure longer joint life, since a fully lubricated joint will not allow dirt to enter. However, if seals leak despite lubrication and seal replacement, the entire joint must be replaced.

a. Lubricate ball joints and inspect for wear and stress.
Frequency: Monthly

6-9 THERMOMETERS.

Thermometers are used to measure temperature at the sensing point.

6-9.1 Dial Thermometers.

Dial thermometers indicate the temperature on the face of a dial.

6-9.1.1 Inspection and Maintenance – Dial Thermometers.

Thermometers are typically bi-metallic or volatile fluid based, and must be periodically inspected.

a. Inspect thermometer for cracked face and proper operational condition. Replace if damaged.
Frequency: Quarterly

b. Check accuracy of thermometer against calibrated master thermometer. Ensure process and calibrated master thermometers are reading the same heat source. Verify accuracy of thermometer is within ±2% of full scale. Calibrate process thermometer if required.
Frequency: Annually

6-10 PIPE AND EQUIPMENT COATINGS.

This section includes information related to periodic inspection of external coating systems that are typically applied to DoD piping systems.

6-10.1 Aboveground Piping and Equipment Coatings.

A three coat system (primer, intermediate, and top coat) is the primary protective coating system for aboveground piping. The primer and intermediate coats should be a two component epoxy-polyamide system and the topcoat should be a UV resistant polyurethane. Refer to UFGS 33 52 43.13 or UFGS 09 97 13.27 for current aboveground exterior pipe coating system requirements. Do not paint stainless steel, aluminum or galvanized surfaces.

6-10.1.1 Inspection and Maintenance – Aboveground Piping and Equipment Coatings.

Coating repairs of aboveground piping, piping in pits, equipment, pipe supports, filter separators, and miscellaneous metal should match color of finish and reflectivity of existing, consistent with the Installation’s Architectural Standards.

Maintenance personnel must determine existing external coating type prior to repairs to ensure proper adhesion. It is recommended to protect surrounding areas of repair by squaring off with masking tape. Ensure the area to be repaired is clean and dry. All surface corrosion or damage coating must be removed per coating manufacturer’s requirements. In addition, abrade immediate area surrounding repair to feathered edge to allow proper adhesion of repair coating layers. Remove all dust particles by brush or vacuum and clean surface with appropriate solvents to prepare area for coating system. Apply coating system in accordance with manufacturer’s instructions. The protective coatings section of UFGS 09 97 13.27 includes coating information and application instructions that should be followed.

a. Visually inspect coatings for signs of deterioration, corrosion or damage. Repair damaged or deteriorated coatings.
Frequency: Quarterly

6-10.2 Underground Piping Coating Repairs.

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a. Three coating types have recently been used for underground piping: 2-layer extruded polyolefin coating over soft adhesive per AWWA C215, fusion-bonded epoxy coatings per AWWA C213, and Federal Specification L-C-530C. Refer to UFGS 33 52 80 or UFGS 33 52 43.13 for current underground exterior coating requirements.

b. Maintenance personnel must determine existing coating type prior to repairs to ensure proper adhesion and longevity of repairs. Polyolefin (AWWAC215), fusion-bonded epoxy (AWWA C213), and Federal Specification L-C-530C are common, but other types of coatings may be encountered. Some older pipes may be coated with a coal tar asbestos wrap. Ensure the coating is identified and that proper procedures are used to handle the hazard level associated with the identified coating. Contact the military service-specific SME with questions regarding coating types and appropriate repair methods.

c. In all cases, surfaces must be clean, dry, grease-free, dust-free, free of rust and damaged coatings and prepared in accordance with repair method chosen and the manufacturer’s published procedures. UFGS 33 52 80 includes additional coating information and application instructions that should be followed.

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6-10.2.1 Two-Layer Extruded Polyolefin Coating Repairs.

The following repair methods must be used for two-layer extruded polyolefin coating:

- Coal Tar Enamel per AWWA C203, Type II enamel, Type III outer wrap.
- Coal Tar Tape per AWWA C203.
- Cold Applied Tape per AWWA C209.
- Petroleum or Petroleum Wax Tape Coating per AWWA C217.
- Heat Shrink Sleeve per AWWA C216.

The military service-specific SME must determine the best repair method for the type of repair required. Weld beads must be covered with one wrap of tape prior to spiral wrapping. Fittings must be wrapped spirally beginning with one complete wrap three inches back from each edge of the coating. For pipe less than 4-inches (100 mm) in diameter, one layer half-lapped must be used. For pipe 4-inches (100 mm) and larger in diameter, two layers half-lapped must be used with the second layer wrapped opposite hand of the first.

6-10.2.2 Fusion-Bonded Epoxy Repairs.

Fusion-bonded epoxy must be repaired with a fusion-bonded epoxy coating per NACE Recommended Practice (RP) 0402 to match existing coating or Liquid-Epoxy Coating System per AWWA C210.

Maintenance personnel must coordinate with military service-specific SME to determine best repair method for the type of repair required.

6-10.2.3 Federal Specification L-C-530C Coating Repairs.

Coatings that meet the requirements of Federal Specification L-C-530C have been used on underground fuel piping. The coating is no longer covered by a UFGS specification but it has continued to be used on a case by case basis. Repair of these coatings must be in accordance with manufacturer's instructions.

6-10.3 Internal Carbon Steel Pipe Coatings.

Epoxy coatings systems meeting the requirements of MIL-PRF-4556 (two component epoxy system) or AWWA C213 (fusion bonded epoxy system) are sometimes used on the interior of carbon steel piping used for the transport of petroleum fuels. These coatings are applied to the piping at the factory and are not typically repaired in the field. The inside edges of each pipe segment is left uncoated 1 to 1.5-inches (25 to 40 mm) from each end to prevent coating damage during welding operations. The inside areas of the welds are left uncoated after welding is complete.

6-11 UNDERGROUND FUEL PITS.

Fuel pits such as low point drain pits, high point vent pits, lateral control valve pits, isolation valve pits, and hydrant pits are included in many fueling systems.

6-11.1 Isolation Valve Pits.

Isolation valve pits are buried fiberglass or concrete pits with a rolling or hinged cover designed in accordance with the DoD Standard Design AW 78-24-28 for isolation valves installed in non-traffic areas on underground petroleum fuel piping systems. Valve pits and valve operators are typically designed so that valves can be operated by personnel without confined space entry.

6-11.1.1 Inspection and Maintenance – Isolation Valve Pits.

a. Isolation valve pits should be inspected to ensure that the pits are dry and clean and that all components within the pit are clean and in good working order. Maintain seals and boot seals as appropriate. Obtain necessary confined space entry permits before entry. Inspect the pit for signs of fuel or water. Water or fuel should be removed from the pit as soon as possible and the source of water infiltration or fuel leak determined.
Frequency: Monthly, or more often based on local conditions.

b. Check for cracks in concrete and check piping penetrations through pit wall or bottom to ensure that mechanical seals and boot seals are in good working condition and are allowing no seepage of water into the pits. Make note of cracks in concrete and schedule maintenance as necessary. Check for fuel leaks at all flanged and other piping connections. Check for rusted or deteriorated ladders or grating platforms that might make entry unsafe. Check pit lids for proper sealing. Check rolling pit covers for ease of operation and signs of deterioration, damage or corrosion. Make sure required locks are in place and locking mechanisms are not broken.
Frequency: Monthly, or more often based on local conditions.

6-11.2 Hydrant Fuel Pits.

Hydrant fuel pits are located close to the aircraft parking positions. Hydrant fuel pits contain fuel block valves, pressure gauges, and hydrant control valves. The pits are equipped with counter-weighted lids. A sump out connection is provided to sump collected water or fuel from the pit. Grating installed in the pit provides access to valves and is removable to allow close inspecting of pit pipe penetration seals and general maintenance.

6-11.2.1 Inspection and Maintenance – Hydrant Fuel Pits.

a. Hydrant fuel pits must be inspected to ensure that they are dry and clean and that all fueling components within the pit are clean and in good working order. Obtain necessary confined space entry permits before entry. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible.
Frequency: Monthly, or more often based on local conditions.

b. Check pipe penetrations through pit walls or bottom to ensure that mechanical and boot seals are in good working condition and are allowing no water seepage into the pits.
Frequency: Monthly

c. Check for fuel leaks at all flanged and other piping connections.
Frequency: Monthly Check pipe penetrations through pit walls or bottom to ensure that mechanical and boot seals are in good working condition

and are allowing no water seepage into the pits.
Frequency: Monthly

d. Check pit lids to ensure that seals are in good working order and are preventing water entry into the pits.
Frequency: Monthly, or more often based on local conditions.

e. Inspect hydrant fuel pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.
Frequency: Monthly

6-11.3 High Point Vent Pits.

High point vent pits are located throughout fueling systems. High point vents are used to vent air from fuel lines during start-up and operation.

6-11.3.1 Inspection and Maintenance – High Point Vent Pits.

a. Inspect high point vent pits to ensure they are dry and free of water and other debris and that pit and piping components are leak free and in good working condition. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible
Frequency: Monthly

b. Check pipe penetrations through pit walls or bottom to ensure that mechanical and boot seals are in good working condition and are allowing no water seepage into the pits.
Frequency: Monthly

c. Check pit lid seals for deterioration and replace as necessary.
Frequency: Monthly

d. Ensure that high point vent valves, quick-disconnect couplings or pit lids are lockable and that locking mechanisms are in good working order.
Frequency: Monthly

e. Inspect high point vent pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.
Frequency: Monthly

6-11.4 Low Point Drain Pits.

Low point drain pits are located throughout fueling systems. Low point drains are used to sump fuel piping where water in the fuel may settle and for draining the pipeline.

6-11.4.1 Inspection and Maintenance – Low Point Drain Pits.

a. Inspect low point drain pits to ensure they are dry and free of water and other debris and that all pit and piping components are leak free and in

good working condition. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible.
Frequency: Monthly

b. Check pipe penetrations through pit wall or bottom to ensure that mechanical seals and boot seals are in good working condition and are allowing no water seepage into the pits.
Frequency: Monthly

c. Check pit lid seals for deterioration and replace as necessary.
Frequency: Monthly

d. Ensure that low point vent valves, quick-disconnect couplings or pit lids are lockable and that locking mechanisms are in good working order.
Frequency: Monthly

e. Inspect low point drain pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.
Frequency: Monthly

6-11.5 Lateral Control Pits.

Lateral control pits are buried fiberglass or concrete pits with rolling or hinged covers. Valve operators installed in lateral control pits are typically designed so that the valves can be operated by personnel without confined space entry. Lateral control pits may include isolation valves and hydrant system automatic control valves.

6-11.5.1 Inspection and Maintenance – Lateral Control Pits.

a. Inspect lateral control pits to ensure they are dry and free of water and other debris and that all pit and piping components are leak free and in good working condition. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible.
Frequency: Monthly

b. Check pipe penetrations through pit wall or bottom to ensure that mechanical seals and boot seals are in good working condition and are allowing no water seepage into the pit.
Frequency: Monthly

c. Check pit lid seals for deterioration and replace as necessary.
Frequency: Monthly

d. Check for fuel leaks at all flanged and other piping connections.
Frequency: Monthly

e. Ensure that pit lids are lockable and that locking mechanisms are in good working order.
Frequency: Monthly

f. Inspect lateral control pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.
Frequency: Monthly

6-12 MINOR PIPING SYSTEMS.

6-12.1 Low Point Drains.

Water and other fuel contaminants that are not removed by filtration tend to end up at low points in a fuel system. Low point drains are provided at low points in a fuel system to allow water and contaminants to be removed.

6-12.1.1 Inspection and Maintenance – Low Point Drains.

a. Visually inspect low point drains. Ensure that quick-disconnect dust caps are in place and that valves are locked closed.
Frequency: Weekly

b. Operate low point drains when system is not under operating pressure. If there is an absence of sufficient line pressure close the low point drain and pressurize the system. Once adequate pressure is available, continue draining until the piping fuel sample is clear and bright with no visible water.
Frequency: Monthly or as required by local conditions. Verify low point drains are closed after maintenance.

6-12.2 High Point Vents.

High point vents are provided in fuel systems to provide a means of venting trapped air.

6-12.2.1 Inspection and Maintenance – High Point Vents.

a. Inspect high point vents. If fuel leaks are observed they should be repaired as soon as possible. Ensure that quick-disconnect dust caps are in place and that high point vent valves are locked.
Frequency: Weekly

6-12.3 Sight Flow Indicators.

Sight flow indicators are used to visually confirm that fuel is flowing through a system. These devices use a wheel installed in the fluid stream behind a transparent glass or plastic film. Flow is indicated when the wheel turns.

6-12.3.1 Inspection and Maintenance - Sight Flow Indicators.

a. Verify there are no leaks around pipe connection fittings and glass seals. Also check glass for indications of cracks.
Frequency: Daily or **at each use**

6-13 ELECTRONIC RELEASE DETECTION MONITORING.

6-13.1 General Inspection of Release Detection Systems.

Piping release detection systems are designed to quickly detect fuel leaks from concealed and underground portions of fueling systems. A licensed and/or certified technician is required to troubleshoot or inspect leak/release sensors for operation. If an issue is suspected, appropriate military service-specific SCP or Installation Environmental Office personnel should be contacted for support. Refer to SPCC plan for further direction on who to contact.

Host nation, state, and local agencies may have additional design, inspection, and maintenance requirements that may be more stringent than DoD or Federal guidance. Facility operators and maintainers must be familiar with the site’s SPCC plan in order to comply with all inspection and recordkeeping requirements

6-13.1.1 Rope Sensor Systems.

Rope sensors are installed along the length of underground piping, either within the interstice of double-wall piping (common) or direct buried (uncommon). Rope sensors can be installed in service pits and sumps as well. This system uses a discrete sensor built along the length of a rope. Rope sensors send a signal to a monitoring panel indicating the location of the detected liquid within a few feet. Rope sensors are sensitive to the presence of any petroleum based product and care should be taken when handling the rope sensor. A licensed and/or certified technician is required to troubleshoot or inspect rope sensors for operation.

6-13.1.1.1 Inspection and Maintenance - Rope Detector Systems.

a. Ensure the monitoring panel associated with the rope sensor(s) is powered on and no alarms are present.
Frequency: Daily

b. Test rope sensor system and ensure it is functional.
Frequency: Annually

6-13.1.2 Point Sensor – Dry.

Dry point sensors are installed at the lowest point within the space between the fueling system and secondary barrier. Dry point sensors send a signal to a monitoring panel indicating liquid detection. Dry point sensors may include float switches, or electrical resistor switches. A licensed and/or certified technician is required to troubleshoot or inspect dry point sensors for correct operation.

In double-wall piping systems these sensors are placed in the low points of the piping and continuously monitor for the presence of fuel in the annulus of the double-wall pipe.

6-13.1.2.1 Inspection and Maintenance - Point Sensor – Dry.

a. Ensure the monitoring panel associated with the point sensor(s) is powered on and no alarms are present.
Frequency: Daily

b. Ensure monitoring space is clear and free of debris and liquid.
Frequency: Monthly

c. Test sensor and ensure it is functional.
Frequency: Annually

6-14 VISUAL RELEASE DETECTION MONITORING.

6-14.1 Visual Monitoring.

Release detection method utilizing inspection ports to visually inspect for the presence of liquids.

6-14.1.1 Inspection and Maintenance – Visual Monitoring.

a. Visually inspect ports for signs of leaks. Remove debris or foreign objects obstructing the view.
Frequency: Weekly

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CHAPTER 7 GROUND VEHICLE FUEL FACILITIES

7-1 GENERAL.

This chapter contains inspection and maintenance information associated with ground vehicle fuel systems.

7-2 DISPENSER NOZZLES.

Dispenser nozzles that meet requirements of **1**\UFGS 33 57 55/**1**/are designed to automatically close when the dispenser nozzle handle is released. When the dispenser nozzle vacuum sensing port is blocked by petroleum fuel it will cause the internal poppet valve to close. This feature helps prevent overfilling vehicle tanks. Dispenser nozzles can also be equipped with automatic nozzle shut-off clips to allow the operator to latch dispenser nozzles open during fuel dispensing. When the dispenser nozzle senses fuel at the vacuum sensing port, the shut-off clip disengages and the nozzle closes. Do not remove automatic shut-off clips on ground vehicle fuel dispenser nozzles. Dispenser nozzles should have splash guards in case of overfill.

Figure 7-1 Dispenser Nozzle

7-2.1 Inspection and Maintenance – Dispenser Nozzles.

a. Inspect dispenser nozzle spout. Ensure it is tight, round, has no cracks, or excessive wear. Inspect automatic shutoff hole. Ensure the hole is open and free of obstructions. Inspect nozzle hold-open latch. Ensure the latch is straight, moves freely, and the return spring operates correctly. Inspect body of nozzle. Ensure the body is in good condition and that the valve stem is clean and free of fuel. Inspect the nozzle to hose connection and ensure it is clean and free of fuel.
Frequency: Daily

b. **1**\ /**1**/

c. Test automatic shutoff feature and ensure it is operating properly. Test automatic shutoff at all nozzle hold-open latch positions.
Frequency: Annually

7-3 DISPENSER HOSES.

Dispenser hoses that meet requirements of **1**\UFGS 33 57 55/**1/**are designed to transfer petroleum fuel from dispensers to motor vehicle fuel tanks. Hoses must be reinforced with metallic mesh that prevents kinks and collapse. Reinforcement mesh also provides a conductive path to direct static charges to ground. The outer surface of hoses must be resistant to abrasion, cuts, and degradation from the surrounding environment. No more than 6 feet (1.8 meters) of the dispenser hose may touch the ground. Hose retractors may be installed to elevate long dispenser hoses. Dispenser hoses with a working pressure under 20 psi (138 kPa) do not require annual pressure testing.

Dispenser systems equipped for Stage II vapor recovery require coaxial hoses which are used to provide a path for reclaimed fuel vapors to return to the petroleum fuel storage tank.

7-3.1 Inspection and Maintenance – Dispenser Hoses.

a. Inspect dispenser hoses and hose whips for gouges, cuts, blisters, or outside wear that may lead to rupture during use. Replace hose or hose whips that show signs of wear. Inspect connection points of hoses and hose whips to the dispenser, breakaways, swivels, and the nozzle and ensure the connection points are clean and free of fuel.
Frequency: Daily

7-4 BREAKAWAYS.

Fuel hose breakaways that meet requirements **1**\UFGS 33 57 55/**1**/are used to connect dispenser hoses to dispensing units. Breakaways are designed to disconnect hoses from dispensers if hoses are subjected to strong tensile stresses such as strong pulling forces. Breakaways are double bonnet systems designed to close off fuel flow.

7-4.1 Inspection and Maintenance – Breakaways.

a. Inspect breakaways for loose connections and signs of damage to poppets. Ensure breakaways are clean and free of fuel.
Frequency: Daily

b. Inspect breakaway for an expiration date established by the manufacturer. Breakaways must be replaced before the indicated expiration date.
Frequency: Monthly

7-5 SWIVELS.

Fuel hose swivels are installed between dispenser nozzles and hoses. They provide flexibility and reduce strain on hoses by allowing nozzles to rotate around the swivel. They also make it easier for operators to handle hoses during fuel dispensing.

7-5.1 Inspection and Maintenance – Swivels.

a. Inspect swivel for loose connections and signs of damage. Ensure swivel rotates easily and is clean and free of fuel.
Frequency: Daily

b. Inspect swivel for expiration date established by manufacturer. Swivels must be replaced before the indicated expiration date.
Frequency: Monthly

7-6 HOSE RETRIEVER.

Hose retrievers support the hose and limit contact of the hose with the ground.

7-6.1 Inspection and Maintenance – Hose Retriever

a. Test hose retriever and ensure it is operating correctly and supporting the hose.
Frequency: Monthly

7-7 DISPENSER CABINET.

Dispenser cabinets enclose the inner components of fuel dispensers. The cabinets protect the inner components from the elements and protect the connection points of the underground supply piping.

7-7.1 Inspection and Maintenance – Dispenser Cabinet.

a. Inspect outside of cabinet and ensure it is free of damage. Inspect for fuel stains on the concrete island around the cabinet and on the outside of the cabinet. Ensure the cabinet is free of dirt and fuel.
Frequency: Monthly

b. Open both sides of the cabinet and inspect the inside of the cabinet. Ensure the inside of the cabinet and all of the components inside the cabinet are clean and free of fuel.
Frequency: Monthly

c. Ensure door panels and locks operate easily. Inspect anchor bolts of cabinet to dispenser island and ensure the bolts are in good condition.
Frequency: Annually

7-8 DISPENSER METERS.

Dispenser meters allow operators to monitor the amount of fuel dispensed into a given vehicle fuel tank. Intelligent dispenser meters can reconcile all fuel dispensed against the operating storage tank level readings to verify usage. Meters are able to constantly recalibrate due to changes in temperature that affect the volumetric flow rate.

7-8.1 Inspection and Maintenance – Dispenser Meters.

a. Inspect meter and ensure meter is clean and free of fuel. Ensure calibration mechanism is sealed.
Frequency: Monthly

b. Since moving parts inside meters are subject to wear, periodic calibration is necessary. Meters must be recalibrated utilizing a certified 5 gallon (20 liter) prover can or other approved method. Meters are considered satisfactory for further operation when the error does not exceed ±0.2% of actual quantity delivered.
Frequency: Annually

7-9 DISPENSER FILTERS.

Dispenser filters that meet requirements of **1**\UFGS 33 57 55/**1**/are used to collect particulates in fuel systems. **1**\ Depending on the fuel type different filter strategies may be recommended. Refer to UFC 3-460-01 for filter strategies for each fuel type**.** /**1**/

7-9.1 Inspection and Maintenance – Dispenser Filters.

a. Inspect filter and ensure filter is clean and free of fuel and that filter is labeled with a legible installation date.
Frequency: Monthly

b. Replace dispenser filters annually or when a change in flow rate is noted.
Frequency: Annually or as needed

7-10 DISPENSER STRAINERS.

Dispenser strainers are designed to capture particulates and protect dispenser pumps and meters in self-contained units or meters in remote units.

7-10.1 Inspection and Maintenance – Dispenser Strainers

a. Inspect and clean strainers. Inspect strainer cover gasket for cracks, distortion, and dry rot. If breaks are detected in strainer mesh, replace the strainer.
Frequency: Annually

7-11 GROUND VEHICLE FUEL PIPING.

Underground lines for ground vehicle petroleum fuel products must be constructed in accordance with UFC 3-460-01 and 40 CFR Part 280.

In addition to 40 CFR Part 280, host nation, state, and local regulations may have additional design, inspection, and maintenance requirements that may be more stringent than DoD or Federal guidance. Facility operators and maintainers must be familiar with the site's SPCC plan in order to comply with all inspection and recordkeeping requirements.

7-11.1 Inspection and Maintenance – Ground Vehicle Fuel Piping.

a. Visually inspect aboveground lines for leaks. Shut down systems that are found with leaks and repair.
Frequency: Daily

b. Visually inspect leak detection systems installed on underground piping. Inspections include line leak detectors and leak detection sensors installed in transition sumps and dispenser sumps. Perform leak testing on pressurized underground piping with installed leak detection equipment and record results.
Frequency: Monthly

c. Test leak detection systems installed on underground piping used for ground vehicle petroleum fuel products. Underground leak detection systems include discrete detection sensors installed in transition and dispenser sumps, and line leak detectors installed at the outlet of pumps used to supply pressurized liquid petroleum fuel to underground lines. Repair faulty components. Execution of this work may require state certification or license.
Frequency: Annually

d. Conduct service station aboveground piping annual test as outlined in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria. Execution of this work may require state certification or license.
Frequency: Annually

e. Conduct service station underground piping annual test outlined in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria. Execution of this work may require state certification or license.
Frequency: Annually

f. Refer to Section 2.7 Signage and Markings for inspection and maintenance requirements of ground vehicle petroleum fuel pipe markings.

g. Refer to Section 6-10.1 Aboveground Piping and Equipment Coatings for inspection and maintenance requirements of ground vehicle petroleum fuel pipe coatings.

7-12 EMERGENCY SHUTOFF VALVES (SHEAR VALVES).

Emergency shutoff valves that meet the requirements of **1**\ UFGS 33 57 55 /**1**/ are located at the base of ground vehicle fuel dispensers and are designed to close if the dispenser is struck or exposed to a fire. Emergency shutoff valves are securely mounted to stabilizer bars installed in the containment sumps mounted under dispensers. The valve is designed to break at a weak point in the body of the valve if the dispenser is struck and dislodged. The valve is also designed to close if the valve is subjected to shock of an impact to the dispenser. In addition, the valve is equipped with a fusible link that will melt in the event of a fire and cause the valve to close.

Figure 7-2 Emergency Shutoff Valve

7-12.1 Inspection and Maintenance – Emergency Shutoff Valves (Shear Valves).

a. Inspect stabilizer bar to ensure that it is securely mounted below the base of the dispenser. Inspect the mounting bolts that secure the emergency shutoff valve to the stabilizer bar.
Frequency: Monthly

b. Inspect fusible link and ensure it is not obstructed. Ensure valve body is clean and free of fuel.
Frequency: Monthly

c. Inspect mechanical links of the valve for correct operation. Conduct test of valve to ensure it operates correctly. Execution of this work may require state certification or license.
Frequency: Annually

7-13 DISPENSER SUMPS.

Dispenser sumps are used to protect and provide access to valves and fuel pipe installed below dispensers.

7-13.1 Inspection and Maintenance – Dispenser Sumps.

a. Inspect for signs of water, fuel, trash, and debris inside sumps. Remove and properly dispose of collected water, fuel, trash, and debris. Visually inspect penetration fittings. If fuel or water is detected investigate the source and repair.
Frequency: Monthly, or more often based on local conditions.

b. Inspect sump pipe transition fittings for tears, cracks, or other signs of deterioration. Check hose clamp seals to ensure they are securely tightened.
Frequency: Quarterly

c. Test dispenser sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.
Frequency: Every three years

7-14 TRANSITION SUMPS.

Transition sumps are used to protect piping as it transitions from aboveground to below ground. In many cases the piping will change configuration as it transitions from aboveground pipe to underground pipe.

7-14.1 Inspection and Maintenance – Transition Sumps.

a. Inspect for signs of water, fuel, trash, and debris inside sumps. Remove and properly dispose of collected water, fuel, trash, and debris. Visually inspect penetration fittings. If fuel or water is detected investigate the source and repair.
Frequency: Monthly, or more often based on local conditions.

b. Inspect sump pipe transition fittings for tears, cracks, or other signs of deterioration. Check hose clamp seals to ensure they are securely tightened.
Frequency: Quarterly

c. Test sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.
Frequency: Every three years

7-15 DISPENSER PUMPS.

Dispenser pumps are either installed as an integral unit to the fuel dispenser or as a remote pump. Integral pumps are typically sliding vane pumps installed in the base of the dispenser unit. Remote pumps are typically submerged turbine pumps mounted on petroleum fuel storage tanks.

7-15.1 Remote Dispenser Pumps.

Fuel dispensers in remote pump systems do not house pumps. Remote dispenser pumps are typically tank mounted submerged turbine pumps. The manufacturer's instructions for installation, operation, and maintenance will further describe pumping unit and parts requiring periodic inspection and maintenance.

7-15.1.1 Inspection and Maintenance – Remote Dispenser Pumps.

a. Refer to Section 7-19.1.2 Automatic Line Leak Detector for maintenance and inspection requirements of automatic line leak detectors installed on submersible turbine pumps.

b. Refer to Section 3-8.1.3 Vertical Turbine/Submerged Turbine Pumps for inspection and maintenance requirements of remote dispenser pumps.

7-15.2 Self-Contained Dispenser Pumps.

Self-contained dispenser pumps are typically belt-driven, sliding vane type positive displacement pumps mounted within the dispenser housing. The pumps draw fuel to the dispenser by creating suction on the fuel line attached to the petroleum fuel storage tank.

7-15.2.1 Inspection and Maintenance – Self-Contained Dispenser Pumps.

a. Inspect self-contained dispenser pump v-belt drives for proper tension and excess wear. Replace belt as recommended by manufacturer.
Frequency: Monthly

b. Inspect pump body. Ensure pump body is clean and free of fuel. Inspect air eliminator. Ensure air eliminator is clean and free of fuel and that the vent tube is not obstructed.
Frequency: Monthly

7-16 EFSO SYSTEMS.

Emergency Fuel Shut-Off (EFSO) systems disable power to dispensers at service stations. Typically military service stations are unattended and require keys or cards to operate the dispensers. EFSO buttons to deactivate the dispensers are typically installed in close proximity to dispensers and at a distance of between 20 and 100 feet (6 to 30 meters) away from dispensers. EFSO systems can be activated by pushing one of the EFSO buttons.

7-16.1 Inspection and Maintenance – EFSO Systems.

a. Check the operation of the EFSO system by activating the fueling system and then pressing each of the EFSO buttons. Ensure that each button disables power to all of the dispensers and fuel pumps installed at the service station.
Frequency: Quarterly

b. Refer to Section 2-7 Signage and Markings for inspection and maintenance requirements of EFSO pushbutton signs.

7-17 VAPOR RECOVERY.

Vapor recovery at service stations is typically classified as Stage I or Stage II. These types of systems are required on fuels with high vapor pressures in many states. For military service station applications this is usually limited to Motor Gasoline (MOGAS).

7-17.1 Stage I Vapor Recovery.

Stage I Vapor Recovery is used for bulk receipt and issue operations and typically includes a vapor balance pipe. The vapor balance pipe is used to connect the head space of the fuel storage tank to the head space of the fuel truck. This allows vapors to move between the fuel storage tank and the fuel truck during receipt and issue operations.

7-17.1.1 Inspection and Maintenance - Stage I Vapor Recovery.

a. Inspect vapor recovery hoses for gouges, cuts or outside wear that may result in vapor leaks.
Frequency: Daily or before each use

b. Inspect caps and camlock fittings for tightness and leaks.
Frequency: Quarterly

c. Refer to Section 7-11 Ground Vehicle Fuel Piping for inspection and maintenance requirements of Stage I vapor recovery piping.

7-17.2 Stage II Vapor Recovery.

Stage II vapor recovery includes the collection of vapors at the dispenser nozzle and may also include the collection of vapors developed from normal tank operations. In most cases these systems include vacuum pumps mounted in dispensers that collect and transfer vapors to petroleum fuel storage tanks. Stage II vapor recovery is no longer a Federal requirement but may still be required by some states. Existing Stage II vapor recovery systems may be phased out in accordance with state regulations. Stage II vapor recovery systems that have not yet been decommissioned (whether required or not) must still be maintained and inspected in accordance with state regulations.

7-17.2.1 Inspection and Maintenance - Stage II Vapor Recovery.

There are several approved vendors for Stage II Vapor Recovery systems. Consult the manufacturer's operation and maintenance manual that was provided with the system for periodic maintenance requirements.

7-17.3 Vapor Burners.

Vapor burners are used to combust vapors from tanks that would otherwise be vented to atmosphere.

7-17.3.1 Inspection and Maintenance - Vapor Burners.

Consult the manufacturer's operation and maintenance manual that was provided with the system for specific periodic maintenance requirements of the unit that is installed.

a. Inspect vapor burners to ensure that the pilot flame system is operating properly. Fans, duct work, and dampeners must also be inspected to ensure proper air to fuel vapor mixtures allow for complete burns.
Frequency: Quarterly

b. Inspect burner knock out pots for condensed fuel vapors and water if equipped.
Frequency: Quarterly

c. Inspect thermowells and gas detection monitors for operability.
Frequency: Quarterly

7-18 TACTICAL REFUELER LOADING.

Tactical refueler loading operations at military service stations are similar to petroleum fuel truck issue systems. Refer to Section 3-5.1 Truck Issue for inspection and maintenance requirements of tactical refueler loading equipment.

7-19 ELECTRONIC RELEASE DETECTION MONITORING.

7-19.1 General Inspection of Release Detection Systems.

Release detection systems are designed to quickly detect fuel leaks from concealed and underground portions of fueling systems. A licensed and/or certified technician is required to troubleshoot or inspect leak/release sensors for operation. If an issue is suspected, appropriate military service-specific SCP or Installation Environmental Office personnel should be contacted for support. Refer to Installation SPCC plan for further direction on who to contact.

7-19.1.1 Point Sensor – Dry.

Dry point sensors are installed at the lowest point within the space between the fueling system and secondary barrier. Dry point sensors send a signal to a monitoring panel indicating liquid detection. Dry point sensors may include float switches or electrical resistor switches. A licensed and/or certified technician is required to troubleshoot or inspect dry point sensors for operation.

These sensors are placed in the low points of the dispenser sumps and fuel pipe transition sumps and continuously monitor for the presence of fuel or water in the sumps.

7-19.1.1.1 Inspection and Maintenance - Point Sensor – Dry.

a. Ensure the monitoring panel associated with the point sensor(s) is powered on and no alarms are present.
Frequency: Daily

b. Ensure monitoring space is clear and free of debris and liquid.
Frequency: Monthly

c. Test sensor and ensure it is functional.
Frequency: Annually

7-19.1.2 Automatic Line Leak Detector.

Automatic line leak detector systems are used on underground pressurized piping to alert the operator to the presence of a leak by restricting or shutting off the flow through the piping or visual alarm. Automatic line leak detectors are commonly installed on submersible turbine pumps and less commonly installed remotely on other pump types.

7-19.1.2.1 Inspection and Maintenance – Automatic Line Leak Detector.

a. Ensure the monitoring panel associated with the detector(s) is powered on and no alarms are present.
Frequency: Daily

b. Simulate a 3 gallons per hour leak at 10 pounds per square inch; the automatic line leak detector must activate within one hour. A licensed and/or certified technician is required to, test, troubleshoot, or calibrate for operation.
Frequency: Annually

7-20 VISUAL RELEASE DETECTION MONITORING.

7-20.1 Visual Monitoring.

Release detection method utilizing inspection ports to visually inspect for the presence of liquids.

7-20.1.1 Inspection and Maintenance – Visual Monitoring.

a. Visually inspect at inspection ports for signs of leaks. Remove debris or foreign objects obstructing the view.
Frequency: Weekly

CHAPTER 8 PETROLEUM STORAGE TANKS

8-1 GENERAL INFORMATION.

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a. This chapter includes information on inspection and maintenance of petroleum fuel storage tanks and associated equipment for the purpose of maintaining mechanical and operational integrity.

b. Commercial codes API 653 and STI SP001 have been used to determine baseline inspection requirements for DoD-owned petroleum fuel tanks. API 653 has been used for field-erected tanks and STI SP001 has been used for shop-fabricated tanks. In some cases API 653 and STI SP001 can be applied to field erected tanks. In cases where API 653 or STI SP001 could be applied, the option to use either protocol has been provided. After a tank's inspection protocol has been set, it should continue following that inspection protocol unless the change is approved by the military service-specific SCP or SME. Contact the military service-specific SCP or SME for guidance if unsure of proper inspection protocol.

c. In some cases API 653 and STI SP001 do not directly apply to a type of petroleum fuel tank installed in the field (e.g. cut and cover tanks). In these cases the requirements of the codes must be adjusted to fit the actual tank installed in the field. Contact military service-specific SCP or SME for guidance.

d. Multi-compartment petroleum fuel tanks are a special case of shop-fabricated tank. Each compartment within a multi-compartment tank should be treated as a separate/individual tank, even though they may share components and secondary containment systems.

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8-2 CONTAMINATION PREVENTION.

Petroleum fuel storage tanks are environments where water can promote microbiological growth which can damage inner tank surfaces, restrict flow, damage downstream components, and degrade petroleum fuel product stability. Though water or other debris are inherent to petroleum fuel handing operations, maintaining petroleum fuel tank (e.g., floating roof seals, vent screens) integrity is critical to preventing additional contamination from entering tanks. Water is typically removed via draw off systems or draining directly from petroleum fuel tank sumps.

8-3 TANK SURFACE COATINGS.

Only coating touch-up repair is performed by staff maintenance personnel on petroleum fuel tanks. Coating repair or replacement for an entire petroleum fuel tank is usually performed under contract.

Interior coating systems are programmed for replacement at 20 year intervals. Exterior coatings may fail more rapidly due to weathering and microbial growth. Numerous factors including surface preparation can lead to failure of the coating material. If inspection shows coating is in acceptable condition, the life may be extended past 20 years. There is generally no need to recoat the interior of petroleum fuel tanks unless the coating has failed or a significant change of petroleum fuel service type is planned. The condition of the internal coatings can only be determined during out-of-service internal tank inspections.

8-3.1 External Tank Coating Repairs.

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a. The external surfaces of petroleum storage tanks are protected with coatings that meet the requirements of UFGS 09 97 13.27. Existing tanks may be protected by alternative coating systems not listed in UFGS specifications. Questions regarding alternative coatings that are encountered in the field should be directed to the military service-specific SME.

b. Maintenance personnel must determine existing external coating type prior to repairs to ensure proper adhesion. It is recommended to protect surrounding areas of repair by squaring off with masking tape. Ensure the area to be repaired is clean and dry. All surface corrosion or damage coating must be removed per coating manufacturer's requirements. In addition, abrade immediate area surrounding repair to feathered edge to allow proper adhesion of repair coating layers. Remove all dust particles by brush or vacuum and clean surface with appropriate solvents to prepare area for coating system.

c. Application information and instructions provided in UFGS 09 97 13.27 must be strictly adhered to when this type of coating system is applied to the exterior of tanks.

8-3.1.1 Vapor Corrosion Inhibitors.

Vapor Corrosion Inhibitors (VCI) technology has potential. VCIs are acceptable for tanks where the underbottom cathodic protection has failed. The tank's ringwall and liner system must not be compromised, such as drilling thru the concrete and flexible membrane liner, for the injection of the VCI. The amount of VCI must be checked annually to determine if additional VCI is required. VCI is not considered as a permanent repair. The cathodic protection system should be repaired during the tank's next out-of-service inspection. **/1/**

8-3.2 Internal Tank Coating Repairs.

There are two primary coating system types used for tank interiors: low VOC epoxy novolac polysulfide coatings that meet the requirements of UFGS 09 97 13.15, and two component epoxy coatings that meet the requirements of UFGS 09 97 13.17. Existing tanks may be protected by alternative coating systems not listed in UFGS. Questions regarding alternative coatings that are encountered in the field should be directed to the military service-specific SME.

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8-3.2.1 Low VOC Epoxy Novolac Polysulfide Interior Coating.
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Epoxy novolac polysulfide interior coating systems are comprised of primer or base coat and top coat that are identical in material except for contrasting colors to allow for identification. When applied correctly, this coating system will last approximately 50 years.

Application information and instructions provided in UFGS 09 97 13.15 must be strictly adhered to when this type of coating system is applied to the interior of tanks.

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8-3.2.2 Two Component Epoxy Interior Coating.
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Two component epoxy coating systems are comprised of an epoxy polyamide primer or base coat in accordance with MIL-DTL-24441/29, and epoxy polyamide intermediate and top coats in accordance with MIL-DTL-24441/31. All primer and intermediate coating materials are supplied by one supplier. When applied correctly, this coating system will last approximately 20 years.

Application information and instructions provided in UFGS 09 97 13.17 must be strictly adhered to when this type of coating system is applied to the interior of tanks.

8-4 ABOVEGROUND FIELD-ERECTED TANKS.

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a. The majority of the above ground field-erected tanks used for petroleum products are built and/or repaired in accordance with API-650 and DoD Standard Design AW 78-24-27.

b. A baseline internal inspection must be conducted on aboveground field-erected tanks before they are placed into service. The baseline inspection must include floor, shell, and roof wall-thickness measurements. These initial measurements will be used by later inspectors to monitor and evaluate corrosion rates of specific tanks.

c. Military service-specific, host nation, state or local regulations may require additional inspections or increased frequency of inspections of field-erected tanks. The Installation must follow the more stringent of this UFC or military service-specific, host nation, state, or local regulations.

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8-4.1 Inspection and Maintenance – Aboveground Field-Erected Tanks.

a. Visually inspect for evidence of leaks; shell distortions; signs of settlement; corrosion, condition of tank foundation, condition of coating, insulation systems, and appurtenances. Inspection must include all components and equipment located inside the containment area such as piping, pipe supports, containment valves, and product saver tanks. Items noted during the inspection will be documented for follow-up action by an authorized inspector. See Appendix F for the Field-Erected Tank Monthly Inspection Checklist.
Frequency: Monthly

b. Visually inspect **1**\ bottom edge projection (chime) /**1**/ to ringwall sealant. Seal should be maintained in good working order to prevent corrosion of the underside of the tank bottom.
Frequency: Monthly

c. Visually inspect the exterior of the tank for leaks, corrosion, or irregularities such as tilting, settling, or out-of-roundness. Give special attention to seams and anchor bolts. Visual inspection must include all components and equipment located inside the tank containment area such as piping, pipe supports, containment valves, and product saver tanks. Retain records of inspections reports for five years. See Appendix F for the Field-Erected Tank Annual Inspection Checklist.
Frequency: Annually

d. Perform a formal in-service external inspection of the tank in accordance with API 653 or STI SP001 to evaluate the tank for conditions which may affect the operational integrity of the storage tank, including minimum shell thickness measurements. This inspection must be performed by an applicable certified inspector. Inspection must include all components and equipment located inside the tank containment area such as piping, pipe supports, containment valves, and product saver tanks.
Frequency: Every five years or as required by an appropriately certified tank inspector in the previous API 653 or STI SP001 inspection report.

e. Perform an out-of-service API 653 or STI SP001 inspection to evaluate the tank for conditions which may affect the operational integrity of the tank floor, shell, roof and floating roof or pan. API 653 or STI SP001 provides a checklist to be used as part of the assessment. This inspection must be performed by an appropriately certified API 653 or STI SP001 inspector. Inspection must include all components and equipment located inside the tank containment area such as piping, pipe supports, containment valves, and product saver tanks. **1**\ The API 653 or STI SP001 inspector must recommend the date of the next inspection. The inspection interval must be based on the date the Suitability for Service

Letter is issued immediately prior to when the tank is returned to service. Frequency: As recommended by the API 653 or STI SP001 inspector. If there is not a previous recommendation, the inspection must be performed within ten years after the tank was placed into operation. /**1**/

8-4.2 Geodesic Dome Roofs.

Geodesic dome roofs for aboveground vertical petroleum fuel storage tanks are constructed of aluminum and either welded or bolted to the vertical wall of the petroleum tank or wind girder and are self-supporting. Geodesic dome roofs are typically installed on petroleum fuel tanks originally constructed with external floating roofs to reduce infiltration of rainwater into the petroleum fuel tank, to protect the floating roof, seals, and internal coatings from the effects of weather, and to help reduce emissions and fuel odors.

8-4.2.1 Inspection and Repair – Geodesic Dome Roofs.

Internal geodesic dome inspections are most effective when the petroleum fuel in the tank is near or at high level and the floating roof is close to its highest position. Access to an internal floating roof is considered a permit required confined space, therefore all military service-specific safety procedures must be followed.

a. Conduct external inspection of geodesic dome roofs, where accessible, for corrosion of tank-to-shell bolts, gasket connections, visible signs of corrosion, apparent roof leaks, clogging or deterioration of vent screens, and damage to the structure or panels.
Frequency: Monthly

b. Conduct internal inspection of geodesic dome roofs from the floating roof, where accessible, for corrosion of tank-to-shell bolts, gasket connections, visible signs of corrosion, apparent roof leaks, clogging or deterioration of vent screens, and damage to the structure or panels.
Frequency: Annually

8-4.3 Foundations.

Field erected petroleum fuel tanks are generally constructed on a concrete ring wall foundation. In some cases tanks are constructed on a concrete mat foundation. Typically the tank is elevated and the tank containment floor is sloped away from the tank shell.

8-4.3.1 Inspection and Repair – Foundations.

a. Inspect visible components of tank foundations for signs of erosion due to heavy rains, wash-down, etc. and repaired as necessary. Also inspect tank foundations for structural cracks, signs of settlement, spalling, or general deterioration. Remove vegetation found around the tank foundation.
Frequency: Monthly

8-5 SHOP-FABRICATED TANKS.

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a. The most common types of shop fabricated tanks for petroleum fuel storage are horizontal cylindrical tanks; however, there are also vertical and rectangular tanks (e.g., Lube Cube® lube oil tanks and ConVault tanks). Shop-fabricated tanks can be constructed with integral secondary containment and fire protection. The most common tanks used for fuel service are described in the sections that follow.

b. A baseline internal inspection must be conducted on shop-fabricated tanks before they are placed into service. The baseline inspection must include, floor, shell, roof, and end wall-thickness measurements as applicable for a specific type of tank. These initial measurements will be used by later inspectors to monitor and evaluate corrosion rates of specific tanks.

c. Military service-specific, host nation, state or local regulations may require additional inspections or increased frequency of inspections of shop-fabricated tanks. The Installation must follow the more stringent of this UFC or military service-specific, host nation, state, or local regulations.

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8-5.1 Aboveground Shop-Fabricated Tanks.

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a. UFC 3-460-01 Section 8-4 limits shop-fabricated tank size diameters to 12 feet (3.66 meter) and maximum capacities of 50,000 gallons (190,000 liters). Aboveground single-wall tanks are designed and constructed to meet the requirements of UL 142.

b. Double-wall tanks are designed with a UL 142 compatible inner tank. Fire resistant doubled-walled tanks are equipped with an outer tank design to meet UL 2080. Protected double-walled tanks are equipped with an outer tank designed to meet UL 2085 requirements. Additional considerations and guidance are specified in NFPA 30. NFPA 30A should be consulted for requirements of tanks used to dispense fuel to ground vehicles or watercraft.

c. In general, inspections fall into the categories of internal (first or subsequent), external (periodic or formal), and leak test. Unless more frequent inspection and testing is specified by military service-specific directives, host nation, state or local regulations or certified inspector as a result of the previous inspection, the inspection and testing protocol defined by STI SP001 based on the classification system shown in **1**\ STI SP001 /**1**/ must be used to determine inspection and testing requirements of aboveground shop fabricated tanks.

d. Inspection protocols must be assigned by the military service-specific SCP or SME. Where multiple inspection protocols could be applied, once selected, the initial inspection protocol should not be changed without prior coordination with the military service-specific SCP or SME. Prior inspection history is key to subsequent inspections being able to identify issues. Each tank's inspection protocol should be clearly documented and used as the basis for future projected inspections.

e. When applying STI SP001 formal testing schedules, select the internal inspection option if the tank is physically able to be entered. Otherwise select the leak test option**1**\/**1**/. Only tanks equipped with a manway at least 18 inches wide (455 mm) should be entered.

f. For multi-compartment tanks, the "tank size" is equivalent to the individual compartment that is being inspected.

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8-5.1.1 Inspection and Maintenance – Aboveground Shop Fabricated Steel Tank Inspections.

a. Monthly External Inspection (Identified as P in **1**\ STI SP001)/**1**/: Visually inspect for exterior signs of corrosion or coating deterioration. Visually inspect weld seams, tank-to-saddle connections, tank supports, tank anchors, foundation and anchor bolts, overfill valves and alarms, normal vents, emergency vents, leak detection probe or water/petroleum accumulation in the interstice on double-walled tanks, leaking valves, fittings, or components, spill containment systems and release prevention barriers. Leaking valves, fittings or components must be repaired immediately or immediately removed from service and isolated to prevent further discharge. Any irregularities, (e.g., missing valve handles, bolts, nuts, screens) will be assessed for priority and repaired as soon as possible or as required depending on the nature of the defect (see Appendix E for an example of the STI SP001 Standard Monthly Inspection Checklist).
Frequency: Monthly

b. Annual External Inspection (Identified as P in **1**\ STI SP001 /**1**/): A more detailed examination of the tank and appurtenances must be performed on an annual basis (See Appendix E for an example of the STI SP001 Standard Annual Inspection Checklist).
Frequency: Annually

c. Formal External Inspection (Identified as E in **1**\ STI SP001 /**1**/): A formal external inspection as defined in STI SP001 must be conducted by certified STI SP001 inspector.
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001. /1/

d. Formal Internal Inspection (Identified as I in **1**\ STI SP001 /**1**/): A formal internal inspection as defined in STI SP001 must be performed by a certified STI SP001 inspector. **1**\ The API 653 or STI SP001 inspector must recommend the date of the next inspection. The inspection interval must be based on the date the Suitability for Service Letter is issued immediately prior to when the tank is returned to service. /**1**/
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001. **/1/**

e. Leak Test (Identified as L in **1**\ STI SP001 /**1**/): A leak test as defined in STI SP001 must be performed in accordance with STI SP001.
Frequency: As established by SCP based on tank size and category\1\ as defined in STI SP001. /1/

8-5.2 Self-Diking or Vaulted Tanks.

Self-diking tanks are designed to UL142 can be of either single or double-wall construction and are designed to sit within a fabricated steel containment dike. The dike is designed to contain small spills or the entire tank contents in the event of a major leak or rupture. These tanks usually range in size from 250 to 12,000 gallons (946 to 45,424 liters) but can be larger. NFPA 30 and NFPA 30A have specific criteria that must be met before using this type of tank. Secondary containment dikes may only be opened for draining purposes and performed in accordance with the Installation's SPCC plan. At a minimum, secondary containment drain valves will be monitored during draining, closed and locked after use.

8-5.2.1 Inspection and Maintenance – Self Diking or Vaulted Tank Inspections.

a. Monthly External Inspection (Identified as P in **1**\ STI SP001 /**1**/): Visually inspect for exterior signs of corrosion or coating deterioration. Visually inspect weld seams, tank-to-saddle connections, tank supports, tank anchors, foundation and anchor bolts, overfill valves and alarms, normal vents, emergency vents, leak detection probe or water/petroleum accumulation in the containment area, leaking valves, fittings, or

components. Leaking valves, fittings or components must be repaired immediately or immediately removed from service and isolated to prevent further discharge. Any irregularities, (e.g., missing valve handles, bolts, nuts, screens) will be assessed for priority and repaired as soon as possible or as required depending on the nature of the defect (See Appendix E for an example of the STI SP001 Standard Monthly Inspection Checklist).
Frequency: Monthly

b. Annual External Inspection (Identified as P in **1**\\ STI SP001 /**1**/): A more detailed examination of the tank and appurtenances must be performed annually. (See Appendix E for an example of the STI SP001 Standard Annual Inspection Checklist).
Frequency: Annually

c. Formal External Inspection (Identified as E in **1**\\ STI SP001 /**1**/): A formal external inspection as defined in STI SP001 must be conducted by certified STI SP001 inspector.
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001. /1/

d. Formal Internal Inspection (Identified as I in **\1** STI SP001 **/1/**): A formal internal inspection as defined in STI SP001 must be performed by a certified STI SP001 inspector.
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001. /1/

e. Leak Test (Identified as L in **1**\\ STI SP001 /**1**/): A leak test as defined in STI SP001 must be performed in accordance with STI SP001.
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001. /1/

8-5.3 Rectangular Concrete-Encased Tanks.

Concrete-encased tanks are constructed in accordance with UL 2085 (e.g., ConVault Tanks). The tank by design has an integral secondary containment in the form of a petroleum resistant plastic sheet encased in concrete. The concrete surface is exposed on the exterior of the tank as opposed to a steel shell. These tanks are maintained and inspected in a similar manner as a double-wall or protected steel tanks. Any formal testing of the primary (interior) tank or interstice must be conducted in accordance with manufacturer’s instructions.

8-5.3.1 Inspection and Maintenance – Concrete-Encased Tank Inspections.

a. Monthly External Inspection (Identified as P in **1**\\ STI SP001 /**1**/): Visually inspect tank supports, anchors and anchor bolts, overfill valve and alarms, normal vent, emergency vent, leaking valves, fittings or other components. In addition the exterior concrete must be visually inspected for cracking,

degradation, excessive calcareous deposits or signs of damage. Leaking valves, fittings or components must be repaired immediately or isolated to prevent further discharge. Any other deficiencies or irregularities noted must be repaired as soon as possible or as required depending on the nature of the defect (See Appendix E for an example of the STI SP001 Standard Monthly Inspection Checklist).
Frequency: Monthly

b. Annual External Inspection (Identified as P in **1**\ STI SP001 /**1**/): A more detailed examination of the tank and appurtenances must be performed on an annual basis (See Appendix E for an example of the STI SP001 Standard Annual Inspection Checklist).
Frequency: Annually

c. Formal External Inspection (Identified as E in **1**\ STI SP001 /**1**/): A formal external inspection must be conducted by certified STI SP001 inspector.
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001 /1/.

d. Formal Interior Inspection **1**\ STI SP001 /**1**/: A modified formal internal inspection as defined in manufacturer's instructions or STI SP001 must be performed on concrete-encased tanks by a certified STI SP001 inspector if the tank interior is accessible.
Frequency: As established by SCP based on tank size and category \1\ as defined in STI SP001 /1/.

8-5.4 Underground Shop-Fabricated Tanks.

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a. UFC 3-460-01 requires tanks to be constructed to meet requirements of NFPA 30 and, if required, NFPA 30A.

b. Underground steel horizontal cylindrical storage tanks are constructed in accordance with UL-58 and conform to environmental requirements of 40 CFR 280.

c. Underground fiberglass horizontal cylindrical storage tanks are constructed in accordance with UL 1316 and also meet requirements of 40 CFR 280.

d. Military service-specific, host nation, state or local regulations may require additional inspections or increased frequency of inspections of shop-fabricated underground tanks. The Installation must follow the more stringent of this UFC or military service-specific, Host

e. Nation, state, or local regulations.

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8-5.4.1 Single-walled Underground Shop-Fabricated Tanks.

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a. Underground shop-fabricated tanks for fuel and oil service installed or replaced after April 11, 2016 must be secondarily contained and use interstitial monitoring in accordance with 40 CFR 280 Section 43. The use of existing single-walled tanks that have been upgraded and are maintained in accordance with 40 CFR 280 Section 21 Upgrading of Existing UST Systems is allowed to continue.

b. In general, inspections fall into the categories of internal, external (monthly and annual), and tightness test. Unless more frequent inspection and testing is specified by military service-specific directives, host nation, state or local regulations or certified inspector as a result of the previous inspection, the inspection and testing protocol defined in \1\ Table 8-1 /1/ must be used to determine inspection and testing requirements of single-walled underground shop fabricated tanks.

c. Strong consideration should be given to the replacement of single-walled underground tanks that are over 30 years old with double-walled tanks equipped with interstitial monitoring that meet the requirements of 40 CFR 280 Section 43.

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Table 8-1 /1/ Single-walled Underground Shop Fabricated Tank Inspection and Testing Schedules*

Tank Size [1] (Gallons)	Release Detection Type	Steel with Cathodic Protection[2]	Fiberglass or Steel with Interior Lining[3]	Steel with Cathodic Protection and Interior Lining[2,3]	Aviation Fuel Tank
111 - 1000	RD-1	P	P	P	P
1001 - 50,000	RD-2	I(10), P	I(INT-1), P	I(15), P	I(10), P
1001 - 50,000	RD-3	I(10), T(INT-2), P	I(INT-1), T(INT-2), P	I(15), T(INT-2), P	I(10), T(INT-2), P

P = periodic inspection (monthly and annual) Use PEI 900 checklists.

I = formal internal inspection by certified inspector. If tank cannot be entered, tanks should be cleaned and inspected with lights and/or cameras through existing openings as deemed practical by a certified tank inspector.

T = tightness test.

( ) = maximum inspection interval, in years.

1 = single-walled tank installed on or before April 11, 2016, that meet the requirements of 40 CFR 280 Section 21 for internal lining, cathodic protection, or both.

2 = Cathodic Protection: At time of cathodic protection installation the integrity of the tank must have been ensured using one of the following methods:

1) The tank was internally inspected and assessed to ensure that the tank was structurally sound and free of corrosion holes prior to installing the cathodic protection system; or
2) The tank had been installed for less than 10 years and has been monitored monthly for releases by automatic tank gauging, vapor monitoring, groundwater monitoring, or statistical inventory reconciliation as defined in 40 CFR 280 Section 43; or
3) The tank had been installed for less than 10 years and was assessed for corrosion holes by conducting two tightness tests. The first tightness test must have been conducted prior to installing the cathodic protection system. The second tightness test must have been conducted between three and six months following the first operation of the cathodic protection system.

3 = interior lining in accordance with 40 CFR 280 Section 33 or constructed of fiberglass.

RD-1 = monitored for release at least every 30 days by automatic tank gauging, vapor monitoring, groundwater monitoring or manual tank gauging as detailed in 40 CFR 280 Section 43.

RD-2 = monitored for release at least every 30 days by automatic tank gauging, vapor monitoring, or groundwater monitoring as defined in 40 CFR 280 Section 43.

RD-3 = monitored for leak detection by inventory control and manual tank gauging as defined in 40 CFR 280 Section 43.

INT-1 = within 10 years after lining, and every 5 years thereafter.

INT-2 = at least every 5 years until 10 years after the tank was installed.

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* Military service-specific, host nation, state, or local regulations may require additional inspections or increased frequency of inspections. The installation must follow the more stringent of this UFC or military service-specific, host nation, state, or local regulations.

8-5.4.1.1 Inspection and Maintenance – Single-walled Underground Shop-Fabricated Tanks.

a. Monthly External Inspection (Identified as P in **1**\ Table 8-1 /**1**/): Ensure all tank port covers are present, are in good condition, and seated firmly on the correct tank. Inspect tank stick gauge and ensure markings are legible and that the stick gauge is not warped or broken. Inspect tank for water using ATG or stick gauge with water-finding paste. Remove water found in tank. Open and inspect tank-top containment sumps and ensure no fuel or water is collected in the sumps. Check for and remove obstructions in tank fill pipe.
Frequency: Monthly

b. Annual External Inspection (Identified as P in **1**\ Table 8-1 /**1**/): Inspect electrical connections and junction boxes in underground sumps and access ports on tank. Ensure boxes are sealed, and that boxes, conduit, and electrical fittings are not corroded. Inspect submerged turbine pumps if present. Ensure pumps are in good condition and that pumps and fittings show no signs of leaking. Inspect tank top containment sumps for cracks, holes, and budges. Ensure tank top containment sump electrical and pipe penetrations are intact and secured. For double-walled piping systems that drain into the tank top containment sump, ensure interstitial space of piping is open and that sump sensor is properly mounted at the bottom of the sump. Ensure tank top containment sump lid gasket and seals are in good condition. Inspect road access covers. Ensure covers are in good condition, that all bolts are present and that handles and lift mechanism is in good condition as applicable. Inspect concrete installed over tank and ensure there is no significant cracking.
Frequency: Annually

c. Tank Tightness Test (Identified as T in **1**\ Table 8-1 /**1**/): Perform test in accordance with 40 CFR 280, Section 43.
Frequency: As established by SCP based on tank size and release detection type listed in \1\ Table 8-1 /1/.

d. Formal Internal Inspection (Identified as I in **1**\ Table 8-1 /**1**/): A formal modified internal inspection in accordance with STI must be conducted by a certified STI SP001 inspector if the interior is accessible. The inspector will need to supplement and/or adapt portions of STI SP001 to evaluate the specific concerns of an underground tank. Check the tank for settlement and ensure that the tank slopes towards the water drain.
Frequency: As established by SCP based on tank size and release detection type listed in \1\ Table 8-1 /1/ or as recommended by an STI SP001 certified tank inspector in the previous inspection report.

e. Test tank-top containment sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.
Frequency: Every three years

8-5.4.2 Double-walled Underground Shop-Fabricated Tanks.

Underground shop-fabricated tanks for fuel and oil service installed or replaced after April 11, 2016 must be secondarily contained and use interstitial monitoring in accordance with 40 CFR 280 Section 43.

In general, inspections fall into the categories of internal and external (monthly and annual) inspections. Unless more frequent inspection and testing is specified by military service-specific directives, host nation, state or local regulations or certified inspector as a result of the previous inspection, the inspection protocol defined in **1**\ Table 8-2 /**1**/ must be used to determine inspection requirements of double-walled underground shop fabricated tanks.

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Table 8-2 /1/ Double-walled Underground Shop Fabricated Tank Inspection and Testing Schedules*

Tank Size[4] (Gallons)	Release Detection Type	Aviation Fuel Tank[6]	Double-wall Steel Non-aviation Interior Coated[5]	Double-wall Steel with no Interior Coating	Double-wall Fiberglass
111 - 1000	RD-4	P	P	P	P
1001 - 50,000	RD-5	I(10), P	I(20), P	I(20), P	I(20), P

P = periodic inspection (monthly and annual) Use PEI 900 checklists.

I = formal internal inspection by certified inspector. If tank cannot be entered, tanks should be cleaned and inspected with lights and/or cameras through existing openings as deemed practical by a certified tank inspector.

( ) = maximum inspection interval, in years.

4 = double-walled tank that meets the requirements of 40 CFR 280 Section 20.

5 = interior epoxy coating.

6 = operating tank that issues fuel to aircraft.

RD-4 = monitored for release at least every 30 days by automatic tank gauging, vapor monitoring, groundwater monitoring, interstitial monitoring or manual tank gauging as detailed in 40 CFR 280 Section 43.

RD-5 = tank installed on or before April 11, 2016, monitored for release at least every 30 days by automatic tank gauging, vapor monitoring, groundwater monitoring, interstitial monitoring, or statistical inventory reconciliation or tanks installed after April 11, 2016 monitored for release at least every 30 days by interstitial monitoring as defined in 40 CFR 280 Section 43.

* Military service-specific, host nation, state, or local regulations may require additional inspections or increased frequency of inspections. The installation must follow the more stringent of this UFC or military service-specific, host nation, state, or local regulations.

8-5.4.2.1 Inspection and Maintenance – Double-Walled Underground Shop-Fabricated Tanks.

a. Monthly External Inspection (Identified as P in **1**\ Table 8-2 /**1**/): Ensure all tank port covers are present, are in good condition, and seated firmly on the correct tank. Inspect tank stick gauge and ensure markings are legible and that the stick gauge is not warped or broken. Inspect tank for water using ATG or stick gauge with water-finding paste. Remove water found in tank. Open and inspect tank-top containment sumps and ensure no fuel or water is collected in the sumps. Check for and remove obstructions in tank fill pipe.
Frequency: Monthly

b. Annual External Inspection (Identified as P in **1**\ Table 8-2 /**1**/): Inspect electrical connections and junction boxes in underground sumps and access ports on tank. Ensure boxes are sealed, and that boxes, conduit, and electrical fittings are not corroded. Inspect submerged turbine pumps if present. Ensure pumps are in good condition and that pumps and fittings show no signs of leaking. Inspect tank top containment sumps for cracks, holes, and budges. Ensure tank top containment sump electrical and pipe penetrations are intact and secured. For double-walled piping systems that drain into the tank top containment sump, ensure interstitial space of piping is open and that sump sensor is properly mounted at the bottom of the sump. Ensure tank top containment sump lid gasket and seals are in good condition. Inspect road access covers. Ensure covers are in good condition, that all bolts are present and that handles and lift mechanism is in good condition as applicable. Inspect concrete installed over tank and ensure there is no significant cracking.
Frequency: Annually

c. Formal Internal Inspection (Identified as I in **1**\ Table 8-2 /**1**/): A formal modified internal inspection in accordance with STI must be conducted by a certified STI SP001 inspector if the interior is accessible. The inspector will need to supplement and/or adapt portions of STI SP001 to evaluate the specific concerns of an underground tank. Check the tank for settlement and ensure that the tank slopes towards the water drain.
Frequency: As established by SCP based on tank size and release detection type listed in \1\ Table 8-2 /1/ or as recommended by an STI SP001 certified tank inspector in the previous inspection report.

d. Test tank-top containment sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.
Frequency: Every three years

8-6 UNDERGROUND FIELD-CONSTRUCTED TANKS (CUT AND COVER TANKS).

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a. Underground field-constructed tanks are vertical or horizontally constructed and can be constructed of welded steel or welded steel interior with concrete exterior. The tanks are covered with soil or buried in the ground.

b. The tank design includes manways that extend to grade level for access to the interior of the tank for inspection and cleaning purposes. Deep-well vertical turbine pumps are mounted to the top of the tank and are enclosed in a small pump house or vault, or tanks are gravity fed and tunnels are used to access tank connections and skin valves. The fill connection extends to the bottom of the tank and is usually equipped with a splash deflector or diffuser. The tank is equipped with a sump pump to remove water from the tank, pressure-vacuum vents, level indicators and transmitters, and level switches.

c. A baseline internal inspection must be conducted on underground field-constructed tanks before they are placed into service. The baseline inspection must include, floor, shell, and roof wall-thickness measurements. These initial measurements will be used by later inspectors to monitor and evaluate corrosion rates of specific tanks.

d. Military service-specific, host nation, state or local regulations may require additional inspections or increased frequency of inspections of underground field-constructed tanks. The Installation must follow the more stringent of this UFC or military service-specific, host nation, state, or local regulations.

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8-6.1 Inspection and Maintenance – Underground Field-Constructed Tanks (Cut and Cover Tanks).

a. Check the level gauge records and interstitial monitoring ports to determine if the tank is leaking.
Frequency: Daily

b. Apply field-erected tank monthly external inspection to the maximum extent possible. Visually inspect tank and appurtenances for evidence of leaks, shell distortions, signs of corrosion, and settlement at accessible locations. Items noted during the inspection will be documented for follow-up action by an authorized inspector (See Appendix F for the Field-Erected Tank Monthly Inspection Checklist).
Frequency: Monthly

c. Check tank under static storage conditions for 24 hours using existing inventory management system to determine if petroleum losses are occurring. If leakage is noted, further investigation must be conducted in accordance with military service-specific guidelines.
Frequency: Monthly

d. Apply field-erected tank annual external inspection to the maximum extent possible. Visually inspect tank and appurtenances for evidence of leaks, shell distortions, signs of corrosion, and settlement at accessible locations. Visually inspect pump/equipment vaults for leaks and cracking in concrete walls and floors. Retain records of inspections reports for five years (See Appendix F for the Field-Erected Tank Annual Inspection Checklist).
Frequency: Annually

e. Perform a modified out-of-Service API 653 internal inspection to evaluate the tank for conditions which may affect the operational integrity of the tank floor, shell, columns and roof by certified API 653 inspector. API 653 provides a checklist to be used as part of the assessment; however the certified API 653 inspector must modify this checklist to incorporate specific needs of underground field-constructed tanks. **1**\\ The API 653 or STI SP001 inspector must recommend the date of the next inspection. The inspection interval must be based on the date the Suitability for Service Letter is issued immediately prior to when the tank is returned to service.
Frequency: As recommended by the API 653 or STI SP001 inspector. If there is not a previous recommendation, the inspection must be performed within ten years after the tank was placed into operation.
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8-7 TANK CLEANING.

Tank cleaning operations are detailed in Appendix H for government personnel. Contractors must utilize UFGS**1**\\33 01 50.65/**1**/for cleaning requirements of tanks. Appendix H provides the minimum standards for safe entry of petroleum tanks.

a. Conduct Tank Cleaning: Unless otherwise mandated by operational concerns or military service directives, schedule and conduct tank cleaning based upon the frequency listed below. After cleaning tanks must be stenciled in accordance with Section 8-8.1 Tank Stenciling Requirements.
Frequency:

- **Air Force – Tanks above 20,000 gallon (75,700 liters) in capacity - Every 10 years unless required more frequently due to fuel quality issues. Contact AFPET and AF Fuel SME for deviations on schedule. Schedule changes are typically accepted based on TO 42B1-1 requirements.**

- **Air Force – Tanks 20,000 gallon (75,700 liters) in capacity and under - During out of service inspection cycle unless required more frequently due to potential fuel quality issues.**
- **Army, Navy, U.S. Marine Corps – During out-of-service inspection cycle unless required more frequently due to potential fuel quality issues.**

8-8 RETURNING TO SERVICE AFTER FORMAL OUT OF SERVICE INSPECTION/REPAIR.

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- Re-install all valves, piping, and manhole covers using new non-asbestos gasket material compatible with the product being stored. Gasket thickness must not be less than the thickness of the gasket replaced. Restore the entire area to its original condition. Reconnect and activate cathodic protection system.
- Limit the fill line and discharge velocity in the piping of the incoming liquid stream into petroleum fuel tanks to 3 feet per second (fps) (0.9 meter per second (mps)) until the fill pipe is submerged in fuel by either two pipe diameters or 2 feet (60 cm), whichever is less. In the case of a floating-roof or pan equipped tank, observe the 3 fps (1 mps) velocity limitation until the roof or pan becomes buoyant. For additional information, see API 2003.

NOTE: Wait thirty minutes after loading or unloading an aboveground fuel tank before gauging a tank. Wait at least 18 hours before attempting entry onto a floating roof or pan after an initial fill.

- At the completion of a tank inspection or cleaning operation, ensure the tank is stenciled in accordance with Section 8-8.1 Tank Stenciling Requirements.
- Documentation that should be provided before a tank is placed back into service after a formal out of service inspection or repair includes the following:

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- A statement signed by an applicable code certified tank inspector indicating the tank is suitable for return to service including any caveats, clarifications, or limitations that would affect tank operations after return to service. The statement must include due dates for the next applicable formal inspections (internal, external, and leak test) and any repairs required prior to those next inspections. Next inspection due dates must be the maximum allowable by code, calculated from the latest of the inspection or repair completion dates.

- A completed inspection report compliant with the applicable code including all required calculations and analysis. Preliminary or field reports cannot be substituted for this requirement.
- A list of repairs identified during the inspection, including completed repairs and repairs that are still pending. All pending repairs must be annotated with a due date.
- Third-party certified calibration ("strapping") charts when a tank is first placed in service, when certified calibration charts did not previously exist, or when repairs were made that would be reasonably expected to change the tank's calibration. For shop-fabricated tanks, manufacturer-provided calibration charts require third-party certification before they can be accepted.
- A statement signed from the Execution Agent and repair contractor that custody of the tank is returned to the Installation and that items listed above have been delivered to the Government.

8-8.1 Tank Stenciling Requirements.

Tank stencils should be 0.75 to 1-inch (19-25 mm) height letters. The information must be stenciled on or next to the manhole covers for aboveground tanks, or stenciled on the manhole cover or tank pit wall for underground tanks. The following information must be stenciled if known:

- Date of the tank cleaning (Month/Year).
- Cleaning completed by (i.e., in-house or contractor's name).
- Name of the individual certifying the cleaning.
- If applicable, the address or contact information for the contractor.
- Date of last formal internal inspection (Month/Year).
- Date of next formal internal inspection (Month/Year).

8-9 TANK APPURTENANCES.

8-9.1 Floating Roofs and Pans.

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a. Floating roofs and pans rest directly on the petroleum surface, minimizing vapor space directly above the petroleum surface when storing light-weight volatile liquids and jet fuels. Floating roofs and pans also minimize water and contaminant infiltration into the petroleum and mitigate fire risks.

b. Floating pans can be constructed of steel or aluminum. Pans float by displacement and are not equipped with large voids or hollow compartments to help provide buoyancy. When aluminum is used the design can include an internal honeycomb in the sheet material. This internal honeycomb includes small void spaces that give the pan additional buoyancy.

c. Pontoon floating pans can be constructed of steel or aluminum. Pontoon floating pans use hollow compartments to provide buoyancy. Typically the hollow compartments are constructed in a circle on the outside diameter of the pontoon floating pan. The compartments or pontoons are individually sealed.

d. Floating roofs are installed on tanks that are not equipped with a sealed cone type roof. In most cases these tanks have been retrofitted with geodesic domes or steel framed roofs to mitigate water entrance into the tank through the open top. Floating roofs are typically constructed of steel and include pontoons for buoyancy. These type roofs are typically equipped with a drain system that will allow rain water that collects on the top of the roof to drain to a point outside of the tank. These roofs drain by sloping to a center sump. The center sump is connected to a hose or multi-jointed pipe extending through the fuel to an outside water draw-off valve.

e. Tanks are typically equipped with internal ladders that can be used to access the top of the floating roof or pan from the top of the tank. In some cases these ladders are installed on rollers and the angle of the ladder changes as the floating roof or pan changes elevation. In other cases these ladders are vertical and penetrate the floating roof or pan and a rubber seal is installed on the floating pan or roof to close the annular space between the ladder and the metal of the floating roof or pan.

f. Floating roofs or pans are equipped with anti-rotation cables or pipes. These anti-rotation devices keep the floating roof or pan in position as the elevation of the floating roof or pan changes due to fuel level changes. They also prevent the floating roof or pan from rotating due to currents produced from fuel receipt or issue operations.

g. Most petroleum fuel tanks are equipped with gauge wells. These wells are used for temperature and level measurement devices. The wells are constructed of vertical pipes that penetrate the floating roof or pan. A rubber seal is installed on the floating roof or pan to close the annular space between the gauge wells and the floating roof or pan. In some cases the vertical risers of vertical ladders are also used as gauge wells.

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Figure 8-1 Floating Roof Seal

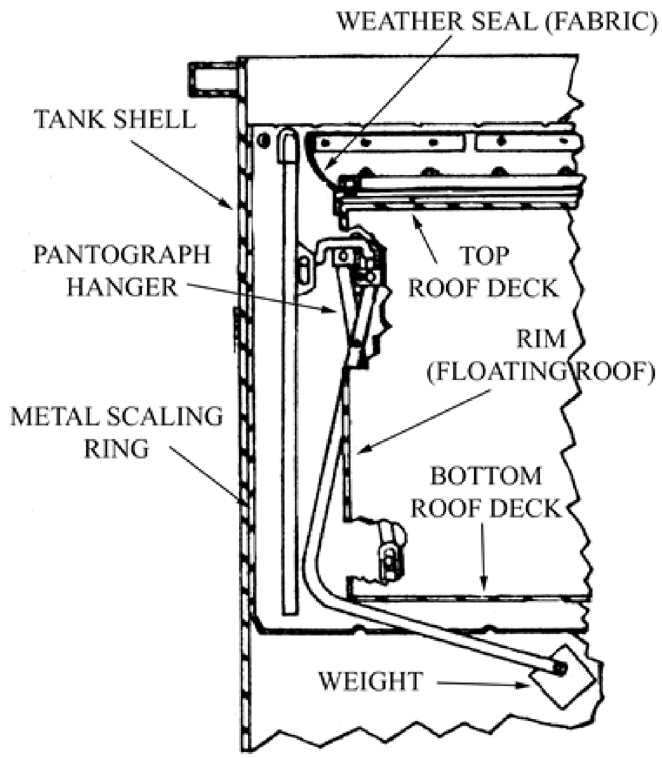


Figure 8-2 Floating Roof Detail

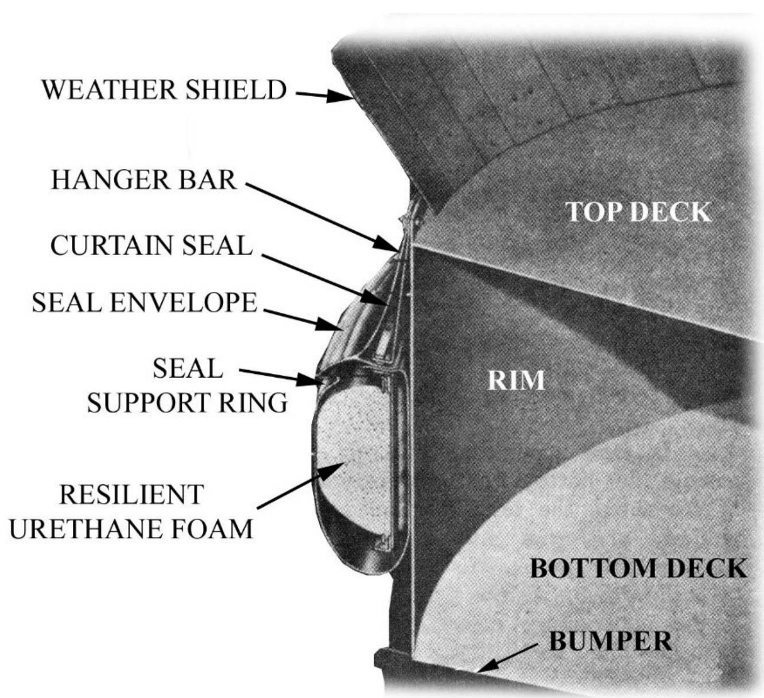
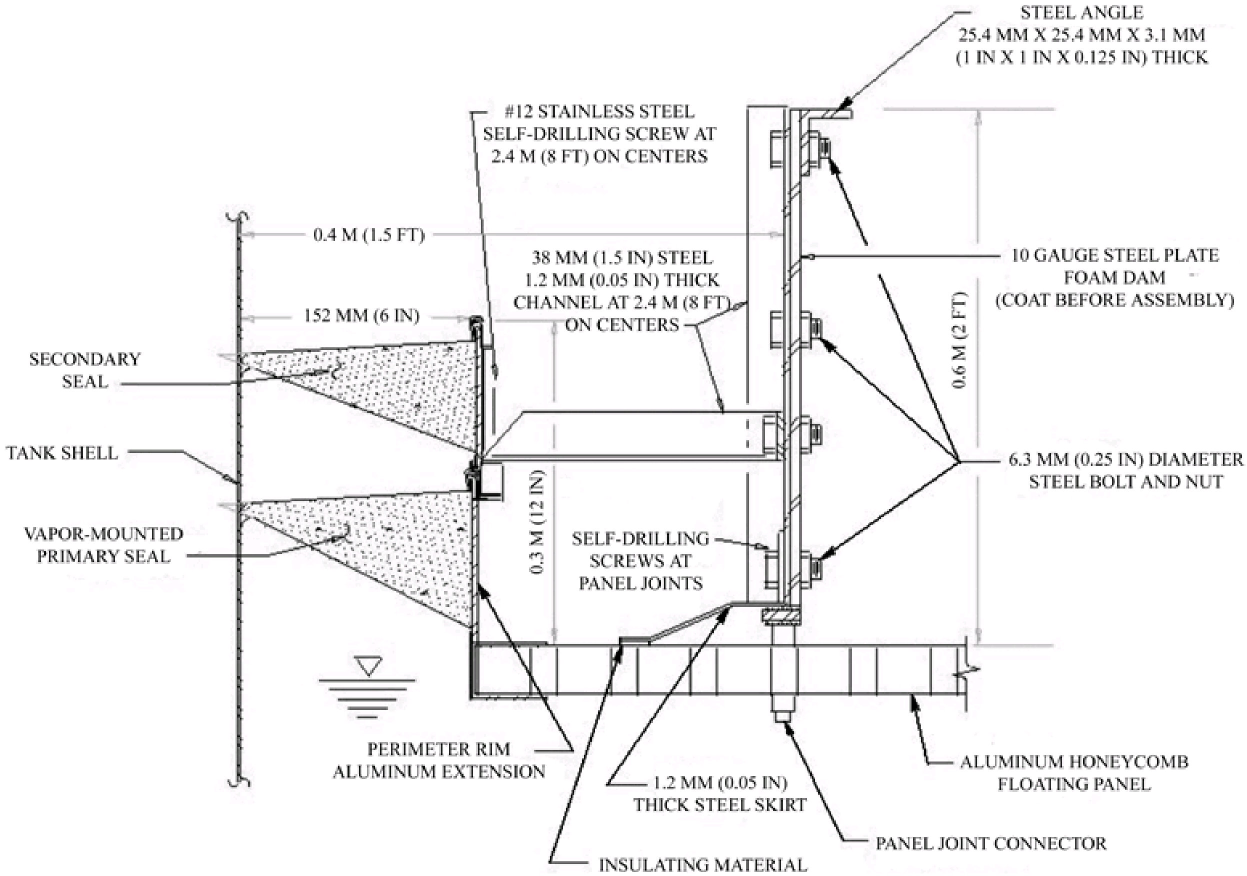


Figure 8-3 Standard Tank Seal on Aluminum Honeycomb Pans



8-9.1.1 Inspection and Maintenance - Aluminum Honeycomb Floating Pans.

Perform visual inspections from fixed roof hatch. Access to internal floating pans is considered a permit-required confined space, therefore all appropriate safety procedures must be followed before conducting internal inspections.

a. Visually inspect pan guide/anti-rotation cables and centering of pan.
Frequency: Monthly

b. Visually inspect pan grounding cables for proper attachment and wear or binding.
Frequency: Monthly

c. Visually inspect for buckling or damage to the pan.
Frequency: Monthly

d. Inspect grounding cables for proper attachment and wear or binding.
Frequency: Annually

e. Inspect all floating roof penetration seals, such as ladder seals, stilling well seals, and other seals to ensure that they are in good working condition.
Frequency: Annually

f. Clean and inspect perimeter tank/pan seals.
Frequency: At time of out of service internal inspection.

g. Refer to Section 8-9.1.5, "Floating Roof and Pan Pressure/Vacuum Vents," for inspection and maintenance requirements of floating pan pressure/vacuum vents.

h. Refer to Section 8-9.1.6, "Floating Roof and Pan Legs," for inspection and maintenance requirements of floating pan legs.

8-9.1.2 Inspection and Maintenance – Steel Floating Pans.

Perform visual inspections from fixed roof hatch. Access to internal floating pans is considered a permit-required confined space, therefore all appropriate safety procedures must be followed before conducting internal inspections.

a. Visually inspect pan guide/anti-rotation cables or pipe and centering of pan.
Frequency: Monthly

b. Visually inspect pan grounding cables for proper attachment and wear or binding.
Frequency: Monthly

c. Visually inspect for buckling or damage to the pan.
Frequency: Monthly

d. Visually inspect for damage or deflection in the rolling ladder (if equipped).
Frequency: Monthly

e. Inspect grounding cables for proper attachment and wear or binding.
Frequency: Annually

f. Inspect all floating pan penetration seals, such as gauge well seals to ensure that they are in good working condition.
Frequency: Annually

g. Inspect gauge wells for abrasions that might indicate out of roundness, or improper centering.
Frequency: Annually

h. Inspect vertical ladder for abrasions that might indicate out of roundness, or improper centering (if equipped).
Frequency: Annually

i. Inspect for damage or deflection in the rolling ladder (if equipped).
Frequency: Annually

j. Clean and inspect perimeter tank/pan seals.
Frequency: At time of out of service internal inspection

k. Refer to Section 8-9.1.5, "Floating Roof and Pan Pressure/Vacuum Vents," for inspection and maintenance requirements of floating pan pressure/vacuum vents.

l. Refer to Section 8-9.1.6, "Floating Roof and Pan Legs," for inspection and maintenance requirements of floating pan legs.

8-9.1.3 Inspection and Maintenance – Pontoon Floating Pans.

Perform visual inspections from fixed roof hatch. Access to pontoon floating pans is considered a permit-required confined space, therefore all appropriate safety procedures must be followed before conducting internal inspections.

a. Visually inspect pan guide/anti-rotation cables or pipes and centering of pan.
Frequency: Monthly

b. Visually inspect grounding cables for proper attachment and wear or binding.
Frequency: Monthly

c. Visually inspect for buckling or damage to the pan.
Frequency: Monthly

d. Visually inspect for damage or deflection in the rolling ladder (if equipped).
Frequency: Monthly

e. Inspect pontoons for standing liquid and presence of strong vapors.
Frequency: Annually

f. Remove mechanical gauge float cover and ensure float is securely fastened to gauge tape. Check gauge tape for ease of movement.
Frequency: Annually

g. Inspect for damage or deflection in the rolling ladder (if equipped).
Frequency: Annually

h. Inspect vertical internal ladder and internal ladder/pan seals for abrasions that might indicate out of roundness, or improper centering (if equipped).
Frequency: Annually

i. Inspect gauge wells and gauge well/pan seals for abrasions that might indicate out of roundness, or improper centering.
Frequency: Annually

j. Inspect steel floating pan coatings for corrosion. Touch up with compatible coating if required (aluminum pans do not require coatings).
Frequency: Annually

k. Clean and inspect perimeter tank/pan seals.
Frequency: At time of out of service internal inspection.

l. Refer to Section 8-9.1.5, "Floating Roof and Pan Pressure/Vacuum Vents," for inspection and maintenance requirements of floating pan pressure/vacuum vents.

m. Refer to Section 8-9.1.6, "Floating Roof and Pan Legs," for inspection and maintenance requirements of floating pan legs.

8-9.1.4 Inspection and Maintenance – Floating Roofs.

Perform visual inspections from fixed roof hatch. Access to floating roofs is considered a permit-required confined space, therefore all appropriate safety procedures must be followed before conducting internal inspections.

a. Visually inspect the center primary roof drain system. Confirm it is water-free.
Frequency: Monthly

b. Visually inspect anti-rotation pipes/roof guides and centering of roof.
Frequency: Monthly

c. Visually inspect grounding cables for proper attachment and wear or binding.
Frequency: Monthly

d. Visually inspect for buckling or damage to the roof.
Frequency: Monthly

e. Visually inspect for standing water on roof deck.
Frequency: Monthly

f. Visually inspect for damage or deflection in the rolling ladder (if equipped).
Frequency: Monthly

g. Ensure that the drip-tight plug is placed in the roof drain opening.
Frequency: Annually

h. Ensure that the roof drain valve is closed. The drain valve is kept in the closed position except after each rain or snowfall when it is opened just long enough to drain the roofline. Tanks with retrofitted geodesic domes or metal roofs may have had the floating roof drain line removed, so before opening the roof drain valve ensure the roof drain line has not been removed.
Frequency: Annually

i. Inspect pontoons for standing liquid and presence of strong vapors.
Frequency: Annually

j. Remove mechanical gauge float cover and ensure float is securely fastened to gauge tape. Check gauge tape for ease of movement.
Frequency: Annually

k. Ensure emergency drain is not blocked with debris (if equipped).
Frequency: Annually

l. Inspect for damage or deflection in the rolling ladder (if equipped).
Frequency: Annually

m. Inspect vertical internal ladder and internal ladder/roof seals for abrasions that might indicate out of roundness, or improper centering (if equipped).
Frequency: Annually

n. Inspect gauge wells and gauge well/roof seals for abrasions that might indicate out of roundness, or improper centering.
Frequency: Annually

o. Inspect the floating roof coating for corrosion. Touch up with compatible coating if required.
Frequency: Annually

p. Clean and check perimeter tank/roof seals.
Frequency: At time of out of service internal inspection.

q. Refer to Section 8-9.1.5, "Floating Roof and Pan Pressure/Vacuum Vents," for inspection and maintenance requirements of floating roof pressure/vacuum vents.

r. Refer to Section 8-9.1.6, "Floating Roof and Pan Legs," for inspection and maintenance requirements of floating roof legs.

8-9.1.5 Floating Roof and Pan Pressure/Vacuum Vents.

Floating roof and pan pressure/vacuum vents are used to relieve vacuum pressure on the floating roof or pan when the legs of the floating roof or pan make contact with the tank bottom and a vapor space is created between the surface of the liquid and the bottom of the floating roof or pan as the liquid level continues to drop. The pressure/vacuum vent also relieves positive pressure as the fluid below the floating roof or pan rises before the surface of the liquid makes contact with the bottom of the floating roof or pan.

8-9.1.5.1 Inspection and Maintenance - Floating Roof and Pan Pressure/Vacuum Vents.

a. Inspect the floating roof or pan pressure/vacuum vent to ensure that the seats and retaining straps or guides are in good working order and that the pressure/vacuum vent is not stuck to its seats, but instead lift easily off of its seats and reseats properly. Inspect gaskets for wear and replace as required. Refer to the manufacturer's operation and maintenance manual

provided with the floating roof or pan for additional guidance on servicing the pressure/vacuum vent.
Frequency: At time of out of service internal inspection.

8-9.1.6 Floating Roof and Pan Legs.

Floating roof and pan legs support the floating roof or pan in its high position for maintenance (approximately 6 foot-3 inch (1.9 meter) clearance from bottom of floating roof or pan to tank bottom), and limit the low position of the floating roof or pan when fuel is drawn down to approximately 2 foot 5-inches (0.7 meter) of clearance from bottom of floating roof or pan to tank bottom or minimum of 6-inch (150 mm) from the top of any internal nozzle flange to the bottom of the floating roof or pan, whichever is higher.

8-9.1.6.1 Inspection and Maintenance - Floating Roof and Pan Legs.

a. Inspect the floating roof or pan legs and tank bottom striker plates for wear; inspect the seals where the legs penetrate the floating roof or pan for leaks; inspect the low leg position stops to make sure they are securely fastened to the legs and will stop the floating roof or pan at the low position; inspect the leg keeper straps to make sure they are securely fastened to the legs to prevent the legs from falling off or through the floating roof or pan; inspect the threaded keeper caps or high position locking mechanisms to ensure they are in proper working order for securing the floating roof or pan in the high position. Refer to the maintenance manual provided with the floating roof or pan for additional guidance on floating roof or pan legs and associated hardware.
Frequency: At time of out of service internal inspection.

8-9.2 Secondary Tank Bottoms.

Secondary tank bottoms are installed to repair original tank bottoms that degraded. Secondary tank bottoms are installed approximately 1-foot (300 mm) above the existing tank bottom. In most cases sand is installed between the original and secondary bottom, although in some cases a new release protection barrier is installed between the original and secondary tank bottom. Tanks equipped with secondary tank bottoms can be identified by the presence of a second chime about 1-foot (300 mm) above the original chime at the tank to concrete foundation interface.

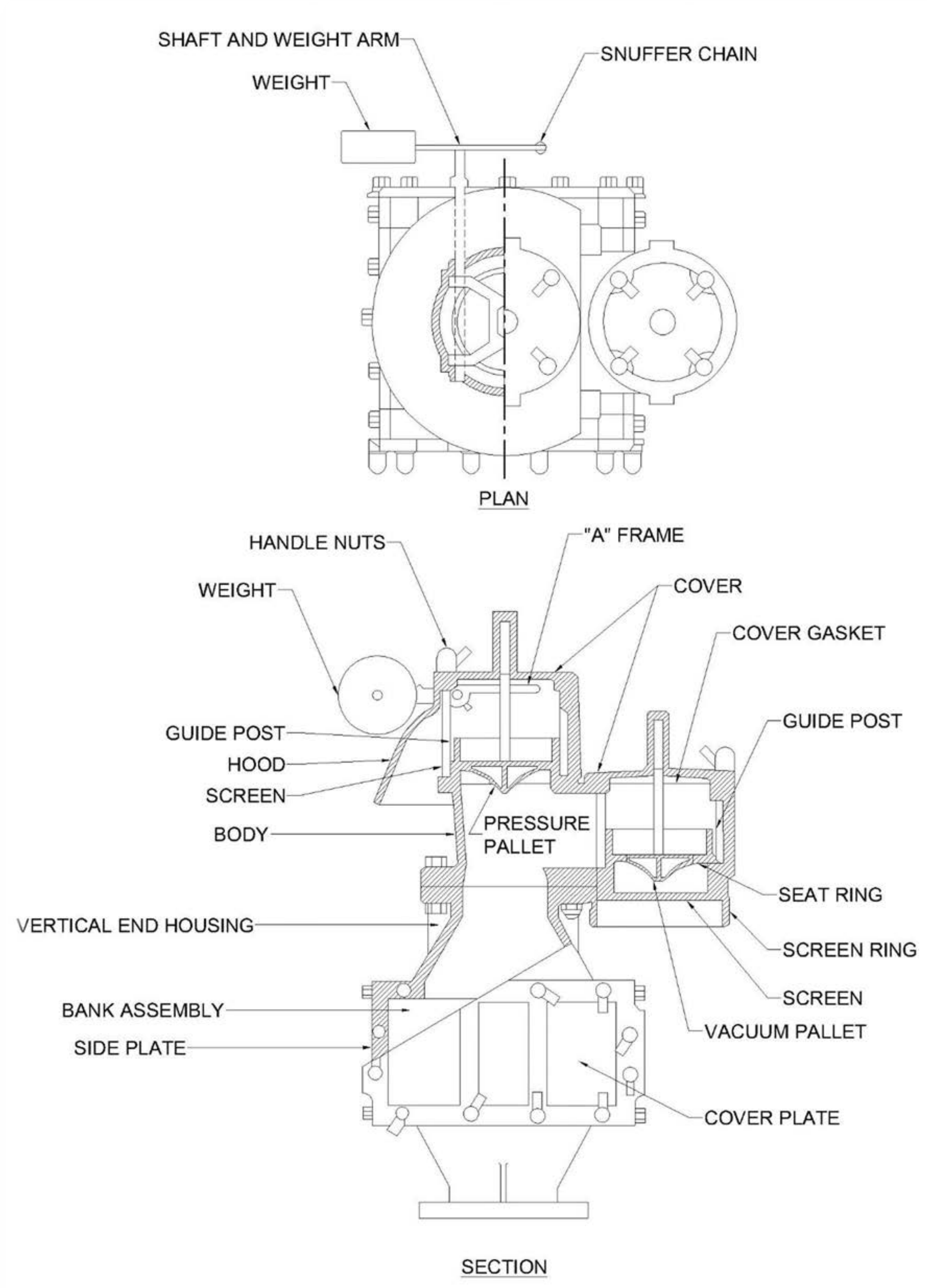
8-9.2.1 Inspection and Maintenance - Secondary Tank Bottoms.

a. Tanks designed with secondary tank bottoms should have tell-tale devices (leak detection ports) to allow for monitoring of the tank’s floor integrity. The tell-tale devices are typically configured as valves or inspection ports to allow for visual monitoring of liquid that may be present between the foundation and the tank floor. The presence of water would indicate a breach in the foundation seals or flooring while the presence of petroleum would indicate integrity loss in the tank floor. Open and check tell-tale valves or inspection ports. Verify the absence of water or petroleum. **Frequency: Monthly**

8-9.3 Tank Pressure/Vacuum Vents.

The pressure/vacuum vent allows air to escape when filling the tank and allows air to enter the tank when the tank is being emptied, or drawn down, in order to keep from damaging the tank and to keep fuels with high vapor pressures from evaporating from the tank. Pressure/vacuum vents are typically installed on petroleum fuel storage tanks storing petroleum fuels with vapor pressures exceeding 0.75 psi (5 kPa). They are not usually installed on API 650 tanks with floating roofs and atmospheric vents. The type and size of vent used can vary greatly.

Figure 8-4 Pressure Vacuum Vent



8-9.3.1 Inspection and Maintenance – Tank Pressure/Vacuum Vents.

a. On underground shop fabricated tanks, ensure tank pressure/vacuum vent is present and that the riser pipe is securely supported and vertical.
Frequency: Monthly

b. Inspect vent settings. Pressure and vacuum settings for pressure/vacuum vents are usually specified on the vent nameplate or in the manufacturer's manual for the vent.
Frequency: Annually

c. Clean the pressure/vacuum vent. Information on the type of pressure/vacuum vent and procedures for the removal of covers, hoods and/or pallet removal and reinstallation should be found in the manufacturer's operation and maintenance manual. Before removing the pallets, brush all accumulations from the protecting screens, the pallets, and all surfaces of the valve. Brush the screens from inside the valve so that dirt and other objects fall to the outer sides. Remove heavy loading weights prior to removing the pallet assembly. Remove deposits or foreign matter using reasonable care not to damage diaphragms or seats.
Frequency: Annually

d. Inspect gaskets, seats, diaphragm, pallet stems and stem guides. Check all mating surfaces which must be free of nicks, cuts, cracks or deposits that might interfere with the proper seating or tightness of the valve. Test the pallets to ensure they move freely up and down over the full range of travel.
Frequency: Annually

8-9.4 Emergency Vents.

Emergency vents are installed on most tanks built to UL 142, UL 2080, UL 2085 and API 650 standards. The type and size of the vent used can vary greatly and is determined by the wetted surface (square feet) or venting capacity (cubic feet per hour) of the tank.

8-9.4.1 Inspection and Maintenance – Emergency Vents.

a. Inspect emergency vents for external damage, such as dents, rusting, severe pitting or obstruction by other equipment, piping or conduits.
Frequency: Annually

b. Remove the vent, if possible, and inspect the seals and diaphragms for cracking or breakdown. Inspect retaining cables to ensure they are fastened to the vent and the manway or tank. Inspect guides to ensure emergency vents can function properly and re-seat.
Frequency: Annually

c. Verify that emergency vents have not been removed or modified. Emergency vents should not be replaced with ATGs, manual sample ports, level alarms, etc.
Frequency: Annually

d. Tanks that are equipped with manways for emergency vents must be inspected for appropriate type, length, number of bolts, and lift clearance of the manway in accordance with UL-142, Sections 8 and 9.
Frequency: Annually

8-9.5 Flame Arrestors.

Flame arrestors are intended to provide a positive flame-stop and prevent a fire from spreading to the interior of storage tanks and are typically installed in conjunction with a pressure/vacuum vent. Flame arrestors normally utilize a tube bank consisting of alternate flat and corrugated metal sheets around a solid core of like material sandwiched between two end sections with uniform precision-ground faces to ensure a tight seal.

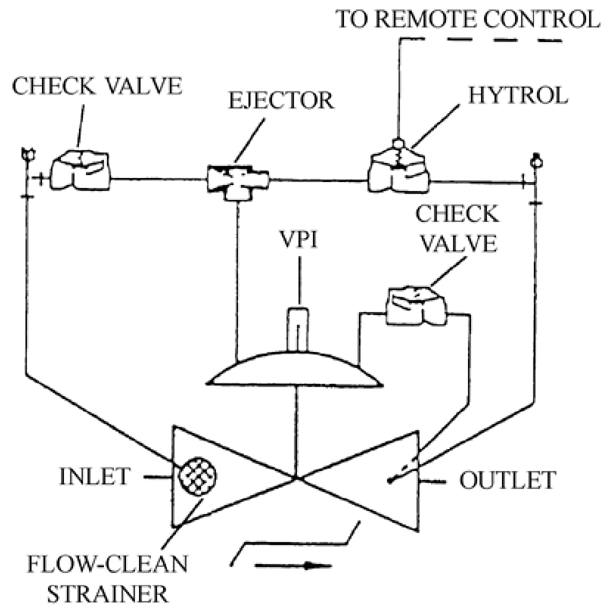
8-9.5.1 Inspection and Maintenance – Flame Arrestors.

a. The tube bank must be removed and cleaned of foreign matter by immersing in an approved solvent solution, taking care not to damage the tube bundle. Gaskets must be inspected and replaced as necessary.
Frequency: Annually

8-9.6 High Level Shut-off Valve (HLSO).

High level shut-off valves are designed to shut off receipts into the tank when a predetermined level is reached.

Figure 8-5 External High Level Shut-off Valve



8-9.6.1 External High Level Shut-off Valves (HLSO).

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a. External High Level Shut-off (HLSO) valves are installed in the receipt piping of tanks. Tanks are configured for the HLSO valve to close at the high alarm level or between the high and high-high alarm level. In most cases, these valves use hydraulic pressure from the upstream side of the fuel piping connected to the valve to open. The valves are equipped with flexible diaphragms and control pilots used to operate the valves. In other cases the valves are solenoid operated and require power to open.

b. Hydraulic actuated valves are controlled by a separate float valve assembly. The float valve can be installed in a sensing chamber on the outside of the tank, or internally installed. The float of the float valve is buoyant in fuel and will rise up to activate the float valve when fuel in the tank reaches the predetermined high level.

c. External float valve sensing chambers are usually accessible from stairs or a platform installed on the outside of tanks. Internal floats are installed in manway covers or tank nozzles at the top of tanks. Tubing from the inlet side of a hydraulic HLSO valve is routed to the float valve and back to both the outlet side of the HLSO valve and to the diaphragm of the HLSO valve. When the level float valve is activated it relieves hydraulic pressure from the diaphragm of the HLSO valve and causes the valve to close.

d. Some newer hydraulic HLSOs are equipped with a solenoid valve that will activate to relieve pressure from the diaphragm of the HLSO valve and cause it to close if the fuel in the tank reaches the high-high level. This solenoid is interlocked with the high-high level alarm. The solenoid feature is installed as a backup to the primary float valve closing feature.

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8-9.6.1.1 Inspection and Maintenance – External HLSO Valve.

a. Activate the tank high-high level alarm and ensure the solenoid valve (if equipped) activates on the HLSO valve. Ensure the HLSO valve closes when the solenoid valve is activated.
Frequency: Quarterly

b. Isolate, drain, and then vent the external float valve chamber (if equipped). Refill (either manually or via the storage tank product saver tank pump) the float chamber to test the float valve. Ensure the HLSO closes when the float is raised.
Frequency: Annually

c. Lift the manual test lever of internally mounted float valve (if equipped). Ensure that the HLSO closes when the float of the float valve is raised.
Frequency: Annually

8-9.6.2 Internal HLSO Valve.

Internal HLSO valves are installed in the internal fill tube of tanks. Internal HLSO valves incorporate a float that closes the valve when the float rises. In some cases these valves also include a by-pass valve mechanism. When the level in the tank reaches a pre-determined height, approximately 90%, the float of the HLSO valve rises and closes the main valve. When the main valve closes at the 90% level the by-pass valve (if equipped) opens and allows approximately 5 gpm (0.3 lps) to enter the tank. If the level in the tank continues to rise and reaches the 95% level the by-pass valve will close and prevent additional fuel from entering the tank.

8-9.6.2.1 Inspection and Maintenance – Internal HLSO Valves.

a. Inspect and test the high level shut-off valve and float mechanism, counter-weights, float rods, and floats to ensure the float mechanism is moving freely and functioning properly to close the high level shut-off valve. If valve is not equipped with a manual test mechanism the level of the tank must be raised to the high level shutoff valve set point in order to test the valve. Ensure valve is installed at a proper height.
Frequency: Annually

8-9.7 Mechanical Tape Gauges.

The mechanical tape gauge readout window is typically mounted in a convenient location on the side of the tank and is visible to the tank operator. On aboveground vertical storage tanks, the tape gauge readout device is typically mounted near the base of the tank stairs. The other end of the tape is attached via a stainless steel cable or tape, enclosed in a conduit with sheaves and pulleys, either to a float that rides on the petroleum fuel surface inside the tank or to a weight that rests directly on top of the floating roof or pan. Note: When attached to a weight that rests on top of the floating roof or pan, the petroleum fuel level will not read below the setting of the floating roof or pan legs.

8-9.7.1 Inspection and Maintenance - Mechanical Tape Gauges.

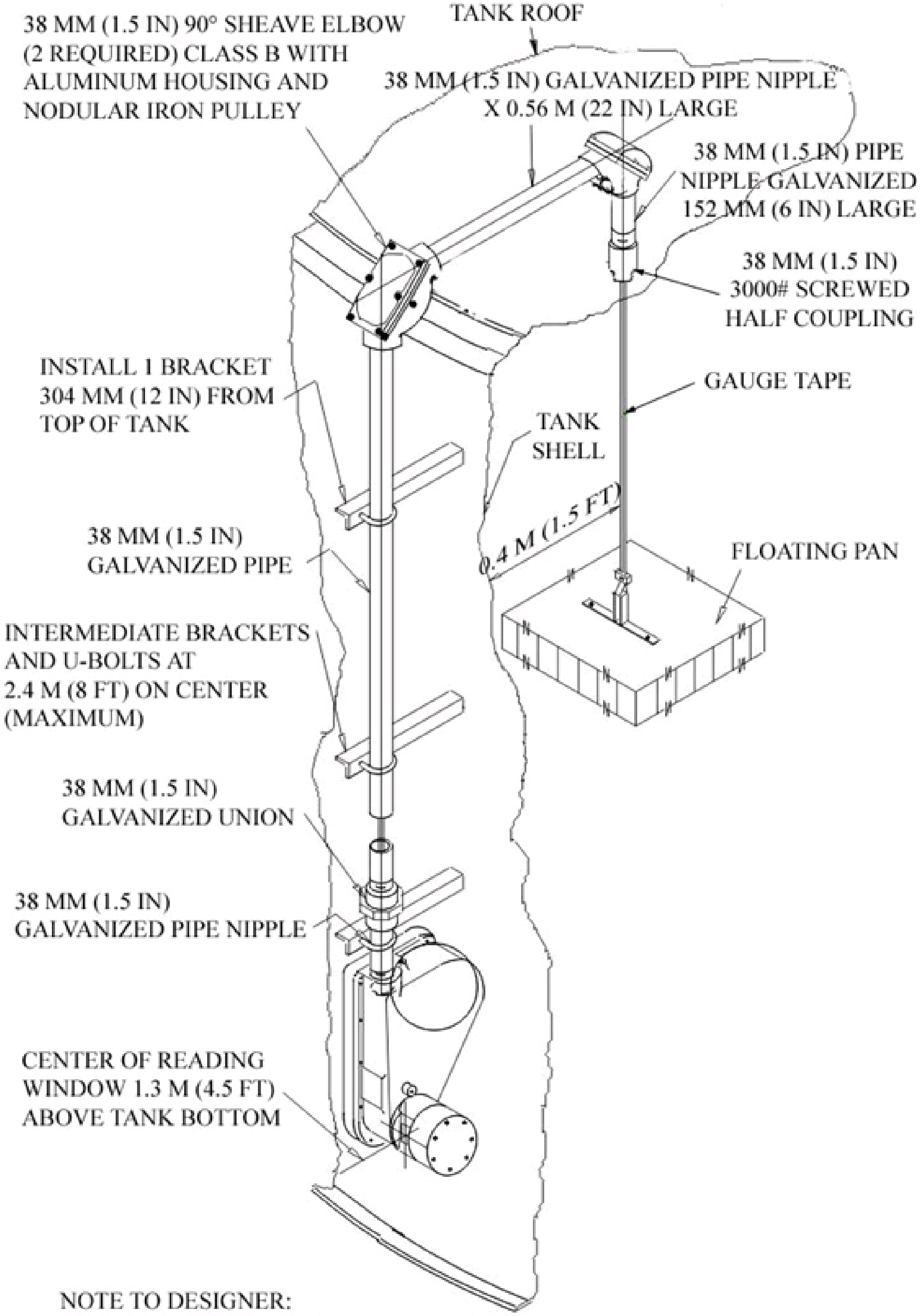
a. Visually check that a liquid level is indicated and that the measurement appears to be accurate.
Frequency: Daily

b. Check the mechanical tape gauge against the automatic electronic tank gauge (if installed) or by manually gauging the tank for relative accuracy and proper working condition. Consult the manufacturer's operation and maintenance manual for additional maintenance and inspection requirements.
Frequency: Quarterly

8-9.8 Automatic Tank Gauges

Automatic Tank Gauges (ATG) are used to measure the fuel level in petroleum fuel tanks.

Figure 8-6 Mechanical Tape Gauge



NOTE TO DESIGNER:
PROVIDE EITHER A SERVO LEVEL GAUGE OR
MECHANICAL TAPE GAUGE BASED ON
USER REQUIREMENTS

8-9.8.1 Mechanically Operated Tape Gauge.

The gauge can be installed on the tank roof or the side of a tank. The level measurement is displayed using a mechanical dial and counter built into the gauge head. An incrementally perforated tape runs from the gauge head through a conduit down into the tank with a float attached at the end. The float moves up and down with the petroleum fuel level. Petroleum fuel level data is electronically transmitted by a level transmitter fitted to the gauge.

The end of the tape should never be attached directly to a floating roof or pan. This type of installation may result in damage to the gauge head or the tape. Existing installations that are currently attached directly to the floating roof or pan should be retrofitted by attaching the tape to a weight placed on top of the floating roof or pan. Varec recommends a ten pound (4.5 kg) weight, and Sand and Jurs recommends a six pound (2.7 kg) weight.

8-9.8.1.1 Inspection and Maintenance – Mechanically Operated Tape Gauge.

Refer to manufacturer’s operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of mechanical float, tape gauge, and electronic level transmitter.

a. Visually inspect the gauge to ensure the power is on, there are no warning alarms or lights and a liquid measurement is indicated and the tank level reading appears to be accurate.
Frequency: Daily

b. Inspect gauge head for buildup of sediment.
Frequency: Quarterly

c. Inspect tape conduit for deformations that would inhibit movement of tape up and down.
Frequency: Quarterly

d. Gauge level accuracy must be checked against a hand dip measurement of the tank. Calibrate as required.
Frequency: Semi-annually

e. Inspect float and guide cable through an opened manway or access cover. Verify that the guide wire is taut and free of kinks. Verify that the float is buoyant and free of sludge or sediment build up.
Frequency: Semi-annually

f. Inspect power and control wires for damage.
Frequency: Semi-annually

g. Inspect wire connection termination points for damage or loose connections.
Frequency: Semi-annually

h. Lubricate moving parts of the gauge head with recommended lubricant.
Frequency: Annually

8-9.8.2 Magnetostrictive Probes.

Magnetostrictive probes are tank gauges that use floats to detect fuel and water levels in tanks. These gauges do not require a stilling well and are typically used on horizontal tanks.

Figure 8-7 Magnetostrictive Probe

8-9.8.2.1 Inspection and Maintenance – Magnetostrictive Probes.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of probe and electronic level transmitter.

a. Visually inspect the gauge to ensure the power is on, there are no warning alarms or lights and a liquid measurement is indicated and the tank level reading appears to be accurate
Frequency: Daily

b. Inspect probe assembly for buildup of sediment.
Frequency: Quarterly

c. Inspect probe assembly and probe shaft for deformations that would inhibit movement of probe.
Frequency: Quarterly

d. Level probe accuracy must be checked against a hand dip measurement of the tank. Calibrate as required.
Frequency: Semi-annually

e. Verify that the probe float is buoyant and free of sludge or sediment build up.
Frequency: Semi-annually

f. Inspect power and control wires for damage.
Frequency: Semi-annually

g. Inspect wire connection termination points for damage or loose connections.
Frequency: Semi-annually

8-9.8.3 Servo Gauge.

Servo gauges are tank top mounted, requiring a stilling well for the gauge's float to follow the fuel level up and down the tank.

Figure 8-8 Servo Gauge

8-9.8.3.1 Inspection and Maintenance – Servo Gauge.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of servo gauge and electronic level transmitter.

a. Visually inspect the gauge to ensure the power is on, there are no warning alarms or lights and a liquid measurement is indicated and the tank level reading appears to be accurate.
Frequency: Daily

b. Inspect gauge head for buildup of sediment.
Frequency: Quarterly

c. Gauge level accuracy must be checked against a hand dip measurement of the tank. Calibrate as required.
Frequency: Semi-annually

d. Inspect float and guide cable through an opened manway or access cover. Verify that the guide wire is taut and free of kinks. Verify that the float is buoyant and free of sludge or sediment build up.
Frequency: Semi-annually

e. Inspect power and control wires for damage.
Frequency: Semi-annually

f. Inspect all wire connection termination points for damage or loose connections.
Frequency: Semi-annually

g. Inspect stilling well. Ensure the stilling well is straight and vertical with no dents so that the float can move freely.
Frequency: Annually

h. Lubricate moving parts of the gauge head.
Frequency: Annually

8-9.9 Level Alarms.

Alarms can include high-high, high, low, and low-low level alarms. On small or underground tanks the level alarms may be suspended inside the tank. On field-erected vertical tanks the alarm switches are typically mounted in chambers mounted to the outside of the tank.

8-9.9.1 Externally Mounted Level Alarms.

Externally mounted level alarm switches are installed in sensing chambers mounted to the outside of the tank. Manual valves are installed at the sensing chamber tank connection points. These valves are used to isolate the chambers in order to perform periodic maintenance and testing of the switches without increasing or decreasing the fuel level within the storage tank.

On newer installations, the product saver system pump is configured to supply fuel to the sensing chambers and to drain fuel back to the product saver tank to facilitate alarm switch testing. Vent valves are also provided on the sensing chambers.

8-9.9.2 Inspection and Maintenance – Externally Mounted Level Alarms.

a. Test level alarm switches by isolating the chambers from the tank using the sensing chamber isolation valves. Vent and drain the chambers. Slowly pour product into the chambers through a funnel on top of the chamber to test the level switch at the specified level setting.
Frequency: Semi-annually

8-9.9.3 Internally Mounted Level Alarms.

Internal level alarms are suspended inside the tank.

8-9.9.4 Inspection and Maintenance – Internally Mounted Level Alarms.

a. Test level alarm switches by activating manual testing levers, if equipped. If alarms switches are not equipped with manual testing levers, adjust the level of fuel in the tank to the alarm points in order to test the alarm switches. If it is not feasible to adjust the level of the fuel in the tank to all of the alarm set points, remove the alarm switches from the tank and test the alarms externally. Reinstall alarm switches in the tank once testing is complete.
Frequency: Annually

8-9.10 Product Saver Tanks.

Product saver tanks are used to remove water from tank bottoms and return useable fuel back to the tank. The product saver tank typically consists of a 55 gallon (208 liter) tank with a cone down bottom and removable top. The tank includes a sight glass with density ball to monitor the fuel to water interface. The tank is equipped with a water draw-off connection and either an electric pump or a hand pump to return useable fuel to the storage tank and/or pump water off to a portable container. Some product saver tanks are configured to pump fuel to the external high level switch chambers and external high level shut-off valve float chambers to facilitate testing those devices.

8-9.10.1 Inspection and Maintenance – Product Saver Tanks.

a. Inspect the product saver tank to ensure all valves are working properly, sight level gauges with density balls are working properly and are not broken, and hand pumps or electric pumps are working properly and are not leaking.
Frequency: Quarterly

8-9.11 Sidestream Filtration Systems.

Sidestream filtration systems are used to filter or polish fuel stored in tanks. Typically, the system consists of a 100 gpm (6.3 lps) pump that draws fuel from the tank low suction line, which extends to the center sump, and then pumps the fuel through a 100 gpm (6.3 lps) filter separator back to the tank's fill line. A connection is sometimes provided downstream of the filter separator to pump fuel off to a tank truck or bowser. The filter separator will polish the fuel, but will also remove water from the bottom of the tank. The filter separator is equipped with a water level conductance probe and a float control pilot to shut the filter separator flow control valve if too much water is present in the filter separator sump. In this case, the product recovery system should first be utilized to draw as much water off the tank bottom as possible before the sidestream filtration operation is continued.

8-9.11.1 Inspection and Maintenance – Sidestream Filtration Systems

a. Check filter separator vent tank (typically 5 gallon (19 liters), if incorporated) and ensure it is empty.
Frequency: Monthly

b. Refer to Section 6-1 Pipe Testing and Inspections for inspection and maintenance requirements of piping.

c. Refer to Section 3-6.4 Basket Strainers for inspection and maintenance requirements of basket strainers.

d. Refer to Section 3-8 Pumps for inspection and maintenance requirements of fuel pumps.

e. Refer to Section 3-6.2 Filter Separators for inspection and maintenance requirements of filter separators.

f. Refer to Section 4-4.2.2 Filter Separator Control Valves for inspection and maintenance requirements of filter separator control valves.

g. Refer to Section 9-1.6 Grounding Systems for inspection and maintenance requirements of grounding systems.

h. Refer to Section 9-1.9 Electronic Equipment for inspection and maintenance requirements of control panels.

8-9.12 Fill Ports.

Fill ports are used to protect tank fuel receipt and vapor balance connection points. They are typically installed on underground and aboveground horizontal tanks. The fill ports can be installed in a pit installed above the tank (underground storage tanks) or on stands installed in close proximity to the tanks (aboveground storage tanks). They also provide a small volume of containment below the receipt connection points. In some cases the fill port is equipped with a small pump or valve that can be used to transfer fuel that collects in the fill port containment area into the receipt line of the respective tank.

8-9.12.1 Inspection and Maintenance - Fill Ports.

a. Ensure fill port covers are installed and are not damaged or broken. Ensure fill port covers are identified by fuel type and are installed on the correct tank. Visually inspect the fill port spill bucket to ensure there are no cracks, budges, or holes. Ensure the spill bucket is clean of dirt, trash, water, and fuel.
Frequency: Daily

b. Inspect drain valve in spill bucket and ensure it is in good condition. Ensure the caps installed on the receipt connection points are vapor tight and are not broken, cracked, or chipped. Ensure the poppet valve of the

vapor recovery port seals tightly and no vapor is escaping from the tank when the valve is closed.
Frequency: Monthly

c. **1**\ Hydrostatically test fill-port to ensure containment is liquid-tight. This test may use opportune rainfall by holding rainwater in the fill-port containment area for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of the 60 minute (minimum) hold period and if the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer to Appendix B for testing procedures and to use to document the testing. /**1**/ Ensure secondary containment area of fill port is fuel tight. Ensure the manual transfer pump or drain valve is operational.
Frequency: \1 \Every 3 years /1/

8-9.13 Release Detection Monitoring.

Release detection is installed on aboveground and underground petroleum fuel storage tanks. Release detection measures vary based on the age and type of tank.

In addition to 40 CFR Part 280, host nation, state, and local regulations may have additional design, inspection, and maintenance requirements that may be more stringent than DoD or Federal guidance. Facility operators and maintainers must be familiar with the Installation’s SPCC plan in order to comply with all inspection and recordkeeping requirements

8-9.13.1 Point Sensor – Dry.

Dry point sensors are installed at the lowest point within the space between the fueling system and secondary barrier. Dry point sensors send a signal to a monitoring panel indicating liquid detection. Dry point sensors may include float switches, or electrical resistor switches. A licensed and/or certified technician is required to troubleshoot or inspect dry point sensors for operation.

Underground and aboveground double-wall tanks (such as product recovery tanks) often have point sensor(s) installed through a connection on top of the tank that extends down near the bottom of the interstitial space between the primary and secondary tank shells. The sensor is used to determine if the primary tank is leaking into the interstitial space between the shells or if groundwater is leaking into the interstitial space. The point sensor is typically of the continuous surveillance type and provides an audible and visible alarm at the operator control panel.

8-9.13.1.1 Inspection and Maintenance – Point Sensor – Dry.

a. Ensure the monitoring panel associated with the point sensor(s) is powered on and no alarms are present.
Frequency: Daily

b. Ensure monitoring space is clear and free of debris and liquid.
Frequency: Monthly

c. Test sensor and ensure it is functional.
Frequency: Annually

8-9.13.2 Point Sensor – Wet.

Wet point sensors are installed within liquid reservoirs that monitor the liquid filled space between the primary tank and secondary barrier (USTs only). A licensed and/or certified technician is required to troubleshoot or inspect wet point sensors for operation.

8-9.13.2.1 Inspection and Maintenance – Point Sensor – Wet.

a. Ensure the monitoring panel associated to the wet point sensor(s) is powered on and no alarms are present.
Frequency: Daily

b. Ensure level of monitoring fluid is within normal range.
Frequency: Monthly

c. Test sensor and ensure it is functional.
Frequency: Annually

8-9.13.3 Point Sensor – Pressure/Vacuum.

Pressure/vacuum point sensors are installed at points within the space between a fueling system and secondary barrier. This space may be under pressure or a vacuum depending on the configuration. Pressure/vacuum point sensors send a signal to a monitoring panel indicating loss of pressure or loss of vacuum. A licensed and/or certified technician is required to troubleshoot or inspect pressure/vacuum point sensors for operation.

8-9.13.3.1 Inspection and Maintenance – Point Sensor – Pressure/Vacuum.

a. Ensure the monitoring panel associated with the pressure/vacuum point sensor(s) is powered on and no alarms are present.
Frequency: Daily

b. Test vacuum sensor for proper operation.
Frequency: Annually

8-9.13.4 Visual Leak Detection.

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a. Visual leak detection systems include the use of tell-tale holes and leak detection ports.

b. Reinforcement plate tell-tale holes are present in reinforcement plates used on steel storage tanks at pipe connection points and appurtenance connection points. The tell-tale holes allow for leaks that form in the interstitial space between the reinforcement plate and tank shell to be seen through visual inspection by leaking of fuel through the tell-tale hole. Never install plugs in reinforcement plate tell-tale holes.

c. Leak detection ports (tell-tales) are present on storage tank structures with ring wall foundations and are located around the perimeter of the ring wall foundations or at a single collection point. Leak detection ports can be manually opened to inspect for leaks.

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8-9.13.4.1 Inspection and Maintenance – Visual Leak Detection.

a. Visually inspect leak detection ports (tell-tales) for signs of leaks. If there are debris or objects obstructing the view, appropriate measures must be taken to remove the debris or remedy the obstructions.
Frequency: During routine inspection of other components or monthly, whichever comes first.

b. Visually inspect reinforcement plate tell-tale holes for signs of leaks. Ensure tell-tale holes have not been plugged by debris or a cap. Pack reinforcement plate tell-tales with white grease to prevent insect nesting and buildup of debris.
Frequency: Quarterly

8-9.14 Floating Suction Lines.

Floating suction lines are used to pull petroleum from a predetermined level below the petroleum liquid surface. The suction line is typically suspended by pontoon-type floats. A cable system connected to the suction arm moves a visual target external to the tank for visual confirmation that the arm is moving properly.

8-9.14.1 Inspection and Maintenance - Floating Suction Lines.

a. Check external floating suction line position indicator to ensure floating suction line is moving freely as the level in the tank rises or falls.
Frequency: Quarterly

b. Inspect cables, floats, and swing joint. Ensure interior of floats have not collected fuel. Ensure cables are securely fastened to anchor points and

are in good working order. Ensure the suction pipe flange used to support the swing joint is level and true and that swing joint moves freely up and down and does not bind.
Frequency: When tank is taken out of service for internal cleaning or inspection.

8-9.15 Foam Fire Protection Systems.

Aqueous Film Forming Foam (AFFF) systems are sometimes installed on petroleum fuel storage tanks. When equipped, AFFF spray nozzles are installed at the top of the tank and, when activated, spray foam into the interior vapor space of the tank. When the foam is sprayed it forms an aqueous film that floats at the top of the petroleum fuel and separates the petroleum fuel from atmospheric oxygen.

8-9.15.1 Inspection and Maintenance - Foam Fire Protection Systems.

Refer to UFC 3-601-02 for inspection and maintenance requirements of tank foam fire protection systems.

8-9.16 Heating Coils.

Some petroleum storage tanks in heavy fuel or lube oil service are equipped with heating coils or heaters to warm the petroleum and lower the viscosity for transfer operations. Coils may also be present on storage tanks for other types of petroleum in cold climates.

8-9.16.1 Steam Type Heating Coils.

Steam is a very effective means of heating heavy petroleum fuel and lube oils. Steam coils are typically installed in the bottom of tanks and can be in a variety of different configurations. Internal corrosion of the coils due to the presence of condensate in the heater coils or tubes is a primary problem in these systems. Depending on the type of heater used, this corrosion can lead to oil in the steam heating system or water in the petroleum. To avoid corrosion, steam coils must be shut off at the tank connections when not in use. Inactive coils must be plugged or removed from tanks. The flow of steam to the heating coil is typically controlled by an automatic temperature-regulating valve to prevent overheating the petroleum in the tank.

8-9.16.1.1 Inspection and Maintenance – Steam Type Heating Coils.

a. Observe the regulating valve and check it against a thermometer to be sure that it controls the tank temperature within a safe range, usually not over 150 °F (65 °C) for No. 6 burner fuel oil. Steam traps must be inspected for proper operation to ensure condensate is evacuated from the steam coil.
Frequency: At each operation

b. Pressure check heating coils to 10% above normal operating pressure.
Frequency: Annually

c. Steam coils must be cleaned and inspected for visible signs of corrosion or wear when the tank is emptied and cleaned for inspection. All components of the steam heating coils, such as weld joins, support points, valves, temperature wells, control valves, and steam traps must be inspected and checked for proper operation and visible wear or damage. The coil may be carefully pressurized with steam and visually checked for leaks if necessary. Leaks or damage found must be repaired.
Frequency: When the tank is taken down for formal internal inspection or sooner if steam heating coil damage is suspected.

8-9.16.2 Thermal Fluid Type Heating Coils.

Thermal fluids are sometimes used instead of steam in tank heating coils for heavy lube oils and other fuel oils. Thermal fluids do not pose the corrosion problems associated with steam and condensate, but do require inspection and maintenance for proper operation. Thermal heating coils are typically installed in the bottom of the tank and can be in a variety of configurations. The flow of thermal fluid to the heating coil is typically controlled by an automatic temperature-regulating valve to prevent overheating the fuel oil in the tank.

8-9.16.2.1 Inspection and Maintenance – Thermal Fluid Type Heating Coils.

a. Observe the regulating valve and check it against a thermometer to be sure that it controls the tank temperature within a safe range, usually not over 150 °F (65 °C) for No. 6 burner fuel oil. All external valves, fittings, and other components must be inspected for visible signs of leaks during operation.
Frequency: At each operation

b. Pressure check heating coils to 10% above normal operating pressure.
Frequency: Annually

c. When tanks are emptied and cleaned for inspection, the heating coils must be cleaned and inspected for visible signs of corrosion, wear, or damage. The coils can be pressurized and checked for leaks at that time with the thermal heating fluid at normal operating pressure, but at ambient temperature to alleviate possible burns to personnel. Leaks must be repaired.
Frequency: When the tank is taken down for formal internal inspection or sooner if thermal heating coil damage is suspected.

8-9.16.3 Electric Rod Type Heating.

Electric rod type heaters are sometimes used to heat liquids directly or they are inserted into sealed pipes that extend into tanks to indirectly heat the fluid. Typically, electric heaters are controlled by a thermostat in conjunction with a thermometer for a visual check to regulate the heat in the tank and turn the electric heater on and off as required.

8-9.16.3.1 Inspection and Maintenance – Electric Rod Type Heating.

Refer to the manufacturer's operation and maintenance manual for additional maintenance requirements.

a. Inspect heater to ensure no fluid leakage around the heater to tank connection and that the heater is performing properly.
Frequency: At each operation.

8-9.17 Stilling Wells.

Stilling wells are used to minimize movement of level and temperature sensing probes and floats in petroleum fuel tanks. Stilling wells are constructed of vertical pipe and are slotted with holes to ensure that the level of fuel in the stilling well matches the level of petroleum fuel in the tank.

8-9.17.1 Inspection and Maintenance - Stilling Wells.

a. Stilling wells must be visually inspected to be vertically straight and free of dents or indentations. Sometimes tank stilling wells are made of bare carbon steel pipe. In these instances the stilling wells must be replaced with aluminum.
Frequency: At time of out of service internal inspection.

b. Inspect floating seals inside stilling wells to ensure they are not worn and are sealing the inside of the stilling well property.
Frequency: At time of out of service internal inspection.

8-10 CONTAINMENT SYSTEMS.

Petroleum storage tanks have various types of secondary containment to protect surrounding areas from petroleum contamination. Secondary containment systems include metal enclosures, diked/bermed areas and remote impounding systems. Secondary containment systems can be made of metal, concrete, concrete with liner, brick, or earthen material equipped with an impervious liner.

Military services typically assign draining of containment areas to various organizations; in all cases, removing of water must be conducted in accordance with the Installation's SPCC or other stormwater pollution prevention plan to ensure only water without sheen is released. Secondary containment areas must be drained based upon local requirements or monthly, whichever comes first.

8-10.1 Inspection and Maintenance – Containment Systems (General).

a. Inspect containment systems for cleanliness, if accessible.
Frequency: Daily

b. Secondary containment systems degrade and will collect debris, which can clog drainage inlets or prevent drain valves from sealing properly. **\1** Hydrostatically test the drainage systems to include containment drain inlets, drain lines and containment drain valves to ensure the containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of a 60-minute (minimum) hold period and if the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer to Appendix B for testing procedures and to use to document the testing

American Concrete International (ACI) Standards 224R “Control of Concrete Cracking” and ACI’s Concrete Repair Manual are two standards that owners/operators can follow to maintain the integrity of the concrete secondary containment. **/1/**
Frequency: \1\ Every 3 years /1/

8-10.2 Concrete and Cement Brick Dike/Berm Walls and Floors.

Aboveground petroleum tanks that have containment system walls constructed of concrete or cement brick must be maintained and inspected to ensure containment system integrity.

8-10.2.1 Inspection and Maintenance – Concrete and Cement Brick Dike/Berm Walls.

a. Inspect for vegetation that has taken root in seals or cracks. All vegetation must be removed in all cases to prevent penetration of seals, joints or cracks in the concrete.
Frequency: Daily

b. Inspect walls constructed of bricks for signs of deterioration (e.g., spalling caused by freeze-thaw conditions, cracks, and joint cracks between bricks). Walls constructed of bricks must be patched immediately to prevent further penetration of the wall structure.
Frequency: Daily

c. Inspect walls constructed of concrete for signs of deterioration (e.g., spalling caused by freeze-thaw conditions and cracks). Clean and seal

cracks with a fuel resistant sealant.
Frequency: Semi-annually

d. Inspect seals and joints in concrete walls. Joint sealant that has retracted from the joint or become unbonded with the joints must be removed and replaced with fuel resistant sealant.
Frequency: Semi-annually

8-10.2.2 Inspection and Maintenance – Dike/Berm Floors.

a. Inspect for vegetation that has taken root in seals or cracks. All vegetation must be removed in all cases to prevent penetration of seals, joints or cracks in the concrete.
Frequency: Daily

b. Inspect floors made of concrete for signs of deterioration (e.g., spalling caused by freeze-thaw conditions and cracks). Clean and seal cracks with a fuel resistant sealant.
Frequency: Semi-annually

c. Inspect joints and seals. Joint sealant that has retracted from the joint or become unbonded with the joints must be removed and replaced with a fuel resistant sealant.
Frequency: Semi-annually

8-10.3 Earthen Dike Walls.

Earthen dike wall secondary containment systems typically include sloped walls with a level surface at the top.

8-10.3.1 Inspection and Maintenance – Earthen Dike Walls.

a. Inspect for vegetation that has taken root. All vegetation must be removed in all cases.
Frequency: Daily

b. Prevent the growth of vegetation inside the containment area. Use fireproof chemicals for sterilization. Only herbicides approved by the Installation Environmental Office must be used.
Frequency: Monthly

c. Inspect for signs of erosion. Inspections should be performed particularly after heavy rains or storms. Repair areas that have deteriorated due to erosion.
Frequency: Quarterly

8-10.4 Self-Diking or Vaulted Tank Containment.

Tanks built using self-diking or vaulted secondary containment features must meet NFPA 30 and in cases where the tank is used for dispensing to vehicles or watercraft, the tank must meet requirements detailed in NFPA 30A. Additional requirements are specified in NFPA 1: Chapter 20, NFPA 1: Chapter 66, and UL 2085.

8-10.4.1 Inspection and Maintenance – Self-Diking or Vaulted Tank Containment.

a. Secondary containment structures on self-diking or vaulted tanks must be inspected visually for integrity breaches with special attention given to pipe penetrations and interstitial drain valves.
Frequency: Daily

8-10.5 Flexible Membrane Liners.

Flexible Membrane Liners (FML) are sometimes installed under concrete in storage tank secondary containment areas and over earthen dikes used as secondary containment. Typically FML is installed over geotextile membranes and the FML is brought up and sealed to the concrete tank foundation on the inside of the secondary containment area and to concrete dike walls that enclose the perimeter of the secondary containment area. Pipe penetrations through the secondary containment area, such as piers and pipe supports, are also sealed to the FML, preventing product from seeping through the liner along the pipe.

8-10.5.1 Inspection and Maintenance – Flexible Membrane Liners.

a. Remove vegetation growing in the gravel and dirt, taking note if the roots have penetrated the FML.
Frequency: Daily

b. Visibly inspect FMLs where attached to ringwalls, dike walls, concrete piers and other projections for deterioration due to weather or wear and repair as necessary.
Frequency: Quarterly

c. Visually inspect FMLs covered with smooth rock or gravel for bare spots where the gravel has been washed away due to storms or heavy rains for tears. Replace gravel taking care not to puncture the liner.
Frequency: Quarterly

d. Visually inspect exposed FML for tears or punctures and repair.
Frequency: Quarterly

8-10.6 Pipe Penetrations.

Some pipe penetrations through containment walls incorporate a pipe sleeve through which the carrier pipe is placed. The carrier pipe is sealed to the pipe sleeve with a link-type mechanical compression seal at both ends. Boot seals between the end of the pipe sleeve and the carrier pipe are sometimes added as an additional containment measure.

In some cases the carrier pipe directly penetrates concrete containment paving and walls. In these cases, the space between the carrier pipe and the concrete paving or wall is sealed with fuel resistant sealant.

8-10.6.1 Inspection and Maintenance – Pipe Penetrations.

a. Inspect boot seals and mechanical link-type seals for wear and cracking. Ensure the seals are in good working order to seal out water or retain the petroleum product as intended. Repair or replace defective boot and link-seals.
Frequency: \2\ Monthly /2/

b. Inspect sealant between pipes and concrete walls, berms, and floors. Sealant that has retracted from the concrete or pipe surfaces must be removed and replaced with new fuel resistant sealant.
Frequency: Semi-annually

8-11 MISCELLANEOUS USE TANKS.

8-11.1 Miscellaneous Use Tanks.

Miscellaneous tanks include electric generator tanks, fire pump tanks, waste oil tanks, ballast water tanks, lube oil tanks, and others. In most cases standalone tanks are below 10,000 gallon (37,850 liter) capacity and fall into the shop fabricated category and are designed and built to UL 142, UL 2080 or UL 2085 standards. However, in some cases the tanks are large field erected tanks and fall into the vertical or cut and cover category. In some cases the tanks are integrated into the system or skid and are built to the skid manufacturer's specifications. This occurs with generator or fire pump belly tanks.

8-11.1.1 Inspection and Maintenance – Miscellaneous Use Tanks.

a. Standalone aboveground tanks that fall into the vertical field erected category must follow the inspection and maintenance requirements listed in Section 8-4 Field-Erected Tanks.

b. Standalone tanks that fall into the shop fabricated tank category must follow the inspection and maintenance requirements listed in Section 8-5 Shop-Fabricated Tanks.

c. Standalone tanks that fall into the cut and cover category must follow the inspection and maintenance requirements listed in Section 8-6 Underground Field-Constructed Tanks.

d. Integrated tanks that are supplied as part of an equipment skid or system must follow manufacturer's inspection and maintenance recommendations.

8-11.1.2 Generator Tanks and Fire Pump Tanks.

These tanks typically hold diesel or kerosene-based fuel use with piston driven engines to operate electrical generators and fire water pumps.

8-11.1.3 Waste Oil Tanks.

Waste oil tanks store petroleum products that are not suitable for use or reclamation. This product is typical stored until appropriate quantities are accumulated for economical sale or disposal. Waste oil tanks take on many types of configurations, and for integrity testing and maintenance, are considered petroleum tanks.

8-11.1.4 Ballast Water Tanks.

Ballast water tanks are used to store water-fuel mixtures that are pumped from marine vessel fuel tanks.

8-11.1.5 Lube Oil Tanks.

Lube oil tanks are used to store and distribute lube oil for turbines and gears, hydraulic equipment and general mechanical lubrication.

8-11.1.6 Additive Tanks.

Additive tanks store bulk additives used to additize jet fuel. They are typically small aboveground tanks.

8-11.1.7 Heating Oil Tanks.

These tanks typically include heating coils which are used to preheat oil before it can be used. These tanks may be field erected tanks, shop fabricated, or cut and cover tanks.

8-11.1.7.1 Inspection and Maintenance – Heating Oil Tanks.

Refer to Section 8-9.16 Heating Coils for inspection and maintenance requirements of heating coils.

CHAPTER 9 ELECTRICAL SYSTEMS

9-1 ELECTRIC CONTROL SYSTEMS AND EQUIPMENT.

9-1.1 Scope and Limitations.

The intent of this section is to provide guidelines for maintenance of electrical equipment rated for up to 1,000 V. The intended audience is electrical maintenance staff or electrical contractors who are engaged in performance of electrical maintenance. Electrical work must be completed by qualified/licensed electricians equipped with the proper PPE (e.g., Arc Flash, CPR, First Aid) for the type of work conducted. The recommended procedures are not intended to contradict electrical codes. The main objectives of this section are:

- To outline procedures to maintain optimal operating conditions of the electrical equipment.
- To establish a system for early detection of potential faults in electrical equipment in an effort to plan repair or replacement before catastrophic failure occurs.

If in the process of implementing the outlined procedures it is determined that more extensive testing is required, then such tests should be performed in accordance with the applicable codes. Due to safety concerns, the maintenance of equipment rated above 1,000 V is not addressed. This equipment must be maintained only by specially trained personnel in accordance with manufacturer's recommendations.

9-1.2 Electrical Equipment.

Maintenance procedures for electrical equipment usually require enclosures to be opened, inspected and cleaned. This poses higher risk of injury than during normal operation and basic rules for electrical safety should be followed:

- Always follow approved lockout/tagout procedures.
- Never work alone when testing electrical equipment. A second person who is First Aid and CPR qualified should be present.
- Never work on energized equipment. Tests that require energized equipment should be performed by specially trained and licensed personnel.
- Use V-rated tools and V-rated gloves. V-rated tools are tools rated and tested for the maximum line-to-line voltage upon which work will be done. V-rated gloves are gloves rated and tested for the maximum line-to-line voltage upon which work will be done.
- Use appropriately rated Personal Protective Equipment (PPE) as indicated by arc flash hazard warning labels as required by NFPA 70E. If such labels are not installed, perform arc flash hazard analysis before

implementing electrical maintenance procedures to determine the appropriate level of PPE.

The preceding list is not exhaustive and does not intend to contradict safety requirements mandated by codes or regulations.

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9-1.2.1 Inspection and Maintenance – Electrical Equipment.
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a. Electrical control systems include: deadman control; ground verification systems; EFSO operation; control panels, motor control, and pump start/stop buttons. These systems must be tested on a periodic basis to ensure proper operation and functionality. In addition, control system Uninterruptible Power Supplies (UPS) must be inspected and replaced as necessary.
Frequency: Quarterly

9-1.3 Power Cables.

The assessment of cable condition is performed mainly by visual inspections. Based on the observations, certain cables may be scheduled for dielectric testing. Visual inspection is usually done while inspecting the equipment to which the cable is connected. Moving or touching of the cables must only be done when the system is de-energized and locked out.

9-1.3.1 Inspection and Maintenance – Power Cables.

a. Visual inspection: Verify that there are no sharp bends. Verify that the cable insulation is intact. Verify that cables are appropriately tagged or otherwise identified. Verify that all connections are tight and not corroded. Open manholes and handholes. Verify that they are not flooded, clogged with debris or infested by pests.
Frequency: Annually

b. Insulation resistance test: This test measures the resistance of the insulation with an Insulation Resistance Tester. During the test, the cable will be disconnected from both ends. Acceptable test values are 100 megaOhms for cables rated between 120 V to 1,000 V. Insulation resistance testing for voltages higher than 1,000 V is to be performed by specialized testing company.
Frequency: As needed based on visual inspection

9-1.4 Motor Controls.

Motor control equipment generally refers to the following: across the line motor starters, reduced voltage auto transformer starters, wye delta starters, partial winding starters, solid state starters, reversing starters, and adjustable frequency drives. All motor control equipment has common components which can be classified as:

a. Overcurrent and overload protective device – circuit breaker or fuse.

b. Electromagnetic contactor.

c. Control logic elements (e.g., relays, switches, pushbuttons).

The motor control equipment may be installed in a motor control center (MCC) or in a standalone enclosure dedicated to a single starter. Usually this equipment is installed in electrical rooms and is protected from the elements. However, standalone enclosures are sometimes located in close proximity to the driven equipment and are exposed to the elements. In such cases special attention should be paid to the physical condition of the enclosure. The maintenance of motor control equipment should be performed together with the maintenance of the motor.

9-1.4.1 Inspection and Maintenance - Motor Controls.

a. Verify the labeling is consistent with the drawings and specifications.
Frequency: Semi-annually

b. Verify that pushbuttons are easy to operate and are not stuck. Verify that there is no grease accumulation around the seating.
Frequency: Semi-annually

c. Verify that indicating lights are functional and replace as needed.
Frequency: Semi-annually

d. Verify that electrical and mechanical interlocks operate according to the design intent. In case of key interlocks, ensure that the number of keys corresponds to the interlock intent. Having more keys than required defeats the intent of the interlocking and poses danger to the service personnel and equipment. If extra keys are found, they should be removed from the equipment.
Frequency: Semi-annually

e. Inspect the enclosure for visible signs of corrosion.
Frequency: Interior annually/exterior semi-annually

f. Open the enclosure – be mindful of insects, rodents and reptiles, particularly if located outdoors. Look for signs of corrosion, dust accumulation, spider webs, etc. Clean the enclosure with compressed air and apply rust inhibitors and paint as needed.
Frequency: Annually

g. Inspect the overcurrent protective devices for proper seating. Verify that rating is appropriate for the motor. Look for signs of attached wire and device overheating.
Frequency: Annually

h. Inspect the arch shoots of contactors and clean as needed. Check that partitions are not burned.
Frequency: Annually

i. Inspect contactors for abnormal wear. Check contacts for pitting, roughness and oxidation. Verify that contact gap, alignment and pressure are in accordance with manufactures recommendations.
Frequency: Annually

j. When contactors are used, listen for the chatter of contacts or buzzing noise. These are indicative of a faulty contactor.
Frequency: Annually

k. Verify that relays and switches are firmly seated in their bases and there are no signs of overheating or vibration.
Frequency: Annually

l. Look for frayed or broken strands in the flexible control wiring and replace if such are found.
Frequency: Annually

m. Perform a functional test of protective devices if they are equipped with self-testing circuits or switches.
Frequency: Annually

n. Perform a functional test of all manual switches and verify proper operation against intended design logic. Replace switches and relays if operation is not satisfactory.
Frequency: Annually

o. Perform insulation resistance test for the control wiring.
(Note: Testing of the control wires may require substantial down time. Therefore, this should only be performed on a case by case basis if there are reasons to suspect that the insulation of the control wiring is deteriorating.)
Frequency: As required

9-1.5 Panelboards.

Panelboards are used to control power supply to equipment, buildings, and structures.

9-1.5.1 Inspection and Maintenance – Panelboards.

Conduct the following actions to complete the inspection:

a. Verify that there are no physical obstructions blocking access to the panelboard. Remove physical obstructions.
Frequency: Quarterly

b. Inspect the enclosure and the surrounding area for water damage and corrosion.
Frequency: Annually

c. Verify that all breakers are either in the “On” or the “Off” position. If there are tripped breakers, investigate the cause of the trip.
Frequency: Annually

d. Verify that there is a breaker schedule. If there is no breaker schedule or the schedule is worn and out-of-date, create and post a new one.
Frequency: Annually

e. Verify that the breaker operation matches the description on the panel schedule.
Frequency: Annually

f. Observe breakers, wires and terminals for signs of overheating or short circuiting.
Frequency: Annually

g. Verify that all breakers are firmly seated and locked in place by slightly shaking them.
Frequency: Annually

h. Verify that all grounding wires are firmly connected to the grounding bar.
Frequency: Annually

i. If a breaker malfunction is identified, leave breaker in the open position and replace as soon as possible. If a breaker cannot disconnect its circuit, the entire panelboard must be switched off using its main disconnecting means and locked out until the breaker is repaired.
Frequency: Annually

9-1.6 Grounding Systems.

Visual inspection of the integrity of the grounding should be performed together with the visual inspection of the grounded equipment, such as motors, motor control centers, piping, filter vessels, petroleum fuel tanks, and transformers. A typical facility will include two types of grounding systems: power grounding and static grounding. Power grounding provides a low-impedance path for the fault current in case of equipment, conductor, and raceway failures. Static grounding provides a path for static electricity discharge to dissipate static electricity build up on equipment.

9-1.6.1 Inspection and Maintenance – Power Grounding Systems.

a. The connections to the grounding system must be surveyed and verified for continuity. If a connection is suspected to be loose, perform further testing. In some occasions, it is more cost effective to replace the suspected connection instead of performing diagnostic tests.
Frequency: Annually

b. Measure the voltage between the equipment grounding conductor and the electrode grounding conductor (usually bare copper). Investigate test results above 3 VAC for a potential ground fault.
Frequency: Annually

c. Measure the voltage between the chassis of the equipment and the electrode grounding conductor. Investigate if the readings exceed 2 VAC.
Frequency: Annually

d. Facility ground resistance check: This type of testing is performed with a four lead, low resistance ohmmeter or digital ohmmeter. Recommended values are between 3 and 5 ohms. In no case should the grounding resistance be higher than 25 ohms.
Frequency: Every five years

9-1.6.2 Inspection and Maintenance – Static Grounding Systems.

a. Inspect ground reels for corrosion. Ensure ground reels are securely mounted to a rigid base. Inspect clamps for serviceability. Replace clamp if jaws are deformed or corroded, spring is weak, or other defects are evident that would prevent a good connection. Inspect cable wires. Replace if more than one-third of the cable wires are broken.
Frequency: Quarterly

b. The connections to the grounding system must be surveyed and verified for continuity. If a connection is suspected to be loose, perform further testing. In some occasions it is more cost effective to replace the suspected connection instead of performing diagnostic tests.
Frequency: Annually

c. Resistance measurement on static grounds: Measure static ground resistance of new and damaged ground rods. Static ground with a resistance greater than 10,000 ohms will be removed or replaced. Static ground mechanically damaged will be repaired and retested.
Frequency: When observed to be physically damaged.

9-1.7 Electric Motors.

a. Based on the operational parameters, motors can be classified as:

- Induction (squirrel cage or asynchronous) motors: These are the most common type and widely used in pumps, fans and other industrial equipment.
- Synchronous motors: These are usually relatively large (500 hp and above) and are used when constant speed is required regardless of the torque on the shaft or power factor correction needed.

- DC motors: These type of motors are rare in industrial applications and are used mainly in traction, cranes and sometimes in elevators.

b. Depending on the applied voltage, motors can be:

- Low voltage (< 1,000 V).
- Medium voltage (2,300 V to 6,000 V). These motors are usually rated 300 hp to 15,000 hp (225 kW to 11.2 MW).

c. Depending on the number of phases, motors are:

- Single phase: Usually small motors less than 10 hp (7.5 kW) and often less than 3 hp (2.2 kW).
- Three phase: Most commonly used for industrial applications larger than 0.5 hp (375 W).

d. The maintenance of synchronous and DC motors should be performed by specialized companies and in accordance with the written instructions of the motor manufacturer.

9-1.7.1 Inspection and Maintenance – Electric Motors.

Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of motor. Follow all applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.

a. Lubricate motor bearings and inspect for vibration and overheating.
Frequency: Quarterly

b. Check for debris and other foreign material in the fan housing.
Frequency: Semi-annually

c. Check motor ground wires. Ensure they are firmly connected to the housing or the junction box.
Frequency: Annually

d. If the motor is installed in a hazardous location, verify that the seals of the connection boxes and conduits are intact.
Frequency: Annually

9-1.8 Lighting.

The purpose of the lighting maintenance is to ensure a relatively constant illumination level and lighting quality for internal and external lighting systems. Most often, the lighting maintenance involves lamp replacement. There are two possible approaches for regular lamp replacement:

1. Spot re-lamping is performed when the lamps in a light fixture are replaced on an as-needed basis. If there is more than one lamp in the light fixture, it is recommended to replace all of the lamps at the same time. This ensures more uniform light output and equal utilization of the lamps.
2. Group re-lamping involves simultaneous replacement of all lamps in a given area regardless of whether they are operational or not.

9-1.8.1 Inspection and Maintenance – Lighting.

a. Verify proper operation of light switch, lighting contactor, photocell or timer as appropriate. If a lighting contactor is used, listen for the chatter of contacts or buzzing noise. These are indicative of a faulty contactor. Replace if required.
Frequency: Annually

b. With the lights turned on, observe individual luminaries for flicker or lights turning on and off. The former is indicative of a faulty choke. The latter is indicative of a faulty starter. Replace the faulty components as required.
Frequency: Annually

c. When light fixtures are located in hazardous areas, verify that the seals are intact and the hazardous rating of the fixture is maintained.
Frequency: Annually

d. Thoroughly clean dust, bugs, and debris from the luminaires. Light solvents or cleaning agents may be used.
Frequency: Annually (in dusty areas the luminaries may require cleaning at shorter intervals)

e. Re-Lamping: With the lights turned off, replace the lamps. In order to prevent accidental turning on of the lights, it is mandatory to switch off and lockout the breaker of the lighting circuit. Ensure the replacement lamps are the same type as those they are replacing. Verify the proper operation of all light fixtures after the lamp replacement.
Frequency: Annually or as required

9-1.9 Electronic Equipment.

Electronic equipment usually operates at voltages less than 120 V and does not have rotating components. As a result, electronic equipment tends to accumulate dust, which interferes with cooling. Overheating is the most likely cause for failure of electronic equipment.

9-1.9.1 Inspection and Maintenance - Electronic Equipment.

If the inspection and maintenance of the equipment does not require functional and operational testing, de-energize and lockout the power source to the equipment.

a. Inspect the outside of the equipment enclosures for dust and evidence of corrosion. Vacuum clean the dust to ensure unobstructed air circulation.
Frequency: Annually

b. Open the enclosure and vacuum clean the dust to ensure unobstructed air circulation. Pay particular attention to fans and air passages. If there is evidence of corrosion, verify that there is no water damage on printed circuit boards or contacts. If water or humidity damage is observed, the electronic components may not work properly and further testing is required.
Frequency: Annually

c. Verify proper operation of the space heater if one is installed.
Frequency: Annually

d. Check fans for proper operations and rotation.
Frequency: Annually

e. Look for signs of overheating such as discoloration and charring.
Frequency: Annually

f. Replace air filters.
Frequency: Annually or more frequently based on local environmental conditions.

g. Verify connection tightness. Lightly pull wires on soldered and terminal screws and ensure the wires are not loose.
Frequency: Annually

h. Verify that circuit boards are properly seated. Ensure that board locking tabs are fully engaged. Do not unplug and plug connectors to verify seating. This will wear out the pins. Unplug only if connector malfunction is suspected.
Frequency: Annually

i. Observe wires for excessive strain, braiding, or wear due to vibration. Replace as required.
Frequency: Annually

9-2 CATHODIC PROTECTION SYSTEMS.

9-2.1 Cathodic Protection.

Cathodic protection must be maintained by appropriately trained personnel (NACE CP tester certified). Personnel must ensure the cathodic protection system is maintained in accordance with UFC 3-570-06 and the most stringent of applicable host nation, Federal, state or local regulations.

Cathodic protection systems are installed on underground piping systems, at the bottom of steel tanks, on underground steel tanks, and on marine pier and anchor systems.

Cathodic protection systems are used to prevent corrosion of these systems and are specifically designed for the system that they are intended to protect.

9-2.1.1 Inspection and Maintenance - Cathodic Protection.

a. Inspect rectifiers in in accordance with UFC 3-570-06.
Frequency: \2\ Monthly /2/

b. Inspect cathodic protection systems in accordance with UFC 3-570-06.
Frequency: Annually

9-2.2 Electrical Isolation.

Electrical isolation components and lightning surge arresters are installed on underground piping systems as part of a complete corrosion protection system.

9-2.2.1 Lightning Surge Arresters.

Lightning surge arresters are devices that protect dielectric insulating flanges from over-voltage transients. These transients are caused by lightning or AC fault currents. The arresters block AC and DC voltages up to a predetermined voltage threshold. Upon voltage exceeding the threshold, the arrester allows the current to safely pass around the insulating flange.

9-2.2.1.1 Inspection and Maintenance – Lightning Surge Arresters.

a. Newer lightning surge arresters are designed to withstand unlimited surges at 50,000 amperes; however, manufacturers of older surge arresters may provide a maximum number of surge events that can occur before it must be replaced. If surge arresters include a maximum number of surge events, a spare arrester must be kept on hand. Refer to the surge arrester manufacturer's operation and maintenance manual for particular inspection instructions and parts. Inspect as part of an overall cathodic protection system inspection.
Frequency: Annually

9-3 CARD AND KEY LOCKS.

Card and proximity readers are used at Automated Fuel Service Station (AFSS) to activate the systems. Card and key lock system issues must be called into the Business System Modernization-Energy (BSME) Help Desk for all issues outside of the annual preventive maintenance visits.

9-3.1 Inspection and Maintenance - Card and Key Locks.

a. Conduct operational check of card and key lock system and ensure that all features provided with the installed system are operational.
Frequency: Annually

9-4 LIGHTNING PROTECTION SYSTEMS.

Lightning protection systems are typically designed to \1\/1/UFC 3-575-01. The systems include air terminals that are installed on top of buildings, canopies, or tall equipment. The air terminals are connected together with heavy-gauge copper or aluminum wires. These copper or aluminum wires are also attached to grounding loops or ground rods installed at the base of the building, canopy, or equipment.

9-4.1 Inspection and Maintenance – Lightning Protection Systems.

a. Inspect air terminals to make sure they are securely attached to the roof of the building, canopy, or the piece of equipment. Check all connections between the air terminals and the grounding loop or grounding rods. Repair damaged or loose connections and perform continuity check after repairs.
Frequency: Annually

9-5 GROUND VERIFICATION SYSTEMS.

Ground verification systems are used in petroleum fuel truck and rail offloading and loading systems. The systems are used to verify that the trucks or rail cars are grounded. In most cases, the systems are interlocked with the receipt or issues controls and will prevent the receipt or issue system from operating if an acceptable ground connection between the truck or rail car and the fueling system is not detected.

9-5.1 Inspection and Maintenance – Ground Verification Systems.

a. Conduct an operational check of the ground verification system and ensure that all features provided with the installed system are operational. Inspect the plug for corrosion, weakness, or loose nuts and replace if heavily dented or deformed.
Frequency: Quarterly

9-6 ELECTRONIC OVERFILL PROTECTION SYSTEMS.

Overfill protection systems are used on petroleum fuel truck and rail issue systems. In some cases, overfill protection switches are permanently installed on petroleum fuel trucks or rail cars. In other cases, probes from the system are applied to the trucks or rail cars at the time of petroleum fuel issue. The overfill protection systems are interlocked with petroleum fuel issues systems and will stop the issue process if a high petroleum fuel level is detected in a truck or rail car.

9-6.1 Inspection and Maintenance – Electronic Overfill Prevention Systems.

a. Conduct operational check of overfill prevention system and ensure that all features provided with the installed system are operational.
Frequency: Quarterly

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CHAPTER 10 ALTERNATE POL FACILITIES

10-1 LIQUEFIED PETROLEUM GAS.

This section includes inspection and maintenance information related to Liquefied Petroleum Gas (LPG) storage and distribution systems. These systems differ from typical fuel systems due to the pressures involved and are covered by additional regulations. LPG systems must follow the equipment, installation and maintenance requirements listed in NFPA 58*.* Operation and maintenance manuals required for LPG systems by NFPA 58 must be developed for each installation.

10-1.1 Liquefied Petroleum Tanks.

Liquefied petroleum tanks are pressure vessels with typical maximum allowable working pressure of 250 psig. These tanks are built to ASME standards for non-fired pressure vessels. These tanks follow the requirements listed in NFPA 58 and API 2510.

10-1.1.1 Inspection and Maintenance – Liquefied Petroleum Tanks.

a. Inspect fuel tank for leaks. If a leak is occurring, the odorizing agent of the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service.
Frequency: Monthly

b. Test operation of emergency shutoff valves. Ensure the fusible link mechanism is attached properly to actuate in case of a fire and that it has not been by-passed, blocked, or damaged in any manner. Ensure the fusible link is not filled with debris or paint which could impact operation.
Frequency: Semi-annually

c. Check settings of tank safety valves and calibrate if required.
Frequency: Every 5 Years

10-1.2 Liquefied Petroleum Pipelines.

Liquefied petroleum lines transfer liquefied petroleum gas between the delivery vehicle and the storage tanks, and between vaporizers and other equipment and storage tanks. These lines operate at the storage pressure of the tank.

10-1.2.1 Inspection and Maintenance – Liquefied Petroleum Pipelines.

a. Conduct visual inspection of pipelines for potential damage and leak points. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.
Frequency: Monthly

b. Inspect coatings and markings on piping. Repair coating deterioration and replace labels that are fading and are difficult to read.
Frequency: Semi-annually

10-1.3 Liquefied Petroleum Vapor Lines.

Liquefied petroleum vapor lines are used to transfer vaporized petroleum gas between the delivery vehicle and the LPG tank and from the LPG tank to use points. Vapor transfer between the LPG tank and the delivery vehicle is at the tank operating pressure and transfer from the tank to the use points is typically at a reduced pressure.

10-1.3.1 Inspection and Maintenance – Liquefied Petroleum Vapor Lines.

a. Inspect vapor lines for leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.
Frequency: Monthly

b. Inspect coatings and markings on piping. Repair coating deterioration and replace labels that are fading and are difficult to read.
Frequency: Semi-annually

10-1.4 LPG Vaporizers.

At large use points, vaporizers are used to vaporize the pressurized liquid into gas for use.

10-1.4.1 Inspection and Maintenance – LPG Vaporizers.

a. Inspect vaporizers for leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.
Frequency: Monthly

b. The manufacturer maintenance schedules and recommendations provided with the LPG vaporizer must be followed.
Frequency: As required

10-1.5 Petroleum Gas Regulators.

Regulators are used to reduce the pressure of petroleum gas before it is used or transferred to the use point.

10-1.5.1 Inspection and Maintenance – Petroleum Gas Regulators.

a. Inspect petroleum gas regulators for leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.
Frequency: Monthly

10-1.6 Liquefied Petroleum Gas Hoses.

Liquefied petroleum gas hoses are used to transfer liquid and vapor between LPG storage tanks and delivery vehicles.

10-1.6.1 Inspection and Maintenance – Liquefied Petroleum Gas Hoses.

a. Inspect hoses for damage and leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. If leaks are detected from a hose discontinue use of the hose and remove it from service. Inspect for damage to outer cover that exposes reinforcement. Inspect for kinks or flattened areas, soft spots or bulges. Inspect couplings and ensure they have not slipped on the hose or been damaged.
Frequency: Annually

10-2 COMPRESSED NATURAL GAS (CNG).

This section includes inspection and maintenance information related to compressed natural gas systems. These systems used compressed gas at pressures up to 5,000 psig (34.5 MPa). CNG systems must follow the equipment, installation and maintenance requirements listed in NFPA 52. Operation and maintenance manuals required for CNG stations by NFPA 52 must be develop for each installation.

10-2.1 CNG Piping.

CNG piping is used between the natural gas source and the compressor. It is also used between the compressor and the CNG tubes or storage tanks and storage and the CNG dispenser. The lines vary from low pressure to high pressure. Some CNG lines may have pressure ratings as high as 5,000 psig (34.5 MPa).

10-2.1.1 Inspection and Maintenance – CNG Piping.

a. Inspect CNG lines for leaks. Inspection of high-pressure CNG lines and equipment must be conducted using proper PPE including but not limited to safety glasses, a face shield, hard hat and fire resistant clothing. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems

that are found with leaks must be taken out of service and repaired.
Frequency: Daily

b. Inspect coatings and markings on piping. Repair coating deterioration and replace labels that are fading and are difficult to read.
Frequency: Semi-annually

10-2.2 CNG Compressors.

Compressors are used to boost the pressure of natural gas from the supply pressure to the high-pressure tube storage pressure. The compressors include up to four stages of compression and are driven by electrical motors or natural gas engines. Designs of compressors and compressor drivers vary by manufacturers.

10-2.2.1 Inspection and Maintenance – CNG Compressors.

a. Compressors will require maintenance based on the model included in the system. Consult the compressor manual for manufacturer’s maintenance requirements.
Frequency: As required

10-2.3 CNG Storage.

High-pressure tubes or spherical storage tanks are used to store CNG at pressures of up to 5,000 psig (34.5 MPa). The tubes and tanks should be ASME stamped pressure vessels. The tubes are typically assembled in bundles of twenty (20).

10-2.3.1 Inspection and Maintenance – CNG Storage.

a. Inspect CNG tubes and tanks for leaks. Inspection of high-pressure CNG lines and equipment must be conducted using proper PPE including but not limited to safety glasses, a face shield, hard hat and fire resistant clothing. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.
Frequency: Daily

b. Inspect coatings and markings on storage tubes or tanks. Repair coating deterioration and replace labels that are fading and are difficult to read.
Frequency: Semi-annually

c. Check operation and calibration of safety valves on tubes and tanks.
Frequency: Every 3 years

10-2.4 CNG Dispensers

Dispensers (Vehicle Fuel Appliances) are used to transfer CNG between storage tubes or tanks and CNG vehicle storage tanks. The system uses a series of valves to cascade the compressed gas from the tubes or tanks into the vehicle storage tank.

10-2.4.1 Inspection and Maintenance – CNG Dispensers

a. Dispensers are listed for service with CNG and will vary by manufacture. Consult the maintenance manual that was supplied with the system for manufacturer's maintenance required for the CNG dispenser.
Frequency: As required

10-2.5 CNG Dispenser Hoses.

Hoses and fill adaptors are used to make the connection between the CNG dispenser and the vehicle storage tank.

10-2.5.1 Inspection and Maintenance – CNG Dispenser Hoses.

a. Inspect hoses for damage, leaks, and cracks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. If leaks are detected from a hose, discontinue the use of the hose and remove it from service.
Frequency: Monthly

b. Test hoses for leaks following manufacturer recommended frequencies and procedures.
Frequency: As required

10-3 HYDRAZINE CHARGING UNITS.

Hydrazine is transferred from 55 gallon (208 liter) drums to small aircraft holding tanks by a closed system charging unit.

10-3.1 Inspection and Maintenance – Hydrazine Charging Units.

a. Hydrazine charging units are self-contained factory fabricated systems. Refer to the manufacturer's maintenance manual that was provided with the system for required periodic maintenance.
Frequency: As required

10-4 JP-10.

JP-10 is a gas turbine fuel developed for missiles. Maintenance for JP-10 system components should follow maintenance requirements for fuel system components listed in this document.

10-5 OTTO.

Information on OTTO fuels is contained in Naval Sea Systems Command (NAVSEA) S6340-AA-MMA-010. Distribution of this document is restricted. Requests for information are handled by Naval Sea Systems Command.

CHAPTER 11 SUPPORT FACILITIES

11-1 SECONDARY CONTAINMENT.

The military services assign responsibility for inspection, maintenance, and draining of secondary containment structures to various organizations (including contractors).

Those organizations or contractors must inspect and maintain secondary containment structures in accordance with military service-specific directives or applicable contract requirements. Refer to Section 8-10 Containment Systems for tank secondary containment inspection and maintenance procedures.

11-1.1 Fuel Truck \1\ and Rail Car /1/ Containment Areas.

Fuel truck **1**\ and rail car /**1**/ containment areas such as refueler parking areas, refueler loading areas, and commercial truck offloading **\1** and loading areas, rail car loading and offloading /**1**/ areas are equipped with secondary containment. Typically these areas are provided with security fence and overhead lighting.

11-1.1.1 Inspection and Maintenance – Fuel Truck \1\ and Rail Car /1/ Containment Areas.

a. Remove debris from around security fence.
Frequency: Monthly

b. Inspect fence grounding points. Ensure connections are not loose or damaged.
Frequency: Monthly

c. Inspect the parking area for cracks in the concrete containment paving and curbs. Remove vegetation that may have established roots in the buildup of dirt or from exposed earth under cracks. Thoroughly clean and seal cracks with a fuel resistant sealant.
Frequency: Quarterly

d. **1**\ Secondary containment systems degrade and will collect debris which can clog drainage inlets or prevent drain valves from sealing properly. Hydrostatically test secondary containment and associated drainage systems to include containment concrete/sealant, drain inlets, drain lines and containment drain valves to ensure containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of a 60-minute (minimum) hold period and if the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are

completed, a new test must be completed. Refer Appendix B for testing procedures and to document the testing. /**1**/
Frequency: \1\ Every 3 years /1/

e. Verify continuity of vehicle grounding system connections. If a connection is suspected to be loose, perform further testing. In some occasions it is more cost effective to replace the suspected connection instead of performing diagnostic tests.
Frequency: Annually

f. Inspect pavement markings and vehicle movement lines for wear and fading. Repair faded or worn pavement markings.
Frequency: Annually

g. Inspect security fence for wear and rust. Inspect barbed wire and ensure it is adequately secured to outriggers. Repair loose fencing components and coatings at areas that show rust.
Frequency: Annually

h. Refer to Section 9-1.8 Lighting for inspection and maintenance requirements of area lighting.

11-1.2 Remote Spill Containment.

Fuel truck parking, loading and offloading areas **\1** and rail car loading and offloading areas, **/1/** are typically equipped with remote containment basins. These basins are used to increase the overall containment volume of the system. The basins are constructed of concrete walls and a concrete floor.

11-1.2.1 Inspection and Maintenance – Remote Spill Containment.

a. Inspect the remote containment basin for cracks in the concrete containment paving, walls, and curbs. Remove vegetation that may have established roots in the buildup of dirt or from exposed earth under cracks. Thoroughly clean cracks with a water spray or air jet. Seal cracks with a fuel resistant sealant.
Frequency: \2\ Monthly /2/

b. If equipped, inspect spill containment sump pump for proper operation.
Frequency: \2\ Monthly /2/

c. **\1** Secondary containment systems degrade and will collect debris which can clog drainage inlets or prevent drain valves from sealing properly. Hydrostatically test secondary containment and associated drainage systems to include containment concrete/sealant, drain inlets, drain lines and containment drain valves to ensure containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time

of year when this would not be as much of an issue. Record the water level at the start of a 60-minute (minimum) period and if the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer Appendix B for testing. **/1/**.
Frequency: \1\ Every 3 years /1/

11-2 PROTECTIVE SHELTERS.

11-2.1 Pumphouse/Filter Buildings.

Pump and filter equipment is typically enclosed within a building or covered by a shelter. These buildings can be constructed of pre-engineered metal or concrete. The floors of these areas should provide secondary containment for the piping and equipment that is installed in the building or under the shelter.

11-2.1.1 Inspection and Maintenance – Pumphouse/Filter Buildings.

a. Inspect the floor and containment curbs for cracks. Thoroughly clean cracks with a water spray or air jet. Seal cracks with a fuel resistant sealant.
Frequency: Annually

b. Refer to **\1** UFC 3-110-03 **/1/** for inspection and maintenance requirements of pumphouse and filter building roof systems.

11-2.2 Canopies.

Canopies are used to cover service station dispensers, containment basins, fuel truck loading and offloading equipment, and equipment installed in remote areas.

11-2.2.1 Inspection and Maintenance – Canopies.

a. Inspect and maintain canopies in accordance with **\1** UFC 3-110-03 **/1/**.

11-3 SAFETY SHOWERS AND EYEWASH FOUNTAINS.

Emergency safety showers and eyewash fountains are installed around fueling areas and pumphouses. They are typically equipped with an activation alarm that energizes a strobe light and horn. In some cases emergency eyewash/showers are equipped with tempered water systems that supply warm water to the emergency eyewash/shower.

11-3.1 Inspection and Maintenance – Emergency Eyewash/Showers.

a. Test operation of the emergency eyewash/shower by pushing on the activation handles. Ensure the water is not brown in color, due to rust in the piping or dirt seeping in from a hole in the buried piping. For systems with tempered water, ensure that the water that is being supplied by the emergency eyewash/shower is between 60 and 100 °F (16 and 39 °C).

For systems with a horn and strobe light, ensure that the horn and strobe light activate when the activation lever on the emergency eyewash/shower is pushed. For systems that interface with Installation or fire emergency systems, pre-coordinate before testing. At some Installations emergency eyewashes and showers act as EFSOs and are tied into the fire alarm systems.
Frequency: Weekly

b. Inspect portable/packaged safety showers and eyewash stations for proper operation. Check fluid levels. Where tap water is used, fluid must be replaced monthly. Less frequent intervals of fluid change, as recommended by the manufacturer, are acceptable where a solution or water additive is used. Ensure packaged eyewash supplies are within the listed expiration date. Tags or labels must be attached to the unit or adjacent to it, indicating the fluid change schedule.
Frequency: Monthly

c. Inspect the exterior coatings of permanently installed units and repair damaged coatings or rust.
Frequency: Quarterly

d. For systems with tempered water systems inspect components of the water heater for correct operation and temperature control. Ensure that the safety valve on the hot water heater tank is not leaking.
Frequency: Semi-annually

e. Inspect signage and labels on the emergency eyewash/shower. Replace missing labels or signage that has become loose. Signs that are faded must be replaced.
Frequency: Annually

11-4 FUELS LABORATORIES.

Fuels laboratories are typically equipped with ventilation hoods. These systems will be periodically inspected to ensure proper operation. Laboratories must comply with the general facility requirements of UFC 3-600-01 and NFPA 45.

11-4.1 Ventilation Hoods.

Ventilation hoods are used to prevent the buildup of flammable and noxious vapors inside of fuels laboratories. The hoods are typically equipped with sliding or rollup doors that can be used to reduce the opening area of the hood. Additional ventilation hood designs employed include laminar flow, elephant trunk and canopy hoods. The systems pull air from inside of the lab through the hood and exhausts outside of the lab through a ventilation stack. Fume hoods must comply with military service-specific directives and/or 29 CFR 1910.1450, and ANSI (American National Standards Institute)/AIHA *Laboratory Ventilation Z9.5*.

11-4.1.1 Inspection and Maintenance – Ventilation Hoods

a. Inspect the operation of the doors. Ensure that they close and open smoothly.
Frequency: Quarterly

b. Inspect the lights inside of the hood to make sure they are operating properly. Replace light bulbs that are no longer working.
Frequency: Semi-annually

c. Verify that all electrical equipment is properly classified in accordance with NFPA 70.
Frequency: Annually

d. Inspect the ventilation system (ductwork, fans, etc.) for signs of disrepair and air leakage and ensure it is operational and pulling air through the hood. Inspect and assure that the lab hood air measuring device for assuring proper air flow is permanently attached and working properly. The ventilation hood must be inspected and **\1** approved by a service specific industrial hygienist or bioenvironmental engineer **/1/** in accordance with OSHA, 29 CFR 1910.1450, and ANSI/AIHA *Laboratory Ventilation Z9.5*.
Frequency: Annually

e. Verify negative pressure is present through the ventilation hood to the exhaust.
Frequency: Annually

11-5 OIL/WATER SEPARATORS.

Oil/water separators are used to remove water from oil/water mixtures. Oil/water separators are sized for a maximum flow rate and this maximum flow rate must not be exceeded. Inspections and maintenance must be conducted in accordance with the regulating authority for the particular location (e.g., Federal, host nation, state and local) and in accordance with the OEM specifications so as not to void warranty.

11-5.1 Inspection and Maintenance – Oil/Water Separators.

a. Inspect the oil/water separator for the buildup of collected petroleum fuel or oil. Remove and properly dispose of accumulated petroleum fuel or oil.
Frequency: Quarterly or as needed based on precipitation events.

b. Drain, clean, and inspect the interior of the oil/water separator. Ensure all divider plates and screens are in good working order. Replace or repair damaged components.
Frequency: Annually or more frequently based on local environmental conditions.

11-6 CRANES AND HOISTS.

Cranes and hoists are used inside of pumphouses and maintenance areas to assist in the removal and installation of petroleum fuel system components.

11-6.1 Inspection and Maintenance – Cranes and Hoists.

a. Inspect cranes and hoists for smooth operation. If the crane or hoist is equipped with electronic controls, check power supply and operational control cords for nicks or damage. A crane service technician must correct binding that may prevent smooth operation and repair damage to power cords.
Frequency: Before each use

b. Apply lubricant or grease to areas that require periodic greasing.
Frequency: Annually

c. Military services-specific, host nation, state, and/or local regulations require cranes and hoists to be certified for operation. Follow the more stringent of military services-specific, host nation, state or local regulations.
Frequency: Annually

CHAPTER 12 FUEL FACILITY TEMPORARY DEACTIVATION OR CLOSURE

12-1 DEACTIVATION OF FUELING FACILITIES.

Prior to deactivation of a fuel facility, maintainers must contact the Installation's Environmental Office to review the requirements and coordinate to ensure that the deactivated facility remains in regulatory compliance throughout the deactivation period. Note: USTs deactivated for an extended period of time may be subject to closure notifications per Federal, state, and local requirements. Contact Installation Environmental Office for further information.

12-2 DEACTIVATED PETROLEUM FUEL TANKS

Deactivated petroleum fuel tanks that require ballast must be filled with a water or anti-corrosion solution to protect against floatation and overturning. Piping connections of tanks must be disconnected and blind flanged. Remaining active pressure relief systems attached to deactivated tanks must be reconnected to active tanks. Tanks must be labeled to indicate the present status of the tanks and the previous contents. Cathodic protection systems on deactivation tanks must continue to be used and maintained.

12-2.1 Inspection and Maintenance – Deactivated Petroleum Fuel Tanks.

a. Inspect water or anti-corrosion level in tank. If level has dropped, investigate potential leak points such as blind flanges. Repair leaks that are detected and refill to appropriate level.
Frequency: Quarterly

b. Check exterior coatings and labels. Repair peeling coatings and/or rusting areas and replace or repair labels which have become faded and difficult to read.
Frequency: Quarterly

c. Inspect cathodic protection system on deactivated tanks for proper operation.
Frequency: Annually

12-3 DEACTIVATED PETROLEUM FUEL PIPELINES.

Deactivated petroleum fuel pipelines must be drained of fuel, vapor freed and isolated by the use of blind flanges, blanks, or spectacle blinds. Once the petroleum fuel pipeline is isolated it must be charged with nitrogen to a pressure of 10 psig (69 kPa), or as otherwise determined based on the size and thickness of the pipe material. Pipeline cathodic protection systems must remain in operation and in good working order throughout the deactivation period.

Inter-terminal pipelines regulated by the DOT must have a written deactivation plan describing the process to be used. The deactivation plan must be submitted to the

Installation Environmental Office and the Pipeline Regulatory Compliance Agency for review and approval prior to taking the inter-terminal pipeline out of service and reclassifying the pipeline into inactive status. Refer to 49 CFR 195 for additional information on closure of DOT regulated pipelines.

12-3.1 Inspection and Maintenance – Deactivated Petroleum Fuel Pipelines.

a. Inspect the pressure of the nitrogen charge applied to the petroleum fuel pipeline with a pressure gauge. If the pressure of the charge has dropped investigate and repair leak points. Once leak points are repaired, recharge with nitrogen.
Frequency: Quarterly

b. Check exterior coatings and labels. Repair peeling coatings and/or rusting areas and replace or repair labels which have become faded and are difficult to read.
Frequency: Quarterly

c. Inspect cathodic protection system for proper operation.
Frequency: Annually

12-4 DEACTIVATED PETROLEUM FUEL PUMPS.

Deactivated petroleum fuel pumps must be disconnected from supply and discharge piping and the interior of the pumps must be treated with a light corrosion-inhibiting oil. The suction and discharge ports of the pump must be equipped with blind flanges or plugs.

12-4.1 Inspection and Maintenance – Deactivated Petroleum Fuel Pumps.

a. Manually rotate pump through several rotations. Ensure that the pump turns freely.
Frequency: Quarterly

b. Check exterior coatings. Repair peeling coatings and/or rusting areas and replace or repair labels which have become faded and are difficult to read.
Frequency: Quarterly

c. Remove isolation flanges and recoat interior of pump with light corrosion-inhibiting oil.
Frequency: Annually

12-5 MISCELLANEOUS DEACTIVATED COMPONENTS.

Deactivated control valves and specialized components must be removed from piping and tanks. The connection ports of the removed components must be equipped with blind flanges, dust caps, or plugs in order to protect the internal surfaces and working parts of the components from environmental exposure. The pipe or tank connection points of the removed components must also be equipped with blind flanges or plugs in order to protect the internal surfaces of the piping or tanks from environmental exposure. The removed components must be stored in a clean dry area protected from the elements.

12-5.1 Inspection and Maintenance – Miscellaneous Deactivated Components.

a. Ensure that blind flanges are tight. Inspect exterior coatings and labels. Repair peeling coatings and/or rusting areas and replace or repair labels that have become faded and are difficult to read.
Frequency: Annually

12-6 TANKS AND PIPELINES.

Refer to Chapter 14 of UFC 3-460-01 for facility closure requirements.

12-7 DOCUMENTATION/RECORDKEEPING.

Refer to Section 14-3 of UFC 3-460-01 for inventory requirements of closed systems.

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APPENDIX A DLA ENERGY PROJECT PROGRAMING

A-1 PROJECT PLANNING STUDIES.

The Planning Study Program is a fence-to-fence analysis of Installation-level infrastructure holding DLA Energy capitalized fuel to identify deficiencies. They are scheduled in 5 year intervals. The program has three over-arching phases:

- Planning Study Site Visit. This phase involves an on-location site visit to identify deficiencies in the fuels infrastructure.
- Planning Study Design Package Development. This phase involves the creation and refinement of the report used to document deficiencies that will be compiled into projects for funding.
- Planning Study Construction Project. This phase involves the construction required to rectify deficiencies identified during the planning study site visit phase.

A-2 RECURRING MAINTENANCE MINOR REPAIR PROGRAM.

The DLA Energy Recurring Maintenance Program is a contract vehicle which provides quarterly, semi-annual, and annual maintenance service for capitalized Installation level real property. Also included is a minor repair and emergency response services for mission essential repairs of a non-technical nature within an established dollar amount. This program is currently executed by the United States Army Corps of Engineers (USACE); however, other executing agencies may be used to address recurring maintenance requirements not covered by this contract.

A-3 FILTER REPLACEMENT PROGRAM.

For facilities eligible for DLA Energy SRM Program, funds have been made available to purchase replacement filter separator cartridges and associated parts such as O-rings and gaskets. **2**\ Refer to the current DLA energy filter requisitioning policy document for further guidance in accordance with DLA-Energy P-22, *Procedures for Requisition, Funding Requests, or Reimbursement of Filter/Coalescer Elements*. /**2**/

A-4 DLA CENTRALLY MANAGED PROGRAMMING.

The Centrally Managed Program (CMP) manages regulatory, compliance, and best practice maintenance processes for deficiencies on assets that are common to all Services.

A-4.1 Tank Integrity Management Program.

The Tank Integrity Management Program for DLA Energy capitalized tanks uses industry standard API 653, *Tank Inspection, Repair, Alteration, and Reconstruction* document or STI SP001, *Standard for the Inspection of Aboveground Storage Tanks*, as the basis of meeting regulatory requirements included in 40 CFR 112 *Oil Pollution Prevention* and state regulations. Many military tanks, such as cut and cover and mined styles, do not fit well into the API 653 standard so the code is applied to the maximum extent possible. It is the policy of DLA Energy to require professional engineering oversight of all inspection and repair programs.

DLA Energy sanctions the use of STI *Standard for the Inspection of Aboveground Storage Tanks*, SP001 as the inspection standard for small shop fabricated DLA Energy capitalize tanks, typically aboveground, horizontal, and up to 45,000 gallons in size. Host nation standards, such as the German TUEV (Technischer Ueberwachungsverein [German safety and standards institution]), are addressed as an “add-on” to the base inspection program.

Military service-specific SCP identifies tanks coming due, are past due or are without a record of inspection and coordinates inspections with DLA Energy. Inspection frequencies are in accordance with applicable standards and codes.

A-4.2 Pipeline Integrity Management Program.

The Pipeline Integrity Management Program provides for the development of Pipeline Integrity Management Plans (PIMPs) and funds API 570 inspections of piping systems.

A-4.3 Pressure Vessel Integrity Management Program.

The Pressure Vessel Integrity Management Program provides for the physical inspection of pressure vessels (e.g., filter separators, micronic or cyclonic separators, relaxation chambers, and air eliminators tanks) in accordance with API 510. Its goal is to reduce the risk of failure, thereby reducing potential environmental damage and/or mission readiness consequences.

A-4.4 Cathodic Protection System Integrity Management Program.

The Cathodic Protection System Integrity Management Program provides for the annual inspection, repair and maintenance of cathodic protection systems. Cathodic protection is a form of corrosion protection applied to underground or underwater metallic structures. Cathodic protection usually works in conjunction with protective coatings on steel/stainless steel structures. Common applications include buried pipelines, underground fuel storage tanks, and the bottom of aboveground fuel storage tanks. Other applications include water storage tanks, and submerged pilings/fender piles on piers and wharves. Federal and state regulations require cathodic protection for many fuel related applications and UFC 3-570-06 requires cathodic protection for all metallic fuel containing structures in direct contact with soil and water.

Corrosion inhibitors are another form of corrosion control covered under this program. Corrosion inhibitors are used in areas where cathodic protection is not possible, usually due to space requirements. A typical inhibitor project would replace a failed or absent cathodic protection system where anode replacement or installation is not economical or feasible. These systems follow the same guidelines and inspection cycle as cathodic protection systems.

A-4.5 Maritime Fuel Facilities/Piers Program.

The Maritime Fuel Facilities/Piers Program provides for the inspection and repair of piers. Routine pier inspections are conducted to identify, quantify, and document deficiencies observed on marine fuel facility structural, electrical, and mechanical systems. The results from inspections are utilized by professional engineers to assess a facility's overall condition and operational readiness (fit for purpose), and to produce maintenance plans and specifications for repairs.

A-4.6 Marine Loading Arm Program.

The Marine Loading Arm (MLA) Program provides for the inspection and repair of loading arms used in Defense Working Capital Fund (DWCF) loading/unloading operations at fixed real property energy infrastructure.

A-4.7 Underwater Hose Program.

Only underwater hoses used in Defense Working Capital Fund (DWCF) loading/unloading operations are eligible for DLA Energy SRM funds. This funding is provided by the Underwater Hose Program.

A-4.8 Dredging Program.

The Dredging Program provides funds for dredging projects. Deficiencies are identified by the Installation. Dredging of dedicated waterways used for vessel movement and delivery of DWCF products is eligible for DLA Energy funding consideration under this program. Dredging of shared-use waterways is cost shared based on a benefit assessment involving all users or in accordance with established Energy Infrastructure Facility Sustainment Model (FSM) rules.

A-4.9 Rails Program.

The Rails Program provides for the maintenance and sustainment of railcar loading/off-loading infrastructure and rail spurs from the Installation fence line. The program covers these systems when they are used for the DWCF fuel mission and coded for DLA Energy sustainment.

A-4.10 Demolition Program.

The Demolition Program provides funds for demolition projects when the real property is no longer required by DLA Energy or the applicable military service. Deficiencies are identified by the Installation. DLA Energy will fund demolition of real property infrastructure if the facility last contained DLA Energy owned product and for which DLA

Energy had SRM funding responsibility. DLA Energy may, depending on the situation, also fund facility demolition using Military Construction (MILCON) appropriation when the MILCON project involves demolition of existing energy infrastructure.

A-4.11 Automated Fuel Handling Equipment/Automatic Tank Gauging Program.

The Automated Fuel Handling Equipment (AFHE)/Automatic Tank Gauging (ATG) Program provides for installation and maintenance of automation systems. Professional engineering assessments, which are required by DLA Energy on capitalized fuel systems, are conducted under this program. These assessments improve overall fuel facility controls, improve inventory accountability, provide fail-safe engineering for spill prevention, increase efficiency, and execute routine maintenance.

This program supports automation programs for AFHE, Automated Fuel Service Station (AFSS), ATG, ATGR, Hydrant Automation Monitoring System (HAMS), Independent Alarm System (IAS), Overfill Protection Equipment (OPE) and Temperature Compensating Meter (TCM). The DLA Energy Installation Support Automation Branch coordinates with the military service-specific SCPs, the Space and Naval Warfare System Center (SPAWAR), and Installations to identify needed projects.

This program also supports automation maintenance programs for AFHE, ATG, IAS, AFSS, OPE, and Hydrant Fueling Automation Maintenance (HFAM). The life cycle maintenance support includes annual preventative maintenance and as-needed corrective maintenance support. Maintenance activities follow an annual cycle, are initiated after the warranty period, have an indefinite duration, and are reviewed annually. This program is also used to provide system support which includes on-call technical support, logistics support, configuration management, system enhancements and modifications.

Deficiencies are grouped into projects based on several factors such as geographic location and the preferences of the executing agents, military service-specific SCPs or other affected parties. Capital automation projects require the development of a Business Case Analysis (BCA), must be included in the Capital Budget 5-Year Plan, listed on the annual Master Operating Plan (MOP) and have the approval of a Capital Execution Package.

A-4.12 Leak Detection Program.

The Leak Detection Program is an Environmental managed and funded program to execute annual, biennial, and quarterly testing and monthly monitoring of DLA capitalized underground fuel storage and distribution systems worldwide for storage tanks, transfer and distribution piping, hydrant systems and ground fuel facilities. Testing is performed to meet environmental regulatory requirements and DLA best management practice testing requirements. The program encompasses leak detection testing, leak confirmation, location and/or inspection and rapid response of suspect leaks at DLA capitalized fuel facilities worldwide.

The Leak Detection program also includes support for permanently installed leak detection systems. This includes the maintenance, repair and certification of the permanently installed leak detection systems and the installation of new permanent leak detection systems at DLA capitalized fuel facilities worldwide.

A-5 REPAIR PROJECTS.

Provide adequate information for input of a deficiency into the DLA Energy Enterprise Business System (EBS) database. Required information for project development include: a cost estimate, justification, impact if not provided, and project description as well as an indication of the expected funding type. The funding types that are available include: Minor Construction (MC), Maintenance and Repair (MR), Maintenance (M) and Environmental (E).

A-6 CAPITALIZED ENVIRONMENTAL FUNDING.

DLA Energy also has an Environmental Managed and Funded Program for the development and revisions of environmental documents and will also support environmental compliance and restoration funding of capitalized fuel facilities for sampling and testing of petroleum, oil, and lubricants (POL) emissions and discharges, removal and disposal of POL wastes (except consumables), fees for spill cooperatives, permit fees, fines and penalties, spill cleanup, removal and disposal of POL wastes associated with facility maintenance projects and update of environmental compliance documents.

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APPENDIX B CONTAINMENT INTEGRITY TESTING CHECKLIST

Secondary Containment/Drainage System Integrity Testing			
UST Facility		**Person Conducting Test**	
Facility Name	Facility ID#	Tester's Name:	
Physical Address		Testing Company:	
City	State	City	State

Testing Requirements	
Type of Test	□ Code of practice developed by a nationally recognized association or independent testing
Purpose of Test	□ Notice of Alleged Violation
	□ Required Annual Test
	□ Post Repair Test

Liquid Tight Test Procedure

1. Clean containment of any debris.
2. Visually exam containment area for problem areas (gaps, cracks, sealant failure, etc.)
3. Make sure drainage valve is completely closed, *IF* adding water.
4. Add water to observe standing water at a highest point within the containment area (or conduct this test after a rain event where water has filled the secondary containment area).

2\ 4a. Fill all containments other than truck fill stands to minimum 1 inch water depth. /**2**/

5. Ensure water is calm (i.e. it is not still raining), and mark and record the high water line (e.g. using a tape measure with 1/16-in increments).
6. Leave water in containment, undisturbed for one hour (i.e. no operations are taking place).
7. Compare the starting water level to the ending level:
   - If the water level is the same or changed less than 1/8th (vertical) inch, the containment passed the test.
   - If the water level has dropped 1/8th inch or more, an investigation must be conducted.
8. After the investigation, justify why this is not a leak or identify the leak and necessary repairs.

Test Data Table						
Test Date						
Containment Item ID No.						
Test Start Time						
Test End Time						
Test Beginning Water Level						
Test Ending Water Level						
Test Result (P/F)						
Comments:						

I hereby certify that all the information contained in this report is true, accurate, and in full compliance with legal requirements. Maintain six (6) years of test records. (Two Test Periods)

Tester's Signature: ______________________________________ Date:______________________

Secondary Containment Drainage System Integrity Testing

General Guidance

Who must complete this form?
Any person or their authorized representative (such as a tester or contractor) that conducts the secondary containment liquid tight testing.

What sites must complete this testing?
All underground secondary containment drainage systems to include bulk fuel storage, aircraft fueling systems, truck and railcar loading & unloading areas, marine facilities, and ground vehicle fuel facilities.

Petroleum Equipment Institute (PEI) Recommended Practice 1200-17: *Recommended Practices for the Testing and Verification of Spill, Overfill, Leak Detection and Secondary Containment Equipment at Underground Storage Tank Facilities* is an acceptable protocol.

Instructions for Completing the Fill-Port Containment Integrity Form:

UST Facility Information: Enter name and complete address of the facility, and the permit identification number for the facility.

Person Conducting the Test: Enter the tester's name and their company (if not completed by site operator) including the city and state from which they operate.

2) Purpose of the Test: Indicate by checking the box why the test is being done. Note: Testing must occur after repairs or replacement of parts connected to secondary containment.

Liquid Tight Test Procedure: Please review the methodology (if this is the desired test) before conducting the test.

Test Data Table:
1) Test Date: Indicate the date YYYYMMDD the test was completed
2) Indicate the starting and ending time for each Fill-Port Containment being tested.
3) Indicate the starting and ending water level for each Fill-Port Containment being tested.
4) Indicate if the test passed (P) or failed (F).
5) Comments: Add any comments or notes, particularly if there were any failing results.

Tester's Signature: The person conducting the test must sign and date the test.

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APPENDIX C MAINTENANCE TABLE

Inspection and maintenance tasks listed below are the minimum required. Additional operation and maintenance tasks may be performed based on specific installation requirements set by facility command.

OM stands for Operator Maintenance, and SM stands for System Maintenance. See Section 1-2 for more information on roles and responsibilities.

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
SIGNAGE AND MARKINGS					
Signage and Markings (Section 2-7)					
Signage and Markings	A. Check permanent signs and markings for adequacy and readability. Repair or replace deteriorated or illegible signs and markings. B. Inspect the location of Department of Transportation (DOT) regulated underground pipelines and ensure they are marked in accordance with 49 Code of Federal Regulations (CFR) 195.410. C. Check that all non-DOT regulated pipelines, tanks, valves, pumps, meters, and other equipment are marked in accordance with UFC 3-460-01. Section **1**\\ 2-17 /**1**/. If markings are missing or insufficient, repair or add markings in accordance with UFC 3-460-01. D. Ensure petroleum fuel system Emergency Fuel Shutoff (EFSO) push buttons are properly identified at each location. Ensure that signage is properly secured and that the lettering is legible from 25 feet (7.5 meters) away and not faded.	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	E. Verify enough movable or temporary signs are maintained in good condition to serve anticipated needs; for example: "DANGER," "CLOSED TO TRAFFIC," “KEEP FLAMES AWAY," "MEN WORKING,” "NO SMOKING,” "DANGER NO OPEN FLAME OR IGNITION SOURCE BEYOND THIS POINT.” Use bilingual signs when appropriate.	Annually	OM	OM	OM
FILTRATION					
Pre-Filter Vessels (Section 3-6.1)					
Pre-Filter Vessels	A. Open drains under flow conditions until clear fuel is observed from the drain valve. B. Monitor differential pressure in filter cartridges. Chart differential pressure measurements from readings taken during normal operations.	Daily	OM	OM	OM
	C. Operate pre-filter isolation valves.	Quarterly	SM	**2**\\ OM /**2**/	SM
	D. Replace filter cartridges when the acceptable maximum differential pressure is reached, the maximum in-service duration has passed, or the fuel becomes visibly dirty or discolored. Acceptable maximum differential pressure for a specific pre-filter is dependent on the system flow rate. The military service-specific SCP may extend in-service duration filter cartridge replacement period based on differential pressure for high throughput systems. Check expiration date of replacement	When differential pressure has reached the lower of manufacturer’s recommendation or 20 psid (140 kPa), filter cartridge in-service period of 24 months has expired, or when fuel becomes visibly dirty or discolored.	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	filter cartridges before installation.				
	E. Refer to Section 6-7.2 Differential Pressure Gauges for inspection and maintenance requirements of differential pressure gauges. F. Refer to Section 3-10.2 Automatic Air Vents for inspection and maintenance requirements of automatic air vents. G. Refer to Section 6-6.3 Thermal and Pressure Relief Valves for inspection and maintenance requirements of thermal and pressure relief valves. H. Conduct inspections of code rated vessels that meet the requirements of UFC 3-430-07	As required	SM	SM	SM
Filter Separators (Section 3-6.2)					
Filter Separators	A. Open drain under flow conditions until clear fuel is observed from the drain valve. B. Monitor differential pressure of coalescer cartridges. The acceptable maximum differential pressure for a specific filter/separator is dependent on the system flow rate. Monitor and chart differential pressure measurements of filter separators from readings taken during normal operations. Investigate sudden drops or	Daily	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	spikes in differential pressure measurement readings.				
	C. Operate filter separator isolation valves. D. Inspect components and check operation of water shutoff system.	Quarterly	\2\ OM /2/	\2\ OM /2/	SM
	E. Change coalescer cartridges. Refer to Section 3-6.2.2 Replacement of Coalescer Cartridges for general instructions on replacement of coalescer cartridges. Military service-specific SCP may extend the coalescer cartridge replacement frequency based on differential pressure if filters separators are used on high throughput systems. Check expiration date of replacement coalescer cartridges before installation. F. Inspect and clean separator cartridges at time of coalescer cartridge change in accordance with Section 3-6.2.3 Separator Cleaning. Worn or damaged separator cartridges must be replaced.	Every 36 months or sooner if required by differential pressure.	SM	SM	SM
	G. Refer to Section 6-7.2 Differential Pressure Gauges for inspection and maintenance requirements of differential pressure gauges. H. Refer to Section 3-10.2 Automatic Air Vents for inspection and maintenance requirements of automatic air vents.	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	I. Refer to Section 6-6.3 Thermal and Pressure Relief Valves for inspection and maintenance requirements of thermal and pressure relief valves. J. Refer to Section 4-4.2.2 Filter Separator Control Valves for inspection and maintenance requirements of filter separator control valves. K. Conduct inspections of code rated vessels that meet the requirements of UFC 3-430-07.				
	2\\ Haypack Filters (Section 3-6.3)				
	A. Refer to manufacturer's operation and maintenance manual for inspection and maintenance requirements of haypack filters.	Per manufacturer's specifications	SM	SM	SM
	B. Refer to Section 2-6.4, Waste Disposal, for disposal requirements.	As required	SM	SM	SM /**2**/
	Basket Strainers (3-6.4)				
Basket Strainers	A. Monitor and chart differential pressure measurements of basket strainers from readings taken during normal operations. Investigate sudden drops or spikes in differential pressure measurement reading.	Daily	OM	OM	OM
	B. Clean and inspect basket and strainer screen. Basket strainer isolation valves must be closed and the strainer body must be drained before removing the cover. After cleaning, the strainer screen must be inserted in the strainer body, and the head tightened and checked for	Semi-annually if basket strainer is equipped with means to measure differential pressure;	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	leakage. If strainer is not equipped with means to measure differential pressure, unit must be opened monthly and inspection.	otherwise monthly.			
	C. Refer to Section 6-7.2 Differential Pressure Gauges for inspection and maintenance requirements of differential pressure gauges.	As required	SM	SM	SM
Filter Separator Sump Heaters (Section 3-6.5)					
Filter Separator Sump Heaters	A. Inspect filter separator sump and drain line heater elements for proper operation per manufacturer's operation and maintenance manual. Ensure heater elements meet manufacturer's requirements by measuring resistance of heater elements with an ohm meter.	Semi-annually	SM	SM	SM
METERS					
Positive Displacement Meters (Section 3-7.1)					
Positive Displacement Meters	A. Inspect counter head for unusual noises and smooth operation.	Monthly	OM	OM	OM
	B. Positive displacement meters must be inspected and calibrated semi-annually or when improper performance is suspected; when unusual sounds or register actions develop; or after repairs have been made which may affect performance. Positive displacement meters are satisfactory when the measurement error in the normal flow direction is within ±0.3% of actual quantity delivered (e.g., ±1.8 gallons for a 600-gallon test (±6.8 liters for a 2275-liter test)).	Semi-annually or as required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	Adjustment of the meter's register will be in accordance with manufacturer's instructions. Identify the next calibration date on meters (example: Mar 14 for March 2014). Use weather resistant label that will remain legible and affixed for at least one year. C. Inspect temperature element operation of meters equipped with temperature compensation feature per manufacturer's operation and maintenance manual.				
Turbine Flow Meters (Section 3-7.2)					
Turbine Flow Meters	A. Turbine flow meters must be inspected and calibrated semi-annually or when improper performance is suspected, register actions develop, or after repairs have been made which may affect performance. Turbine flow meters are satisfactory when the measurement error in the normal flow direction is within ±0.5% of actual quantity delivered (e.g., ±3 gallons for a 600-gallon test (±11 liters for a 2275-liter test)). Adjustment of the meter's register will be in accordance with the manufacturer's instructions. Identify the next calibration date on meters (example: Mar 14 for March 2014). Use weather resistant label that will remain legible and affixed for at least one year. B. Inspect temperature element operation of meters equipped with temperature compensation feature per manufacturer's	Semi-annually or as required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	operation and maintenance manual.				
Orifice Flow Meters (Section 3-7.3)					
Orifice Flow Meters	A. Refer to Section 6-7.2 Differential Pressure Gauges for inspection and maintenance requirements of differential pressure gauges. B. Refer to Section 6-7.4 Differential Pressure Transmitters for inspection and maintenance requirements of differential pressure transmitters.	As required	SM	SM	SM
PUMPS					
Centrifugal Pumps (Section 3-8.1)					
Centrifugal Pumps	A. Check for proper operations while pump is in use. Check suction and discharge pressure gauge for abnormal readings. B. Check for unusual noise, vibration, overheating of bearings or case. C. If equipped with lubricating oil charge, check oil level and adjust as necessary. D. Tighten or replace loose, missing or damaged nuts, bolts, or screws. E. Inspect suction and discharge isolation dampeners for misalignment and wear F. Inspect mechanical seals, if possible, for proper operating temperature, drips, leaks and dirt.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	G. Check alignment, clearances, and rotation of shaft and coupler (requires removal of coupler shroud or cover). H. Lubricate pump bearings. I. If equipped with lubricating oil charge, drain old oil, and fill with new to full mark on sight indicator (also fill bulb).	Annually	SM	SM	SM
	J. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.	As required	SM	SM	SM
Vertical Inline Pumps (Section 3-8.1.2)					
Vertical Inline Pumps	A. Check for proper operations while pump is in use. Check suction and discharge pressure gauges for abnormal readings. B. Check for unusual noise, vibration, overheating of bearings. C. Tighten or replace loose, missing or damaged nuts, bolts, or screws. D. Inspect suction and discharge isolation dampeners for misalignment and wear. E. Inspect mechanical seals, if possible, for proper operating temperature, drips, leaks and dirt.	Quarterly	SM	SM	SM
	F. Check alignment, clearances, and rotation of shaft and	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	coupler (requires removal of coupler shroud or cover). G. Lubricate pump bearings.				
	H. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.	As required	SM	SM	SM
Vertical Turbine/Submerged Turbine Pumps (Section 3-8.1.3)					
Vertical Turbine/Sub-merged Turbine Pumps	A. Check for proper operations while pump is in use. Check discharge pressure gauge for abnormal readings. B. Check for unusual noise, vibration, overheating of bearings or case. C. If equipped with lubricating oil charge, check oil level and adjust as necessary. D. Tighten or replace loose, missing or damaged nuts, bolts, or screws. E. Inspect mechanical seals, if possible, for proper operating temperature, drips, leaks and dirt.	Quarterly	SM	SM	SM
	F. Inspect anti-rotation device for proper operation.	Semi-annually	SM	SM	SM
	G. Check alignment, clearances, and rotation of shaft and coupler (requires removal of coupler shroud or cover). H. Lubricate pump bearings. I. If equipped with lubricating oil charge, drain old oil, and fill with	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	new oil to full mark on sight indicator (also fill bulb).				
	J. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.	As required	SM	SM	SM
Sliding Vane Pumps (Section 3-8.2.1)					
Sliding Vane Pumps	A. Inspect pump for unusual noise, vibrations, and overheating of bearings and case. B. Inspect mechanical seals, if possible, for drips or leaks and dirt. C. Lubricate pump bearings.	Quarterly	SM	SM	SM
	D. Inspect pump and motor coupling for proper alignment. E. Refer to manufacturer's operation and maintenance manual for internal pressure relief testing and calibration procedures.	Annually	SM	SM	SM
	F. Refer to Section 3-8.4 Gearboxes for inspection and maintenance of reduction gearboxes. G. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.	As required	SM	SM	SM
Gear Pumps (Section 3-8.2.2)					
Gear Pumps	A. Inspect pump for unusual noise, vibrations, and overheating of bearings and case.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	B. Inspect mechanical seals, if possible, for drips or leaks and dirt. C. Lubricate pump bearings				
	D. Inspect pump and motor coupling for proper alignment.	Annually	SM	SM	SM
	E. Refer to Section 3-8.4 Gearboxes for inspection and maintenance of reduction gearboxes. F. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors.	As required	SM	SM	SM
Diaphragm Pumps (Section 3-8.2.3)					
Diaphragm Pumps	A. Inspect hose for cracks or dry rot. B. Inspect compressed air connections for signs of leaks. C. Inspect compressed air hose coupling safety pins or safety wires for wear and damage. Replace damaged components.	Quarterly	SM	SM	SM
	D. Diaphragm pumps should have the internal diaphragm replaced if the pump shows decreased performance. Also check operation of actuator valve and ensure ball checks seat properly.	As required	SM	SM	SM
Internal Combustion Drives (Section 3-8.3)					
Internal Combustion Drives	A. Refer to manufacturer's operation and maintenance manual for specific maintenance procedures and schedules associated with a specific model of internal	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	combustion drive. Follow all applicable general maintenance and safety requirements listed in the manufacturer's operation and maintenance manual.				
Gearboxes (Section 3-8.4)					
Gearboxes	A. Inspect gearboxes for signs of smoke near shaft connections or discoloration of the gearbox from overheating. B. Verify that the oil in the sight glass is not dark or appears to have foam. Adjust oil level if required.	Quarterly	SM	SM	SM
	C. Lubricate bearings per manufacturer's recommendations. D. Check motor and gear box and gear box and pump couplers for wear and alignment.	Semi-annually	SM	SM	SM
	E. Inspect gear alignment within gearbox. F. Replace lubricant oil in accordance with manufacturer's specifications and recommendations.	Annually	SM	SM	SM
HOSES					
Loading Fuel Hoses (Section 3-9.1)					
Loading Fuel Hoses	A. Visually inspect hoses for loose covers, cracks, brittle surface coatings, exposed wire braids, exposed reinforcement, flattening, kinks, and bulges or soft spots which might indicate broken or displaced reinforcement.	Weekly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	B. Pressurize hose to normal working pressure. Check flanged and threaded connections for leaks and inspect hose couplers for fluid seepage by pushing at the base of the coupling with your thumbs; a hose softened by fluid seepage must be replaced.	Monthly	OM	OM	OM
	C. Check for coupling slippage. Replace hose that shows signs of coupling slippage.	Quarterly	SM	**\2** OM **/2/**	SM
	D. **\1\/1/** E. Conduct test of fuel hose electrical resistivity using an electrostatic meter in accordance with NFPA 77 & API 2003.	Annually	SM	SM	SM
Offloading Fuel Hoses (Sections 3-9.2)					
Offloading Fuel Hoses	A. Visually inspect hoses for cracks brittle surface coatings, exposed wire braids, exposed reinforcement, flattening, kinks, and bulges or soft spots which might indicate broken or displaced reinforcement.	Weekly	OM	OM	OM
	B. Check flanged and threaded connections for leaks and inspect hose couplers for fluid seepage by pushing at the base of the coupling with thumbs; a hose softened by petroleum fluid seepage must be replaced. Damaged or leaking hoses must be replaced immediately or isolated and taken out of service.	**\2** Monthly **/2/**	**\2** OM **/2/**	**\2** OM **/2/**	**\2** OM/ **2/**
	C. Conduct test of offloading fuel hose electrical resistivity as	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	directed in NFPA 77 and API 2003.				
AIR ELIMINATOR TANKS					
Air Eliminator Tanks (Section 3-10.1)					
Air Eliminator Tanks	A. Inspect operation of fuel level probes. Ensure probes operate correctly when the level of fuel in the tank rises to the level of the probe sensing unit. B. Remove the float vent valve from the air eliminator tank. Clean and inspect the sealing surfaces of the float vent valve. Ensure the float is buoyant in fuel and test the valve to ensure it closes properly.	Annually	SM	SM	SM
	C. Refer to Section 8-9.3 Tank Pressure/Vacuum Vents for in- spection and maintenance require- ments of pressure vacuum vents.	As required	SM	SM	SM
Automatic Air Vents (Section 3-10.2)					
Automatic Air Vents	a. Check for proper operation of the automatic air vent. Ensure the vent opens to allow air to escape and ensure the float of the vent is buoyant in petroleum fuel and rises to close the vent when the float is suspended in petroleum fuel.	Annually	SM	SM	SM
FUEL ADDITIVE INJECTORS					
Fuel Additive Injectors (Section 3-11)					
Fuel Additive Injectors	a. Inspect injectors to ensure they are operating properly.	When fuel system has flow through it, inspect weekly. When fuel system is sitting idle, inspect	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
		injectors monthly.			
	b. Calibrate injector to ensure proper additive to fuel ratio.	Annually	SM	SM	SM
CONTROL VALVES – TYPE II HYDRANT SYSTEM					
General System Control Valves (Section 4-3.2.1)					
General System Control Valves	A. Verify operating settings of valve. Valve adjustment must be in accordance with manufacturer's operation and maintenance manuals and final start-up and commissioning set points. Use of DoD standard set points should only be used as a reference starting point as pipe size and other hydraulic factors influence final system settings.	Quarterly	SM	SM	SM
	B. Remove and clean strainer installed in the petroleum fuel supply line to the pilot and main valve diaphragm. This strainer is provided to prevent clogging of the orifice in the supply line. Clogging of the screen will cause malfunctioning of the valve	Annually for unfiltered systems and as required for filtered systems.	SM	SM	SM
	C. Diaphragms must be removed and inspected for deterioration and breaks at the flexing joint. Damage is often caused by pipe scale, pipe tape, and thread sealant compound that collect above the diaphragm and become lodged between the diaphragm and bonnet of the valve. Damage may also be caused by a change of operational petroleum fuel type	Every 10 years	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	or grade (such as a change from JP-4 to JP-8).				
Refuel Control Valves (Section 4-3.2.5)					
Refuel Control Valves	A. Verify refuel control valve is set to maintain 100 psig (690 kPa) (typ- ical operating pressure) as meas- ured at the furthest hydrant outlet. B. Verify pressure-reducing control will open at 5 psig (35 kPa) above normal operating pressure (typ- ically 105 psig (725 kPa) as meas- ured at the farthest hydrant outlet) C. Verify refueling control valve opening rate is set between 15 and 20 seconds. The valve should open as quickly as possible without tripping the pressure differential control shut-off. D. Verify operation of the excess flow shut-off function. E. Verify operation of solenoid.	Quarterly	SM	SM	SM
	F. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Pressure Relief Valves (Section 4-3.2.6)					
Pressure Relief Valves	A. Verify pressure relief valve will open at 10 psig (69 kPa) above normal inlet pressure to the refuel control valve.	Semi-annually	SM	SM	SM
	B. Refer to Section 4-3.2.1 General System Control Valves for	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	additional inspection and maintenance requirements.				
Defuel Control Valves (Section 4-3.2.7)					
Defuel Control Valves	A. Verify the defuel control valve opens when the solenoid on the defuel control valve is energized.	Quarterly	SM	SM	SM
	B. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Dual Rate-of-Flow Control Valves (Section 4-3.2.8)					
Dual Rate-of-Flow Control Valves	A. Verify dual rate-of-flow control valve is set to maintain a flow rate of 200 gpm (12.5 lps). B. Verify check valve feature is operational.	Quarterly	SM	SM	SM
	C. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Combination Dual Rate-of-Flow Control and Solenoid Valves (Section 4-3.3.1)					
Combination Dual Rate-of-Flow Control and Solenoid Valves	A. Verify valve is set to maintain a flow rate of 300 gpm (19 lps). B. Verify operation of check valve feature. C. Verify solenoid operation.	Quarterly	SM	SM	SM
	D. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Dual Pressure Relief, Solenoid Shutoff, and Check Valves (Section 4-3.3.2)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Dual Pressure Relief, Solenoid Shutoff, and Check Valves	A. Verify high pressure relief control will open at 5 psig (35 kPa) above the refuel control valve pressure relief control set point (typically set at 110 psig (760 kPa)). B. Verify low pressure relief control will open at 5 psig (35 kPa) when refueling pumps are stopped. C. Verify closing speed provides a smooth, pulsation free operation. D. Verify operation of solenoid valve.	Quarterly	SM	SM	SM
	E. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
CONTROL VALVES – TYPE III HYDRANT SYSTEM					
Non-Surge Check Valves (Section 4-4.2.1)					
Non-Surge Check Valves	A. Verify main valve opening speed (typically 20 seconds). Adjust if required. B. Verify valve maintains 650 gpm (41 lps) flow rate (some instances 950 gpm (60 lps) flow rate). Adjust if required. C. Ensure the check valve function is operating properly.	Semi-annually	SM	SM	SM
	D. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements .	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Filter Separator Control Valves (Section 4-4.2.2)					
Filter Separator Control Valves	A. Test FSCV emergency shut off solenoid under flow conditions and ensure that valve closes within 10 seconds of EFSO button activation. Coordinate with overall EFSO test listed in Section 9-1.2.1 Inspection and Maintenance - Electrical Equipment. B. Operate test button (if installed) to ensure the FSCV closes at high water level. Physically press the test button, while recirculating fuel, and ensure the FSCV closes. Note: closing speed is a function of the number of open filters separators and the number of pumps operating. With all filters open and only one pump operating, the valve will close very slowly.	Quarterly	SM	SM	SM
	C. Verify valve maintains flow rate (typically 600 gpm (38 lps), operating range based on commissioning documentation). Adjust flow rate if required. Flow rate is determined by filter separator vessel gpm (lps) rating, or element flow rate, whichever is less. Use return venturi to measure and confirm flow rate during valve testing and adjustment. D. Ensure check valve function is operating properly.	Semi-annually	SM	SM	SM
	E. Test buoyancy of water level float. Remove the ball or float assembly and place it in a bucket of water. Correctly operating ball or float will float at the top of the water's surface.	When coalescer cartridges are changed.	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	F. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Defuel/Flush Valves (Section 4-4.2.3)					
Defuel/Flush Valves	A. Ensure Solenoids A and B are de-energized with system in automatic mode and lead pump operating. B. Ensure Solenoid A is energized and Solenoid B is de-energized to allow main valve to open and drop system pressure to 80 psig (550 kPa) (typical set pressure) with system in automatic mode and lead pump off. C. Ensure Solenoid A is de-energized and Solenoid B is energized when system is in flush mode. D. Ensure Solenoids A and B are de-energized when system is in tightness test mode. E. Check opening and closing speed. Speed should be as fast as possible while still maintaining smooth operation.	Quarterly	SM	SM	SM
	F. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Issue Venturi (Section 4-4.2.4)					
Issue Venturi	A. Ensure issue venturi DPTs are reading the same value within ± 2% full scale.	Semi-annually	SM	SM	SM
	B. Refer to Section 6-7.4 Differential Pressure Transmitters for inspection and	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	maintenance requirements of DPTs				
Return Venturi (Section 4-4.2.5)					
Return Venturi	A. Ensure return venturi DPTs are reading the same value within ± 2% full scale.	Semi-annually	SM	SM	SM
	B. Refer to Section 6-7.4 Differential Pressure Transmitters for inspection and maintenance requirements of DPTs.	As required	SM	SM	SM
Back Pressure Control Valves (Section 4-4.2.6)					
Back Pressure Control Valves	A. Verify constant upstream pressure is maintained at the setpoint established and listed in the system commissioning documents. Adjust setting of BPCV as necessary. B. Ensure Solenoid A is energized and Solenoid B is de-energized while lead pump is operating in automatic mode. C. Ensure Solenoids A and B are de-energized prior to lead pump shutdown and system going to stand-by. D. Ensure Solenoids A and B are de-energized while system is in flush mode. E. Ensure that Solenoid A is de-energized and Solenoid B is energized while system is in tightness test mode. F. Verify closing speed control. Valve should close as fast as possible while still maintaining smooth operation.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	G. Check solenoid EFSO feature when equipped. Coordinate test with overall EFSO test listed in Section 9-1.2.1 Inspection and Maintenance - Electrical Equipment.				
	H. Refer to Section 4-4.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Pressure Control Valves (Section 4-4.2.7)					
Pressure Control Valves	A. Ensure Solenoid A is energized and Solenoid B is de-energized while system is in automatic mode and lead pump is operating. B. Ensure Solenoids A and B are de-energized while system is in automatic mode and lead pump is off. Verify valve opens to maintain system pressure at 75 psig (515 kPa). C. Ensure Solenoid A is energized and Solenoid B is de-energized while system is in flush mode and lead pump is operating. D. Ensure Solenoids A and B are de-energized while system is in flush mode and pumps are off. E. Ensure Solenoids A and B are energized while system is in tightness test mode. F. Verify closing speed control. Valve should close as fast as possible while still maintaining smooth operation.	Quarterly	SM	SM	SM
	G. Refer to Section 4-3.2.1 General System Control Valves for	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	additional inspection and maintenance requirements.				
Hydrant Control Valves (Section 4-4.2.8)					
Hydrant Control Valves	A. Verify HCV maintains 45 psig (310 kPa) nozzle pressure at a flow of 50 to 600 gpm (3 to 38 lps). B. Verify HCV closes when nozzle pressure exceeds 50 psig (345 kPa). C. Verify HCV opening rate is set at a minimum of 20 seconds. D. Ensure HCV opens when the deadman control level is pressed. E. Verify HCV closes in five seconds maximum after the deadman lever is released.	Quarterly	SM	SM	SM
	F. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Emergency Shut-off Valves (Section 4-4.2.9)					
Emergency Shut-off Valves	A. Ensure Solenoids A and B are energized under normal operations. B. Ensure Solenoids A and B are de-energized during emergency stop conditions. C. Test emergency stop function of the valve under flow conditions. Ensure the valve closes within 10 seconds of EFSO button activation. Coordinate test with overall EFSO test listed in Section 9-1.2.1 Inspection and Maintenance - Electrical Equipment.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	D. Verify differential control maintains a constant seven psig (48 kPa) differential pressure between the inlet and outlet of the valve. E. Ensure thermal relief function (ball check valve) relieves excess pressure when cover chamber pressure exceeds inlet pressure.				
	F. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
CONTROL VALVES – TYPE IV AND V HYDRANT SYSTEMS					
Pantograph Control Valves (Section 4-5.2.12)					
Pantograph Control Valves	A. Verify PTCV maintains 55 psig (380 kPa) nozzle pressure at a flow of 50 to 600 gpm (3 to 38 lps). B. Verify PTCV opens when the deadman control lever is pressed. C. Verify PTCV closes in a maximum of 10 seconds after deadman lever is released.	Quarterly	SM	SM	SM
	D. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Pantograph Pressure Control Valves (Section 4-5.2.13)					
Pantograph Pressure Control Valves	A. Verify PPCV opens at 75 psig (515 kPa). B. Verify PPCV opening and closing speed are three seconds.	Quarterly	SM	SM	SM

<table>
<tr><th>ITEM</th><th>PARAGRAPH</th><th>FREQUENCY</th><th>Army</th><th>Navy/ USMC</th><th>Air Force</th></tr>
<tr><td colspan="6">Fixed Pantographs (Section 4-7.1.1)</td></tr>
<tr><td rowspan="3">Fixed Pantographs</td><td>A. Place entire pantograph under static pump head pressure and check for leaks, ease of movement, and damaged grounding or bonding wire.</td><td>Monthly</td><td>OM</td><td>OM</td><td>OM</td></tr>
<tr><td>B. Inspect wheels (if equipped) for warping, cracking, and uneven wear.
C. Inspect exposed piping and components for corrosion.</td><td>Quarterly</td><td>SM</td><td>SM</td><td>SM</td></tr>
<tr><td>D. Refer to Section 4-7.3 Fueling Nozzles for inspection and maintenance requirements of fueling nozzle.</td><td>As required</td><td>SM</td><td>SM</td><td>SM</td></tr>
<tr><td colspan="6">\1\ Detachable /1/ Pantographs (Section 4-7.1.2)</td></tr>
<tr><td rowspan="3">\1\ Detachable /1/ Pantographs</td><td>A. Place entire pantograph under static pump head pressure and check for leaks, ease of movement, and damaged grounding or bonding wire.
B. \2\ Inspect exposed piping and components for corrosion. /2/</td><td>Monthly</td><td>OM</td><td>OM</td><td>OM</td></tr>
<tr><td>C. Lubricate wheels.
D. Inspect wheels for warping, cracking and uneven wear.</td><td>Quarterly</td><td>SM</td><td>SM</td><td>SM</td></tr>
<tr><td>E. Refer to Section 4-7.2 Hydrant Adapters for inspection and maintenance requirements of pantograph hydrant adapters.
F. Refer to Section 4-7.3 Fueling Nozzles for inspection and maintenance requirements of fueling nozzles.</td><td>As required</td><td>SM</td><td>SM</td><td>SM</td></tr>
<tr><td colspan="6">HYDRANT ADAPTERS AND NOZZLES</td></tr>
<tr><td colspan="6">Hydrant Adapters (Section 4-7.\1\2/1/)</td></tr>
</table>

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Hydrant Adapters	A. Inspect hydrant adapter for proper operation, damage, and wear. B. Test operation of dry break system.	Quarterly	SM	SM	SM
Fueling Nozzles (Section 4-7.\1\3/1/)					
Fueling Nozzles	A. Inspect the condition of the dust cap at the aircraft adapter end and ensure it is in good working order. Dust caps must be attached to nozzles when they are not is use. B. Test leak resistance of poppet valve against full pump pressure. Unusual conditions found during this test indicate that repair is necessary and the nozzle must be removed from service. C. Inspect storage racks for moisture or dirt accumulation. Correct conditions that may be attributing to accumulation of moisture or dirt in the storage racks. D. Remove nozzle for inspection of content impinged upon the mesh screen. Clean and dry screens before nozzles are returned to service. If a strainer ball valve is installed upstream of the nozzle only the strainer in the strainer ball valve needs to be check. Nozzles should not be used while strainers are removed from upstream strainer ball valves. E. Tests nozzle interlocks. Ensure interlocks prevent release of fuel when the fueling nozzle is not properly connected. Adjust	**1**\Monthly/**1**/	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	the seating of the poppet valve if required. F. Check the operation of the manual valve crank assembly for smooth and positive motion on a special test stand.				
SUPPRESSORS					
Surge Suppressors (Section 4-7.**1**\\4/**1**/)					
Surge Suppressors	A. Inspect for nitrogen leaks. B. Bladder pressure inside surge suppressors must be validated and recharged as needed with nitrogen. Some surge suppressors are also equipped with needle valves. Settings established in the startup and commissioning documents should be maintained. Adjust nitrogen charge per manufacturer's recommendations.	Quarterly	SM	SM	SM
2\\ Aircraft Fueling Hoses (Section 4-7.5)					
Aircraft Fueling Hoses	A. Visually inspect hoses for loose covers, cracks, brittle surface coatings, exposed wire braids, exposed reinforcement, flattening, kinks, and bulges or soft spots which might indicate broken or displaced reinforcement.	Monthly	OM	OM	OM
	B. Pressurize hose to normal working pressure. Check flanged and threaded connections for leaks and inspect hose couplers for fluid seepage by pushing at the base of the coupling with thumbs. A hose softened by petroleum fluid seepage must be replaced.	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	C. Check for coupling slippage. Replace hose that shows signs of coupling slippage.	Quarterly	SM	SM	SM
	D. For hot pit refueling hoses only, refer to Appendix D, Section D-2.1, Loading Hose Hydrostatic Test, for loading hose hydrostatic testing requirements and procedures.	Annually	SM	SM	SM
	E. Conduct test of petroleum fuel hose electrical resistivity using an electrostatic meter in accordance with NFPA 77 and API 2003.	Annually	SM	SM	SM /**2**/
HYDRANT SYSTEM PRODUCT RECOVERY					
Overfill Valve for Product Recovery Tanks (Section 4-8.1)					
Overfill Valve for Product Recovery Tanks	A. Verify that a green light is illuminated on the pump control panel graphic display when OV is open. B. Ensure pressure reservoir bladder is charged with 13 to 15 psig (90 to 103 kPa) of nitrogen and that the reservoir holds fuel pressure. C. Verify that the OV closes when the control float is lifted (normally 95% full). Use the manual tester to lift the float. NOTE: When the float in the product recovery tank rises and the OV closes, the pressure in the pressure reservoir tank will decrease. D. Verify that a red light is illuminated and that an alarm is activated on the pump control panel graphic display when OV is closed. Alarm is activated by	Semi-annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	a limit switch installed on the OV. E. Ensure the pressure reservoir tank holds FTP deadhead pressure when the pump is deactivated. F. Open and clean reservoir inlet strainer.				
	G. Refer to Section 6-6.3 Thermal and Pressure Relief Valves for inspection and maintenance requirements of thermal and pressure relief valves.	As required	SM	SM	SM
MARINE RECEIVING AND DISPENSING EQUIPMENT					
\1\ Piers and Wharves Fuel Containment Systems (5-1.2) /1/					
\1\ Piers and Wharves /1/	\1\ A. Hydrostatically test the secondary containment and associated drainage systems to include containment concrete/sealant, drain inlets, drain lines and containment drain valves to ensure containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of the 60-minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Refer to Appendix B for testing	\1\ Every 3 Years /1/	\1\ SM /1/	\1\ SM /1/	\1\ SM /1/

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	procedures and to document the testing./**1**/.				
Marine Receipt (5-2)					
Marine Receipt	A. Conduct a shore side inspection of the pier or wharf for signs of damage as soon as marine barge or tanker disembarks.	After each use	OM	OM	OM
	B. Inspect the ground switch used between the marine barge or tanker and the petroleum fuel receipt piping. C. Inspect mooring lines, cleats, bollards, bitts, pulley blocks, steel wire ropes, and winches. Use UFC 4-150-08 as a guide when conducting inspections. Repair or replace damaged components as required.	Monthly	OM	OM	OM
	D. Refer to Section 6-1 Pipe Testing and Inspections for inspection and maintenance requirements of petroleum fuel pipelines installed above water surfaces. These pipelines are regulated under 33 CFR 154 and 156. Any additional requirements listed under 33 CFR 154 and 156 must also be followed. E. Refer to Section 5-5.1 Marine Transfer Hoses for inspection and maintenance requirements of petroleum fuel marine hoses. F. Refer to Section 5-4 Marine Loading Arms for inspection and maintenance requirements of petroleum fuel marine loading arms. G. Refer to Section 3-6.4 Basket Strainers for inspection and maintenance requirements of basket strainers.	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	H. Refer to Section 3-7 Meters for inspection and maintenance requirements of petroleum fuel meters. I. Refer to Section 3-8.2 Positive Displacement Pumps for inspection and maintenance requirements of stripper pumps. J. Refer to Section 9-1.6 Grounding Systems for inspection and maintenance requirements of grounding systems.				
Marine Issue (Section 5-3)					
Marine Issue	A. Inspect pier or wharf for signs of damage as soon as marine barge or tanker disembarks.	After each use	OM	OM	OM
	B. Inspect the ground switch between the fueling tanker/barge and the fuel system. C. Inspect mooring lines, cleats, bollards, bitts, pulley blocks, steel wire ropes, and winches. Use UFC 4-150-08 as a guide when conducting inspections. Repair or replace damaged components as required.	Monthly	OM	OM	OM
	D. Refer to Section 6-1 Pipe Testing and Inspections for inspection and maintenance requirements of petroleum fuel pipelines installed above water surfaces. These pipelines are regulated under 33 CFR 154 and 156. Any additional requirements listed under 33 CFR 154 and 156 must also be followed. E. Refer to Section 3-6.4 Basket Strainers for inspection and	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	maintenance requirements of basket strainers. F. Refer to Section 3-8 Pumps for inspection and maintenance requirements of marine loading and stripper pumps. G. Refer to Section 3-7 Meters for inspection and maintenance requirements of petroleum fuel meters. H. Refer to Section 5-5.1 Marine Transfer Hoses for inspection and maintenance requirements of petroleum fuel marine hoses. I. Refer to Section 5-4 Marine Loading Arms for inspection and maintenance requirements of petroleum fuel marine loading arms. J. Refer to Section 9-1.6 Grounding Systems for inspection and maintenance requirements of grounding systems.				
Marine Loading Arms (Section 5-4)					
Marine Loading Arms	A. Check swivel for smooth operation. Check seals for signs of wear and discoloration which may indicate a seal or ball bearing failure.	**\2** Monthly **/2/**	**\2** OM **/2/**	**\2** OM **/2/**	**\2** OM **/2/**
	B. Inspect ball bearings when accessible. Rough and/or uneven wear on the surface are indications of swivel joint failure C. Conduct pressure test of marine loading arms in accordance with 33 CFR 156.170 *Equipment Tests and Inspections*, Section (f)(1).	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Marine Bulk Transfer Hoses (Section 5-5.1)					
Marine Bulk Transfer Hoses	A. Visually inspect transfer hoses. Transfer hoses must have no loose covers, kinks, bulges, soft spots, and no gouges, cuts or slashes that penetrate the hose reinforcement. Hoses must also have no external deterioration.	Before each use	OM	OM	OM
	B. Visually survey petroleum fuel marine hoses. Observe the general condition and look for fluid puddles, fine mists, physical damage such as jacket abrasion or deformation, and deteriorated joints. Use sense of smell to detect petroleum vapor. Look for improper hose handling that may overstress the hose by stretching, relative movement, or kinking.	During each use	OM	OM	OM
	C. Refer to Appendix D, Section D-2.2 Marine and Underwater Transfer Hose Hydrostatic Test for marine transfer hose hydrostatic testing requirements and procedures.	Annually or not less than 30 days prior to the first transfer conducted past one year from the date of the last test and inspection.	SM	SM	SM
Underwater Hoses (Section 5-5.2)					
Underwater Hoses	A. Refer to Appendix D, Section D-2.2 Marine and Underwater Transfer Hose Hydrostatic Test for underwater hose hydrostatic testing requirements and procedures.	Annually or not less than 30 days prior to the first transfer conducted past one year from the date of the last test and inspection.	SM	SM	SM
Single Point Mooring Systems (Section 5-7.1)					
	A. Inspect and, if necessary, repair or replace all mooring hawsers or lines, deck hose, chain, chair	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Single Point Mooring Systems	stoppers, flange adaptors, gaskets or other gear used in mooring the marine tanker and in connecting hoses.				
	B. Inspect air-compressor for proper operation. C. Inspect navigation aids and mooring buoy, in accordance with NAVFAC MO-124 *Mooring Maintenance Manual*, for evidence of damage and possible movement or dragging by vessels, current or winds. D. Divers must conduct underwater inspections of mooring chains, shackles and anchors attaching buoys to bay/harbor floors.	Annually	SM	SM	SM
	E. Conduct overhaul of single point mooring buoys every 3 to 5 years. Single point mooring buoys must be brought ashore for repair in these instances.	Every 5 years	SM	SM	SM
Multi Point Mooring Systems (Section 5-7.2)					
Multi Point Mooring Systems	A. Inspect and, if necessary, repair or replace all mooring hawsers or lines, deck hose, chain, chair stoppers, flange adaptors, gaskets or other deck gear used in mooring the marine tanker and in connecting underwater hoses.	Monthly	OM	OM	OM
	B. Inspect navigation aids and mooring buoys, in accordance with NAVFAC MO-124 *Mooring Maintenance Manual*, for evidence of damage and possible movement or dragging by vessels, current or winds. C. Divers must conduct underwater inspections of mooring chains, shackles and anchors attaching	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	buoys to bay/harbor floors.				
SUBMERGED PIPING SYSTEMS					
Submerged Piping Systems (Section 5-8)					
Submerged Piping Systems	A. Inspect water above submerged pipelines and their seaward end for tell-tale petroleum fuel slicks indicating leakage from pipes or underwater hoses.	Weekly	OM	OM	OM
	B. If equipped, electrically check the cathodic protection rectifier for proper performance.	Six times each calendar year with intervals not exceeding 2½ months	SM	**2**\\ OM /**2**/	SM
	C. Divers must inspect submerged pipe and hoses for signs of incipient failure or indications of rapid wear of parts subject to wave motion or abrasion on the ocean floor.	Semi-annually	SM	SM	SM
	D. Conduct annual pipe test as specified in Appendix G – Petroleum Fuel Pipeline Pressure testing Guidelines and Criteria. Testing requirements of marine pipelines are regulated under 33 CFR 154 and 156, particularly 33 CFR 156 Section 170. E. Conduct cathodic protection tests on the protected pipeline as specified in Section 9.2.1 Cathodic Protection at least once each calendar year with intervals not exceeding 15 months between tests from consecutive years.	Annually	SM	SM	SM
Boom Reels (Section 5-9)					
Boom Reels	A. Visually inspect hydraulic drives	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	and hose connections for leaks. B. Grease bearings. C. Inspected boom reel for signs of corrosion. Inspect breaking system and ensure it is in good working order.				
	D. Inspect boom for wear, rips, and tears. Repair or replace as required to ensure containment of petroleum fuel in the event of a spill.	Annually	SM	SM	SM
ON-BASE PIPELINES					
On-Base Pipelines (Section 6-1.1)					
On-Base Pipelines	A. Conduct petroleum fuel pipeline visual Inspection of aboveground piping in accordance with Section 6-1.5 Pipeline Visual Inspection.	Monthly	\2\ OM /2/	\2\ OM /2/	SM
	B. Conduct line walk in areas of petroleum fuel piping in accordance with Section 6-1.6 Line Walk..	Conduct during transfer operations, or monthly, at a minimum	OM	OM	OM
	C. Conduct annual test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.	Annually	SM	\2\ OM /2/	SM
	D. Conduct cathodic protection tests as specified in Section 9.2.1 Cathodic Protection on protected petroleum fuel pipelines at least once each calendar year, but with intervals not exceeding 15 months.	Annually	SM	SM	SM
	E. Conduct five year test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.	Every five years	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	F. Conduct petroleum fuel pipeline API 570 inspection in accordance with Section 6-1.9 API 570 Inspections.	Every 5 or 10 years depend-ing on API class piping or in accordance with Pipeline Integ-rity Manage-ment Plan (PIMP).	SM	SM	SM
	G. Conduct petroleum fuel pipeline cleaning in accordance with Section 6-2 General Pipeline Cleaning.	As required to ensure fuel quality.	SM	SM	SM
INTER-TERMINAL PIPELINES					
Non-DOT Regulated (Section 6-1.2.1)					
Non-DOT Regulated	A. Conduct petroleum fuel pipeline volume check in accordance with Section 6-1.8 Volume Check.	Monthly	OM	OM	OM
Non-DOT Regulated	B. Conduct line patrol in areas of underground petroleum fuel pipeline in accordance with Section 6-1.7 Line Patrol.	Annually	OM	OM	OM
Non-DOT Regulated	C. Government operated inter-terminal petroleum fuel pipelines must follow the maintenance requirements listed in Section 6-1.1.1 for On-Base Pipelines.	As required	SM/OM	SM/OM	SM/OM
Aboveground Piping (Section 6-1.3)					
Aboveground Piping	A. Conduct petroleum fuel piping visual Inspection in accordance with Section 6-1.5 Pipeline Visual Inspection.	Weekly	OM	OM	OM
Aboveground Piping	B. Conduct petroleum fuel piping annual test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.	Annually	SM	SM	SM
Aboveground Piping	C. Conduct petroleum fuel piping API 570 inspection in accordance with Section 6-1.9	Every 5 or 10 years depend-ing on API class piping or	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	API 570 Inspections.	in accordance with Pipeline Integ-rity Manage-ment Plan (PIMP).Manage ment Plan (PIMP).			
	D. Conduct cleaning of petroleum fuel piping in accordance with Section 6-2 General Pipeline Cleaning.	As required to ensure fuel quality.	SM	SM	SM
Double-Wall Piping (Section 6-1.4)					
Double-Wall Piping	A. Conduct petroleum fuel pipeline visual Inspection of aboveground piping in accordance with Section 6-1.5 Pipeline Visual Inspection.	Monthly	OM	OM	OM
	B. Conduct annual carrier pipe test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria. C. Conduct cathodic protection tests as specified in Section 9.2.1 Cathodic Protection on protected petroleum fuel pipelines at least once each calendar year, but with intervals not exceeding 15 months.	Annually	SM	SM	SM
	D. Conduct containment pipe test as specified in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria.	Every three years	SM	SM	SM
	E. Conduct petroleum fuel pipeline API 570 inspection in accordance with Section 6-1.9 API 570 Inspections.	Every 5 or 10 years depend-ing on API class piping or in accordance with Pipeline Integ-rity Manage-ment	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
		Plan (PIMP).Management Plan (PIMP).			
	F. Conduct petroleum fuel pipeline cleaning in accordance with Section 6-2 General Pipeline Cleaning.	As required to ensure fuel quality.	SM	SM	SM
MANUAL VALVES					
Plug Valves – Lubricated (Section 6-6.2.1)					
Plug Valves - Lubricated	A. Open and close valve to check for ease of operation.	Quarterly	SM	SM	SM
	B. Lubricate valve operator stems and all grease fittings. C. Inspect valve exterior for corrosion and tightness of bolts. Repaint/tighten as required.	Semi-annually	SM	SM	SM
Plug Valves – Non-lubricated (Section 6-6.2.2)					
Plug Valves Non-Lubricated	A. Open and close valve to check for ease of operation. Adjust or replace packing as needed.	Quarterly	SM	SM	SM
	B. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.	Semi-annually	SM	SM	SM
Gate Valves (Section 6-6.2.3)					
Gate Valves	A. Open and close valve to check for ease of operation. Adjust or replace packing as needed.	Quarterly	SM	SM	SM
	B. Lubricate valve operator stem.	Semi-annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	C. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.				
Ball Valves (Section 6-6.2.4)					
Ball Valves	A. Open and close valve to check for ease of operation. B. Lubricate overhead ball valve chain operator gears. C. Adjust packing per manufacturer's specifications. D. Inspect valve exterior for corrosion and tightness of bolts. Repaint/tighten as required.	Quarterly	SM	SM	SM
	E. Refer to Section 6-6.2.10 Manual Valve Gear Operators for inspection and maintenance of gear operators if equipped.	As required	SM	SM	SM
Double Block and Bleed Valves (Section 6-6.2.5)					
Double Block and Bleed Valves	A. Open and close valve to check for ease of operation. B. Lubricate overhead valve chain operator gears if equipped. C. Adjust packing per manufacturer's specifications. D. Inspect valve exterior for corrosion and tightness of bolts. Repaint and tighten as required. E. Operate the body cavity drain when valve is in closed position to ensure that the valve is closing properly.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	F. **2**\ Keep the valve operator housing full of lubricant to displace and prevent moisture from accumulating and freezing, in accordance with manufacturer's recommendations.	Semi-Annually	SM	SM	SM
	G. Remove bottom drain plug and drain valve.	Annually	SM	SM	SM
	H. Refer to Section 6-6.2.10, Manual Valve Gear Operators, for inspection and maintenance of gear operators, if equipped. I. Some double block and bleed valves are equipped with integrated pressure/thermal relief valves. Refer to Section 6-6.3, Thermal and Pressure Relief Valves, for inspection and maintenance requirements of pressure/thermal relief valves. /**2**/	As required	SM	SM	SM
Butterfly Valves (Section 6-6.2.6)					
Butterfly Valves	A. Open and close valve to check for ease of operation. Ensure that lever operators and locking mechanisms are in place and working properly. B. Adjust packing per manufacturer's specifications as needed. If butterfly valves are leaking or not shutting off flow, tightening the gland flange to tighten the stem packing or remove the valve from service and replace the seats as necessary. C. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Globe Valves (Section 6-6.2.7)					
Globe Valves	A. Open and close valve to check for ease of operation. B. Adjust packing per manufacturer's specifications as needed. C. Inspect valve exterior for corrosion and tightness of bolts. Repaint/tighten as required	Quarterly	SM	SM	SM
Check Valves (Section 6-6.2.8)					
Check Valves	A. Use external test lever to make sure the valve is not sticking if equipped. If a check valve is suspected of not checking and cannot be serviced in place, it must be removed from the piping system and serviced in a shop. B. Inspect valve exterior for corrosion and tightness of bolts. Repaint and retighten as required.	Quarterly	SM	SM	SM
Line Blanks, Ring Spacers, and Spectacle Blinds (Section 6-6.2.9)					
Line Blanks, Ring Spacers, and Spectacle Blinds	A. Inspect exposed side of spectacle blinds. The exposed side must be kept clean and free of corrosion. B. Spectacle blinds should be inspected to ensure they are installed with the correct orientation for the desired flow or no-flow condition.	Quarterly	SM	SM	SM
Manual Valve Gear Operators (Section 6-6.2.10)					
Manual Valve Gear Operators	A. Lubricate gear driven operators and check for smooth operation	Quarterly	SM	SM	SM
RELIEF VALVES					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Thermal and/or Pressure Relief Valves (Section 6-6.3)					
Thermal and Pressure Relief Valves	A. Thermal and pressure relief valves must be inspected for signs of leak-by. Inspect relief valves for leaks by visually inspecting downstream flow indicators (if installed) for flow. If no flow indicators are installed listen for possible leaks. If suspect: isolate and test the relief valve; check opening pressure; and verify re-seating. Malfunctioning valves must be repaired or replaced. B. Ensure manual isolation valves installed upstream and downstream of thermal and pressure relief valves are open with valve handles are removed, wired open or locked.	Monthly	OM	OM	SM
	C. Inspect valve exterior of thermal and pressure relief valves for corrosion. Repaint as required. Information plates attached to thermal and pressure relief valves must not be painted over.	Quarterly	SM	SM	SM
	D. Verify thermal and pressure relief valve setting by consulting as-built and historical data. E. Thermal and pressure relief valves must be validated for proper calibration by isolating the valve and using the test connection provided on the piping in conjunction with a hand pump and portable reservoir. The operating pressure must be checked against the set pressure listed on the stamped information plate attached to the valve. The operating pressure must be adjusted to the	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	stamped set pressure if necessary.				
SEMI-AUTOMATIC VALVES					
Fire Valves (Section 6-6.4.1)					
Fire Valves	A. Ensure the fusible link mechanism is attached properly to actuate in case of a fire and that it has not been by-passed, blocked, or damaged in any manner. Ensure the fusible link is not filled with debris or paint which could impact operation. **1**\\ Maintain fusible links per manufacturer's recommendation./**1**/	Quarterly	SM	SM	SM
	B. Check the closing mechanism to ensure that it closes the valve properly.	Annually	SM	SM	SM
Fusible Line Butterfly Valves (Section 6-6.4.2)					
Fusible Link Butterfly Valves	A. Ensure the fusible link mechanism is attached properly to actuate in case of a fire and that it has not been by-passed, blocked, or damaged in any manner. Ensure the fusible link is not filled with debris or paint which could impact operation. **1**\\ Maintain fusible links per manufacturer's recommendation./**1**/	Quarterly	SM	SM	SM
	B. Test the operation of spring closure unit. Ensure that the spring actuator closes the valve and that the valve closes securely against the seat.	Annually	SM	SM	SM
	C. Refer to Section 6-6.2.6 Butterfly Valves for additional inspection and maintenance requirements of butterfly valves.	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
AUTOMATIC VALVES					
Truck Fill Valves (Section 6-6.5.1)					
Truck Fill Valves	A. Verify TFV maintains 35 psig (240 kPa) nozzle pressure at a flow range of 50 to 600 gpm (3 to 38 lps). B. Verify TFV closes rapidly when outlet pressure exceeds control set point. C. Verify TFV opens when the deadman control lever is pressed. D. Verify TFV closes after the deadman control lever is released. E. If equipped, verify operation of solenoid connected to grounding verification system. Ground verification system should energize solenoid when an acceptable ground is detected by the ground verification unit. F. Systems that have overflow protection systems must be inspected and maintained concurrently with the inspection and maintenance of TFVs.	Quarterly	SM	SM	SM
	G. Refer to Section 4-3.2.1 General System Control Valves for additional inspection and maintenance requirements.	As required	SM	SM	SM
Motor Operators (Section 6-6.6)					
Motor Operators	A. Visually inspect motor operators to ensure smooth movement during opening and closing operation and adjust, if	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	necessary, to ensure that they are opening and closing fully. Listen for and investigate unusual noises during operation. B. Lubricate mechanical overrides (if equipped).				
	C. Refer to Section 9-1.7 Electric Motors for inspection and maintenance requirements of electric motors	As required	SM	SM	SM
PRESSURE/VACUUM INSTRUMENTATION					
Pressure and Pressure/Vacuum Gauges (Section 6-7.1)					
Pressure and Pressure/ Vacuum Gauges	A. Check operation of gauge. Ensure gauge is indicating pressure of the system.	Monthly	OM	OM	OM
	B. Clean outside of gauge glass.	Quarterly	SM	SM	SM
	C. Inspect liquid filled gauges for leakage, refill/replace as needed.	Semi-annually	SM	SM	SM
	D. Conduct calibration check by comparing readings of the process gauge with the readings of a certified master calibration gauge which has been calibrated within the last year. The process gauge and the master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of gauge is within ±2% of full scale. Calibrate gauge if required.	Annually	SM	SM	SM
Differential Pressure Gauges (Section 6-7.2)					
Differential Pressure Gauges	A. Verify proper operation of differential gauge in accordance with gauge manufacturer's procedures.	Monthly	**\2** OM **/2/**	**\2** OM **/2/**	**\2** OM **/2/**
	B. Clean outside of gauge glass.	Quarterly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	C. Conduct calibration check by comparing readings of the differential process gauge with the readings of a certified differential master calibration gauge which has been calibrated within the last year. The differential process gauge and the differential master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of gauge is within ±2% of full scale. Calibrate if required.	Annually	SM	SM	SM
	D. Some differential pressure gauges have a small gauge protection filter located at the high pressure inlet of the gauge that must be checked and replaced as needed. Filters need to be replaced if the indicator is moving slow or sluggishly inside the sight glass or if the sight glass is dirty. Refer to manufacturer’s operation and maintenance manual for filter replacement procedure.	Annually for inspections and maximum 5 years of service between filter replacements.	SM	SM	SM
Pressure Transmitters (Section 6-7.3)					
Pressure Transmitters	A. Inspect the exterior of the transmitter enclosure for accumulated oil, dust, and dirt. Clean if required. B. Check that both enclosure caps are fully threaded onto the enclosure, compressing the O-ring between the cap and the enclosure. The O-ring must not be cracked, broken, or otherwise damaged. C. Inspect the display viewing glass for cleanliness and damage. Replace the enclosure	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	cap assembly if the glass is damaged or missing. No accumulation of dust, dirt, or water (condensate) should be present inside the enclosure. D. Inspect transmitter and mounting bracket hardware for tightness. Tighten loose hardware as necessary. E. Inspect for loose, bent, or cracked sensing lines. Replace damaged sensing lines. F. Check operation of transmitter. Ensure transmitter is indicating accurate pressure of the system.				
	G. Bleed sensing lines between the transmitter and the main line to ensure they are clean and free of suspended solids and air.	Semi-annually	SM	SM	SM
	H. Check that all wire connections inside enclosure are tight. I. Pressure Transmitters (PTs) and Pressure Indicating Transmitters (PITs) must be calibrated mechanically and electrically with test equipment and adjusted if applicable. The presence of air in the sensing line of a pressure transmitter is a common cause for failure. Conduct calibration check by comparing readings of the PT or PIT with the readings of a certified master calibration gauge which has been calibrated within the last year. The PT or PIT and the master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of PT or PIT	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	gauge is within ±2% of full scale. Calibrate in accordance with manufacturer's operation and maintenance manual if required.				
Differential Pressure Transmitters (Section 6-7.4)					
Differential Pressure Transmitters	A. Inspect the exterior of the transmitter enclosure for accumulated oil, dust, and dirt. Clean as required. B. Check that both enclosure caps are fully threaded onto the enclosure, compressing the O-ring between the cap and the enclosure. The O-ring must not be cracked, broken, or otherwise damaged. C. Inspect the display viewing glass for cleanliness and damage. Replace the enclosure cap assembly if the glass is damaged or missing. No accumulation of dust, dirt, or water (condensate) should be present inside the enclosure. D. Inspect transmitter and mounting bracket hardware for tightness. Tighten loose hardware as necessary. E. Inspect for loose, bent, or cracked sensing lines. Replace damaged sensing lines. F. Check operation of transmitter. Ensure transmitter is indicating accurate pressure of the system	Quarterly	**2**\\ OM /**2**/	SM	**2**\\ OM /**2**/
	G. Bleed sensing lines between the transmitter and the main	Semi-annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	line to ensure they are clean and free of suspended solids and air.				
	H. Check that all wire connections inside enclosure are tight. I. DPTs must be calibrated mechanically and electrically with test equipment and adjusted, if applicable. The presence of air in sensing lines of differential pressure transmitters is a common cause for failure. Conduct calibration check by comparing readings of the DPT with the readings of a certified differential master calibration gauge which has been calibrated within the last year. The DPT and the differential master calibration gauge must be connected to the same pressure source for testing. Verify accuracy of DPT is within ±2% of full scale. Calibrate in accordance with manufacturer's operation and maintenance manual if required.	Annually	SM	SM	SM
FLEXIBLE BALL JOINTS					
Flexible Ball joints (Section 6-8)					
Flexible Ball Joints	A. Lubricate ball joints and inspect for wear and stress.	Monthly	**2**\\ OM /**2**/	**2**\\ OM /**2**/	SM
THERMOMETERS					
Dial Thermometer (Section 6-9.1)					
Dial Thermometer	A. Inspect thermometer for cracked face and proper operational condition. Replace if damaged.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	B. Check accuracy of thermometer against calibrated master thermometer. Ensure process and calibrated master thermometer are reading the same heat source. Verify accuracy of thermometer is within ±2% of full scale. Calibrate process thermometer if required.	Annually	SM	SM	SM
PIPE COATINGS					
Aboveground Piping and Equipment Coatings (Section 6-10.1)					
Aboveground Piping and Equipment Coatings	A. **2**\\ Visually inspect coatings for signs of minor deterioration, corrosion, or damage. Repair damaged or deteriorated coatings. B. Coatings needing major repairs will be accomplished by system maintainers. /**2**/	**2** \\Monthly /**2**/	**2**\\ OM /**2**/	**2**\\ OM /**2**/	SM
UNDERGROUND FUEL PITS					
Isolation Valve Pits (Section 6-11.1)					
Isolation Valve Pits	A. Isolation valve pits should be inspected to ensure that the pits are dry and clean and that all components within the pit are clean and in good working order. Main- tain seals and boot seals as appro- priate. Obtain necessary confined space entry permits before entry. Inspect the pit for signs of fuel or water. Water or fuel should be removed from the pit as soon as possible and the source of water infiltration or fuel leak determined. B. Check for cracks in concrete and check piping penetrations through pit wall or bottom to ensure that mechanical seals	Monthly, or more often based on local conditions	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	and boot seals are in good working condition and are allowing no seepage of water into the pits. Make note of cracks in concrete and schedule main- tenance as necessary. Check for fuel leaks at all flanged and other piping connections. Check for rusted or deteriorated ladders or grating platforms that might make entry unsafe. Check pit lids for proper sealing. Check rolling pit covers for ease of operation and signs of deterioration, damage or corrosion. Make sure required locks are in place and locking mechanisms are not broken.				
Hydrant Fuel Pits (Section 6-11.2)					
Hydrant Fuel Pits	A. Hydrant fuel pits must be inspected to ensure that they are dry and clean and that all fueling components within the pit are clean and in good working order. Obtain necessary confined space entry permits before entry. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible. B. Check pipe penetrations through pit walls or bottom to ensure that mechanical and boot seals are in good working condition and are allowing no water seepage into the pits. C. Check for fuel leaks at all flanged and pipe connections. D. Check pit lids to ensure that seals are in good working order	Monthly, or more often based on local conditions	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	and are preventing water entry into the pits. E. Inspect hydrant fuel pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.				
High Point Vent Pits (Section 6-11.3)					
High Point Vent Pits	A. Inspect high point vent pits to ensure they are dry and free of water and other debris and that pit and piping components are leak free and in good working condition. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible. B. Check pipe penetrations through pit walls or bottom to ensure that mechanical and boot seals are in good working condition and are allowing no water seepage into the pits. C. Check pit lid seals for deterioration and replace as necessary. D. Ensure that high point vent valves, quick-disconnect couplings or pit lids are lockable and that locking mechanisms are in good working order. E. Inspect high point vent pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.	Monthly	OM	OM	OM
Low Point Drain Pits (Section 6-11.4)					
Low Point Drain Pits	A. Inspect low point drain pits to ensure they are dry and free of water and other debris and that	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	all pit and piping components are leak free and in good working condition. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible. B. Check pipe penetrations through pit wall or bottom to ensure that mechanical seals and boot seals are in good working condition and are allowing no water seepage into the pits. C. Check pit lid seals for deterioration and replace as necessary. D. Ensure that low point vent valves, quick-disconnect couplings or pit lids are lockable and that locking mechanisms are in good working order. E. Inspect low point drain pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.				
Lateral Control Pits (Section 6-11.5)					
Lateral Control Pits	A. Inspect lateral control pits to ensure they are dry and free of water and other debris and that all pit and piping components are leak free and in good working condition. Inspect the pit for fuel or water. Fuel or water found in the pit must be sumped out as soon as possible. B. Check pipe penetrations through pit wall or bottom to ensure that mechanical seals	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	and boot seals are in good working condition and are allowing no water seepage into the pit. C. Check pit lid seals for deterioration and replace as necessary. D. Check for fuel leaks at all flanged and other piping connections. E. Ensure that pit lids are lockable and that locking mechanisms are in good working order. F. Inspect lateral control pit bonding cables for corrosion and ensure electrical continuity between bonded equipment.				
MINOR PIPING EQUIPMENT					
Low Point Drains (Section 6-12.1)					
Low Point Drains	A. Visually inspect low point drains. Ensure that quick-disconnect dust caps are in place and that valves are locked closed.	Weekly	OM	OM	OM
	B. Operate low point drains when system is not under operating pressure. If there is an absence of sufficient line pressure close the low point drain and pressurize the system. Once adequate pressure is available, continue draining until the piping fuel sample is clear and bright with no visible water.	Monthly or as required by local conditions. Verify low point drains are closed after maintenance	OM	OM	OM
High Point Vents (Section 6-12.2)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
High Point Vents	A. Inspect high point vents. If fuel leaks are observed they should be repaired as soon as possible. Ensure that quick-disconnect dust caps are in place and that high point vent valves are locked.	Weekly	OM	OM	OM
Sight Flow Indicators (Section 6-12.3)					
Sight Flow Indicators	A. Verify there are no leaks around pipe connection fittings and glass seals. Also check glass for indications of cracks.	Daily or at each use	OM	OM	OM
ELECTRONIC RELEASE DETECTION MONITORING					
Rope Sensor Systems (Section 6-13.1.1)					
Rope Sensor System	A. Ensure the monitoring panel associated with the rope sensor(s) is powered on and no alarms are present.	Daily	OM	OM	OM
	B. Test rope sensor system and ensure it is functional.	Annually	SM	SM	SM
Point Sensor - Dry (Section 6-13.1.2)					
Point Sensor - Dry	A. Ensure the monitoring panel associated with the point sensor(s) is powered on and no alarms are present.	Daily	OM	OM	OM
	B. Ensure monitoring space is clear and free of debris and liquid.	Monthly	OM	OM	OM
	C. Test sensor and ensure it is functional.	Annually	SM	SM	SM
Visual Monitoring (Section 6-14.1)					
Visual Monitoring	A. Visually inspect ports for signs of leaks. Remove debris or foreign objects obstructing the view.	Weekly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
FILLING STATION DISPENSERS					
Dispenser Nozzles (Section 7-2)					
Dispenser Nozzles	A. Inspect dispenser nozzle spout. Ensure it is tight, round, has no cracks, or excessive wear. Inspect automatic shutoff hole. Ensure the hole is open and free of obstructions. Inspect nozzle hold-open latch. Ensure the latch is straight, moves freely, and the return spring operates correctly. Inspect body of nozzle. Ensure the body is in good condition and that the valve stem is clean and free of fuel. Inspect the nozzle to hose connection and ensure it is clean and free of fuel.	Daily	OM	OM	OM
	B. \1/	\1/	\1/	\1/	\1/
	C. Test automatic shutoff feature and ensure it is operating properly. Test automatic shutoff at all nozzle hold-open latch positions	Annually	SM	SM	SM
Dispenser Hoses (Section 7-3)					
Dispenser Hoses	A. Inspect dispenser hoses and hose whips for gouges, cuts, blisters, or outside wear that may lead to rupture during use. Replace hose or hose whips that show signs of wear. Inspect connection points of hoses and hose whips to the dispenser, breakaways, swivels, and the nozzle and ensure the connection points are clean and free of fuel.	Daily	OM	OM	OM
Breakaways (Section 7-4)					
Breakaways	A. Inspect breakaways for loose connections and signs of	Daily	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	damage to poppets. Ensure breakaways are clean and free of fuel.				
	B. Inspect breakaway for an expiration date established by the manufacturer. Breakaways must be replaced before the indicated expiration date	Monthly	OM	OM	OM
Swivels (Section 7-5)					
Swivels	A. Inspect swivel for loose connections and signs of damage. Ensure swivel rotates easily and is clean and free of fuel.	Daily	OM	OM	OM
	B. Inspect swivel for expiration date established by manufacturer. Swivels must be replaced before the indicated expiration date.	Monthly	OM	OM	OM
Hose Retriever (Section 7-6)					
Hose Retriever	A. Test hose retriever and ensure it is operating correctly and supporting the hose.	Monthly	OM	OM	OM
Dispenser Cabinet (Section 7-7)					
Dispenser Cabinet	A. Inspect outside of cabinet and ensure it is free of damage. Inspect for fuel stains on the concrete island around the cabinet and on the outside of the cabinet. Ensure the cabinet is free of dirt and fuel. B. Open both sides of the cabinet and inspect the inside of the cabinet. Ensure the inside of the cabinet and all of the	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	components inside the cabinet are clean and free of fuel.				
	C. Ensure door panels and locks operate easily. Inspect anchor bolts of cabinet to dispenser island and ensure the bolts are in good condition.	Annually	SM	SM	SM
Dispenser Meters (Section 7-8)					
Dispenser Meters	A. Inspect meter and ensure meter is clean and free of fuel. Ensure calibration mechanism is sealed.	Monthly	OM	OM	OM
	B. Since moving parts inside meters are subject to wear, periodic calibration is necessary. Meters must be recalibrated utilizing a certified 5 gallon (20 liter) prover can or other approved method. Meters are considered satisfactory for further operation when the error does not exceed ±0.2% of actual quantity delivered.	Annually	SM	SM	SM
Dispenser Filters (Section 7-9)					
Dispenser Filters	A. Inspect filter and ensure filter is clean and free of fuel and that filter is labeled with a legible installation date.	Monthly	OM	OM	OM
	B. Replace dispenser filters annually or when a change in flow rate is noted.	Annually or as needed	SM	SM	SM
Dispenser Strainer (Section 7-10)					
Dispenser Strainers	A. Inspect and clean strainers. Inspect strainer cover gasket for cracks, distortion, and dry rot. If breaks are detected in strainer mesh, replace the strainer.	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
GROUND FUEL PIPING					
Ground Vehicle Fuel Piping (Section 7-11)					
Ground Vehicle Fuel Piping	A. Visually inspect aboveground lines for leaks. Shut down systems that are found with leaks and repair.	Daily	OM	OM	OM
	B. Visually inspect leak detection systems installed on underground piping. Inspections include line leak detectors and leak detection sensors installed in transition sumps and dispenser sumps.**2**\\ /**2**/	Monthly	**2**\\ OM /**2**/	**2**\\ OM /**2**/	**2**\\ OM /**2**/
	C. Perform leak testing on pressurized underground piping with installed leak detection equipment and record results. D. Test leak detection systems installed on underground piping used for ground vehicle petroleum fuel products. Underground leak detection systems include discrete detection sensors installed in transition and dispenser sumps, and line leak detectors installed at the outlet of pumps used to supply pressurized liquid petroleum fuel to underground lines. Repair faulty components. Execution of this work may require state certification or license. E. Conduct service station aboveground piping annual test as outlined in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria. Execution of this	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	work may require state certification or license. F. /**2**/Conduct service station underground piping annual test outlined in Appendix G – Petroleum Fuel Pipeline Pressure Testing Guidelines and Criteria. Execution of this work may require state certification or license.				
	G. Refer to Section 2.7 Signage and Markings for inspection and maintenance requirements of ground vehicle petroleum fuel pipe markings. H. Refer to Section 6-10.1 Aboveground Piping and Equipment Coatings for inspection and maintenance requirements of ground vehicle petroleum fuel pipe coatings.	As required	SM	SM	SM
Emergency Shutoff Valves (Shear Valves) (Section 7-12)					
Emergency Shutoff Valves (Shear Valves)	A. Inspect stabilizer bar to ensure that it is securely mounted below the base of the dispenser. Inspect the mounting bolts that secure the emergency shutoff valve to the stabilizer bar. B. Inspect fusible link and ensure it is not obstructed. Ensure valve body is clean and free of fuel.	Monthly	OM	OM	OM
	C. Inspect mechanical links of the valve for correct operation. Conduct test of valve to ensure it operates correctly. Execution of this work may require state certification or license.	Annually	SM	SM	SM
Dispenser Sumps (Section 7-13)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Dispenser Sumps	A. Inspect for signs of water, fuel, trash, and debris inside sumps. Remove and properly dispose of collected water, fuel, trash, and debris. Visually inspect penetration fittings. If fuel or water is detected investigate the source and repair.	Monthly	OM	OM	OM
	B. Inspect sump pipe transition fittings for tears, cracks, or other signs of deterioration. Check hose clamp seals to ensure they are securely tightened.	Quarterly	SM	SM	SM
	C. Test dispenser sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.	Every three years	SM	SM	SM
Transition Sumps (Section 7-14)					
Transition Sumps	A. Inspect for signs of water, fuel, trash, and debris inside sumps. Remove and properly dispose of collected water, fuel, trash, and debris. Visually inspect penetration fittings. If fuel or water is detected investigate the source and repair.	Monthly	OM	OM	OM
	B. Inspect sump pipe transition fittings for tears, cracks, or other signs of deterioration. Check hose clamp seals to ensure they are securely tightened.	Quarterly	SM	SM	SM
	C. Test sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.	Every three years	SM	SM	SM
DISPENSER PUMPS					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Remote Dispenser Pumps (Section 7-15.1)					
Remote Dispenser Pumps	A. Refer to Section 7-19.1.2 Automatic Line Leak Detector for maintenance and inspection requirements of automatic line leak detectors installed on submersible turbine pumps. B. Refer to Section 3-8.1.3 Vertical Turbine/Submerged Turbine Pumps for inspection and maintenance requirements of remote dispenser pumps.	As required	SM	SM	SM
Self-Contained Dispenser Pumps (7-15.2)					
Self-Contained Dispenser Pumps	A. Inspect self-contained dispenser pump v-belt drives for proper tension and excess wear. Replace belt as recommended by manufacturer. B. Inspect pump body. Ensure pump body is clean and free of fuel. Inspect air eliminator. Ensure air eliminator is clean and free of fuel and that the vent tube is not obstructed.	Monthly	**\2** OM **/2/**	**\2** OM **/2/**	SM
EFSO SYSTEMS					
EFSO Systems (Section 7-16)					
EFSO Systems	A. Check the operation of the EFSO system by activating the fueling system and then pressing each of the EFSO buttons. Ensure that each button disables power to all of the dispensers and fuel pumps installed at the service station.	Quarterly	SM	SM	SM
	B. Refer to Section 2-7 Signage and Markings for inspection and	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	maintenance requirements of EFSO pushbutton signs.				
VAPOR RECOVERY					
Stage I Vapor Recovery (Section 7-17.1)					
Stage I Vapor Recovery	A. Inspect vapor recovery hoses for gouges, cuts or outside wear that may result in vapor leaks	Daily or before each use	OM	OM	OM
	B. Inspect caps and camlock fittings for tightness and leaks.	Quarterly	SM	SM	SM
	C. Refer to Section 7-11 Ground Vehicle Fuel Piping for inspection and maintenance requirements of Stage I vapor recovery piping.	As required	SM	SM	SM
2\\ Stage II Vapor Recovery (Section 7-17.2)					
Stage II Vapor Recovery	A. There are several approved vendors for Stage II Vapor Recovery systems. Consult the manufacturer's operation and maintenance manual provided with the system for periodic maintenance requirements.	Per manufacturer's specifications	SM	SM	SM /**2**/
Vapor Burners (Section 7-17.3)					
Vapor Burners	A. Inspect vapor burners to ensure that the pilot flame system is operating properly. Fans, duct work, and dampeners must also be inspected to ensure proper air to fuel vapor mixtures allow for complete burns. B. Inspect burner knock out pots for condensed fuel vapors and water if equipped.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	C. Inspect thermowells and gas detection monitors for operability.				
ELECTRONIC RELEASE DETECTION MONITORING					
Point Sensor - Dry (Section 7-19.1.1)					
Point Sensor - Dry	A. Ensure the monitoring panel associated with the point sensor(s) is powered on and no alarms are present.	Quarterly	OM	OM	OM
	B. Ensure monitoring space is clear and free of debris and liquid	Monthly	OM	OM	OM
	C. Test sensor and ensure it is functional.	Annually	SM	SM	SM
Automatic Line Leak Detector (Section 7-19.1.2)					
Automatic Line Leak Detector	A. Ensure the monitoring panel associated with the detector(s) is powered on and no alarms are present.	Daily	OM	OM	OM
	B. Simulate a 3 gallons per hour leak at 10 pounds per square inch; the automatic line leak detector must activate within one hour. A licensed and/or certified technician is required to, test, troubleshoot, or calibrate for operation.	Annually	SM	SM	SM
Visual Monitoring (Section 7-20.1)					
Visual Monitoring	A. Visually inspect at inspection ports for signs of leaks. Remove debris or foreign objects obstructing the view.	Weekly	OM	OM	OM
STORAGE TANKS					
Aboveground Field-Erected Tanks (Section 8-4)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Aboveground Field-Erected Tanks	A. Visually inspect for evidence of leaks; shell distortions; signs of settlement; corrosion, condition of tank foundation, condition of coating, insulation systems, and appurtenances. Inspection must include all components and equipment located inside the containment area such as piping, pipe supports, containment valves, and product saver tanks. Items noted during the inspection will be documented for follow-up action by an authorized inspector. See Appendix F for the Field-Erected Tank Monthly Inspection Checklist. B. Visually inspect chime to ringwall sealant. Seal should be maintained in good working order to prevent corrosion of the underside of the tank bottom.	Monthly	OM	OM	OM
	C. Visually inspect the exterior of the tank for leaks, corrosion, or irregularities such as tilting, settling, or out-of-roundness. Give special attention to seams and anchor bolts. Visual inspection must include all components and equipment located inside the tank containment area such as piping, pipe supports, containment valves, and product saver tanks. Retain records of inspections reports for five years. See Appendix F for the Field-Erected Tank Annual Inspection Checklist.	Annually	OM	OM	OM
	D. Perform a formal in-service external inspection of the tank in accordance with API 653 or STI SP001 to evaluate the tank for conditions which may affect the	Every five years or as required by an appropriately certified tank	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	operational integrity of the storage tank, including minimum shell thickness measurements. This inspection must be performed by an applicable certified inspector. Inspection must include all components and equipment located inside the tank containment area such as piping, pipe supports, containment valves, and product saver tanks.	inspector in the previous API 653 or STI SP001 inspection report.			
	E. Perform an out-of-service API 653 or STI SP001 inspection to evaluate the tank for conditions which may affect the operational integrity of the tank floor, shell, roof and floating roof or pan. API 653 or STI SP001 provides a checklist to be used as part of the assessment. This inspection must be performed by an appropriately certified API 653 or STI SP001 inspector. Inspection must include all components and equipment located inside the tank containment area such as piping, pipe supports, containment valves, and product saver tanks. **2**\\ The API 653 or STI SP001 inspector must recommend the date of the next inspection. The inspection interval must be based on the date the Suitability for Service Letter is issued immediately prior to when the tank is returned to service. /**2**/	**2**\\ As recom-mended by the API 653/STI SP001 inspector. If there is not a previous recom-mendation, the inspection must be performed within ten years after the tank was placed into operation. /**2**/	SM	SM	SM
Geodesic Dome Roofs (Section 8-4.2)					
	A. Conduct external inspection of geodesic dome roofs, where	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	accessible, for corrosion of tank-to-shell bolts, gasket connections, visible signs of corrosion, apparent roof leaks, clogging or deterioration of vent screens, and damage to the structure or panels.				
Geodesic Dome Roofs	B. Conduct internal inspection of geodesic dome roofs from the floating roof, where accessible, for corrosion of tank-to-shell bolts, gasket connections, visible signs of corrosion, apparent roof leaks, clogging or deterioration of vent screens, and damage to the structure or panels.	Annually	OM	OM	OM
Foundations (Section 8-4.3)					
Foundations	A. Inspect visible components of tank foundations for signs of erosion due to heavy rains, wash-down, etc. and repaired as necessary. Also inspect tank foundations for structural cracks, signs of settlement, spalling, or general deterioration. Remove vegetation found around the tank foundation.	Monthly	OM	OM	OM
Aboveground Shop Fabricated Tanks (Section 8-5.1)					
Aboveground Shop Fabricated Tanks	A. Monthly External Inspection (Identified as P in **1**\\STI SP001/**1**/): Visually inspect for exterior signs of corrosion or coating deterioration. Visually inspect weld seams, tank-to-saddle connections, tank supports, tank anchors, foundation and anchor bolts, overfill valves and alarms, normal vents, emergency vents, leak detection probe or water/petroleum accumulation in the interstice on double-walled	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	tanks, leaking valves, fittings, or components, spill containment systems and release prevention barriers. Leaking valves, fittings or components must be repaired immediately or immediately removed from service and isolated to prevent further discharge. Any irregularities, (e.g., missing valve handles, bolts, nuts, screens) will be assessed for priority and repaired as soon as possible or as required depending on the nature of the defect (See Appendix E for an example of the STI SP001 Standard Monthly Inspection Checklist).				
	B. Annual External Inspection (Identified as P in **1**\\STI SP001/**1**/): A more detailed examination of the tank and appurtenances must be performed on an annual basis (See Appendix E for an example of the STI SP001 Standard Annual Inspection Checklist).	Annually	OM	OM	OM
	C. Formal External Inspection (Identified as E in**1**\\ STI SP001 /**1**/): A formal external inspection as defined in STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be conducted by certified STI SP001 inspector. D. Formal Internal Inspection (Identified as I in**1**\\ STI SP001 /**1**/): A formal internal inspection as defined in STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be performed by a certified STI SP001 inspector. **2**\\ The API 653 or STI SP001	As established by SCP based on tank size and category listed in **1**\\ STI SP001 /**1**/	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	inspector must recommend the date of the next inspection. The inspection interval must be based on the date the Suitability for Service Letter is issued immediately prior to when the tank is returned to service. /**2**/ E. Leak Test (Identified as L in **1**\\ STI SP001 /**1**/): A leak test as defined in STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be performed in accordance with STI SP001 *Standard for the Inspection of Aboveground Storage Tanks*.				
Self-Diking or Vaulted Tanks (Section 8-5.2)					
Self-Diking or Vaulted Tanks	A. Monthly External Inspection (Identified as P in **1**\\STI SP001 /**1**/): Visually inspect for exterior signs of corrosion or coating deterioration. Visually inspect weld seams, tank-to-saddle connections, tank supports, tank anchors, foundation and anchor bolts, overfill valves and alarms, normal vents, emergency vents, leak detection probe or water/petroleum accumulation in the containment area, leaking valves, fittings, or components. Leaking valves, fittings or components must be repaired immediately or immediately removed from service and isolated to prevent further discharge. Any irregularities, (e.g., missing valve handles, bolts, nuts, screens) will be assessed for priority and repaired as soon as possible or as required depending on the nature of the defect (See Appendix E for an example of	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	the STI SP001 Standard Monthly Inspection Checklist).				
	B. Annual External Inspection (Identified as P in **1**\\STI SP001/**1**/): A more detailed examination of the tank and appurtenances must be performed annually. (See Appendix E for an example of the STI SP001 Standard Annual Inspection Checklist).	Annually	**2**\\ SM /**2**/	OM	**2**\\ SM /**2**/
	C. Formal External Inspection (Identified as E in **1**\\ STI SP001 /**1**/): A formal external inspection as defined in STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be conducted by certified STI SP001 inspector. D. Formal Internal Inspection (Identified as I in **1**\\ STI SP001 /**1**/): A formal internal inspection as defined in STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be performed by a certified STI SP001 inspector. E. Leak Test (Identified as L in **1**\\STI SP001/**1**/): A leak test as defined in STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be performed in accordance with STI SP001 *Standard for the Inspection of Aboveground Storage Tanks*.	As established by SCP based on tank size and category listed in **1**\\ STI SP001 /**1**/	SM	SM	SM
Rectangular Concrete-Encased Tanks (Section 8-5.3)					
Rectangular Concrete-Encased Tanks	A. Monthly External Inspection (Identified as P in **1**\\ STI SP001 /**1**/): Visually inspect tank supports, anchors and anchor bolts, overfill valve and alarms,	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	normal vent, emergency vent, leaking valves, fittings or other components. In addition the exterior concrete must be visually inspected for cracking, degradation, excessive calcareous deposits or signs of damage. Leaking valves, fittings or components must be repaired immediately or isolated to prevent further discharge. Any other deficiencies or irregularities noted must be repaired as soon as possible or as required depending on the nature of the defect (See Appendix E for an example of the STI SP001 Standard Monthly Inspection Checklist)..				
	B. Annual External Inspection (Identified as P in **1**\\ STI SP001 /**1**/): A more detailed examination of the tank and appurtenances must be performed on an annual basis (See Appendix E for an example of the STI SP001 Standard Annual Inspection Checklist).	Annually	SM	SM	SM
	C. Formal External Inspection (Identified as E in **1**\\ STI SP001 /**1**/): A formal external inspection must be conducted by certified STI SP001 inspector. D. Formal Interior Inspection (Identified as I in **1**\\ STI SP001 /**1**/): A modified formal internal inspection as defined in manufacturer's instructions or STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be performed on concrete-encased tanks by a certified STI SP001	As established by SCP based on tank size and category listed in **1**\\ STI SP001 /**1**/	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	inspector if the tank interior is accessible.				
Underground Single-walled Shop-Fabricated Tanks (Section 8-5.4.1)					
Underground Single-walled Shop-Fabricated Tanks	A. Monthly External Inspection (Identified as P in Table 8-**1**\1/**1**/): Ensure all tank port covers are present, are in good condition, and seated firmly on the correct tank. Inspect tank stick gauge and ensure markings are legible and that the stick gauge is not warped or broken. Inspect tank for water using ATG or stick gauge with water-finding paste. Remove water found in tank. Open and inspect tank-top containment sumps and ensure no fuel or water is collected in the sumps. Check for and remove obstructions in tank fill pipe.	Monthly	OM	OM	OM
	B. Annual External Inspection (Identified as P in Table 8-**1**\1/**1**/): Inspect electrical connections and junction boxes in underground sumps and access ports on tank. Ensure boxes are sealed, and that boxes, conduit, and electrical fittings are not corroded. Inspect submerged turbine pumps if present. Ensure pumps are in good condition and that pumps and fittings show no signs of leaking. Inspect tank top containment sumps for cracks, holes, and budges. Ensure tank top containment sump electrical and pipe penetrations are intact and secured. For double-walled piping systems that drain into the tank top containment sump, ensure interstitial space of piping is open and that sump	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	sensor is properly mounted at the bottom of the sump. Ensure tank top containment sump lid gasket and seals are in good condition. Inspect road access covers. Ensure covers are in good condition, that all bolts are present and that handles and lift mechanism is in good condition as applicable. Inspect concrete installed over tank and ensure there is no significant cracking.				
	C. Tank Tightness Test (Identified as T in Table 8-**1**\\1/**1**/): Perform test in accordance with 40 CFR 280, Section 43.	As established by SCP based on tank size and release detection type listed in Table 8-**1**\\1/**1**/.	SM	SM	SM
	D. Formal Internal Inspection (Identified as I in Table 8-1): A formal modified internal inspection in accordance with STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be conducted by a certified STI SP001 inspector if the interior is accessible. The inspector will need to supplement and/or adapt portions of STI SP001 to evaluate the specific concerns of an underground tank. Check the tank for settlement and ensure that the tank slopes towards the water drain.	As established by SCP based on tank size and release detection type listed in Table 8-**1**\\1/**1**/ or as recommended by an STI SP001 certified tank inspector in the previous inspection report.	SM	SM	SM
	E. Test tank-top containment sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.	Every three years	SM	SM	SM
Underground Double-walled Shop-Fabricated Tanks (Section 8-5.4.2)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Underground Double-walled Shop-Fabricated Tanks	A. Monthly External Inspection (Identified as P in Table 8-**1**\\2/**1**/): Ensure all tank port covers are present, are in good condition, and seated firmly on the correct tank. Inspect tank stick gauge and ensure markings are legible and that the stick gauge is not warped or broken. Inspect tank for water using ATG or stick gauge with water-finding paste. Remove water found in tank. Open and inspect tank-top containment sumps and ensure no fuel or water is collected in the sumps. Check for and remove obstructions in tank fill pipe.	Monthly	OM	OM	OM
	B. Annual External Inspection (Identified as P in Table 8-**1**\\2/**1**/): Inspect electrical connections and junction boxes in underground sumps and access ports on tank. Ensure boxes are sealed, and that boxes, conduit, and electrical fittings are not corroded. Inspect submerged turbine pumps if present. Ensure pumps are in good condition and that pumps and fittings show no signs of leaking. Inspect tank top containment sumps for cracks, holes, and budges. Ensure tank top containment sump electrical and pipe penetrations are intact and secured. For double-walled piping systems that drain into the tank top containment sump, ensure interstitial space of piping is open and that sump sensor is properly mounted at the bottom of the sump. Ensure tank top containment sump lid gasket and seals are in	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	good condition. Inspect road access covers. Ensure covers are in good condition, that all bolts are present and that handles and lift mechanism is in good condition as applicable. Inspect concrete installed over tank and ensure there is no significant cracking.				
	C. Formal Internal Inspection (Identified as I in Table 8-**1**\\2/**1**/): A formal modified internal inspection in accordance with STI SP001 *Standard for the Inspection of Aboveground Storage Tanks* must be conducted by a certified STI SP001 inspector if the interior is accessible. The inspector will need to supplement and/or adapt portions of STI SP001 to evaluate the specific concerns of an underground tank. Check the tank for settlement and ensure that the tank slopes towards the water drain.	As established by SCP based on tank size and release detection type listed in Table 8-**1**\\ 2 /**1**/ or as recommended by an STI SP001 certified tank inspector in the previous inspection report.	SM	SM	SM
	D. Test tank-top containment sumps and ensure they are liquid tight by using vacuum, pressure, or liquid testing in accordance with 40 CFR 280, Section 43.	Every three years	SM	SM	SM
Underground Field-Constructed Tanks (Cut and Cover Tanks) (Section 8-6)					
Underground Field-Constructed Tanks	A. Check the level gauge records and interstitial monitoring ports to determine if the tank is leaking.	Daily	OM	OM	OM
	B. Apply field-erected tank monthly external inspection to the maximum extent possible. Visually inspect tank and appurtenances for eviden- ce of leaks, shell distortions, signs of corrosion, and settlement at	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	accessible locations. Items noted during the inspection will be docu- mented for follow-up action by an authorized inspector (See Appendix F for the Field-Erected Tank Month- ly Inspection Checklist). C. Check tank under static storage conditions for 24 hours using exist- ing inventory management system to determine if petroleum losses are occurring. If leakage is noted, further investigation must be con- ducted in accordance with Military service-specific guidelines.				
	D. Apply field-erected tank annual ex- ternal inspection to the maximum extent possible. Visually inspect tank and appurtenances for eviden- ce of leaks, shell distortions, signs of corrosion, and settlement at ac- cessible locations. Visually inspect pump/equipment vaults for leaks and cracking in concrete walls and floors. Retain records of inspec- tions reports for five years (See Appendix F for the Field-Erected Tank Annual Inspection Checklist).	Annually	SM	SM	SM
	E. Perform a modified out-of-Service API 653 internal inspection to eval- uate the tank for conditions which may affect the operational integrity of the tank floor, shell, columns and roof by certified API 653 inspector. API 653 provides a checklist to be used as part of the assessment; however the certified API 653 ins- pector must modify this checklist to incorporate specific needs of	Every ten years or as recommended by an appropriately certified tank inspector in the previous API 653 inspection report.	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	under- ground field-constructed tanks.				
Tank Cleaning (Section 8-7)					
Tank Cleaning	A. Conduct Tank Cleaning: Unless otherwise mandated by operational concerns or military service directives, schedule and conduct tank cleaning based upon the frequency listed below. After cleaning tanks must be stenciled in accordance with Section 8-8.1 Tank Stenciling Requirements.	a. Air Force – Tanks above 20,000 gallon (75,700 liters) in capacity - Every 10 years unless required more frequently due to fuel quality issues. Contact AFPET and AF Fuel SME for deviations on schedule. Schedule changes are typically accepted based on TO 42B1-1 requirements. b. Air Force – Tanks 20,000 gallon (75,700 liters) in capacity and under - During out of service inspection cycle unless required more frequently due to potential fuel quality issues. c. Army, Navy, U.S. Marine Corps – During out-of-service inspection cycle unless required more frequently due to potential fuel quality issues.	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Aluminum Honeycomb Floating Pan (Section 8-9.1.1)					
Aluminum Honeycomb Floating Pan	A. Visually inspect pan guide/anti-rotation cables and centering of pan. B. Visually inspect pan grounding cables for proper attachment and wear or binding. C. Visually inspect for buckling or damage to the pan.	Monthly	OM	OM	OM
	D. Inspect grounding cables for proper attachment and wear or binding. E. Inspect all floating roof penetration seals, such as ladder seals, stilling well seals, and other seals to ensure that they are in good working condition.	Annually	SM	SM	SM
	F. Clean and inspect perimeter tank/pan seals.	At time of out of service internal inspection	SM	SM	SM
	G. Refer to Section 8-9.1.5 Floating Roof and Pan Pressure/Vacuum Vents for inspection and maintenance requirements of floating pan pressure/vacuum vents. H. Refer to Section 8-9.1.6 Floating Roof and Pan Legs for inspection and maintenance requirements of floating pan legs.	As required	SM	SM	SM
Steel Floating Pan (Section 8-9.1.2)					
Steel Floating Pan	A. Visually inspect pan guide/anti-rotation cables and centering of pan.	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	B. Visually inspect pan grounding cables for proper attachment and wear or binding. C. Visually inspect for buckling or damage to the pan. D. Visually inspect for damage or deflection in the rolling ladder (if equipped).				
	E. Inspect grounding cables for proper attachment and wear or binding. F. Inspect all floating pan penetration seals, such as gauge well seals to ensure that they are in good working condition. G. Inspect gauge wells for abrasions that might indicate out of roundness, or improper centering. H. Inspect vertical ladder for abrasions that might indicate out of roundness, or improper centering (if equipped). I. Inspect for damage or deflection in the rolling ladder (if equipped).	Annually	SM	SM	SM
	J. Clean and inspect perimeter tank/pan seals.	At time of out of service internal inspection	SM	SM	SM
	K. Refer to Section 8-9.1.5 Floating Roof and Pan Pressure/Vacuum Vents for inspection and maintenance requirements of floating pan pressure/vacuum vents. L. Refer to Section 8-9.1.6 Floating Roof and Pan Legs for inspection and maintenance	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	requirements of floating pan legs.				
Pontoon Floating Pan (Section 8-9.1.3)					
Pontoon Floating Pan	A. Visually inspect pan guide/anti-rotation cables or pipes and centering of pan. B. Visually inspect pan grounding cables for proper attachment and wear or binding. C. Visually inspect for buckling or damage to the pan. D. Visually inspect for damage or deflection in the rolling ladder (if equipped).	Monthly	OM	OM	OM
	E. Inspect pontoons for standing liquid and presence of strong vapors. F. Remove mechanical gauge float cover and ensure float is securely fastened to gauge tape. Check gauge tape for ease of movement. G. Inspect for damage or deflection in the rolling ladder (if equipped). H. Inspect vertical internal ladder and internal ladder/pan seals for abrasions that might indicate out of roundness, or improper centering (if equipped). I. Inspect gauge wells and gauge well/pan seals for abrasions that might indicate out of roundness, or improper centering. J. Inspect steel floating pan coatings for corrosion. Touch up with compatible coating if required (aluminum pans do not require coatings).	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	K. Clean and inspect perimeter tank/pan seals.	At time of out of service internal inspection	SM	SM	SM
	L. Refer to Section 8-9.1.5 Floating Roof and Pan Pressure/Vacuum Vents for inspection and maintenance requirements of floating pan pressure/vacuum vents. M. Refer to Section 8-9.1.6 Floating Roof and Pan Legs for inspection and maintenance requirements of floating pan legs.	As required	SM	SM	SM
Floating Roof (Section 8-9.1.4)					
Floating Roofs	A. Visually inspect the center primary roof drain system is water-free B. Visually inspect anti-rotation pipes/roof guides and centering of roof. C. Visually inspect grounding cables for proper attachment and wear or binding. D. Visually inspect for buckling or damage to the roof. E. Visually inspect for standing water on roof deck. F. Visually inspect for damage or deflection in the rolling ladder (if equipped).	Monthly	OM	OM	OM
	G. Ensure that the drip-tight plug is placed in the roof drain opening. H. Ensure that the roof drain valve is closed. The drain valve is kept in the closed position except after each rain or	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	snowfall when it is opened just long enough to drain the roofline. Tanks with retrofitted geodesic domes or metal roofs may have had the floating roof drain line removed, so before opening the roof drain valve ensure the roof drain line has not been removed. I. Inspect pontoons for standing liquid and presence of strong vapors. J. Remove mechanical gauge float cover and ensure float is securely fastened to gauge tape. Check gauge tape for ease of movement. K. Ensure emergency drain (if equipped) is not blocked with debris. L. Inspect for damage or deflection in the rolling ladder (if equipped). M. Inspect vertical internal ladder and internal ladder/roof seals for abrasions that might indicate out of roundness, or improper centering (if equipped). N. Inspect gauge wells and gauge well/roof seals for abrasions that might indicate out of roundness, or improper centering. O. Inspect the floating roof coating for corrosion. Touch up with compatible coating if required.				
	P. Clean and inspect perimeter tank/pan seals.	At time of out of service internal inspection	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	Q. Refer to Section 8-9.1.5 Floating Roof and Pan Pressure/Vacuum Vents for inspection and maintenance requirements of floating roof pressure/vacuum vents. R. Refer to Section 8-9.1.6 Floating Roof and Pan Legs for inspection and maintenance requirements of floating roof legs.	As required	SM	SM	SM
Floating Roof and Pan Pressure/Vacuum Vents (Section 8-9.1.5)					
Floating Roof and Pan Pressure/ Vacuum Vents	A. Inspect the floating roof or pan pressure/vacuum vent to ensure that the seats and retaining straps or guides are in good working order and that the pressure/vacuum vent is not stuck to its seats, but instead lift easily off of its seats and reseats properly. Inspect gaskets for wear and replace as required. Refer to the manufacturer's operation and maintenance manual provided with the floating roof or pan for additional guidance on servicing the pressure/vacuum vent.	At time of out of service internal inspection	SM	SM	SM
Floating Roof and Pan Legs (Section 8-9.1.6)					
Floating Roof and Pan Legs	A. Inspect the floating roof or pan legs and tank bottom striker plates for wear; inspect the seals where the legs penetrate the floating roof or pan for leaks; inspect the low leg position stops to make sure they are securely fastened to the legs and will stop the floating roof or pan at the low position; inspect the leg keeper straps to make sure they are securely fastened to the legs to prevent the legs from falling off or through the	At time of out of service internal inspection	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	floating roof or pan; inspect the threaded keeper caps or high position locking mechanisms to ensure they are in proper working order for securing the floating roof or pan in the high position. Refer to the maintenance manual provided with the floating roof or pan for additional guidance on floating roof or pan legs and associated hardware.				
Secondary Tank Bottoms (Section 8-9.2)					
Secondary Tank Bottoms	A. Tanks designed with secondary tank bottoms should have tell-tale devices (leak detection ports) to allow for monitoring of the tank's floor integrity. The tell-tale devices are typically configured as valves or inspection ports to allow for visual monitoring of liquid that may be present between the foundation and the tank floor. The presence of water would indicate a breach in the foundation seals or flooring while the presence of petroleum would indicate integrity loss in the tank floor. Open and check tell-tale valves or inspection ports. Verify the absence of water or petroleum.	Monthly	OM	OM	OM
Tank Pressure/Vacuum Vents (Section 8-9.3)					
Tank Pressure/ Vacuum Vents	A. On underground shop fabricated tanks, ensure tank pressure/vacuum vent is present and that the riser pipe is securely supported and vertical.	Annually	OM	OM	OM
	B. Inspect vent settings. Pressure and vacuum settings for pressure/vacuum vents are	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	usually specified on the vent nameplate or in the manufacturer's manual for the vent. C. Clean the pressure/vacuum vent. Information on the type of pressure/vacuum vent and proced- ures for the removal of covers, hoods and/or pallet removal and reinstallation should be found in the manufacturer's operation and maintenance manual. Before removing the pallets, brush all accumulations from the protecting screens, the pallets, and all surfaces of the valve. Brush the screens from inside the valve so that dirt and other objects fall to the outer sides. Remove heavy loading weights prior to removing the pallet assembly. Remove deposits or foreign matter using reasonable care not to damage diaphragms or seats. D. Inspect gaskets, seats, diaphragm, pallet stems and stem guides. Check all mating surfaces which must be free of nicks, cuts, cracks or deposits that might interfere with the proper seating or tightness of the valve. Test the pallets to ensure they move freely up and down over the full range of travel.				
Emergency Vents (Section 8-9.4)					
Emergency Vents	A. **2**\\ Inspect emergency vents for external damage, such as dents, rusting, severe pitting, or obstruction by other equipment, piping, or conduits.	Annually	OM	OM	SM /**2**/

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	B. Remove the vent, if possible, and inspect the seals and diaphragms for cracking or breakdown. Inspect retaining cables to ensure they are fastened to the vent and the manway or tank. Inspect guides to ensure emergency vents can function properly and re-seat. C. Verify that emergency vents have not been removed or modified. Emergency vents should not be replaced with ATGs, manual sample ports, level alarms, etc. D. Tanks that are equipped with manways for emergency vents must be inspected for appropriate type, length, number of bolts, and lift clearance of the manway in accordance with UL 142 Standard for *Steel Aboveground Tanks for Flammable and Combustible Liquids*, Section 8 and 9.	Annually	SM	SM	SM
Flame Arrestors (Section 8-9.5)					
Flame Arrestors	A. The tube bank must be removed and cleaned of foreign matter by immersing in an approved solvent solution, taking care not to damage the tube bundle. Gaskets must be inspected and replaced as necessary.	Annually	SM	SM	SM
External High Level Shutoff Valves (HLSO) (Section 8-9.6.1)					
External High Level Shutoff Valves (HLSO)	A. Activate the tank high-high level alarm and ensure the solenoid valve (if equipped) activates on the HLSO valve. Ensure the HLSO valve closes when the solenoid valve is activated.	Quarterly	SM	SM	SM
	B. Isolate, drain, and then vent the external float valve chamber (if equipped). Refill (either	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	manually or via the storage tank product saver tank pump) the float chamber to test the float valve. Ensure the HLSO closes when the float is raised. C. Lift the manual test lever of internally mounted float valve (if equipped). Ensure that the HLSO closes when the float of the float valve is raised.				
Internal HLSO Valve (Section 8-9.6.2)					
Internal HLSO Valves	A. Inspect and test the high level shut-off valve and float mechanism, counter-weights, float rods, and floats to ensure the float mechanism is moving freely and functioning properly to close the high level shut-off valve. If valve is not equipped with a manual test mechanism the level of the tank must be raised to the high level shutoff valve set point in order to test the valve. Ensure valve is installed at a proper height.	Annually	SM	SM	SM
Mechanical Tape Gauges (Section 8-9.7)					
Mechanical Tape Gauges	A. Visually check that a liquid level is indicated and that the measurement appears to be accurate.	Daily	OM	OM	OM
	B. Check the mechanical tape gauge against the automatic electronic tank gauge (if installed) or by manually gauging the tank for relative accuracy and proper working condition. Consult the manufacturer's operation and maintenance manual for additional maintenance and inspection requirements	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Automatic Tank Gauges					
Mechanically Operated Tape Gauge (Section 8-9.8.1)					
Mechanically Operated Tape Gauge	A. Visually inspect the gauge to ensure the power is on, there are no warning alarms or lights and a liquid measurement is indicated and the tank level reading appears to be accurate.	Daily	OM	OM	OM
	B. Inspect gauge head for buildup of sediment. C. Inspect tape conduit for deformations that would inhibit movement of tape up and down.	Quarterly	SM	SM	SM
	D. Gauge level accuracy must be performed against a hand dip measurement of the tank. Calibrate as required. E. Inspect float and guide cable through an opened manway or access cover. Verify that the guide wire is taut and free of kinks. Verify that the float is buoyant and free of sludge or sediment build up. F. Inspect power and control wires for damage. G. Inspect wire connection termination points for damage or loose connections.	Semi-annually	SM	SM	SM
	H. Lubricate moving parts of the gauge head	Annually	SM	SM	SM
Magnetostrictive Probes (Section 8-9.8.2)					
Magnetostrictive Probes	A. Visually inspect the gauge to ensure the power is on, there are no warning alarms or lights and a liquid measurement is	Daily	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	indicated and the tank level reading appears to be accurate.				
	B. Inspect probe assembly for buildup of sediment. C. Inspect probe assembly and probe shaft for deformations that would inhibit movement of probe.	Quarterly	SM	SM	SM
	D. Level probe accuracy must be performed against a hand dip measurement of the tank. Calibrate as required. E. Verify that the probe float is buoyant and free of sludge or sediment build up. F. Inspect power and control wires for damage. G. Inspect wire connection termination points for damage or loose connections.	Semi-annually	SM	SM	SM
Servo Gauge (Section 8-9.8.3)					
Servo Gauge	A. Visually inspect the gauge to ensure the power is on, there are no warning alarms or lights and a liquid measurement is indicated and the tank level reading appears to be accurate.	Daily	OM	OM	OM
	B. Inspect gauge head for buildup of sediment.	Quarterly	SM	SM	SM
	C. Gauge level accuracy must be performed against a hand dip measurement of the tank. Calibrate as required. D. Inspect float and guide cable through an opened manway or access cover. Verify that the	Semi-annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	guide wire is taut and free of kinks. Verify that the float is buoyant and free of sludge or sediment build up. E. Inspect power and control wires for damage. F. Inspect all wire connection termination points for damage or loose connections.				
	G. Inspect stilling well to be straight and vertical with no dents so that the float can move freely. H. Lubricate moving parts of the gauge head.	Annually	SM	SM	SM
Level ALARMS					
Externally Mounted Level Alarms (Section 8-9.9.1)					
Externally Mounted Level Alarms	A. Test level alarm switches by isolating the chambers from the tank using the sensing chamber isolation valves. Vent and drain the chambers. Slowly pour product into the chambers through a funnel on top of the chamber to test the level switch at the specified level setting.	Semi-annually	SM	SM	SM
Internally Mounted Level Alarms (Section 8-9.9.3)					
Internally Mounted Level Alarms	A. Test level alarm switches by activating manual testing levers, if equipped. If alarms switches are not equipped with manual testing levers, adjust the level of fuel in the tank to the alarm points in order to test the alarm switches. If it is not feasible to adjust the level of the fuel in the tank to all of the alarm set points, remove the alarm switches from the tank and test	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	the alarms externally. Reinstall alarm switches in the tank once testing is complete.				
PRODUCT SAVER TANKS					
Product Saver Tanks (Section 8-9.10)					
Product Saver Tanks	A. Inspect the product saver tank to ensure all valves are working properly, sight level gauges with density balls are working properly and are not broken, and hand pumps or electric pumps are working properly and are not leaking.	Quarterly	SM	SM	SM
SIDESTREAM FILTRATION SYSTEMS					
Sidestream Filtration Systems (Section 8-9.11)					
Sidestream Filtration Systems	A. Check (typically 5 gallon (19 liters), if incorporated) filter separator vent tank and ensure it is empty.	Monthly	OM	OM	OM
	B. Refer to Section 6-1 Pipe Testing and Inspections for inspection and maintenance requirements of piping. C. Refer to Section 3-6.4 Basket Strainers for inspection and maintenance requirements of basket strainers. D. Refer to Section 3-8 Pumps for inspection and maintenance requirements of fuel pumps. E. Refer to Section 3-6.2 Filter Separators for inspection and maintenance requirements of filter separators. F. Refer to Section 4-4.2.2 Filter Separator Control Valves for inspection and maintenance	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	requirements of filter separator control valves. G. Refer to Section 9-1.6 Grounding Systems for inspection and maintenance requirements of grounding systems. H. Refer to Section 9-1.9 Electronic Equipment for inspection and maintenance requirements of control panels.				
FILL PORTS					
Fill Ports (Section 8-9.12)					
Fill Ports	A. Ensure fill port covers are installed and are not damaged or broken. Ensure fill port covers are identified by fuel type and are installed on the correct tank. Visually inspect the fill port spill bucket to ensure there are no cracks, budges, or holes. Ensure the spill bucket is clean of dirt, trash, water, and fuel	Daily	OM	OM	OM
	B. Inspect drain valve in spill bucket and ensure it is in good condition. Ensure the caps installed on the receipt connection points are vapor tight and are not broken, cracked, or chipped. Ensure the poppet valve of the vapor recovery port seals tightly and no vapor is escaping from the tank when the valve is closed.	Monthly	**2**\\ OM /**2**/	**2**\\ OM /**2**/	SM
	C. **1**\\Hydrostatically test fill-port to ensure containment is liquid-tight. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at	**1**\\Every 3 Years/**1**/	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of the 60-minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer to Appendix B for testing procedures and to use to document the testing.**/1/** Ensure secondary containment area of fill port is fuel tight. Ensure the manual transfer pump or drain valve is operational.				
LEAK DETECTION					
Point Sensor - Dry (Section 8-9.13.1)					
Point Sensor - Dry	A. Ensure the monitoring panel associated with the point sensor(s) is powered on and no alarms are present.	Daily	OM	OM	OM
	B. Ensure monitoring space is clear and free of debris and liquid	Monthly	**\2** OM **/2/**	**\2** OM **/2/**	**\2**OM**/2/**
	C. Test sensor and ensure it is functional	Annually	SM	SM	SM
Point Sensor - Wet (Section 8-9.13.2)					
Point Sensor - Wet	A. Ensure the monitoring panel associated to the wet point sensor(s) is powered on and no alarms are present.	Daily	OM	OM	OM
	B. Ensure level of monitoring fluid is within normal range.	Monthly	**\2** OM **/2/**	**\2** OM **/2/**	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	C. Test sensor and ensure it is functional.	Annually	SM	SM	SM
Point Sensor – Pressure/Vacuum (Section 8-9.13.3)					
Point Sensor – Pressure/ Vacuum	A. Ensure the monitoring panel associated with the pressure/vacuum point sensor(s) is powered on and no alarms are present.	Daily	OM	OM	OM
	B. Test vacuum sensor for proper operation	Annually	SM	SM	SM
Visual Leak Detection (Section 8-9.13.4)					
Visual Leak Detection	A. Visually inspect leak detection ports (tell-tales) for signs of leaks. If there are debris or objects obstructing the view, appropriate measures must be taken to remove the debris or remedy the obstructions.	During routine inspection of other components or monthly, whichever comes first.	OM	OM	OM
	B. Visually inspect reinforcement plate tell-tale holes for signs of leaks. Ensure tell-tale holes have not been plugged by debris or a cap. Pack reinforcement plate tell-tales with white grease to prevent insect nesting and buildup of debris	Quarterly	OM	OM	OM
FLOATING SUCTION LINES					
Floating Suctions Lines (Section 8-9.14)					
Floating Suction Lines	A. Check external floating suction line position indicator to ensure floating suction line is moving freely as the level in the tank rises or falls.	Quarterly	SM	SM	SM
	B. Inspect cables, floats, and swing joint. Ensure interior of floats have not collected fuel. Ensure cables are securely fastened to	When tank is taken out of service for internal	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	anchor points and are in good working order. Ensure the suction pipe flange used to support the swing joint is level and true and that swing joint moves freely up and down and does not bind.	cleaning or inspection			
HEATING COILS					
Steam Type Heating Coils (Section 8-9.16.1)					
Steam Type Heating Coils	A. Observe the regulating valve and check it against a thermometer to be sure that it controls the tank temperature within a safe range, usually not over 150 °F (65 °C) for No. 6 burner fuel oil. Steam traps must be inspected for proper operation to ensure condensate is evacuated from the steam coil.	At each operation	OM	OM	OM
	B. Pressure check heating coils to 10% above normal operating pressure.	Annually	SM	SM	SM
	C. Steam coils must be cleaned and inspected for visible signs of corrosion or wear when the tank is emptied and cleaned for inspection. All components of the steam heating coils, such as weld joins, support points, valves, temperature wells, control valves, and steam traps must be inspected and checked for proper operation and visible wear or damage. The coil may be carefully pressurized with steam and visually checked for leaks if necessary. Leaks or damage found must be repaired.	When the tank is taken down for formal internal inspection or sooner if steam heating coil damage is suspected.	SM	SM	SM
Thermal Fluid Type Heating Coils (Section 8-9.16.2)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Thermal Fluid Type Heating Coils	A. Observe the regulating valve and check it against a thermometer to be sure that it controls the tank temperature within a safe range, usually not over 150 °F (65 °C) for No. 6 burner fuel oil. All external valves, fittings, and other components must be inspected for visible signs of leaks during operation.	At each operation	OM	OM	OM
	B. Pressure check heating coils to 10% above normal operating pressure.	Annually	SM	SM	SM
	C. When tanks are emptied and cleaned for inspection, the heating coils must be cleaned and inspected for visible signs of corrosion, wear, or damage. The coils can be pressurized and checked for leaks at that time with the thermal heating fluid at normal operating pressure, but at ambient temperature to alleviate possible burns to personnel. Leaks must be repaired.	When the tank is taken down for formal internal inspection or sooner if thermal heating coil damage is suspected.	SM	SM	SM
Electric Rod Type Heating (Section 8-9.16.3)					
Electric Rod Type Heating	A. Inspect heater to ensure no fluid leakage around the heater to tank connection and that the heater is performing properly.	At each operation	OM	OM	OM
STILLING WELLS					
Stilling Wells (Section 8-9.17)					
Stilling Wells	A. Stilling wells must be visually inspected to be vertically straight and free dents or indentations. Sometimes tank stilling wells are made of bare carbon steel pipe. In these	At time of out of service internal inspection	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	instances the stilling wells must be replaced with aluminum. B. Inspect floating seals inside stilling wells to ensure they are not worn and are sealing the inside of the stilling well property.				
CONTAINMENT SYSTEMS					
Containment Systems (General) (Section 8-10.1)					
Containment Systems (General)	A. Inspect containment systems for cleanliness, if accessible.	Daily	OM	OM	OM
	B. Secondary containment systems degrade and will collect debris which can clog drainage inlets or prevent drain valves from seating properly. **1**\\Hydrostatically test the drainage systems to include containment drain inlets, drain lines and containment drain valves to ensure the containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of the 60-minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs Record the water level at the start of the 60 minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an	**1**\\Every 3 years/**1**/	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	investigation to determine the cause and any required repairs. Refer to Appendix B for testing procedures and to use to document the testing American Concrete International (ACI) Standards 224R "Control of Concrete Cracking" and ACI's Concrete Repair Manual are two standards that owners/operators can follow to maintain the integrity of the concrete secondary containment.**/1/**				
Concrete and Cement Brick Dike/Berm Walls and Floors (Section 8-10.2)					
Concrete and Cement Brick Dike/Berm Walls and Floors	A. Inspect for vegetation that has taken root in seals or cracks. All vegetation must be removed in all cases to prevent penetration of seals, joints or cracks in the concrete. B. Inspect walls constructed of bricks for signs of deterioration (e.g., spalling caused by freeze-thaw conditions, cracks, and joint cracks between bricks). Walls constructed of bricks must be patched immediately to prevent further penetration of the wall structure.	Daily	OM	OM	OM
	C. Inspect walls constructed of concrete for signs of deterioration (e.g., spalling caused by freeze-thaw conditions and cracks). Clean and seal cracks with a fuel resistant sealant. D. Inspect seals and joints in concrete walls. Joint sealant that has retracted from the joint or become unbonded with the joints must be removed and	Semi-annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	replaced with fuel resistant sealant.				
Dike/Berm Floors (Section 8-10.2.2)					
Dike/Berm Floors	A. Inspect for vegetation that has taken root in seals or cracks. All vegetation must be removed in all cases to prevent penetration of seals, joints or cracks in the concrete.	Daily	OM	OM	OM
	B. Inspect floors made of concrete for signs of deterioration (e.g., spalling caused by freeze-thaw conditions and cracks). Clean and seal cracks with a fuel resistant sealant. C. Inspect joints and seals. Joint sealant that has retracted from the joint or become unbonded with the joints must be removed and replaced with a fuel resistant sealant.	Semi-annually	SM	SM	SM
Earthen Dike Walls (Section 8-10.3)					
Earthen Dike Walls	A. Inspect for vegetation that has taken root. All vegetation must be removed in all cases.	Daily	OM	OM	OM
	B. Prevent the growth of vegetation inside the containment area. Use fireproof chemicals for sterilization. Only herbicides approved by the Installation Environmental Office must be used.	Monthly	OM	OM	OM
	C. Inspect for signs of erosion. Inspections should be performed particularly after heavy rains or storms. Repair areas that have deteriorated due to erosion.	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Self-Diking or Vaulted Tank Containment (Section 8-10.4.)					
Self-Diking or Vaulted Tank Containment	A. Secondary containment structures on self-diking or vaulted tanks must be inspected visually for integrity breaches with special attention given to pipe penetrat- ions and interstitial drain valves.	Daily	OM	OM	OM
Flexible Membrane Liners (Section 8-10.5)					
Flexible Membrane Liners	A. Remove vegetation growing in the gravel and dirt, taking note if the roots have penetrated the FML.	Daily	OM	OM	OM
	B. Visibly inspect FMLs where attached to ringwalls, dike walls, concrete piers and other projections for deterioration due to weather or wear and repair as necessary. C. Visually inspect FMLs covered with smooth rock or gravel for bare spots where the gravel has been washed away due to storms or heavy rains for tears. Replace gravel taking care not to puncture the liner. D. Visually inspect exposed FML for tears or punctures and repair.	**\2** Monthly **/2/**	**\2** OM **/2/**	**\2** OM **/2/**	**\2** OM **/2/**
Pipe Penetrations (Section 8-10.6)					
Pipe Penetrations	A. Inspect boot seals and mechanical link-type seals for wear and cracking. Ensure the seals are in good working order to seal out water or retain the petroleum product as intended. Repair or replace defective boot and link-seals.	**\2** Monthly **/2/**	**\2** OM **/2/**	**\2** OM **/2/**	**\2** OM **/2/**
	B. Inspect sealant between pipes and concrete walls, berms, and floors. Sealant that has	Semi-annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	retracted from the concrete or pipe surfaces must be removed and replaced with new fuel resistant sealant.				
ELECTRICAL CONTROL SYSTEMS AND EQUIPMENT					
Electrical Equipment (Section 9-1.2)					
Electrical Equipment	A. Electrical control systems include: deadman control; ground verifica- tion systems; EFSO operation; con- trol panels, motor control, and pump start/stop buttons. These sys- tems must be tested on a periodic basis to ensure proper operation and functionality. In addition, con- trol system Uninterruptible Power Supplies (UPS) must be inspected and replaced as necessary.	Quarterly	SM	SM	SM
Power Cables (Section 9-1.3)					
Power Cables	A. Visual inspection: Verify that there are no sharp bends. Verify that the cable insulation is intact. Verify that cables are appropriately tagged or otherwise identified. Verify that all connections are tight and not corroded. Open manholes and handholes. Verify that they are not flooded, clogged with debris or infested by pests.	Quarterly	SM	SM	SM
	B. Insulation resistance test: This test measures the resistance of the insulation with an Insulation Resistance Tester. During the test, the cable will be disconnected from both ends. Acceptable test values are 100 megaohms for cables rated between 120 V to 1000 V. Insulation resistance testing for voltages higher than 1000 V are to be performed by specialized testing company.	As needed based on visual inspection	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Motor Controls (Section 9-1.4)					
Motor Controls	A. Verify that the labeling is consistent with the drawings and specifications. B. Verify that pushbuttons are easy to operate and are not stuck. Verify that there is no grease accumulation around the seating Verify that indicating lights are functional and replace if required. C. Verify that indicating lights are functional and replace as needed. D. Verify that electrical and mechanical interlocks operate according to the design intent. In case of key interlocks, ensure that the number of keys corresponds to the interlock intent. Having more keys than required defeats the intent of the interlocking and poses danger to the service personnel and equipment. If extra keys are found, they should be removed from the equipment.	Semi-annually	SM	SM	SM
	E. Inspect the enclosure for visible signs of corrosion.	Interior annually/ exterior semi-annually	SM	SM	SM
	F. Open the enclosure – be mindful of insects, rodents and reptiles, particularly if located outdoors. Look for signs of corrosion, dust accumulation, spider webs, etc. Clean the enclosure with compressed air and apply rust inhibitors and paint as needed. G. Inspect the overcurrent protective devices for proper seating. Verify that rating is	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	appropriate for the motor. Look for signs of attached wire and device overheating. H. Inspect the arch shoots of contactors and clean as needed. Check that partitions are not burned. I. Inspect contactors for abnormal wear. Check contacts for pitting, roughness and oxidation. Verify that contact gap, alignment and pressure are in accordance with manufactures recommendations. J. When contactors are used, listen for the chatter of contacts or buzzing noise. These are indicative of a faulty contactor. K. Verify that relays and switches are firmly seated in their bases and there are no signs of overheating or vibration. L. Look for frayed or broken strands in the flexible control wiring and replace if such are found. M. Perform a functional test of protective devices if they are equipped with self-testing circuits or switches. N. Perform a functional test of all manual switches and verify proper operation against intended design logic. Replace switches and relays if operation is not satisfactory.				
	O. Perform insulation resistance test for the control wiring. (NOTE: Testing of the control wires may require substantial down time. Therefore, this should only be performed on a case by case basis if there are	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	reasons to suspect that the insulation of the control wiring is deteriorating.)				
Panelboards (Section 9-1.5)					
Panelboards	A. Verify that there are no physical obstructions blocking access to the panelboard. Remove physical obstructions	Quarterly	OM	OM	OM
	B. Inspect the enclosure and the surrounding area for water damage and corrosion. C. Verify that all breakers are either in the “On” or the “Off” position. If there are tripped breakers, investigate the cause of the trip. D. Verify that all breakers are either in the “On” or the “Off” position. If there are tripped breakers, investigate the cause of the trip. E. Verify that the breaker operation matches the description on the panel schedule. F. Observe breakers, wires and terminals for signs of overheating or short circuiting. G. Verify that all breakers are firmly seated and locked in place by slightly shaking them. H. Verify that all grounding wires are firmly connected to the grounding bar. I. If a breaker malfunction is identified, leave breaker in the open position and replace as soon as possible. If a breaker cannot disconnect its circuit, the	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	entire panelboard must be switched off using its main disconnecting means and locked out until the breaker is repaired.				
Grounding Systems (Section 9-1.6.1)					
Power Grounding Systems	A. The connections to the grounding system must be surveyed and verified for continuity. If a connection is suspected to be loose, perform further testing. In some occasions, it is more cost effective to replace the suspected connection instead of performing diagnostic tests. B. Measure the voltage between the equipment grounding conductor and the electrode grounding conductor (usually bare copper). Investigate test results above 3 VAC for a potential ground fault. C. Measure the voltage between the chassis of the equipment and the electrode grounding conductor. Investigate if the readings exceed 2 VAC.	Annually	SM	SM	SM
	D. Facility ground resistance check: This type of testing is performed with a four lead, low resistance ohmmeter or digital ohmmeter. Recommended values are between 3 and 5 ohms. In no case should the grounding resistance be higher than 25 ohms	Every five years	SM	SM	SM
Grounding Systems (Section 9-1.6.2)					
	A. Inspect ground reels for corrosion. Ensure ground reels	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Static Grounding Systems	are securely mounted to a rigid base. Inspect clamps for serviceability. Replace clamp if jaws are deformed for corroded, spring is weak, or other defects are evident that would prevent a good connection. Inspect cable wires. Replace if more than one-third of the cable wires are broken.				
	B. The connections to the grounding system must be surveyed and verified for continuity. If a connection is suspected to be loose, perform further testing. In some occasions it is more cost effective to replace the suspected connection instead of performing diagnostic tests.	Annually	SM	SM	SM
	C. Resistance measurement on static grounds: Measure static ground resistance of new and damaged ground rods. Static ground with a resistance greater than 10,000 ohms will be removed or replaced. Static ground mechanically damaged will be repaired and retested.	When observed to be physically damaged.	SM	SM	SM
Electric Motors (Section 9-1.7)					
Electric Motors	A. Lubricating motor bearings and inspect for vibration and overheating.	Quarterly	SM	SM	SM
	B. Check for debris and other foreign material in the fan housing	Semi-annually	SM	SM	SM
	C. Check motor ground wires. Ensure they are firmly	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	connected to the housing or the junction box. D. If the motor is installed in a hazardous location, verify that the seals of the connection boxes and conduits are intact.				
Lighting (Section 9-1.8)					
Lighting	A. Verify proper operation of light switch, lighting contactor, photocell or timer as appropriate. If a lighting contactor is used, listen for the chatter of contacts or buzzing noise. These are indicative of a faulty contactor. Replace if required. B. With the lights turned on, observe individual luminaries for flicker or lights turning on and off. The former is indicative of a faulty choke. The latter is indicative of a faulty starter. Replace the faulty components as required. C. When light fixtures are located in hazardous areas, verify that the seals are intact and the hazardous rating of the fixture is maintained.	Quarterly	SM	SM	SM
	D. Thoroughly clean dust, bugs, and debris from the luminaire. Light solvents or cleaning agents may be used.	Annually (in dusty areas the luminaries may require cleaning at shorter intervals)	SM	SM	SM
	E. Re-Lamping: With the lights turned off, replace the lamps. In order to prevent accidental turning on of the lights, it is mandatory to switch off and lockout the breaker of the	Annually or as required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	lighting circuit. Ensure the replacement lamps are the same type as those they are replacing. Verify the proper operation of all light fixtures after the lamp replacement.				
Electronic Equipment (9-1.9)					
Electronic Equipment	A. Inspect the outside of equipment enclosures for dust and evidence of corrosion. Vacuum clean the dust to ensure unobstructed air circulation. B. Open the enclosure and vacuum clean the dust to ensure unobstructed air circulation. Pay particular attention to fans and air passages. If there is evidence of corrosion, verify that there is no water damage on printed circuit boards or contacts. If water or humidity damage is observed, the electronic components may not work properly and further testing is required. C. Verify proper operation of the space heater if one is installed. D. Check if fans for proper operations and rotation. E. Look for signs of overheating such as discoloration and charring. F. Replace air filters. G. Verify connection tightness. Lightly pull wires on soldered and terminal screws and ensure the wires are not loose. H. Verify that circuit boards are properly seated. Ensure that	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	board locking tabs are fully engaged. Do not unplug and plug connectors to verify seating. This will wear out the pins. Unplug only if connector malfunction is suspected. I. Observe wires for excessive strain, braiding, or wear due to vibration. Replace as required.				
CATHODIC PROTECTION SYSTEMS					
Cathodic Protection (Section 9-2.1)					
Cathodic Protection	A. Inspect rectifiers in in accordance with UFC 3-570-06	**2**\\ Monthly /**2**/	**2**\\ OM /**2**/	**2**\\ OM /**2**/	SM
	B. Inspect cathodic protection systems in accordance with UFC 3-570-06	Annually	SM	SM	SM
Lightning Surge Arresters (Section 9-2.2.1)					
Lightning Surge Arresters	A. Newer lightning surge arresters are designed to withstand unlimited surges at 50,000 amperes; however, manufacturers of older surge arresters may provide a maximum number of surge events that can occur before it must be replaced. If surge arresters include a maximum number of surge events, a spare arrester must be kept on hand. Refer to the surge arrester manufacturer's operation and maintenance manual for particular inspection instructions and parts. Inspect as part of an overall cathodic protection system inspection.	Annually	SM	SM	SM
Card and Key Locks (Section 9-3)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Card and Key Locks	A. Conduct operational check of card and key lock system and ensure that all features provided with the installed system are operational.	Annually	SM	SM	SM
Lightning Protection Systems (Section 9-4)					
Lightning Protection Systems	B. Inspect air terminals to make sure they are securely attached to the roof of the building, canopy, or the piece of equipment. Check all connections between the air terminals and the grounding loop or grounding rods. Repair damaged or loose connections and perform continuity check after repairs.	Annually	SM	SM	SM
Ground Verification System (Section 9-5)					
Ground Verification System	A. Conduct an operational check of the ground verification system and ensure that all features provided with the installed system are operational. Inspect the plug for corrosion, weakness, or loose nuts and replace if heavily dented or deformed.	Quarterly	SM	SM	SM
Electronic Overfill Protection Systems (Section 9-6)					
Electronic Overfill Protection Systems	A. Conduct operational check of overfill prevention system and ensure that all features provided with the installed system are operational.	Quarterly	SM	SM	SM
ALTERNATE POL FACILITIES					
Liquefied Petroleum Tanks (Section 10-1.1)					
Liquefied Petroleum Tanks	A. Inspect fuel tank for leaks. If a leak is occurring, the odorizing agent of the gas should be detectable. Use a soap and	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service.				
	B. Test operation of emergency shutoff valves. Ensure the fusible link mechanism is attached properly to actuate in case of a fire and that it has not been by-passed, blocked, or damaged in any manner. Ensure the fusible link is not filled with debris or paint which could impact operation.	Semi-annually	SM	SM	SM
	C. Check settings of tank safety valves and calibrate if required	Every 5 years	SM	SM	SM
Liquefied Petroleum Pipelines (Section 10-1.2)					
Liquefied Petroleum Pipelines	A. Conduct visual inspection of pipelines for potential damage and leak points. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.	Monthly	OM	OM	OM
	B. Inspect coatings and markings on piping. Repair coating deterioration and replace labels that are fading and are difficult to read.	Semi-annually	SM	SM	SM
Liquefied Petroleum Vapor Lines (Section 10-1.3)					
Liquefied Petroleum Vapor Lines	A. Inspect vapor lines for leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	B. Inspect coatings and markings on piping. Repair coating deterioration and replace labels that are fading and are difficult to read.	Semi-annually	SM	SM	SM
LPG Vaporizers (Section 10-1.4)					
LPG Vaporizers	C. Inspect vaporizers for leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.	Monthly	OM	OM	OM
	D. The manufacturer's maintenance schedules and recommendations provided with the LPG vaporizer must be followed.	As Required	SM	SM	SM
Petroleum Gas Regulators (Section 10-1.5)					
Petroleum Gas Regulators	A. Inspect petroleum gas regulators for leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.	Monthly	OM	OM	OM
Liquefied Petroleum Gas Hoses (Section 10-1.6)					
Liquefied Petroleum Gas Hoses	A. Inspect hoses for damage and leaks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. If leaks are detected from a hose discontinue use of the hose and remove it from service. Inspect for damage to outer cover that exposes reinforcement. Inspect	Monthly	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	for kinks or flattened areas, soft spots or bulges. Inspect couplings and ensure they have not slipped on the hose or been damaged.				
CNG Piping (Section 10-2.1)					
CNG Piping	A. Inspect CNG lines for leaks. Inspection of high-pressure CNG lines and equipment must be conducted using proper PPE including but not limited to safety glasses, a face shield, hard hat and fire resistant clothing. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.	Daily	OM	OM	OM
	B. Inspect coatings and markings on piping. Repair coating deteriora- tion and replace labels that are fading and becoming difficult to read.	Semi-annually	SM	SM	SM
CNG Compressors (Section 10-2.2)					
CNG Compressors	A. Compressors will require maintenance based on the model included in the system. Consult the compressor manual for maintenance requirements	As Required	SM	SM	SM
CNG Storage (Section 10-2.3)					
CNG Storage	A. Inspect CNG tubes and tanks for leaks. Inspection of high-pressure CNG lines and equipment must be conducted using proper PPE including but not limited to safety glasses, a face shield, hard hat and fire resistant clothing. If leaks are occurring, the odorizing agent in	Daily	OM	OM	OM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. Systems that are found with leaks must be taken out of service and repaired.				
	B. Inspect coatings and markings on storage tubes or tanks. Repair coating deterioration and replace labels that are fading and becoming difficult to read.	Semi-annually	SM	SM	SM
	C. Check operation and calibration of safety valves on tubes or tanks.	Every 3 years	SM	SM	SM
CNG Dispensers (Section 10-2.4)					
CNG Dispensers	A. Dispensers are listed for service with CNG and will vary by manu- facturer. Consult the maintenance manual that was supplied with the system for manufacturer's maintenance required for the CNG dispenser.	As Required	SM	SM	SM
CNG Dispenser Hoses (Section 10-2.5)					
CNG Dispenser Hoses	A. Inspect hoses for damage, leaks, and cracks. If leaks are occurring, the odorizing agent in the gas should be detectable. Use a soap and water solution to spray on areas suspected of leaks. If leaks are detected from a hose, discontinue the use of the hose and remove it from service.	Monthly	OM	OM	OM
	B. Test hoses for leaks following manufacturer recommended frequencies and procedures.	As required	SM	SM	SM
Hydrazine Charging Units (Section 10-3)					
Hydrazine Charging Units	A. Hydrazine charging units are self-contained factory fabricated systems. Refer to the	As Required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	manufacturer's maintenance manual that was provided with the system for required periodic maintenance.				
SUPPORT FACILITIES					
	Fuel Truck **1**\\and Rail/**1**/ Containment Areas (Section 11-1.1)				
Fuel Truck Containment Areas	A. Remove debris from around security fence. B. Inspect fence grounding points. Ensure connections are not loose or damage. C. **2**\\ Inspect the parking area for cracks in the concrete containment paving and curbs. Remove vegetation that may have established roots in the buildup of dirt or from exposed earth under cracks. /**2**/	Monthly	OM	OM	OM
	D. Inspect the parking area for cracks in the concrete containment paving and curbs. Remove vegetation that may have established roots in the buildup of dirt or from exposed earth under cracks. Thoroughly clean and seal cracks with a fuel resistant sealant.	Quarterly	SM	SM	SM
	E. **1**\\ Secondary containment systems degrade and will collect debris which can clog drainage inlets or prevent drain valves from sealing properly. Hydrostatically test secondary containment and associated drainage systems to include containment concrete/sealant, drain inlets, drain lines and containment drain valves to ensure containment is liquid tight. This test may use opportune rainfall by holding	**1**\\Every 3 Years/**1**/	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at the start of the 60-minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer Appendix B for testing procedures and to document the testing. /**1**/. F. Verify continuity of vehicle grounding system connections. If a connection is suspected to be loose, perform further testing. In some occasions it is more cost effective to replace the suspected connection instead of performing diagnostic tests. G. Inspect pavement markings and vehicle movement lines for wear and fading. Repair faded or worn pavement markings. H. Inspect security fence for wear and rust. Inspect barbed wire and ensure it is adequately secured to outriggers. Repair loose fencing components and coatings at areas that show rust.				
	I. /**2**/Refer to Section 9-1.8 Lighting for inspection and maintenance requirements of area lighting	As required	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Remote Spill Containment (Section 11-1.2)					
Remote Spill Containment	A. Inspect the remote containment basin for cracks in the concrete containment paving, walls, and curbs. Remove vegetation that may have established roots in the buildup of dirt or from exposed earth under cracks. **2**\ /**2**/ B. If equipped, inspect spill containment sump pump for proper operation.	**2**\Monthly/**2**/	**2**\OM/**2**/	/**2**/OM/**2**/	**2**\OM/**2**/
	C. **2**\ Inspect the remote containment basin for cracks in the concrete containment paving, walls, and curbs. Thoroughly clean cracks with a water spray or air jet. Seal cracks with a fuel-resistant sealant. /**2**/	Quarterly	SM	SM	SM
	D. **1**\ Secondary containment systems degrade and will collect debris which can clog drainage inlets or prevent drain valves from sealing properly. Hydrostatically test secondary containment and associated drainage systems to include containment concrete/sealant, drain inlets, drain lines and containment drain valves to ensure containment is liquid tight. This test may use opportune rainfall by holding rainwater in the containment system for one hour. Where evaporation is a concern, conduct the testing when this concern would be minimized, such as at night/early morning or during a time of year when this would not be as much of an issue. Record the water level at	**1**\Every 3 Years/**1**/	**2**\ SM /**2**/	**2**\ SM /**2**/	**2**\ SM /**2**/

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	the start of the 60-minute (minimum) hold period. If the water level drops by 1/8 inch or more, perform and record an investigation to determine the cause and any required repairs. Once repairs are completed, a new test must be completed. Refer Appendix B for testing. /**1**/.				
Pumphouse/Filter Buildings (Section 11-2.1)					
Pumphouse/ Filter Buildings	A. Inspect the floor and containment curbs for cracks. Thoroughly clean cracks with a water spray or air jet. Seal cracks with a fuel resistant sealant.	Annually	SM	SM	SM
	B. Refer to UFC **1**\\ 3-110-03 /**1**/ for inspection and maintenance requirements of pumphouse and filter building roof systems	As required	SM	SM	SM
Canopies (Section 11-2.2)					
Canopies	A. Inspect and maintain canopies according to UFC **1**\\ 3-110-03 /**1**/.	As required	SM	SM	SM
Emergency Eyewash/Showers (Section 11-3)					
Emergency Eyewash/ Showers	A. Test operation of the emergency eyewash/shower by pushing on the activation handles. Ensure water is not brown in color, due to rust in the piping or dirt seeping in from a hole in the buried piping. For systems with tempered water, ensure that water that is being supplied by the emergency eyewash/shower is between 60 and 100 °F (16 and 39 °C). For systems with a horn and strobe light, ensure that the horn and strobe light activate	Weekly	**1**\\OM/**1**/	**1**\\OM/**1**/	**1**\\OM/**1**/

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	when the activation lever on the emergency eyewash/shower is pushed. For systems that interface with Installation or fire emergency systems, pre-coordinate before testing. At some Installations emergency eyewashes and showers act as EFSOs and are tied into the fire alarm systems.				
	B. Inspect portable/packaged safety showers and eyewash stations for proper operation. Check fluid levels. Where tap water is used, fluid must be replaced monthly. Less frequent intervals of fluid change, as recommended by the manufacturer, are acceptable where a solution or water additive is used. Ensure packaged eyewash supplies are within the listed expiration date. Tags or labels must be attached to the unit or adjacent to it, indicating the fluid change schedule.	Monthly	**1**\OM/**1**/	**1**\OM/**1**/	**1**\OM/**1**/
	C. Inspect the exterior coatings of permanently installed units and repair damaged coatings or rust.	Quarterly	SM	SM	SM
	D. For systems with tempered water systems inspect components of the water heater for correct operation and temperature control. Ensure that the safety valve on the hot water heater tank is not leaking.	Semi-annually	SM	SM	SM
	E. Inspect signage and labels on the emergency eyewash/shower. Replace missing labels or signage that	Annually	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	has become loose. Signs that are faded must be replaced				
Ventilation Hoods (Section 11-4.1)					
Ventilation Hoods	A. Inspect the operation of the doors. Ensure that they close and open smoothly.	Quarterly	SM	SM	SM
	B. Inspect the lights inside of the hood to make sure they are operating properly. Replace light bulbs that are no longer working.	Semi-annually	SM	SM	SM
	C. Verify that all electrical equipment is properly classified in accordance with NFPA 70 *National Electrical Code*. D. Inspect the ventilation system (ductwork, fans, etc.) for signs of disrepair and air leakage and ensure it is operational and pulling air through the hood. Inspect and assure that the lab hood air measuring device for assuring proper air flow is permanently attached and working properly. The ventilation hood must be inspected and **\1**approved by a service specific industrial hygienist or bioenvironmental engineer**/1/** in accordance with OSHA, 29 CFR 1910.1450 *Occupational Exposure to Hazardous Chemicals in Laboratories*, and ANSI/AIHA *Laboratory Ventilation Z9.5*. E. Verify negative pressure is present through the ventilation hood to the exhaust.	Annually	SM	SM	SM
Oil/Water Separators (Section 11-5)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Oil/Water Separators	A. Inspect the oil/water separator for the buildup of collected petroleum fuel or oil. Remove and properly dispose of accumulated petroleum fuel or oil.	Quarterly or as needed based on precipitation events	SM	SM	SM
	B. Drain, clean, and inspect the interior of the oil/water separator. Ensure all divider plates and screens are in good working order. Replace or repair damaged components.	Annually or more frequently based on local environmental conditions.	SM	SM	SM
Cranes and Hoists (Section 11-6)					
Cranes and Hoists	A. Inspect cranes and hoists for smooth operation. If the crane or hoist is equipped with electronic controls, check power supply and operational control cords for nicks or damage. A crane service technician must correct binding that may prevent smooth operation and repair damage to power cords.	Before each use	OM	OM	OM
	B. Apply lubricant or grease to areas that require periodic greasing. C. Military services-specific, host nation, state, and/or local regulations require cranes and hoists to be certified for operation. Follow the more stringent of military services-specific, host nation, state or local regulations.	Annually	SM	SM	SM
FUEL FACILITY TEMPORARY DEACTIVATION OR CLOSURE					
Deactivated Fuel Tanks (Section 12-2)					
Deactivated Fuel Tanks	A. Inspect water or anti-corrosion level in tank. If level has dropped, investigate potential leak points such as blind flanges. Repair leaks that are	Quarterly	SM	SM	SM

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
	detected and refill to appropriate level. B. Check exterior coatings and labels. Repair peeling coatings and/or rusting areas and replace or repair labels which have become faded and difficult to read.				
	C. Inspect cathodic protection system for proper operation.	Annually	SM	SM	SM
Deactivated Pipelines (Section 12-3)					
Deactivated Pipelines	A. Inspect the pressure of the nitrogen charge applied to the petroleum fuel pipeline with a pressure gauge. If the pressure of the charge has dropped investigate and repair leak points. Once leak points are repaired, recharge with nitrogen. B. Check exterior coatings and labels. Repair peeling coatings and/or rusting areas and replace or repair labels which have become faded and are difficult to read.	Quarterly	SM	SM	SM
	C. Inspect cathodic protection system for proper operation.	Annually	SM	SM	SM
Deactivated Pumps (Section 12-4)					
Deactivated Pumps	A. Manually rotate pump through several rotations. Ensure that the pump turns freely. B. Check exterior coatings. Repair peeling coatings and/or rusting areas and replace or repair labels which have become faded and difficult to read.	Quarterly	SM	SM	SM
	C. Remove isolation flanges and recoat interior of pump with light corrosion-inhibiting oil.	Annually	SM	SM	SM
Miscellaneous Deactivated Components (Section 12-5)					

ITEM	PARAGRAPH	FREQUENCY	Army	Navy/ USMC	Air Force
Miscellaneous Deactivated Components	A. Ensure that blind flanges are tight. Inspect exterior coatings and labels. Repair peeling coatings and/or rusting areas and replace or repair labels that have become faded and are difficult to read.	Annually	SM	SM	SM

<u>Note:</u> Follow manufacturer's recommendation and published operation and maintenance manuals for items and equipment not discussed in this document.

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APPENDIX D MAINTENANCE PROCEDURES

D-1 D-1 FILTER SEPARATOR COALESCER CARTRIDGE REPLACEMENT AND SEPARATOR CARTRIDGE CLEANING.

D-1.1 Coalescer Cartridge Replacement in Vertical Filter Separator.

a. Drain the filter separator completely.

b. Raise the cover. CAUTION: Do not touch new coalescer cartridges or the separator cartridges with your bare hand. The oil on your hand will cause damage to the water-removal capability of these components.

c. Where there is an outer separator cartridge, remove, clean (D-1.3), and set it aside for reuse.

d. Remove and discard the old coalescer cartridges in an approved manner. Coordinate disposal of coalescer cartridges with Installation Environmental Office.

e. Check the adapter gasket and adapter to make sure the gasket and adapter threads are clean.

f. Complete the installation of the coalescer cartridge assemblies by lowering each of the coalescer cartridge assemblies onto one of the deck plate nipples. Make sure that each of the coalescer cartridge assemblies is screwed down onto its deck plate nipple and the gasket is seated properly and seals tightly. Next, apply the procedures in items (1) through (6) below:

1. Replace the cover gasket with a new gasket of the same grade and manufacturer as the old one.
2. Swing the cover back into place, lowering the lifting handle as you do so.
3. Swing the eyebolts up into place and tighten the nuts using the crisscross method. Do this so that the cover gasket and cover are seated properly. When tightening cover bolts and nuts, use a torque wrench. Tighten nuts just enough to prevent leaking through the dome cover seal (refer to manufacturer's instructions for torque requirements) and to eliminate possible damage to the vessel.
4. Close the manual water drain valve.
5. Slowly fill the separator. Filling a filter separator must take a minimum of ten minutes to perform. Conduct slow filling by use of the slow fill valve on the filter separator, if equipped, or by filling all of the filter separators on a system at one time. Slow filling is the

only authorized method of refilling an empty filter separator. This slows buildup of static electricity in fuel, reducing the possibility of a spark igniting the explosive atmosphere inside the vessel. In most cases, coalescer elements cannot be grounded or bonded to dissipate the static electric charge that is generated during filling.

6. Pressurize the vessel to inspect all gaskets and screwed connections for leaks; tighten all loose connections.

g. Note: Remember, once a system is opened for any reason it must be sampled before aircraft are serviced.

h. Notify the facility supervisor that the filter separator is ready to be put back into service and is awaiting QC flushing and sampling. (This is necessary to ensure the fuel meets quality requirements.)

i. After the coalescer cartridges have been replaced and the filter separator is ready to be put back into service, follow the steps below:

1. Stencil the filter separator in accordance with Section 3-6.2.4.

2. Set up and keep a logbook or wall chart in the maintenance shop. Record the following information in this book or chart: pumphouse facility number; filter separator number; month and year replacement coalescer cartridges were installed; serial number of the coalescer cartridges; number of coalescer cartridges; and manufacturer’s coalescer cartridge lot number, if available.

D-1.2 Coalescer Cartridge Replacement in Horizontal Filter Separator.

a. After the vessel has been drained thoroughly, remove the head flange bolts and open the vessel. For the original KMU-416/F modification kit, use the following method:

1. Starting with the bottom (left) coalescer cartridge, loosen the 0.5-inch (12.7-millimeter) nut on the adapter mounting rod. Slowly drain the fuel trapped in the manifold by loosening the bottom coalescer cartridge.

2. After the fuel has been drained from the manifold, remove the fifteen coalescer cartridges on the outlet side of the manifold.

3. To remove the coalescer cartridge hold-down plate, use a screwdriver for leverage to pry the seals outward from the cartridge. The O-ring seals on the cartridge mounts may be removed more easily by applying a slight twisting motion instead of a direct pull.

4. Loosen and remove the Victaulic coupling from the inlet pipe, sliding the sealing gasket down on the manifold pipe section. Be sure to use a static bonding wire.

5. Remove the manifold. This requires two people to slide the manifold forward, using the protruding coalescer cartridge hold-down rods as handles to help in removing the manifold. CAUTION: Have a container available to place the manifold in and catch fuel that might spill out of the manifold. Dispose of the used coalescer cartridges in an approved manner. Do not allow fuel-soaked coalescer cartridges to be left in the area or disposed of in a manner that can create a safety or fire hazard. Be careful when handling used coalescer cartridges because they are toxic and combustible or flammable, depending on the fuel's flashpoint.

6. Remove the separator cartridges and follow the steps outlined in Section D-1.3 when cleaning.

7. Clean the inside of the filter separator with rags.

8. Install new coalescer cartridges and cleaned separator cartridges on the manifold and reinstall the manifold.

9. Align and bolt in the Victaulic coupling.

10. Replace cover and tighten bolts using the crisscross method. Tighten nuts just enough to prevent leaking through the dome cover seal (refer to manufacturer's instructions for torque requirements) to eliminate possible damage to the vessel.

b. For modified KMU-416/F (300 gallons per minute (1135 liters per minute) kits with nine additional coalescer cartridges on the back side of the manifold, remove only the bottom front six coalescer cartridges instead of all fifteen. This will balance the manifold, and make it easier to remove. Remove the manifold from the vessel.

c. For KMU-417/F kits (600 gallons per minute (2271 liters per minute), leave all coalescer cartridges in place when removing the manifold. This provides balance and lets you remove the manifold easily.

D-1.3 Separator Cartridge Cleaning, Repairing, and Handling.

a. Cleaning: Separator cartridges, when new, operate in a satisfactory manner, but after processing millions of gallons of fuel that contain additives and contaminants they gradually become less effective. Every time the coalescer cartridges are changed the separator cartridges should be inspected and cleaned according to the following procedure:

1. Connect a water hose to a hot water supply. Attach a nozzle to the hose and direct a high-velocity stream of water at a downward angle against the outer surface of the separator cartridge. Hold the separator cartridge assembly vertically by the end to avoid touching the cartridge surface. Begin at the top and work downward along

the length of the separator cartridge. Rotate the separator cartridge slowly so the entire surface is subject to the jet of hot water. Repeat as necessary until the separator cartridge is clean.

2. After cleaning, shake excess water from the separator cartridge and allow the remaining water to evaporate, or use clean, dry, oil-free compressed air. Air quality must be very clean. If the air quality is doubtful, do not use.

3. After each separator cartridge is dry, hold it horizontally and pour tap water onto the cartridge from a height of 1 to 2 inches (25 to 50 millimeters) above the cartridge. Pour water along the entire length of the separator cartridge while slowly rotating the cartridge. Under test, observe the way the water appears on the surface of the separator cartridge. If the water soaks through the separator cartridge instead of beading up or rolling off, the cartridge must be recleaned.

4. The Teflon or nylon coating of the separator cartridge must be visually inspected for small cuts and breaks. Small breaks in the Teflon or nylon coating of the separator cartridge can be repaired for temporary service by patching with a fuel-resistant sealant, epoxy adhesive, or epoxy-base putty. If major holes appear in the Teflon or nylon coating of the separator cartridge, rendering it impracticable to repair, the separator cartridge should be replaced.

b. Installation and Handling: Just before installing separator cartridges, agitate the cartridges briefly in a container of clean fuel to flush off all remaining water. (Use the same type of fuel being filtered). Extra care must be taken during installation to ensure separator cartridges are not damaged. Separator cartridges must be installed very carefully to prevent physical damage to the Teflon or nylon coating. When installing the separator cartridge assembly, the securing nut should not be over torqued, as this can damage the cartridge assembly.

D-2 D-2 HOSE HYDROSTATIC TEST.

D-2.1 Loading Hose Hydrostatic Test.

a. Prior to hydrostatic test of fuel loading hose, determine the maximum allowable pressure rating of attached valves, meters, or swivels to prevent possible injury to personnel or damage to the equipment. It may be necessary to remove the fueling hose prior to testing.

b. Test fluid may be water or liquid petroleum fuel with a flash point of 100 °F (37.7 °C) or more. If liquid petroleum fuel is used as the test medium, the test should be conducted in a place where contamination of adjacent waters will not occur if there is spillage.

c. Provide blind flanges, nipples, valves, pressure gauges, and pumps of appropriate size and rating for the test to be performed.

d. Lay the hose out flat and straight, uniformly supported.

e. Fill the hose with test fluid, expel all air and raise the pressure to 10 psig (69 kPa).

f. Hold the pressure for at least five minutes. During the test interval, measure the length of the hose, end-of-rubber to end-of-rubber. Record the measured length as original length.

g. If the hose is maintaining 10 psig, raise the pressure to the lower of 1.5 times the pump deadhead pressure or the maximum allowable working pressure of the hose and hold the pressure for a minimum of 15 minutes. Measure the length of the hose, end-of rubber to end-of-rubber and record the measured length as test pressure length.

h. During the test the hose must not burst, bulge, leak, or abnormally distort under static liquid pressure.

i. Calculate the elongation as a percentage of original length versus test pressure length. If the elongation of the hose exceeds 15% it is an indication that there is a serious internal weakness and the hose should be removed from service and retired.

D-2.2 Marine and Underwater Transfer Hose Hydrostatic Test.

a. Hydrostatic testing of marine and underwater petroleum fuel transfer hose must meet the requirements of 33 CFR 156, Section 170.

b. Prior to hydrostatic test the hose must meet the following requirements:

1. Have no unrepaired loose covers, kinks, bulges, soft spots or other defects which would permit the discharge of fuel through the hose material, and no gouges, cuts, or slashes that penetrate the first layer of the hose reinforcement.
2. Have no external deterioration and, to the extent internal inspection is possible with both ends of the hose open, no internal deterioration.

c. Test fluid may be water or liquid petroleum fuel with a flash point of 100 °F (37.7 °C) or more. If liquid petroleum fuel is used as the test medium, the test should be conducted in a place where contamination of adjacent waters will not occur if there is spillage.

d. Provide blind flanges, nipples, valves, pressure gauges, and pumps of appropriate size and rating for the test to be performed.

e. Lay the hose out flat and straight, uniformly supported.

f. Fill the hose with test fluid, expel all air and raise the pressure to 10 psig (69 kPa).

g. Hold the pressure for at least five minutes.

h. If the hose is maintaining 10 psig, raise the pressure to 1.5 times the maximum allowable working pressure of the hose and hold the pressure for a minimum of 15 minutes.

i. During the test the hose must not burst, bulge, leak, or abnormally distort under static liquid pressure.

APPENDIX E TANK INSPECTION CHECKLISTS

STI SP001 MONTHLY INSPECTION CHECKLIST

General Inspection Information:

Inspection Date: ____________________ Prior Inspection Date: ______________________ Retain Until Date: ______________________

Inspector Name (print): ______________________________________ Title: ______________________________________

Inspector's Signature: ____

Tanks Inspected (ID #'s): ____

Regulatory facility name and ID number (if applicable) ____

Inspection Guidance:

- This checklist is intended as a model. Locally developed checklists are acceptable as long as they are substantially equivalent (as applicable). Inspections of multiple tanks may be captured on one form as long as the tanks are substantially the same.
- For equipment not included in this Standard, follow the manufacturer recommended inspection/testing schedules and procedures.
- The periodic AST Inspection is intended for monitoring the external AST condition and its containment structure. This visual inspection does not require a Certified Inspector. It must be performed by an owner's inspector per paragraph 4.1.2 of the standard.
- Upon discovery of water in the primary tank, secondary containment area, interstice, or spill container, remove promptly or take other corrective action. Inspect the liquid for regulated products or other contaminants and dispose of properly.
- Non-conforming items important to tank or containment integrity require evaluation by an engineer experienced in AST design, a Certified Inspector, or a tank manufacturer who will determine the corrective action. Note the non-conformance and corresponding corrective action in the comment section.
- Retain the completed checklists for at least 36 months.
- **After severe weather (snow, ice, wind storms) or maintenance (such as painting) that could affect the operation of critical components (normal and emergency vents, valves), an inspection of these components is required as soon as the equipment is safely accessible after the event.**

ITEM		STATUS	COMMENTS/DATE CORRECTED
Tank and Piping			
1	Is tank exterior (roof, shell, heads, bottom, connections, fittings, valves, etc.) free of visible leaks? **Note:** *If "No", identify tank and describe leak and actions taken.*	□Yes □No	

ITEM		STATUS	COMMENTS/DATE CORRECTED
2	Is the tank liquid level gauge legible and in good working condition?	□Yes □No □N/A	
3	Is the area around the tank (concrete surfaces, ground, containment, etc.) free of visible signs of leakage?	□Yes □No	
4	Is the primary tank free of water or has another preventative measure been taken? NOTE: Refer to paragraph 6.10 and 6.11 of the standard for alternatives for Category 1 tanks. N/A is only appropriate for these alternatives.	□Yes □No □N/A	
5	For double-wall or double bottom tanks or CE-ASTs, is interstitial monitoring equipment (where applicable) in good working condition?	□Yes □No □N/A	
6	For double-wall or double bottom tanks or CE-ASTs, is interstice free of liquid? Remove the liquid if it is found. If tank product is found, investigate possible leak.	□Yes □No □N/A	
Equipment on Tank			
7	If overfill equipment has a "test" button, does it activate the audible horn or light to confirm operation? If battery operated, replace battery if needed.	□Yes □No □N/A	
8	Is overfill prevention equipment in good working condition? If it is equipped with a mechanical test mechanism, actuate the mechanism to confirm operation.	□Yes □No □N/A	
9	Is the spill container (spill bucket) empty, free of visible leaks and in good working condition?	□Yes □No □N/A	
10	Are piping connections to the tank (valves, fittings, pumps, etc.) free of visible leaks? **Note:** *If "No", identify location and describe leak.*	□Yes □No	
11	Do the ladders/platforms/walkways appear to be secure with no sign of severe corrosion or damage?	□Yes □No □N/A	
Containment (Diking/Impounding)			
12	Is the containment free of excess liquid, debris, cracks, corrosion, erosion, fire hazards and other integrity issues?	□Yes □No □N/A	
13	Are dike drain valves closed and in good working condition?	□Yes □No □N/A	

ITEM		STATUS	COMMENTS/DATE CORRECTED
14	Are containment egress pathways clear and any gates/doors operable?	□Yes □No □N/A	
	Concrete Exterior AST (CE-AST)		
15	Inspect all sides for cracks in concrete. Are there any cracks in the concrete exterior larger than 1/16"?	□Yes □No □N/A	
16	Inspect concrete exterior body of the tank for cleanliness, need of coating, or rusting where applicable. Tank exterior in acceptable condition?	□Yes □No □N/A	
17	Visual inspect all tank top openings including nipples, manways, tank top overfill containers, and leak detection tubes. Is the sealant between all tank top openings and concrete intact and in good condition?	□Yes □No □N/A	
	Other Conditions		
18	Is the system free of any other conditions that need to be addressed for continued safe operation?	□Yes □No	

Additional Comments:

Additional Comments:

STI SP001 Annual Inspection Checklist

General Inspection Information:

Inspection Date: ____________ Prior Inspection Date: ____________ Retain Until Date: ____________

Inspector Name (print): ____________ Title: ____________

Inspector's Signature: ____________

Tanks Inspected (ID #'s): ____________

Regulatory facility name and ID number (if applicable) ____________

Inspection Guidance:

- This checklist is intended as a model. Locally developed checklists are acceptable as long as they are substantially equivalent (as applicable).
- For equipment not included in this Standard, follow the manufacturer recommended inspection/testing schedules and procedures.
- The periodic AST Inspection is intended for monitoring the external AST condition and its containment structure. This visual inspection does not require a Certified Inspector. It must be performed by an owner's inspector per paragraph 4.1.2 of the standard.
- Remove promptly standing water or liquid discovered in the primary tank, secondary containment area, interstice, or spill container. Before discharge to the environment, inspect the liquid for regulated products or other contaminants and disposed of it properly.
- In order to comply with EPA SPCC (Spill Prevention, Control and Countermeasure) rules, a facility should regularly test liquid level sensing devices to ensure proper operation (40 CFR 112.8(c)(8)(v)).
- Non-conforming items important to tank or containment integrity require evaluation by an engineer experienced in AST design, a Certified Inspector, or a tank manufacturer who will determine the corrective action. Note the non-conformance and corresponding corrective action in the comment section.
- Retain the completed checklists for at least 36 months.
- Complete this checklist on an annual basis supplemental to the owner monthly-performed inspection checklists.
- **Note: If a change has occurred to the tank system or containment that may affect the SPCC plan, the condition should be evaluated against the current plan requirement by a Professional Engineer knowledgeable in SPCC development and implementation.**

	ITEM	STATUS	COMMENTS/DATE CORRECTED
	Tank Foundation/Supports		
1	Free of tank settlement or foundation washout?	☐Yes ☐No	
2	Concrete pad or ring wall free of cracking and spalling?	☐Yes ☐No ☐N/A	
3	Tank supports in satisfactory condition?	☐Yes ☐No ☐N/A	

ITEM		STATUS	COMMENTS/DATE CORRECTED
4	Is water able to drain away from tank if tank is resting on a foundation or on the ground?	☐Yes ☐No ☐N/A	
5	Is the grounding strap between the tank and foundation/supports in good condition?	☐Yes ☐No ☐N/A	
Tank Shell, Heads and Roof			
6	Free of visible signs of coating failure?	☐Yes ☐No	
7	Free of noticeable distortions, buckling, denting, or bulging?	☐Yes ☐No	
8	Free of standing water on roof?	☐Yes ☐No ☐N/A	
9	Are all labels and tags intact and legible?	☐Yes ☐No	
Tank Manways, Piping, and Equipment			
10	Flanged connection bolts tight and fully engaged with no sign of wear or corrosion?	☐Yes ☐No ☐N/A	
Tank Equipment			
11	Normal and emergency vents free of obstructions?	☐Yes ☐No	
12	Normal vent on tanks storing gasoline equipped with pressure/vacuum vent?	☐Yes ☐No ☐N/A	
13	Are flame arrestors free of corrosion and are air passages free of blockage?	☐Yes ☐No ☐N/A	
14	Is the emergency vent in good working condition and functional, as required by manufacturer? Consult manufacturer's requirements. Verify that components are moving freely (including long-bolt manways).	☐Yes ☐No ☐N/A	
15	Is interstitial leak detection equipment in good condition? Are windows on sight gauges clear? Are wire connections intact? If equipment has a test function, does it activate to confirm operation?	☐Yes ☐No ☐N/A	

	ITEM	STATUS	COMMENTS/DATE CORRECTED
16	Are all valves free of leaks, corrosion and other damage? Follow manufacturers' instructions for regular maintenance of these items. Check the following and verify (as applicable): ☐Anti-siphon valve ☐Check Valve ☐Gate Valve ☐Pressure regulator valve ☐Expansion relief valve ☐Solenoid valve ☐Fire valve ☐Shear valve	☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A ☐Yes ☐No ☐N/A	
17	Are strainers and filters clean and in good condition?	☐Yes ☐No ☐N/A	
Insulated Tanks			
18	Free of missing Insulation? Insulation free of visible signs of damage? Insulation adequately protected from water intrusion?	☐Yes ☐No ☐N/A	
19	Insulation free of noticeable areas of moisture?	☐Yes ☐No ☐N/A	
20	Insulation free of mold?	☐Yes ☐No ☐N/A	
21	Free of visible signs of coating failure?	☐Yes ☐No ☐N/A	
Tank/Piping Release Detection			
22	Is inventory control being performed and documented if required?	☐Yes ☐No ☐N/A	
23	Is release detection being performed and documented if required?	☐Yes ☐No ☐N/A	

ITEM		STATUS	COMMENTS/DATE CORRECTED
Other Equipment			
24	Are electrical wiring and boxes in good condition?	☐Yes ☐No ☐N/A	
25	Has the cathodic protection system on the tank been tested as required by the designing engineer?	☐Yes ☐No ☐N/A	

Additional Comments:

APPENDIX F TANK INSPECTION CHECKLISTS

Field Erected Tank Monthly Inspection Checklist

General Inspection Information:

Inspection Date: ____________________ Retain Until Date: ______________________ (36 months from inspection date)

Prior Inspection Date: ____________________ Inspector Name: ____________________________________

Tanks Inspected (ID #'s): ____

Item	Task	Status	Comments
1.	Inspect the reinforcement plate weep holes for signs of fuel and remove pipe plugs if installed.	☐Yes ☐No ☐N/A	
2.	Inspect all tank bottom tell tales and monitoring wells. Remove any water if present.	☐Yes ☐No ☐N/A	
3.	For tanks equipped with floating-roof ensure the center primary roof drain system is free of water, the drip-tight plug is placed in the roof drain opening, and drain valve is closed.	☐Yes ☐No ☐N/A	
4.	Inspect floating roof systems for:		
	4.1. Inspect the roof for buckling or damage.	☐Yes ☐No ☐N/A	
	4.2. Inspect for standing water on the roof deck.	☐Yes ☐No ☐N/A	
	4.3. Ensure the roof drain system is water-free.	☐Yes ☐No ☐N/A	
	4.4. Check the floating roof guides.	☐Yes ☐No ☐N/A	
	4.5. Visually inspect the roof for centering.	☐Yes ☐No ☐N/A	
5.	Check the product recovery system for; proper pump operation; sight glass is clear; float assembly is functioning.	☐Yes ☐No ☐N/A	

Item	Task	Status	Comments
6.	Ensure the ladders, platforms, handrails, and stairs are secured to the structure and inspect for signs of corrosion.	☐Yes ☐No ☐N/A	
7.	Visually check the exterior of the tank (i.e., welds, plates, bolts, fill ports, appurtenances) for leaks, corrosion.	☐Yes ☐No ☐N/A	
8.	Visually inspect tank foundation berms for signs of erosion, and irregularities such as tilting, settling, out-of-roundness, and growth of vegitation.	☐Yes ☐No ☐N/A	
9.	Visually inspect tank concrete ring wall foundations for cracks or signs of settlement.	☐Yes ☐No ☐N/A	
10.	Inspect and clean the protective screens at pressure and vacuum ports and tank exterior.	☐Yes ☐No ☐N/A	
11.	Inspect the manual liquid level gauge for proper operation. If installed verify manual gauge to the ATG.	☐Yes ☐No ☐N/A	
12.	If applicable; inspect swing lines for fraying and operability.	☐Yes ☐No ☐N/A	
13.	Check all signs and markings for adequacy and readability.	☐Yes ☐No ☐N/A	
14.	If additional maintenance actions are required, compile list of discrepancies and submit for correction.	☐Yes ☐No ☐N/A	

Additional Comments:

Field Erected Tank Annual Inspection Checklist

General Inspection Information:

Inspection Date: ____________________ Retain Until Date: ______________________ (36 months from inspection date)

Prior Inspection Date: ____________________ Inspector Name: ___________________________________

Tanks Inspected (ID #'s): ____

Item	Task	Status	Comments
1.	Pack the reinforcement plate weep holes with white grease to prevent water and/or dirt infiltration	☐Yes ☐No ☐N/A	
2.	Inspect floating roof seals for:		
	2.1. Inspect and clean perimeter tank seals.	☐Yes ☐No ☐N/A	
	2.2. Roof guide cables for wear, fraying, and corrosion.	☐Yes ☐No ☐N/A	
	2.3. Roof grounding cables for binding and secure attachment.	☐Yes ☐No ☐N/A	
	2.4. Inspect the ladder for damage and deflection (if equipped).	☐Yes ☐No ☐N/A	
	2.5. Check interior shell for abrasions that may indicate shell out of roundness or improper centering.	☐Yes ☐No ☐N/A	
	2.5.1. If abrasions are discovered, inspect seals for wear.	☐Yes ☐No ☐N/A	
	2.6. Check floating roof for corrosion, apply touch up with compatible coating.	☐Yes ☐No ☐N/A	
	2.7. Inspect pontoons for standing liquid and presence of vapors.	☐Ye* ☐No ☐N/A	
3.	Ensure the ladders, platforms, handrails, and stairs are secured to the structure and inspect for signs of corrosion.	☐Yes ☐No ☐N/A	

Item	Task	Status	Comments
4.	Visually check the exterior of the tank (i.e., welds, plates, bolts, appurtenances) for leaks, corrosion, or irregularities such as tilting, settling, or out-of-roundness.	☐Yes ☐No ☐N/A	
5.	Inspect, clean, and repair tank vacuum and pressure vents as follows:		
	5.1. Clean seating surfaces of pallets and valve seats carefully with an approved suitable cleaning solvent.	☐Yes ☐No ☐N/A	
	5.2. Inspect seating surfaces for damage or undue wear.	☐Yes ☐No ☐N/A	
6.	Inspect and clean the protective screens at pressure and vacuum ports and tank exterior.	☐Yes ☐No ☐N/A	
7.	Remove mechanical gauge float cover and ensure float is securely fastened to gauge tape. Check gauge tape for ease of movement.	☐Yes ☐No ☐N/A	
8.	Check all signs and markings for adequacy and readability.	☐Yes ☐No ☐N/A	
9.	If additional maintenance actions are required, compile list of discrepancies and submit for correction.	☐Yes ☐No ☐N/A	

Additional Comments:

APPENDIX G PETROLEUM FUEL PIPELINE PRESSURE TESTING GUIDELINES AND CRITERIA

G-1 INTRODUCTION.

G-1.1 Scope.

This appendix contains general criteria and standard guidelines for Petroleum, Oil, and Lubricant (POL) pipeline pressure testing. These procedures are based on current codes and criteria in addition to field experience and best management practices. This appendix clarifies the requirements for the procedures, frequency, duration, and test pressures for POL pipeline integrity testing. This appendix also provides a consistent definition of many of the terms used for pressure testing guidelines and procedures. In addition, an overall criteria list surrounding pipeline pressure testing is provided, along with a statement on the impact to the guidance given.

G-2 PIPELINE PRESSURE TESTING GUIDELINES.

G-2.1 Introduction.

G-2.1.1 Best Management Practice.

Testing criteria is to be adopted on a best management practice basis, with overall guidelines and minimum criteria established for a broad range of piping, with exceptions and special cases noted where required.

G-2.1.2 Regulations.

Host nation, Federal, state and local regulations with jurisdiction must be followed when more stringent than criteria outlined herein.

G-2.1.3 New Pipelines.

Testing of new pipelines, segments of existing pipelines after major repairs, or segment replacement must be in accordance with current piping codes and UFGS specifications.

G-2.1.4 Existing Pipelines.

Testing of existing pipelines must be in accordance with site specific criteria developed to provide integrity management consistent with the published guidelines and the procedures stated in Sections G-2.2 thru G-2.5.

G-2.2 GENERAL REQUIREMENTS.

G-2.2.1 Aboveground Pipe Testing.

Aboveground pipe testing should be based on the premise that it can be visually inspected on a regular basis, and is observable during the testing process. Overwater or near overwater piping is a special case and should receive a higher level of integrity testing due to the consequence of failure (and in some cases higher risk of failure due to increased corrosion).

G-2.2.2 Underground Pipe Testing.

Underground pipe testing should be based on the premise that it cannot be visually inspected during the test. The testing program needs to address greater safety factors, frequency of testing, and procedures to minimize the impact of temperature change of fuel during testing to assure integrity of testing.

G-2.2.3 Overall Testing Methodology Criteria.

The following items apply to all integrity pressure testing.

a. A job-specific written procedure (pressure test plan) must be used when performing a pressure test. Detailed procedures must be developed to address safety, procedural, and equipment issues for each pipeline segment.

b. Periodic testing must determine both long term safety of operation, as well as determining if the pipeline is currently leaking.

c. Preferred testing is via increasing pressure to a level consistent with reasonably predictable peak pressures, plus a comfort factor that reflects time between testing, future risk of failure, and consequence of failure.

d. Integrity testing using a fuel inoculant (e.g. tracer additive) can be considered in certain cases. In order to qualify as an integrity test, the procedure should utilize a pressure consistent with integrity management principles, instead of the minimum pressure required to conduct the test.

e. Integrity testing using a third-party certified, National Work Group on Leak Detection Evaluations (NWGLDE) listed, short duration proprietary procedure is acceptable in principle. Selected method must be certified for system parameters such as pipe size and liquid volume. To qualify as an integrity test the procedure must utilize a pressure consistent with integrity management principles, instead of the minimum pressure required to conduct the test. Alternatively, a lower pressure third-party certified leak test can be conducted after a strength test meeting the requirements of Section G-2.2.11 has been conducted.

G-2.2.4 Test Fluid.

Test fluid should be the system fuel such as DF-2, JP-5, JP-8, or F-76 when testing is within normal ANSI Class 150 ranges, and stress does not exceed 50% of Specified Minimum Yield Stress (SMYS) of the pipe. Table G-2.1 provides examples of maximum test pressures for a selection of frequently used carbon and stainless steel pipe based on

SMYS calculations (pipe only, not flanges, components). Testing with fuel with a pressure that induces a yield greater than 50% of SMYS is possible but factors such as pipe location (off-base or on-base) and proximity to occupied structures must be carefully considered. The method of calculating the pipe pressure properties for off base pipelines may require a slight variation and therefore should use the appropriate design code.

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Table G-1 /1/ Pipe Properties

Pipe Size (D) x (t)	Material	SMYS / allowable stress (S) psi (kPa)	Max Design Pressure psi (kPa) (note 1)	Pressure @ SMYS psi (kPa) (note 1)	Pressure @ 50% of SMYS psi (kPa)
8.625 dia. x .322	ASTM A 53/A 53M, Type S Grade B	35,000/20,000 (241,316.5/137,895.	1,539 (10611.0)	2,614 (18022.9)	1,307 (9011.4)
10.75 dia. x .365	ASTM A 53/A 53M, Type S Grade B	35,000/20,000 (241,316.5/137,895.	1,396 (9625.1)	2,376 (16381.0)	1,188 (8191.0)
12.75 dia. x .375	ASTM A 53/A 53M, Type S Grade B	35,000/20,000 (241,316.5/137,895.1)	1,205 (8308.1)	2,058 (14189.4)	1,029 (7094.7)
14.00 dia. x .250	ASTM A 358/A 358M, Grade 304L	25,000/16,700 (172,368.9/115,142.1)	605 (4171.3)	892 (6150.0)	446 (3075.1)
16.00 dia. x .250	ASTM A 358/A 358M, Grade 304L	25,000/16,700 (172,368.9/115,142.	528 (3640.4)	781 (5384.8)	390 (2689.0)
20.00 dia. x .250	ASTM A 358/A 358M, Grade 304L	25,000/16,700 (172,368.9/115,142.	422 (2909.6)	625 (4309.2)	312 (2151.2)

Note 1: P= 2SEt/D, E=1 for seamless and ERW pipe (ASME B31.3 Barlow equation). Consult ASME B31.3 and/or API 570 for other pipe materials, quality factors and wall thickness

G-2.2.5 Exceptions to Test Fluid.

Testing with water should be limited as much as possible to high pressure testing (greater than 450 psig (3102.6 kPa), testing over water, testing at high pressures outside of military property, and where mandated by regulatory jurisdiction (when waiver cannot be obtained). Testing with JP-8 which has a minimum flash point of 100 °F (37.8 °C) may require special permission when regulations permit testing with the fuel only when the associated flash point is above 120 °F (48.9 °C). Testing of motor gasoline lines must use potable water due to its low flash point and associated safety concerns.

G-2.2.6 Thermal Relief and Surge Considerations.

All testing programs need to consider system pressures that may be developed by thermal relief valve settings and possible dynamic transient surge (water hammer) conditions. Testing at a pressure less than these potential conditions will not provide adequate assurances of system integrity.

Pressure relief valve settings should be confirmed prior to pressurization to ensure correct test pressure and relief valve operation.

G-2.2.7 Dynamic Surge.

Evaluate the maximum surge pressure for systems known to have dynamic surge potential. The test pressure must be such that the qualified maximum operating pressure is high enough to support predictable surge pressure. (Under ASME B31.3 max surge = 133% of qualified maximum allowable operating pressure, under ASME B31.4 max surge = 110% of qualified maximum operating pressure).

G-2.2.8 System Components.

Testing programs need to consider all components within the test segments, such as strainers, sight glasses, meters, pressure gauges, pressure transmitters, check valves, instrumentation fittings and filter separators. Testing at 150% of the maximum operating pressure may overpressure system components and must be accordingly considered. Removal of lower pressure components from test segments by valve closure or blinding should be considered rather than reducing test pressure. In accordance with API RP 1110, these components should be identified with information from the component manufacturer such as maximum operating pressure, serial numbers, and other pertinent information. These components and manufacturer’s information should be listed in the pressure test plan.

Special consideration must be given to systems having non-standard fittings such as mitered elbows, orange peel reducers, stab-in connections, and similar. Note that under ASME B31.3, some of these fittings are acceptable when operation pressure results in stress less than 20% of SMYS.

G-2.2.9 Pressure Test Plan.

For all pressure class systems, a specific plan must be developed for pressure testing. For pressure class systems greater than ANSI Class 150, prepare a very detailed site specific engineering evaluation and code documentation to assure adequate and safe pressure testing. Some systems can contain more than one class of flange, so the pressure test plan must be based on the lowest class of flange present. For OCONUS locations, confirm pressure class of non-ASME components. Some OCONUS locations may incorporate a lower pressure class of flanges/components.

Any test section that includes an elevation difference of over 100 feet (30.5 meters) requires a pressure versus elevation plot and associated calculations to ensure that the lower points in the piping are not over pressurized and the highest points are subjected to the proper test pressure. These calculations and plot must be included in the pressure test plan.

G-2.2.10 Conventional Leak Test.

A conventional leak test as used in this report is a temperature compensated and volume/pressure change reconciled pressure test at not less than 150% of pump deadhead pressure by a qualified individual/organization with API 1110 developed procedures.

G-2.2.11 Strength Test.

A strength test as used in this report is a pressure test at not less than the greater of 150% of pump deadhead pressure or thermal pressure relief valve resultant pressure, including cascade, conducted with a calibrated pressure gauge, for a duration of not less than four (4) hours. The strength test does not attempt to reconcile pressure change with fuel temperature change as required by the conventional leak test. As a result, low volume leaks may go unrecognized when conducting this test.

G-2.2.12 US Coast Guard Criteria for Marine Pipelines.

Testing of lines under USCG criteria needs to carefully consider required test pressure, and jurisdiction of testing (i.e., how much of system). Testing to 150% of “tanker rail” pressure may not be high enough. USCG rules require consideration of either pump deadhead pressure, safety shutoff, or over pressure thermal relief settings as the basis for the 150% test. Commonly this may result in a test pressure requirement of 225 psig (1550 kPa). Another factor with USCG jurisdiction systems is possible deadhead pressure when pumping to tankers, which may exceed tanker offload pressures, and thus may require a test pressure higher than 225 psig (1550 kPa). The governing worst case scenario may be the dynamic surge possible when outloading with terminal pumps and a pier side emergency stop valve is rapidly closed.

G-2.2.13 Off-Base Systems.

Receipt pipelines from or connected to commercial off-base systems must be tested at a pressure that recognizes deviations or maximum system capability within flange ratings, which are normally much higher than pressures from normal receipt operations. Many off-base pipelines are constructed to ANSI Class 300 standards and connect to ANSI Class 150 systems at the point of pipeline ownership change. Discussions with off-base pipeline operators is important to determine operating characteristics, including pump deadhead pressure, safety shutdown considerations, and protection of lower pressure class piping. Federal regulations (49 CFR 195) mandate that a means of “over pressure prevention” is required if a higher pressure class pipeline is connected to a lower pressure class pipeline.

An overpressure condition can be caused by rapidly closing a Base valve, or startup of a receipt operation against a closed Base valve.

G-2.2.14 Minimum Test Pressure.

The test pressure for all pipelines subject to pump discharge pressure must not be less than 100 psig (689.4 kPa). The test pressure for pump suction lines may be between 50 psig (344.7 kPa) to 100 psig (689.4 kPa).

G-2.2.15 Maximum Test Pressures.

G-2.2.15.1 General Requirements.

Ensure that the flanges are stamped with B16.5, otherwise the flange may not conform to B16.5. Additionally, prior to testing, verify that all the nuts and bolts are properly engaged with sufficient threads past the nut.

G-2.2.15.2 ASME B16.5 Flange Ratings.

Test must not exceed test pressures permitted by ASME B16.5 (Flange Ratings) as follows:

- Carbon Steel, ANSI Class 150: 450 psig (3102.6 kPa)
- Stainless Steel, ANSI Class 150, with 304 or 304/304L flanges: 425 psig (2930.3 kPa)
- Stainless Steel, ANSI Class 150, with 304L flanges: 350 psig (2413.2 kPa)
- Carbon Steel, ANSI Class 300: 1050 psig (7239.5 kPa)
- No ANSI Class Flange: As noted by code authority

G-2.2.16 Service Station Piping.

Service station piping is considered a special case and is discussed in Section G-2.5, with separate criteria for integrity testing.

G-2.2.17 Non-metallic Piping.

Systems containing non-metallic piping such as fiberglass or coaxial flexible systems must be evaluated for pressure rating, or practical pressure limits based on historical failures of these types of piping systems.

\1\ G-2.2.18 Small Bore Piping.

Small bore piping, less than 4 inches (100 mm) in diameter, typically leading to and from small fuel tanks should be run aboveground. Inspection of these lines is required per Service Station Piping as discussed in Section G-2.5. Do not remove paint as part of the visual inspection. If the piping is in a containment area, such as a tank dike, the piping is not required to be pressure tested. In addition, if the piping cannot be pressure tested due to no means (tank valve) of isolation, a visual inspection for exterior pipe corrosion will satisfy integrity requirements. **/1/**

G-2.3 DEPARTMENT OF DEFENSE (DoD) PETROLEUM FUEL PIPELINES.

G-2.3.1 General.

Consistent with API 570, underground systems should undergo periodic pressure tests above normal operating pressures, whereas fully inspectable aboveground piping should undergo periodic pressure testing at normal operating pressure. Note that the Service Control Points can authorize deviations and alternate equivalent testing methodologies from these criteria. Section G-5 provides a summary of pipeline pressure testing guidelines.

G-2.3.2 On-Base Aboveground Piping Annual Test.

The test pressure for the annual test must not be less than pump deadhead pressure, the pressure resulting from thermal relief valve settings, or 100 psig (689.4 kPa) (whichever is greater) for a duration of two hours minimum. The duration of the test may extend longer to allow time to inspect the entire aboveground piping section being tested. When piping is not subject to pump discharge pressures a minimum test pressure of 100 psig (689.4 kPa) is required for the annual test. The pressure for the annual test may be reduced to 50 psig (344.7 kPa) for systems not subject to pump discharge pressure that contain threaded components. All components undergoing the annual test must be visually inspected for leaking during the test. Addition or withdrawal of fuel during the annual test is permitted due to loss of pressure from valve seat bypass or to prevent overpressure (thermal gain). On-Base aboveground piping does not require a five year test, as long as annual testing is conducted.

G-2.3.3 On-Base Single-Wall Underground Piping Annual Test.

G-2.3.3.1 Pressure Testing Options.

The options to complete the test include:

a. Annual Option 1: The test pressure for the annual test must not be less than pump deadhead pressure, or the pressure resulting from thermal relief valve settings (whichever is greater) for duration of two hours minimum. Perform accurate pressure and ambient temperature monitoring. All instrumentation should be of sufficient quality to Ensure accurate test data collection. The pressure change, if any, must be within a small range and/or reconciled with fuel temperature change. To minimize the effect of changing temperature, the fuel should be allowed to reach equilibrium, and testing is to occur at time of day with little solar influence or rapid temperature change. The acceptable pressure deviation or pressure change criteria are to be established by the Service Control Point. The allowable pressure change is to be based on installation’s location, size of system, and historical testing results.

b. Annual Option 2: Perform annual test at not less than pump deadhead pressure or the pressure resulting from thermal relief valve settings (whichever is greater), with third-party certified NWGLDE listed leak test. By doing annual third-party certified test at NOT LESS THAN the pump deadhead pressure or the pressure resulting from thermal relief valve settings (whichever is greater), the requirement for a five-year test is waived.

G-2.3.4 On Base Double-Wall Underground Carrier Piping Annual Test.

Test the carrier pipe using piping test methods, as applicable, as described in Section G-2.3.3 **\1\/1/**. After testing, confirm that there is no product at all low point locations in the secondary containment system. If the “double wall” system cannot be tested for both pressure integrity and presence of fuel leaks or water intrusion the system must be treated as a single-walled pipe and the requirements listed in section G-2.3.6 for the five-year test must be conducted in addition to the tests required in this section.

G-2.3.5 \1\ On /1/ Base Double-Walled Underground Containment Piping Test.

Interstitial Breach of Integrity testing must take place at three to five year intervals, depending on regulatory requirements and local practice.

The containment pipe of a double-wall pipe system must have the ability to be check for leakage thru low point check points. In addition, the annular space between the containment pipe and the carrier pipe must have the ability to be air-tested for the presence of hydrocarbon vapor with a calibrated atmospheric meter. Most secondary containment piping is equipped with test ports at each end and may be equipped with low point drains.

In the event that the pipeline is located in a jurisdiction that requires double wall systems, and the secondary system fails, then the system will be considered out of compliance. The system should then either be repaired or taken out of service.

G-2.3.5.1 Interstitial Breach of Integrity Testing Three-to-Five-Year Test.

Conduct a containment interstitial space breach of integrity test per manufacturer’s instructions. This test pressure is normally 5-10 psig (34.4-68.9 kPa) and held for two hours. The test could be a vacuum test if leaks are suspected as a safe alternative. All test equipment should be calibrated and suitable for the low pressure. A failure of the containment pipe test and a successful carrier pipe test would indicate defective end seals (depending on the type of containment piping: i.e.: FRP, SS, CS, etc.) or a breach in the wall of the containment pipe. The acceptable pressure deviation or pressure change criterion is 0%.

G-2.3.6 On Base Single-Wall Underground Piping Five-Year Test.

G-2.3.6.1 Test Pressure.

The test pressure for the five-year pressure test must be 150% of pump deadhead pressure minimum (including elevation difference from base of tank to pump plus full tank fuel level). Preferably, perform a pump deadhead test to confirm peak pressure, and adjust for fuel level in tank. Reasonable consideration should be taken to assure that selected test pressure is not less than 110% of pressures resulting from thermal pressure relief valve settings, which may be much higher than pump deadhead pressure (such as Type III Hydrant Systems).

G-2.3.6.2 Pressure Testing Options.

The options to complete the test include:

a. Five-year Option 1: Perform a strength test and conventional leak test at not less than 150% of pump deadhead or at 110% of the pressure resulting from thermal relief valve settings (whichever is greater). The testing must be executed by a qualified individual/organization experienced with using procedures meeting API 1110 procedures and performing pressure/temperature compensation calculations. Test duration must be a minimum of four hours for the strength test and four hours for the conventional leak test. The conventional leak test must immediately follow the strength test. A thorough visual inspection during the strength test should identify leaking flanges, instrument fittings, relief lines, valve stems, valve seats, etc. These deficiencies should be corrected prior to the conventional leak test by removing the components, installing flange skillets, plugging, or other methods of isolation or repair.

b. Five-year Option 2A: Perform a four hour strength test at not less than 150% of pump deadhead pressure or 110% of the pressure resulting from thermal relief valve settings (whichever is greater), and monitor calibrated gauges for potential leak causing pressure decay. Immediately follow the strength test by a third-party certified NWGLDE listed leak test at a pressure consistent with the certification of the system, and optimum for testing (generally 120 psig (827.4 kPa) to 150 psig (1034.1 kPa)).

c. Five-year Option 2B: Pressurized to the test pressure, and hold the pressure for two hours prior to a third-party certified test. Next, perform a third-party certified NWGLDE listed leak test at a pressure not less than 150 % of pump deadhead pressure or 110% of the pressure resulting from thermal relief valve settings (whichever is greater).

If the pipeline has been tested ANNUALLY by a third-party certified test at a pressure NOT LESS THAN pump deadhead pressure or the pressure resulting from thermal relief valve settings (whichever is greater), the requirement for a five-year test is waived.

G-2.3.7 Third Party Certified “Leak Detection” Systems.

Monthly testing with permanently installed proprietary vendor third-party certified “leak detection” systems that have received listing by the NWGLDE organization can be substituted for on base underground single-walled piping five year test as noted in Sections G-2.3.6.2(e) and G-2.3.3.1(b). Test must be conducted at NOT LESS THAN the pump deadhead pressure or the pressure resulting from thermal relief valve settings (whichever is greater). These systems are required to receive annual re-certification by the equipment vendor.

G-2.3.8 Off-Base Transfer or Supply Pipeline Annual Test.

An engineering assessment must be made to determine appropriate annual test pressure. In most cases, provide annual pump deadhead pressure test as noted for on-base pipeline systems in Section G-2.3.3, so long as flange ratings are not exceeded. Note that this will result in portion of the piping on longer pipelines being subject to test pressures considerably higher than normal operating pressures and thus is most appropriate when the system is constructed as an ANSI Class 150 system with a maximum allowable operating pressure of 275 psig (1896.1 kPa), and maximum test pressure of 450 psig (3102.6 kPa). For systems of higher ANSI pressure class construction and operating characteristics, a testing program must be developed and consider actual operating pressures along the pipeline, type of development along pipeline, age of system, history of cathodic protection, results from in-line intelligent pigging program and test liquid (fuel or water).

G-2.3.9 Off-Base Transfer or Supply Pipeline Five Year Test.

An engineering assessment must be made to determine appropriate five-year test pressure, or equivalent means of integrity management. Perform five-year test regime as follows:

a. Provide five-year strength and conventional leak test at a pressure higher than operating conditions ***only*** when required by state or Federal regulations or Service Control Point. Particular attention needs to be given to actual test pressures based on pipeline pumping operations, elevation changes along the pipeline, surge potential and type of development and population density along the pipeline. Test media (water or fuel) must be determined in accordance with regulatory and criteria documents. Testing with fuel is the preferred method.

b. Test methods as noted in Section G-2.3.6 for on-base pipeline systems can be considered, and must be coordinated with the Federal, state, and local regulations, and the Service Control Point.

c. For piggable off base pipelines, the use of in-line intelligent pigging on periodic basis (10 years maximum) to monitor corrosion and mechanical damage can significantly improve integrity management and eliminate the need for a 5-year pressure test regime, except when required by state or local regulatory body. Note that a written integrity management plan using in-line intelligent pigging has resulted in some regulatory bodies waiving the need for a 150% pump deadhead pressure test.

d. Note that under 49 CFR 195.452, if a pipeline is located in a "High Consequence Area," use of intelligent pigging on a five year increment is mandatory, (when the pipeline is considered regulated) and recommended otherwise, as a powerful threat assessment approach. The five year smart pigging interval will satisfy the need to perform a five-year pressure test, and has the added advantage of not resulting in testing of a pipeline with fuel at pressures far above normal operating pressure.

G-2.4 MARINE PIPELINES.

This section applies to areas under direct United States Coast Guard (USCG) jurisdiction, and Outside Continental United States (OCONUS) Installations with over-the-water fuel transfers.

G-2.4.1 33 CFR 154 and 33 CFR 156.

Marine facilities (or installation components that fall under marine conditions) must be tested in accordance with USCG regulations 33 CFR 154 and 33 CFR 156.

G-2.4.2 Piping Over Water.

Piping over water and not having a secondary containment system should consider testing with water when testing is above the maximum normal operating pressure. Pressure testing at maximum normal operating pressure may be with fuel. Where testing with fuel the use of spill containment booms around the test area is encouraged.

G-2.4.3 Tanker Offload Pressure.

The test pressure for the annual pressure test must be not be less than 150% of maximum delivery tanker pressure at the tanker rail before loading arm or hose, taking into consideration the pressure relief valve setting or high pressure cut off switch setting. It is recommended that the test pressure be not less than 225 psig (1551.3 kPa) based on most tankers' shutdown pressure setting of 150 psig (1034.1 kPa).

G-2.4.4 Barge Offload Pressure.

The test pressure for the annual pressure test must not be less than 150% of maximum delivery barge pressure at the barge rail before loading arm or hose, taking into consideration the pressure relief valve setting or high pressure cut off switch setting. It is recommended that the test pressure be not less than 175 psig (1206.6 kPa) based on most barges' shutdown pressure setting of 115 psig (792.9 kPa).

G-2.4.5 Issue Pressure.

When issuing to tankers and barges is possible, issue test pressure must be evaluated. The issue test pressure must consider the deadhead pressure of installation pumps, the static elevation difference, and the dynamic surge caused by pier emergency stop valves. It is possible for the issue test pressure to exceed the tanker/barge offload test pressure. When such conditions exist, use the issue test pressure for all piping, loading arm and hoses up to the point of connection to the receiving tanker/barge.

G-2.4.6 Aboveground Marine Piping Annual Test.

The test pressure for the annual pressure test must be derived from paragraphs G-2.4.3, G-2.4.4 and G-2.4.5 for duration of two hours minimum. All components must be visually inspected for leaking. Addition or withdrawal of fuel during testing is permitted due to loss of pressure from valve seat bypass or to prevent overpressure (thermal gain). Addition or withdrawal of fuel during testing is only permitted if entire system is aboveground. If any portion of the piping is underground and cannot be visually inspected, underground pipeline testing procedures must apply.

G-2.4.7 Underground Marine Piping Annual Test.

The options to complete the test include:

a. Annual Option 1: Perform a strength test and conventional leak test at a pressure derived from paragraphs G-2.4.3, G-2.4.4, or G-2.4.5 as appropriate. The testing must be executed by a qualified individual/organization experienced using procedures meeting API 1110 procedures and performing pressure/temperature compensation calculations. Test duration must be a minimum of four hours for the strength test and four hours for the conventional leak test. The leak test must immediately follow the strength test. A thorough visual inspection during the strength test should identify leaking flanges, instrument fittings, relief lines, valve stems, valve seats, etc. These deficiencies should be corrected prior to the conventional leak test by removing the components, installing flange skillets, plugging, or other methods of isolation or repair.

b. Annual Option 2: Conduct a two hour pressure soak at a pressure derived in paragraphs G-2.4.3, G-2.4.4, or G-2.4.5 as appropriate, and monitor calibrated gauges for potential leak causing pressure decay, followed by third-party certified NWGLDE listed leak test, at the same pressure, with the permission of the USCG Captain of the Port (COTP). Note: During a pressure soak, the tester blocks in the pressure and does not allow for volume change. During the test, pressure is relieved to prevent over-pressurizing if required.

G-2.5 SERVICE STATION PIPELINES.

G-2.5.1 General Requirements.

Due to the multiple types of piping system materials, single or double-wall pipe, piping components (line leak detectors, leak detection systems), fiberglass and coaxial piping, small bore piping (2 inch and less) and low operating pressures (less than 50 psig (344.7 kPa)), the annual and 5-year testing requirements as described in Section G-2.3 do not translate well for this type of system. Wherever possible, the requirements of state or host nation rules must be utilized to satisfy pipe integrity investigation to maintain consistency on regulated tank and connected piping installations. When specific state or host nation rules are lacking, the piping integrity must be considered. The use of a third-party certified NWGLDE listed leak test (see NWGLDE website, many vendors and systems are approved) may be appropriate. Even when tanks are aboveground, if underground piping is used to service dispensers, the use of a NWGLDE vendor and procedure is still appropriate.

G-2.5.2 Service Station Aboveground Piping Annual Test.

The test pressure for the annual pressure test must be not less than pump deadhead pressure for duration of two hours minimum. All components must be visually inspected for leaking. Addition or withdrawal of fuel during testing is permitted due to loss of pressure from valve seat bypass or to prevent overpressure (thermal gain). Note that in very small systems receiving fuel from delivery vehicle pump, observation of the receipt line under pressure is sufficient when there is no means (tank valve) to otherwise test the receipt line. When a small system consists of a suction withdrawal from the tank, with closely positioned dispenser with pump, and the suction line cannot be tested when there is no means (tank valve) of isolation, a visual inspection for exterior pipe corrosion will satisfy integrity requirements.

G-2.5.3 Service Station Underground Piping Annual Test.

The test pressure for the annual pressure test must be not less than pump deadhead pressure for duration of two hours minimum unless being tested in combination with an attached UST. The test procedure must be as required and approved by the host nation, state or local regulatory jurisdiction.

G-2.5.4 Service Station Combined Aboveground and Underground Annual Test.

When testing aboveground and underground piping together due to configuration of system, use of a third-party certified and NWGLDE procedure is encouraged, or utilizes a pump deadhead pressure test only when the underground piping is in secondary containment. The test must include a check of secondary containment for fuel after the pressure test.

G-3 CRITICAL TERM DEFINITION.

G-3.1 Introduction.

This section provides guidance on the definition of terms normally used in developing pressure testing documentation. Several of the guidance/criteria documents use poorly defined terms. Table G-3.1 summarizes what can be determined or inferred from the available information. Unfortunately, mixing the definition of the terms, or applying them too loosely may result in inappropriate conclusion

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Table G-2 /1/ Definition of Terms

Item	Term	Abbreviation For	Definition and Commentary
A	MOP, MAOP	"Colloquial version" Maximum Operating Pressure, or Maximum Allowable Operating Pressure	Must be the worst case sustained internal pressure under the worst combination of internal and external pressure at a given point on a pipeline, and must consider deadhead of pumping, static head, and resultant pressure from thermal relief conditions (and cascade). Some exceptions apply depending on frequency and duration. Pressure must be supported by a qualifying hydrostatic test at 125% (B31.4) or 150% (B31.3).Does not include transient pressure, such as a surge event, which can exceed (to a limit) MOP under many codes.
B	MAWP	Maximum Allowable Working Pressure API 570 §3.1.49	"The maximum internal pressure permitted in the piping system for continued operation at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service. It is the same as the design pressure, as defined in ASME B31.3 and other code sections, and is subject to the same rules relating to allowances for variations of pressure or temperature or both."
C	NOP	"Colloquial version" Normal Operating Pressure	Generally considered the pressure of dynamic operations, such as the pressure gauge on a pump discharge, or the pressure at any point on a pipeline taking into consideration elevation and pressure gradient.
D		From ASME B31.4 § 400.2	"*internal design pressure:* internal pressure used in calculations or analysis for pressure design of a piping component (see para. 4-1.2.2): Comment: Internal design pressure must be not less than maximum steady state operating pressure.
E	MOP	Maximum Operating Pressure defined under 40 CFR 195 § 195.2	*"Maximum operating pressure (MOP)* means the maximum pressure at which a pipeline or segment of a pipeline may be normally operated under this part." (Similar to ASME B31.4 definition for NOP)

Item	Term	Abbreviation For	Definition and Commentary
F	NOP	NOP from ASME B31.4 § 400.2	"*maximum steady state operating pressure:* Maximum pressure (sum of static head pressure, pressure required to overcome friction losses, and any back pressure) at any point in a piping system when the system is operating under steady state conditions.
G	MAWP	Maximum Allowable Working Pressure 33 CFR 154.500	"(b) The maximum allowable working pressure (MAWP) for each hose assembly must be more than the sum of the pressure of the relief valve setting (or the maximum pump pressure when no relief valve is installed) plus the static head pressure of the transfer system, at the
H		design pressure API 570 § 3.1.18	"The pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service."
I		overwater piping API 570 § 3.1.60	"Piping located where leakage (liquid or solids) would result in discharge into streams, rivers, bays, etc., resulting in a potential environmental incident." *(Note, does not require pipe to be physically over the water)*

G-4 CRITERIA SURROUNDING PIPELINE PRESSURE TESTING.

G-4.1 INTRODUCTION.

This section provides the current criteria for pipeline pressure testing and the discussion of its applicability to the Department of Defense POL pipelines and methods of testing and determination for integrity assessment. Tables G-4.1 and G-4.2 lists the criteria and provides a discussion of its applicability to the guidelines stated in Section G-2.

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Table G-2 /1/ Military Requirements

Item		Issue - Parameter	Testing Requirement
i	1	Testing Requirement – UFGS 33 52 43	UFGS Specification Section 33 52 43 "Aviation Fuel Distribution Systems," May 2011. This specification is to be used for new piping or major renovated piping systems. Extract of pressure testing requirements follows: 3.2.2.4 Hydrostatic Test Hydrostatically test product piping with the system operating fuel. Test at the corresponding pressures identified in Table 2 for the corresponding product piping material type. Maintain the pressure within the piping for 4 hours with no leakage or reduction in gauge pressure. If leaks are discovered, repair the leaks accordingly and retest. Table 2. Hydrostatic Test Pressures Product Piping Material Type / Min Test Pressure / Max Test Pressure Carbon Steel / 2930 kPa 425 psig / 3103 kPa 450 psig Stainless Steel (1) / 2758 kPa 400 psig / 2930 kPa 425 psig Stainless Steel (2) / 2241 kPa 325 psig / 2413 kPa 350 psig Aluminum / 1724 kPa 250 psig / 1896 kPa 275 psig Notes: 1. Grade F304 Flanges Used 2. Grade F304L Flanges Used
	2	Waivers and Deviations to Criteria	The Air Force, Army, and Navy Criteria specialists (Service HQ) are able to grant waivers or deviations.
	3	Comment and Recommendation	Pressures stated in the UFGS were derived from ASME B16.5. Water can be used and easily disposed of if the piping is new and no part of it has ever had fuel in it, and it can be thoroughly drained from the pipeline. ASTM B31.3 permits testing with fuels having a flash point of 120 °F (48.9 °C). Testing with fuel is acceptable in special cases (i.e., when draining of water is not obtainable). Obtain waiver for testing with JP-8 (100° minimum flash point) when needed.

Notes:

1. Pump deadhead pressure is the maximum pressure at no flow with fuel level at or near high condition in source tank. For the purposes of the pressure determination, do not use normal operating pressure. Dead head pressure is normally 10% to 25% above normal operating pressure. Determine deadhead pressure by starting pump and slowly closing discharge valve and reading the maximum discharge pressure. Do not operate at no flow for more than a minute.
2. Most thermal pressure relief valves associated with pump discharge piping in the pumphouse in particular must be set above pump deadhead otherwise they would discharge every time the pump deadheads. Normally they should be set a minimum of 10% above system deadhead pressure. If system testing is only to pump deadhead, it is not as high as the relief valve settings. For annual testing this is generally considered acceptable. For periodic integrity testing (i.e. five-year test), the test pressure should exceed the thermal relief valve pressure, in order to provide a valid strength test. This is the case with a five-year test at 150% of pump

deadhead. As thermal relief most likely is 10%-20% above pump deadhead, a test at 150% above deadhead will be above peak pressure of thermal relief valves.

3. ANSI Class 150 systems may be tested to the limit of flanges, per ASME B16.5 as follows:

Pipe Class and Material	Maximum Operating Pressure	Maximum Test Pressure
Class 150 Carbon Steel	285 psig 1965.0 kPa	450 psig 2102.6 kPa
Class 150 Stainless Steel (with 304 or 304/304L flanges)	275 psig 1896.1 kPa	425 psig 2930.3 kPa
Class 150 Stainless Steel (with 304L flanges)	230 psig 1585.8 kPa	350 psig 2413.2 kPa

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Table G-3 /1/ Commercial and Industrial Guidelines

ITEM		ISSUE - PARAMETER	TESTING REQUIREMENT
A	1	Testing protocol & Requirement – API 570	API 570 Piping Inspection Code, Third Edition (11-2009)
	2	Test Pressure Criteria and duration- aboveground piping.	The majority of API 570 addresses aboveground piping. API 570 5.8 states "Pressure tests are not normally conducted as a part of routine inspection", but when performed, must be completed in accordance with ASME B31.3 requirements.
	3	Test Pressure Criteria, modified systems	8.2.7 covers pressure testing after making system repairs or modifications that include welding of the pipe, in accordance with ¶5.8. When pressure testing is not practical, certain NDE steps may be substituted for the pressure test so long as other installation requirements are met.
	4	Pressure Testing Alternatives	5.8.5 Addresses special cases: "Appropriate NDE must be specified and conducted when a pressure test is not performed after a major repair or alteration. Substituting NDE procedures for a pressure test after an alteration is allowed only after the engineer and inspector have approved the substitution. For cases where UT is substituted for radiographic inspection, the owner/user must specify industry-qualified UT shear wave examiners or the application of ASME B31 *Code Case* 179/181, as applicable, for closure welds that have not been pressure tested and for welding repairs identified by the engineer or inspector.

<table>
<tr><th>ITEM</th><th></th><th>ISSUE - PARAMETER</th><th>TESTING REQUIREMENT</th></tr>
<tr><td></td><td>5</td><td>Test Pressure Criteria and duration- underground piping (Section 9 specifically deals with underground piping)</td><td>9.3.7 Indicates that a pressure test may be used as an integrity management tool in lieu of other methods. The pressure test is a leak test at not less than 110% of the maximum operating pressure, at an interval shown in Table 9-1 for a cathodically protected system and at ½ the interval for an underground system that is not cathodically protected.
The test must be 8 hours in duration, with the first 4 hours to stress the system, and the last 4 hours being the actual data collection period.
If the pressure drops more than 5% over the course of the test, an investigation must be conducted, including internal and external evaluation of corrosion.</td></tr>
<tr><td></td><td>6</td><td>Comment:</td><td>Table 5 below is primarily the intervals indicated for smart pigging or direct excavation, when deemed important for determining integrity of system, but is also used for the intervals for pressure testing as noted above.</td></tr>
<tr><td></td><td>7</td><td>Table 5 from API 570</td><td>Table 5—Frequency of Inspection for Buried Piping Without Effective Cathodic Protection
<table>
<tr><th>Soil Resistivity (ohm-cm)</th><th>Inspection Interval (years)</th></tr>
<tr><td><2,000</td><td>five</td></tr>
<tr><td>2000 to 10,000</td><td>10</td></tr>
<tr><td>>10,000</td><td>15</td></tr>
</table></td></tr>
<tr><td></td><td>8</td><td></td><td>API 570 9.3.7 also recognizes the use of other testing procedures including temperature corrected volumetric, pressure, and addition of a tracer inoculant.</td></tr>
<tr><td></td><td>9</td><td>Comment and Interpretation</td><td>API 570 supports the premise that a leak, pressure or hydrostatic test provides satisfactory investigation into the integrity of underground piping. Note that API 2611 (draft) calls for 150% testing of MOP, not 110% of MOP as in API 570. This may be a result of pressure testing of terminal piping that may not be done to a standard as high as in a refinery.
Lacking other evidence (such as leak history) or direct knowledge on pipe surface condition from excavation or smart pigging, use of pressure/leak testing is the appropriate degree of investigation necessary. Use of smart pigging, LRUT, or excavation is not a mandatory API requirement. As API 570 does not clearly identify what is “maximum operating pressure”. This document defines it to be the greater of maximum system deadhead, or thermal relief valve setting.</td></tr>
<tr><td></td><td>10</td><td>Test Fluid</td><td>5.8.1 states that test fluid must be water, unless damage may occur due to freezing, or unless contamination presents unacceptable environmental risk. If tested with fuel, the flash point must be 120 °F (48.9 °C) or greater.</td></tr>
</table>

ITEM		ISSUE - PARAMETER	TESTING REQUIREMENT
	11	Comment and Interpretation	JP-8 (100 °F (37.8 °C) flash point) is regularly used in the military for pipeline pressure and hydrotesting due to the greater risk of product contamination from testing with water. JP-5 (140 °F (60 °C) flash point) meets the criteria. The military has accepted the risk of using JP-8 for testing. Need to confirm state requirements as well to see if a waiver is needed. Some states, such as CA, mandate water but have permitted using JP-5 on some tests.
B	1	Testing protocol & Requirement – API RP 2611	API RP 2611 1st Edition, June 01, 2011, *Terminal Piping Inspection – Inspection of In-Service Terminal Piping Systems*. *Note, the document is in response to the industry needing a companion to API 570 that better reflects operating conditions, risk and consequence of terminal operations, as compared to refinery operations covered under API 570.*
	2	Test Pressure Criteria and duration- aboveground piping.	API RP 2611 5.5.5 states that leak testing is not a stand-alone integrity test, but should be performed in conjunction with other integrity tests such as corrosion under insulation and wall thickness analysis.
	3	Test Pressure Criteria and duration - underground piping.	§ 7 addresses the overall assessment of underground piping and stresses use of both knowledge of the age and history of a system, cathodic testing and coating testing procedures, but does not specifically call for pressure testing. However pressure testing is noted as a viable means of integrity assessment, with little stated on its pressure levels or duration. The frequency of testing is dependent on a variety of factors noted, and ranges from 5 to 25 years.
	4	Frequency of Inspection	Table 6-1 in API RP 2611 is primarily the intervals indicated for smart pigging or direct excavation, when deemed important for determining integrity of system, but is also used for the intervals for pressure testing as noted.
	5	Comment and interpretation	• API RP 2611 supports the premise that a leak, pressure or hydrostatic test provides satisfactory investigation into the integrity of underground piping. • Lacking other evidence (such as leak history) or direct knowledge on pipe surface condition from excavation, use of pressure/leak testing is an appropriate degree of investigation necessary. Use of smart pigging, Long-Range Ultrasonic testing (LRUT), or excavation is not a mandatory API requirement. As API RP 2611 does not clearly identify what is "maximum operating pressure". This document defines it to be the greater of maximum system deadhead, or thermal relief valve setting.
C	1	Testing protocol & Requirement -ASME B31.3	ASME B31.3 Process Piping, 2012

ITEM		ISSUE - PARAMETER	TESTING REQUIREMENT
	2	Test Pressure Criteria and Duration	345.4.2 states that pipe must be tested to not less than 1.5 times the maximum design pressure. "Design Pressure is the most severe combination of internal and external pressure expected during service" (ASME B31.3 Par 301.2.1). Note that the test pressure is limited to the maximum rating for flange testing per ASTM B16.5, Flanges. Per 345.2.2, the minimum test duration for examination of connections and joints is 10 minutes. Most systems will take longer to physically inspect. 345.2.1 (b) permits the use of a pneumatic test at up to 25 psig (172.4 kPa) to find major leaks, prior to the liquid hydrotesting.
	3	Comment and Interpretation	ASME B31.3 was written for new piping installation into a new, or modified system. It was not written for periodic integrity testing. Several codes, such as API 570, reference ASME B31.3 as the governing document for pressure testing in certain circumstances.
	4	Test Fluid	345.4.1 states that test fluid must be water, unless damage may occur due to freezing, or unless contamination presents unacceptable environmental risk. If tested with fuel, the flash point must be 120 °F (48.9 °C) or greater.
	5	Comment and Interpretation	JP-8 (100 °F (37.8 °C) flash point) is regularly used in the military for pipeline pressure and hydrotesting due to the greater risk of product contamination from testing with water. JP-5 (140 °F (60 °C) flash point) meets the criteria.
	6	Closure Weld Testing	345.2.3 Addresses testing of closure welds (tie-in welds). So long as the components/piping being installed into the system have been pre- tested, the final closure or tie-in weld need not be leak tested provided the weld is examined in-process in accordance with 344.7 and passes with 100% radiography or 100% ultrasonic examination in accordance with 344.6.
	7	Comment and Interpretation	This paragraph is important as it validates not hydrotesting an existing system, when a change or repair is made, so long as more rigorous examinations are made of the tie-in weld, and the new components are pretested.
	8	Testing of Vessels and piping together	345.4.3 addresses the testing of vessels and pipe together so long as the following is met: If the test pressure of the pipe is equal or less than test pressure of the vessel, testing to the piping test pressure is permitted. If the test pressure of the pipe exceeds the test pressure of the vessel, combined testing is permitted at the vessel test pressure, provided the owner approves of the reduced test pressure, and the pressure is not less than 77% of the piping test pressure calculated in accordance with 345.4.2(b)
	9	Comment and Interpretation	Testing together simplifies many testing scenarios.

ITEM		ISSUE - PARAMETER	TESTING REQUIREMENT
D	1	Testing protocol & Requirement - ASME B31.4	ASME B31.4 Pipeline Transportation for Liquid Hydrocarbons – 2012 Although commonly applied to cross country pipelines, ASME B31.4 can also be applied to connected terminals, in lieu of ASME B31.3, although there is no particular advantage in doing so.
	2	Test Pressure Criteria and duration	437.4.1 states that piping systems operated at a hoop stress of more than 20% of Specified Minimum Yield Strength (SMYS) must be proof tested to not less than 1.25 times the internal design pressure at that point per 401.2.2. The test duration is not less than 4 hours. 401.2.2 "Internal Design Pressure" is not less than the steady state operating pressure at that location, or static pressure when higher. Per 437.4.1(2) if the line undergoing testing is not fully inspectable for leaks, the proof test must be followed by a leak test at not less than 1.10 times the internal design pressure, for not less than an additional 4 hours.
	3	Comment and Interpretation	This piping code was written for long transportation pipelines with potential large grade and hydraulic grade changes. Once placed in operation these lines have a greater predictable operating pressure range, thus the less conservative 1.25 test as compared to ASME B31.3 with a 1.5 times pressure test.
	4	Test Fluid	437.l.1(c) Test fluid must be water, except liquid petroleum that does not vaporize rapidly may be used provided: The pipeline is outside of a city and populated area, and is not underwater. All buildings within 300 ft (91.5 meters) of the pipeline are unoccupied during the test when the pressure produces a hoop stress exceeding 50% of SMYS.
	5	Comment and Interpretation	JP-8 (100 °F (37.8 °C) flash point) meets the criteria of permissible petroleum for testing.
	6	Tie-in Weld Testing	437.1.4 Addresses testing of closure welds (tie-in welds). So long as the components/piping being installed into the system have been pre-tested, the final closure or tie-in weld need not be leak tested provided the weld is examined in- process and passes with 100% radiography or 100% ultrasonic examination in accordance with 434.8.5(a)(4).
	7	Comment and Interpretation	This paragraph is important as it validates not hydrotesting an existing system, when a change or repair is made, so long as more rigorous examinations are made of the tie-in weld, and the new components are pretested.
E	1	Testing Protocol & Requirement - 49 CFR 195	Subpart E – Pressure Testing

ITEM		ISSUE - PARAMETER	TESTING REQUIREMENT
	2	Test Pressure Criteria and duration	§ 195.304 "…maintain for 4 hours at a pressure equal to 125%, or more, of the operating pressure and, in the case of a pipeline that is not visually inspected for leakage during the test for at least an additional 4 continuous hours at a pressure equal to 110% or more, of the ***maximum operating pressure***. (Nov. 4, 1998).
	3	Comment and Interpretation	"Maximum Operating Pressure is defined in § 195.2 "Definitions" as: *Maximum operating pressure (MOP)* means the maximum pressure at which a pipeline or segment of a pipeline may be normally operated under this part. B31.4 uses the term "maximum internal design pressure" as the basis for design, as well as the starting point for the 125% test pressure. B31.4 further states that the maximum internal design pressure must not be less than the steady state operating pressure at any point on a pipeline. Taking the above into consideration, the design engineer may use steady state operating pressure or deadhead pressure as the basis for the 125% pressure test. Presumably, if the steady state pressure is used, there must be operational controls that are failsafe in not permitting a pipeline to deadhead at a higher pressure than steady state pressure. For typical short military pipelines this report recommends using deadhead as the basis for any pressure testing due to any means of preventing a dead head (such as startup) is an unrealistic expectation.
	4	Test Fluid	§195.306 Requires water to be used for testing but permits the use of a flammable liquid if the pipeline is not offshore and is outside of cities and populated areas, the fluid does not rapidly vaporize, and if the test pressure results in a hoop stress greater than 50% of SMYS, all buildings must be unoccupied within 300 feet (91 meters) of the pipeline under test, and there is continuous communication along the entire test section.
	5	Comment and Interpretation	The use of water and fuel as a test medium is similar in nature to ASME B31.3, except an actual flash point of the fuel is not noted.
F	1	Testing protocol & Requirement - 33CFR Part 154 and Part 156	33 CFR Part 154 Facilities Transferring Oil or Hazardous Material in Bulk 33 CFR Part 156 Oil and Hazardous Material Transfer Operations (i.e., USCG regulations for ports)
	2	Test Pressure Criteria and duration- aboveground piping and equipment.	§156.170, Equipment Tests and Inspections, (c)(iii) requires that hose and loading arms not burst at 1½ times the Maximum Allowable Working Pressure (MAWP). The Operations Manual must indicate per §154.310(a)(16) "The maximum allowable working pressure (MAWP) of each loading arm, transfer pipe hose assembly required to be tested by §156.170 of this chapter, including the maximum relief valve setting (or maximum system pressure when relief valves are not provided) for each transfer system."

ITEM		ISSUE - PARAMETER	TESTING REQUIREMENT
	3	Test Pressure Criteria and duration-	§156.170 (f)(1) Requires the tests to have been accomplished within the last 12 months prior to a transfer ¶(h) permits alternative compliance testing when approved by the Captain of the Port (COTP). §154.105 "Definitions" defines "Marine Transfer Area" to be the part of the waterfront area between the vessel and the first valve inside a containment required by 40 CFR 112 or 49 CFR 195, or if no containment area, to the valve on the receiving tank.
	4	Comment and Interpretation	The requirements for testing of piping and systems under USCG jurisdiction is not clear, and requires a read of various sections as noted above. Traditionally the maximum over the water transfer pressure is limited to 150 psig (1034.1 kPa) by agreement or mandate of the COTP. This does vary. Traditionally the maximum over the water transfer pressure at government facilities is 100 psig (689.4 kPa). This has been attributed to tradition or in some cases, the contract maximum under the MSLC tanker contracts, but has not been verifiable. Traditionally the required test pressure in many ports has been 150 psig x 150% = 225 psig (1034.1 kPa x 150% = 1551.3 kPa). This however can be deficient when a variety of factors and system features could lead to a higher surge pressure that is within the capability of a properly tested ANSI Class 150 system. It is clear testing is required annually. It is not clear what the duration or test standard requirement is. Traditionally the test is for one hour, with procedures left up to the local region and owner. Consideration must be given to issue to ships and barges operations having higher deadhead conditions than a delivery tanker, thus hydrotesting must be accomplished to a higher pressure.
	5	Test Fluid	§156.170 (c)(iv) The test medium does not need to be water.
	6	Comment and Interpretation	This paragraph is discussing the testing of hoses, which is normally done above deck, within a contained area, thus testing with fuel is possible if deemed appropriate. This paragraph should not be considered a justification to test over the water piping with fuel. That decision is best made based on the risk of failure and consequential spill to the water.

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G-5 PIPELINE PRESSURE TESTING GUIDELINES AND CRITERIA SUMMARY TABLE

Pipeline Pressure Testing Guidelines and Criteria SUMMARY TABLE				
Pipe Location/Test	**Basis of Test Pressure**	**Duration**	**Type of Testing**	**Comments**
USCG/Marine Service, Over water/aboveground - Annual Pressure Test	150% of highest delivery pressure (relief valve or pressure switch)	2 hr	100% observation for leaks (1)	225 psig (1551.3 kPa) test suggested in most cases (based on tankers with 150 psig (1034.1 kPa) relief/shutdown) or 175 psig (1206.6 kPa) (based on barges with 115 psig (792.9 kPa) relief/shutdown). Also, the issue pressure must be calculated as this pressure may exceed offload pressures.
USCG/Marine Service, Underground - Annual Pressure Test	150% of highest delivery pressure (relief valve or pressure switch)	2 hr (min)	Accurate pressure monitor, reconcile temperature-pressure change (2) 5-year Option 1 testing meets criteria. 5-year Option 2B acceptable with permission of the USCG COTP	225 psig (1551.3 kPa) test suggested in most cases (based on tankers with 150 psig (1034.1 kPa) relief/ shutdown) or 175 psig (1206.6 kPa) (based on barges with 115 psig (792.9 kPa) relief/shutdown). Also, the issue pressure must be calculated as this pressure may exceed offload pressures.
Base Piping, Aboveground - Annual	Greater of pump deadhead, or PSV setting/cascade	2 hr	100% observation for leaks (1)	Suggest not less than 50-100 psig (344.7-689.4 kPa) for pump suction lines not subject to discharge pressure.
Base Piping, Underground - Annual (Annual Option 1)	Greater of pump deadhead, or PSV setting/cascade	2 hr (min)	Accurate pressure monitoring, pressure change, if any, must be within small range and or reconciled with fuel temperature change (2)	To minimize effect of changing temperature, fuel should be allowed to reach equilibrium, and testing occur at time of day with little solar influence or rapid temperature change.
Base Piping, Underground - Annual (Annual Option 2)	Test at greater of deadhead or PSV setting/cascade using third- party certified procedure	Per certs	Third-party certified and NWGLDE listed and DLA-E approved procedure (6)	If conducted ***every year*** this procedure, with lower pressure testing also satisfies the 5-year 150% testing requirement.
Base Piping, Double Wall Underground – Annual (with air testable and low point checking secondary containment capability) (8)	Test carrier pipe using USCG or non-USCG annual piping (as applicable)	Per above	Per above procedure selected	After testing, confirm no product at all low points in secondary containment system. **Every 5 years provide secondary containment integrity test per manufacturer's instructions, normally a 2 hour 10-15 psig (68.9-103.4 kPa) test.**
Base Piping, Underground - (5-year Option 1)	Greater of 150% of deadhead or 110% of PSV setting/cascade	8 hr	Precision temperature and pressure measurement and reconciliation of temperature-pressure change (3)	Minimum 4 hour analysis period over test cycle.
Base Piping, Underground - (5-year Option 2A)	Strength test at greater of 150% of deadhead or 110% of PSV setting/ cascade, followed by third-party certified leak test	4 hr strength	Strength (4) Leak – Third-party certified and NWGLDE listed (5)	Acceptable even when 150% strength test pressure is above leak test pressure.

Pipeline Pressure Testing Guidelines and Criteria SUMMARY TABLE				
Pipe Location/Test	**Basis of Test Pressure**	**Duration**	**Type of Testing**	**Comments**
Base Piping, Underground - (5-year Option 2B)	Test at greater of 150% of deadhead or 110% of PSV setting/cascade using third-party certified leak test	2 hr soak	2 hr "soak" at test pressure to bring to equilibrium, followed by third-party certified and NWGLDE listed (5) (10)	Generally appropriate only when the 150% test pressure is within the third-party certified test protocol limits.
Base Piping, Underground - with in- situ leak detection system	Per third-party certification, scheduled for testing on monthly frequency minimum	Per certs	Third-party certified and NWGLDE listed (5)	Annual recertification required.
Off Base, Underground - Annual	Greater of pump deadhead, or PSV setting/cascade	2 hr	Accurate pressure monitor, reconcile temperature-pressure change (2)	Actual test pressure needs to be validated and to consider resultant pressure along entire pipeline, test media (flash point restrictions), and density/type of population.
Off Base, Underground - Annual (Alternative)	Leak test	Per certs	Leak – Third-party certified and NWGLDE listed (5)	An engineering review required to determine appropriate test pressure.
Off Base, Underground - 5-year	Higher then operating-deadhead conditions, but must be assessed. In some cases use of high pressure shutdown is acceptable. (may be up to 150%)	Per reg	Precision temperature and pressure measurement and reconciliation of temperature-pressure change (3)	Only required when mandated by regulations. (Not a normal requirement) Consider intelligent pigging as integrity management tool (7).
Off Base, Underground - 5-year -Alternative	Equal to or higher then operating-deadhead conditions, but must be assessed. In some cases use of high pressure shutdown is acceptable.	Per reg	Strength (4) Leak – Third-party certified and NWGLDE listed (5)	Only required when mandated by regulations or Service Control Point. (Not a normal requirement) Consider intelligent pigging as integrity management tool (7).
Service Station, Above and Underground - Annual or Periodic	Pump deadhead, or per state Regulations	Per reg	If all aboveground, visual. If above and underground, precision test as required/approved by local/state regulatory jurisdiction (9)	Meet UST regulations.

Pipeline Pressure Testing Guidelines and Criteria

SUMMARY TABLE

Pipe Location/Test	Basis of Test Pressure	Duration	Type of Testing	Comments

1. Visual test, maintain pressure over duration and inspect 100% of system for weeps and leaks.
2. Acceptable pressure deviation or pressure change criteria established by Service Control Point, taking into consideration installation location, size of system, and historical testing results.
3. A conventional pressure test as used in this Table is a temperature compensated and volume/pressure change leak test at not less than 150% of pump deadhead by a qualified individual/organization with API 1110 developed procedures. Use of the California State Fire Marshall's procedure is acceptable, but not necessarily conclusive in all cases.
4. A strength test as used in this Table is a pressure test at not less than 150% of pump deadhead, conducted with a calibrated pressure gauge, for a duration of not less than 4 hours, but does not attempt to reconcile pressure change with fuel temperature change as is required by conventional pressure test. Low volume leaks may go unrecognized. To qualify for integrity testing, a strength test must be followed by a conventional leak test.
5. Integrity testing using a third-party certified and National Work Group on Leak Detection Evaluations (NWGLDE) listed short duration proprietary procedures are acceptable in principle. Selected method must be certified for system parameters such as pipe size and liquid volume. To qualify as an integrity test the procedure ***must utilize a pressure consistent with integrity management principles***, not just a minimum pressure required to conduct the test. Alternatively, a lower pressure third-party certified leak test can be conducted after a strength test.
6. Note that a third-party certified NWGLDE listed procedure, if conducted every year ***at not less than greater of pump deadhead or PSV settings*** is an acceptable means of meeting the 5-year testing requirement (without requiring a 5-year 150% test).
7. For piggable off base pipelines, the use of in-line intelligent pigging on periodic basis (10 years maximum) to monitor corrosion and mechanical damage can significantly improve integrity management and eliminate the need for any 5-year testing regime, except when required by local or state regulatory body.
8. If secondary containment is not air pressure testable and capable of being checked at all low points for liquid, the primary carrier piping system must be tested using any one of the appropriate underground pipe testing methods.
9. Due to the myriad of piping system materials, single or double wall pipe, and piping components (line leak detectors, leak detection systems), fiberglass and coaxial piping, the annual and 5-year testing requirements do not translate well for this type of system, with small bore piping (2" and less) and low operating pressures (less than 50 psig (344.7 kPa)), thus use of a certified testing procedure and company is more appropriate company is more appropriate. Even when tanks are aboveground, if underground piping used to service dispensers, the use of UST testing organizations still is appropriate.
10. It is the intent that the 2-hour "soak" permit the piping segment under test be visually inspected for leaks and weeps, and to stretch to test pressure, thus improving testing accuracy. This 2-hour soak can be coincident with a similar purpose procedure of the testing organization,

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APPENDIX H TANK CLEANING GUIDANCE

This Appendix provides minimum standards for safe entry, inspection, and cleaning guidance of liquid petroleum fuel tanks for DoD personnel.

H-1 RESPONSIBILITY.

Military services will comply with their respective safety equipment certification (e.g., respirator) and task training certification (e.g., confined space entry, tank cleaning, medical) programs.

H-2 COORDINATION.

Coordinate with facility agencies (i.e., tank operators, Installation Environmental Office, Installation Safety Office, local fire department, and military service-specific headquarters), when applicable, to facilitate lowering product levels in tanks, alternate tank use during cleaning, hot work permits, disposal of waste, and coordination of safety related procedures (i.e., egress, rescue, and fire).

H-3 TANK CLEANING PREPARATION.

H-3.1 Unless superseded by Military service-specific directives, the following guidance details the minimum requirements for tank preparation prior to cleaning.

H-3.2 Secure (e.g., fence, rope, tape) and clear the work areas of all non-essential personnel. Isolate tank openings by establishing a perimeter of 50 feet (15.2 meters) and post warning signs (e.g., Do Not Enter Tank Entry in Progress) to identify the work being accomplished. If the area is subject to high foot or vehicle traffic; tank cleaning team members should be posted to ensure that unauthorized personnel and vehicles do not enter the established perimeter.

H-3.3 Consider projected weather conditions to ensure a safe working environment throughout the cleaning process. The potential of electrical storms, severe weather, or changes in the direction may produce hazardous conditions that could impact the cleaning process.

H-3.4 Remove all ignition sources from surrounding areas.

H-3.5 Move all flame-producing devices to a designated safe area prior to entry.

H-3.6 Inspect equipment and tools for serviceability and hazards. Complete necessary adjustments and calibrations prior to entry. Cleaning equipment and tools should be placed upwind of tank openings and at the highest elevation possible to minimize hazards. Cleaning equipment and tools should never be placed in an area lower than the surrounding terrain.

H-3.7 Inspect grounding and bonding cable connection points, wires, and clips for serviceability. In addition, check wire and connections for electrical continuity with an ohmmeter. Replace damaged and broken items prior to beginning tank cleaning operations.

H-3.8 Turn off cathodic protection systems prior to disconnecting pipelines from tanks.

H-3.9 Verify PPE is in proper working order.

H-3.10 Test the area around the tank for explosive vapors using a combustible gas detector before equipment is started which may be a source of ignition.

H-3.11 Ensure an emergency shower/eyewash is available and serviceable in the immediate area. Portable emergency eyewash units are acceptable if approved by the facility's authorizing agency.

H-4 TANK PREPARATION.

H-4.1 Isolate the tank to ensure product does not reenter the tank once draining procedures have commenced.

H-4.2 Tank isolation must be conducted in accordance with military service or contract lockout/tagout procedures. Ensure tank isolation is established to prevent product from reentering the tank.

H-4.3 Lockout/tagout all electrical equipment and necessary valves. Isolate all piping by removing valves and installing blind flanges, spectacle blinds, or skillet flanges to prevent fuel or vapors from returning to the tank.

H-4.4 Blind and spectacle flanges must be able to withstand any pressure the system is able to produce. If spectacle blinds are used, insert the blind between the tank valve and the flange nearest the tank.

H-4.5 No valve or piping is to be disconnected from any tank component until it is verified that the line has been emptied of product and a bonding cable has been installed between pipe flanges.

H-4.6 Tanks with floating roofs or pans pose additional inspection requirements. All applicable military service directives or industry standards will apply when inspecting floating roofs or pans (e.g. harness, confined space, atmospheric testing).

H-4.7 Qualified personnel must visually inspect the floating roof or pan to ensure the roof or pan is safe for inspection. Personnel will ensure the roof or pan support legs and sleeves (to the extent possible) have the ability to support the roof or pan.

H-4.8 Inspect the roof or pan pontoons, buoyant foam panels, and seals for fuel and water and drain as necessary to facilitate vapor and gas freeing of the tank space.

H-4.9 Qualified personnel must inspect anti-rotation pipes and guide cables to ensure proper function as the roof or pan descends.

H-4.10 Floating roof or pan leg pins must be placed in the high roof or pan position to allow for maximum space under the roof or pan to facilitate tank cleaning operations.

H-4.11 If the tank has a double bottom, a qualified individual must inspect the bottom annular space to ensure the space is free of petroleum product or vapors.

H-4.12 Ensure tank operators or responsible organizations have removed petroleum from the tank to the lowest point possible using installed pumps. Extra precautions such as gravity flow and reduced pumping rates must be considered to ensure the floating roof or pan settles and rests on legs as the fuel level drops below the high leg position of the roof or pan. If applicable use secondary pumps (i.e., air-operated, double-diaphragm pumps, explosion proof electric) to remove remaining petroleum fuel once the petroleum fuel level drops below the installed pumps suction point. Secondary pumps must be located upwind of the tank and at least 50 feet (15.2 meters) from the farthest manhole or vent.

H-5 VAPOR FREEING.

H-5.1 The tank must be ventilated using air-operated eductors, such as COPIS or Lamb air movers. The roof and shell manhole covers must be removed to allow air to circulate freely by natural ventilation to aid in removing vapors. Do not use air moving systems that would blow air into the tank.

H-5.2 Consider local conditions when placing ventilating equipment. Ventilation discharge locations must be selected to maximize diffusion of vapors into the surrounding air. This will minimize the possibility of a flammable mixture forming at ground level. Position ventilating equipment to push vapor through roof manholes.

H-5.3 Petroleum vapors are heavier than air and usually accumulate in the bottom of tanks. Blowing air into a tank can dilute the vapors, but it may take longer for the vapor-air ratio to drop to an acceptable level. Eductor-type air movers with a flexible oil-proof hoses inserted near the bottom of the tank will remove vapors in a shorter period of time.

H-5.4 The primary goals of tank preparation prior to entry are to eliminate sources of ignition and reduce the amount of fuel sludge. A near vapor free work area will drastically reduce the possibility of hazardous conditions (toxicity, asphyxiation, fire, explosion) inside the tank and in the surrounding area.

H-5.5 Eductors must be operated for at least one hour or until LEL and oxygen are within safe limits. Test the tank for LEL and oxygen immediately prior to entry and throughout the operation to ensure a safe atmosphere.

H-5.6 The interior of the tank is considered an explosive atmosphere until all sludge and loosely adhering rust and scale has been removed, regardless of the type of petroleum stored.

H-5.7 All personnel entering the tank prior to and during cleaning must wear authorized PPE including supplied air respirator (SAR) with emergency egress SCBA until the tank is declared hazard-free in accordance with military service-specific directives.

H-5.8 Before entry to the tank without PPE, the LEL reading must be zero, oxygen levels between 19.5% and 23.5%, and lead, benzene, and other toxic material levels within safe limits. Refer to API Standard 2015 for additional information.

H-5.9 The tank being cleaned will be considered leaded unless positive proof exists that the tank has never contained leaded fuel, or the tank has been coated.

H-5.10 Vapors will be present as long as petroleum product, scale, or sludge are inside the tank. Operate air eductors continuously until all these materials have been removed.

H-6 ATMOSPHERIC TESTING.

H-6.1 Tank entrants will follow military services directives detailing specific safety, medical, certification, and testing procedures for confined spaces and safe atmospheric standards.

H-6.2 Personnel will not enter a tank without proper respiratory protection unless the LEL is zero, the oxygen level is within tolerances (19.5% to 23.5%), and the facility’s authorized agency has determined that airborne benzene and other toxic vapors are within permissible exposure limits. Personnel may enter the tank when vapor levels are below 10% of LEL if they are equipped with approved SAR with emergency SCBA.

H-6.3 Provided personnel are wearing appropriate PPE based upon the current LEL, toxicity, and oxygen levels, eductors may be shutdown while workers are in the tank if the eductors impair the ability of personnel to communicate.

H-6.4 If vapor levels cannot be reduced below the 10% LEL, or in some cases below 20% LEL, the following situations may exist:

H-6.4.1 Insufficient time has passed to reduce vapor concentrations (which in turn can affect facility mission requirements and maintenance costs).

H-6.4.2 The amount of remaining fuel and solid sludge has not been reduced to an appropriate level.

H-7 TANK CLEANING.

H-7.1 All entrants must be equipped with approved PPE. In addition, the entry supervisor (or Military service equivalent) must be aware of equipment that is used inside the tank and ensure equipment (where applicable) is explosion proof, has ground fault interrupters and is bonded to the tank. If pressure washers are used, the washer nozzle must be electrically bonded to the tank.

H-7.2 Tanks must be cleaned from the outside first. Ventilation and vapor readings at the manhole must continue during cleaning from the outside. Entry is authorized once the flammable atmosphere tester registers 10% LEL or less. Since vapors will be present as long as fuel, scale, or sludge remains inside the tank, continue forced ventilation until all such material has been removed.

H-7.3 Maintain an uninterrupted air supply until all persons are out of the tank and have removed their face pieces. Personnel who are inside the tank while wearing PPE that detect an odor (such as petroleum products) must leave the tank immediately and not re-enter until the cause has been determined and equipment repaired or replaced.

H-7.4 Unless otherwise directed by military service-specific directives, continue testing for explosive vapors at fifteen-minute intervals while personnel are in the tank. Stirring sludge releases vapors and increases the vapor concentration. Remove puddles of fuel-water sludge to keep vapor readings below 20% LEL.

H-7.5 Personnel will continue to remove sludge from the tank by scraping the bottom of the tank and 3 feet (0.9 meters) up the sides of the tank until all loosely adhering rust and scale have been removed.

H-7.6 Wash down the remainder of the tank with high-pressure hoses. Include the metal supports, braces, the upper portion of horizontal tanks, and the decks (tops) of vertical tanks. Wash these areas until the water pumped out of the tank is clean.

H-7.7 Water discharged from the tank must be contained and disposed of as instructed by the authorized facility environmental agency.

H-7.8 Remaining non-recoverable sludge residue and deposits may be removed by several different methods, including, but not limited to:

H-7.8.1 Wash brush, squeegee, and sweep material (i.e., sludge, deposits) into portable containers.

H-7.8.2 Spray or wash down material with water hose streams and remove by pump or vacuum. If additional liquids are needed to reduce tank material (e.g., sludge, deposits) the use of diesel, solvent, or approved chemicals can be used in accordance with military service-specific directives.

H-7.9 Use of solvents and soap can create additional undesired reactions if used incorrectly, the tank cleaning team must only use approved substances in accordance with manufacturer's instructions.

Solvents and soaps reactions can range from polymerization (depletion of inhibitor or excessively high temperature), saponification (creation of hard soap forming a layer on the tank requiring acid cleaning or even removal by hydroblasting), or drying/hardening (formation of hard debris that is no longer soluble, requiring treatment with a solvent).

H-7.10 Once washing is completed, allow the floor to dry. When interior tank vapor readings are 0% of the LEL on unleaded tanks, personnel may enter the tank without protective equipment if the testing required by API Standard 2015 has been done, and the facility's authorized agent determines that airborne benzene and other toxic vapors are below the permissible exposure limits.

A clean dry tank that has been ventilated overnight will provide the best atmosphere for entry without protective gear.

H-7.11 Pipes used for center poles and braces, pontoons, and leaking bottoms are potential sources of explosive vapors even after the tank is cleaned. In as little as one to two hours a safe tank may reach the explosive range because of these sources. While unprotected personnel are in the tank, take hazardous atmosphere readings at least every fifteen minutes. Where pontoon-type floating roofs or pans are installed in aboveground tanks, check each pontoon with a hazardous atmosphere tester.

H-7.12 Petroleum products irritate and burn the skin and may cause serious discomfort and injury. Promptly remove clothing that becomes splashed with sludge or fuel to prevent contact with the skin. Before continuing work, wash the affected area with soap and water (if a small area), or shower and put on a fresh change of clothing. Clothing contaminated by petroleum products must be kept away from any source of ignition.

H-7.13 Unless a full-face respirator is worn, wear goggles during scraping and spreading loose absorbent material. If hands are frequently wet with fuel and it is not practical to wear protective gloves, the hands may be coated with commercial non-greasy cream that gives the desired protection. NOTE: If work site has contained leaded gasoline, approved protective gloves or other impermeable gloves must be worn throughout the operation.

H-7.14 Keep manholes and adjacent areas clear of equipment or material that would hamper rescue operations in an emergency situation.

H-8 MATERIAL TREATMENT AND DISPOSAL.

Residue (i.e., sludge, deposits) will be treated and disposed of in accordance with Military service-specific environmental directives or contract requirements.

H-9 RETURNING TANK TO SERVICE.

H-9.1 The tank cleaning team supervisors must inspect the tank after cleaning to evaluate the condition of the tank for any follow-on repairs.

H-9.2 Once the inspection is complete and any necessary work completed, the tank must be brought back into service by reinstalling all valves, piping, and manhole covers using new non-asbestos gasket material compatible with the product being stored. The gasket thickness must not be less than the thickness of the gasket that is being replaced.

H-9.3 Refer to UFC 3-460-03 Section 8-8, "Returning to Service after Formal Out of Service Inspection/Repair," for maximum fuel line velocities for initial fills of petroleum fuel tanks that will be returned to service.

H-9.4 Petroleum fuel tanks must be stenciled before they are returned to service after cleaning. Refer to UFC 3-460-03 Section 8-8.1, "Stenciling Requirements."

H-10 TANK CLEANING EQUIPMENT AND PROTECTIVE CLOTHING.

H-10.1 Tank cleaning equipment must meet the following requirements:

H-10.1.1 All electrical equipment and conductors used within 50 feet (15.2 meters) of petroleum pipes or storage tanks, or where a hazardous accumulation of flammable vapors may exist, will be NFPA 70 for Class 1, Division 1, Group D (or higher) (or Class 1, Zone 0, or Zone 1) locations. The maximum temperature rating will be "T2D" – 419 °F (215 °C), as defined in the NEC for use in hazardous (explosive) areas.

H-10.1.2 Hazardous atmosphere detectors must meet military service requirements.

H-10.1.3 Air movers will be of the eductor type capable of educting vapors from the tank, and will be either air-driven or explosion-proof electrically operated. Electrically operated air movers must meet the minimum requirements of NFPA 70 for Class 1, Division 1, Group D (or higher) (or Class 1, Zone 0, or Zone 1) locations.

H-10.2 Tank cleaning personnel must be equipped and trained to use protective clothing (i.e., impervious coveralls, gloves, footwear, head coverings, face shields) that is compliant with safety related military service directives.

H-10.2.1 The tank cleaning team will review the Safety Data Sheets of the petroleum product to select the type of respirator that is applicable with the type of tank and petroleum product used. Caution must be exercised to select a respirator that will not deteriorate or corrode when exposed to the petroleum product or solvents used in the tank cleaning process.

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APPENDIX I /1/ ACRONYMS

ACRONYMS

A4A	Airlines for America
AFCEC	Air Force Civil Engineering Center
AFHE	Automated Fuel Handling Equipment
AFI	Air Force Instruction
AFSS	Automated Fuel Service Station
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
AST	Aboveground Storage Tank
ATG	Automatic Tank Gauge
AWS	American Welding Society
BIA	Bilateral Infrastructure Agreement
BPCV	Back Pressure Control Valve
BSME	Business System Modernization-Energy
CFR	Code of Federal Regulations
CMP	Centrally Managed Program
CNG	Compressed Natural Gas
CP	Cathodic Protection
CPR	Cardiopulmonary Resuscitation
CRA	Pressure-Reducing Control
CRL	Pressure-Relief Control

DBB	Double Block and Bleed
D/FV	Defuel/Flush Valve
DLA	Defense Logistics Agency
2\\ DAFMAN	Department of the Air Force Manual /**2**/
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DPT	Differential Pressure Transmitter
DWCF	Defense Working Capital Fund
EBS	Enterprise Business System
EFSO	Emergency Fuel Shutoff
EI	Energy Institute
ESO	Emergency Shut-Off
1\\ FDWG	Fuels Discipline Working Group /**1**/
FML	Flexible Membrane Liner
FPS	Feet per Second
FSCV	Filter Separator Control Valve
GPM	Gallons Per Minute
HAMS	Hydrant Automation Monitoring System
HCV	Hydrant Control Valve
HDBK	Handbook
HFAM	Hydrant Fuels Automation Maintenance
HNFA	host nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers

IAS	Independent Alarm System
IAW	In Accordance With
LCP	Lateral Control Pit
LEL	Lower Explosive Limit
LNG	Liquefied Natural Gas
LPS	Liter per Second
MIL	Military
MILCON	Military Construction
MLA	Marine Loading Arm
MOGAS	Motor Gasoline
MPS	Meter per Second
NACE	National Association of Corrosion Engineers
NATO	North Atlantic Treaty Organization
NAVFAC	Naval Facilities Engineering Command
NAVOSH	Navy Occupational Safety & Health
NAVSEA	Naval Sea Systems Command
NEC	National Electrical Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
OM	Operator Maintenance
OMES	Operation, Maintenance, Environment, and Safety Plan
OMSI	Operation and Maintenance Support Information
PCV	Pressure Control Valve
PEI	Petroleum Equipment Institute

PIT	Pressure Indicating Transmitter
PHMSA	Pipeline and Hazardous Material Safety Administration
PLC	Program Logic Controller
POL	Petroleum, Oil, and Lubricant
RP	Recommended Practice
SAE	Society of Automotive Engineers
SCP	Service Control Point
SOFA	Status of Forces Agreements
SM	System Maintenance
SME	Subject Matter Expert
SPAWAR	Space and Naval Warfare Systems Center
SPCC	Spill Prevention Control and Countermeasures
SRM	Sustainment, Restoration, and Modernization
STANAG	Standardization Agreement
STI	Steel Tank Institute
STD	Standard
TM	Technical Manual
TO	Technical Order
UFC	Unified Facility Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriters Laboratory
UPS	Uninterruptible Power Supply
USAF	United States Air Force
USAFE	United States Air Force Europe

UST	Underground Storage Tank
1\ VCI	Vapor Corrosion Inhibitors /**1**/

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APPENDIX J /1/ REFERENCES

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI/AIHA Laboratory *Ventilation* Z9.5

AMERICAN PETROLEUM INSTITUTE

API Manual of Petroleum Measurement Standards

API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*

API RP 1110, *Recommended Practice for the Pressure Testing of Steel Pipelines for the Transportation of Gas, Petroleum Gas, Hazardous Liquids, Highly Volatile Liquids, or Carbon Dioxide*

API Specification 6D, *Specifications for Pipeline and Piping Valves*

API STD 510, *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*

API STD 570, *Piping Inspection Code: In-Service Inspection, Rating, Repair, and Alteration of Piping Systems*

API STD 607, *Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats*

API STD 650, *Welded Steel Tanks for Oil Storage*

API STD 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME Section IX, *Boiler and Pressure Vessel Code*

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM D975, *Standard Specification for Diesel Fuel Oils*

ASTM F1449, *Standard Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing*

ASTM 5798 *Standard Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines*

ASTM 6751, *Standard Specification for Biodiesel Fuel Stock (B100) for Middle Distillate Fuels*

AMERICAN WATER WORKS ASSOCIATION

AWWA C203 *Coal-Tar Protective Coatings and Linings for Steel Water Pipelines—Enamel and Tape—Hot Applied*

AWWA C209, *Standard for Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines*

AWWA C210 *Liquid Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines*

AWWA C213 *Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines*

AWWA C215 *Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines*

AWWA C216 *Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines*

AWWA C217 *Petrolatum and Petroleum Wax Tape Coatings for the Exterior of Connections and Fittings for Steel Water Pipelines*

\2\ DEFENSE LOGISTICS AGENCY

DLA-Energy P-22, *Procedures for Requisition, Funding Requests, or Reimbursement of Filter/Coalescer Elements* /**2**/

DEPARTMENT OF ENERGY

DOE/GO-102016, Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends

FEDERAL SPECIFICATION

L-C-530C *Coating, Pipe, Thermoplastic Resen*

DEPARTMENT OF DEFENSE

2\ DoD Standard Design AW 78-24-27, *Aboveground Vertical Steel Fuel Tanks with Fixed Roofs* /**2**/

DoD Standard Design AW 78-24-28 *Pressurized Hydrant Fueling System*

DoD 4140.25-M Volume V, *Management of Bulk Petroleum Products, Storage, and Distribution Facilities*

ARMY CORPS OF ENGINEERS

EM 385-1-1, *Safety and Health Requirements Manual*

UNITED STATES MILITARY DETAIL SPECIFICATION SHEET

MIL-DTL-24441/29, *Paint, Epoxy-Polyamide, Green Primer, Formula 150, Type IV*

MIL-DTL-24441/31, *Paint, Epoxy-Polyamide, White, Formula 152, Type IV*

UNITED STATES MILITARY PERFORMANCE SPECIFICATION

MIL-PRF-4556 *Coating Kit, Epoxy, For Interior of Steel Fuel Tanks*

UNITED STATES MILITARY STANDARD

MIL-STD-3004, *Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*

MIL-STD-3007G, *Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications*

AIR FORCE

AFI 23-201, *Fuels Management*

AFI 32-1065, *Grounding Systems*

2\ **1**\ DAFMAN 91-203, *Air Force Occupational Safety, Fire, And Health Standards* /**1**/ /**2**/

T.O. 37-1-1, *General Operation and Inspection of Installed Fuel Storage and Dispensing Systems*

United States Air Force Europe (USAFE) Volume 1 *General Description and Operation*

USAFE Volume 2 Maintenance and Repair, Standardization Agreement (STANAG) 3609 *Standards for Maintenance of Fixed Aviation Fuel Receipt, Storage and Dispensing Systems*

NAVY

2\ /**2**/

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

NACE RP 0402, *Field-Applied Fusion-Bonded Epoxy (FBE) Pipe Coating Systems for Girth Weld Joints: Application, Performance, and Quality Control*

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 1, *Fire Code*

NFPA 10, *Standard for Portable Fire Extinguishers*

NFPA 30, *Flammable and Combustible Liquids*

NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*

NFPA 45, *Standard on Fire Protection for Laboratories using Chemicals*

NFPA 52 *Vehicular Gaseous Fuel Systems Code*

NFPA 58, *Liquefied Petroleum Gas Code*

NFPA 70, NEC, National Electrical Code

NFPA 70, NEC, Article 501*, Class I Locations for Class I liquids*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 77*, Recommended Practice on Static Electricity*

NFPA 2112*, Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*

NFPA 2113*, Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*

PETROLEUM EQUIPMENT INSTITUTE

PEI/RP900, *Recommended Practices for Inspection and Maintenance of UST Systems*

STEEL TANK INSTITUTE

STI *Standard for the Inspection of Aboveground Storage Tanks*, SP001

UNDERWRITERS LABORATORY

UL 58, *Standard for Steel Underground Tanks for Flammable and Combustible Liquids*

UL 142, *Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids*

UL 1316 *Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol-Gasoline Mixtures*

UL 2080 *Standard for Fire Resistant Tanks for Flammable and Combustible Liquids*

UL 2085, *Standard for Protected Aboveground Tanks for Flammable and Combustible Liquids*

UNIFIED FACILITIES CRITERIA

\1 UFC 3-110-03, *Roofing* **/1/**

UFC 3-430-07, *Operations and Maintenance: Inspection and Certification of Boilers and Unfired Pressure Vessels*

UFC 3-460-01, *Design: Petroleum Fuel Facilities*

UFC 3-570-06, *Operation and Maintenance: Cathodic Protection Systems*

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 3-601-02, *Operation and Maintenance: Inspection, Testing, and Maintenance of Fire Protection Systems*

UFC 4-150-07, *Maintenance and Operation: Maintenance of Waterfront Facilities*

\2\ UFC 4-150-08, *Mooring Hardware Inspection* /**2**/

\2\ UFC 4-159-03, *Moorings* /**2**/

UNIFORM FIRE CODE

UFC Article 52, *Motor Vehicle Fuel Dispensing Stations: Public and Private Operations*

UFC Article 79 *Flammable and Combustible Liquids*

UNIFIED FACILITIES GUIDANCE SPECIFICATIONS

UFGS 09 97 13.15, *Low VOC Polysulfide Interior Coating of Welded Steel Petroleum Fuel Tanks*

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\2\ **\1**\ UFGS 33 52 23.15, *POL Service Piping Welding* /**1**/ /**2**/

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UFGS 33 52 43.12, *Aviation Fuel Pantographs*

UFGS 33 52 43.13, *Aviation Fuel Piping*

UFGS 33 52 43.14*, Aviation Fuel Control Valves*

UFGS 33 52 43.23, *Aviation Fuel Pumps*

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UFGS 33 52 80, *Liquid Fuels Pipeline Coating System*

\2\ **1**\ UFGS 33 57 55, *Fuel Systems Components (Non-Hydrant)* /**1**/ /**2**/

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29 CFR 1910.1450, *Occupational Exposure to Hazardous Chemicals in Laboratories*

29 CFR 1910, Subpart P / OSHA 3080, *Hand and Power Tools*)

33 CFR Part 154, *Facilities Transferring Oil or Hazardous Materials in Bulk*

33 CFR Part 156, *Oil and Hazardous Material Transfer Operations*

40 CFR Part 112, *Oil Pollution Prevention*

40 CFR Part 280, *Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks*

49 CFR Part 195, *Transportation of Hazardous Liquids by Pipeline*

UFC 3-470-01
12 January 2018

UNIFIED FACILITIES CRITERIA (UFC)

UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-470-01
12 January 2018

UNIFIED FACILITIES CRITERIA (UFC)

UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 3-470-01, dated May 2012.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-470-01 *Utility Monitoring and Control System (UMCS) Front End and Integration,* formerly *"LonWorks® Utility Monitoring and Control System (UMCS)*

Superseding: UFC 3-470-01, dated May 2012

Description: UFC 3-470-01 is revised throughout to address changes in UFGS 25 10 10 and to add support for the BACnet® protocol, Modbus® protocol, DNP®, Niagara Framework® and OPC®. Changes include:

- Changes to the UFC title including removal of the word "LonWorks" and clarification that the UFC covers the UMCS front-end and integration
- Removal of "educational" text not needed to support "instructive" text
- Removal of some LonWorks-specific information
- Addition of information on BACnet, Modbus, DNP®, Niagara Framework and OPC
- Explanation of the difference between utility control systems and building control systems
- Removal or updating of out-of-date information

Reasons for Document: The changes to UFC 3-470-01 (and to UFGS 25 10 10) were required as a result of the requirements contained in the National Defense Authorization Act of FY2010 (NDAA 2010).

Impact: There are no direct cost impacts to the changes to this UFC. The changes will support the proper design and implementation of UMCS in accordance with UFGS 25 10 10 in support of meeting NDAA 2010 requirements and the procurement of open control systems.

Unification Issues: Due to differences in approach, structure, procurement processes, and technical capabilities some requirements differ between the services. These differences have been documented in this UFC and in UFGS 25 10 10 (using Tailoring Options) and do not pose a barrier to unification.

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FIGURES

TABLES

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Designers, installers, and operation and maintenance (O&M) staff have struggled with the complexities and incompatibilities of multi-vendor direct digital control (DDC) systems almost since they were introduced in the 1980s. DDC systems are routinely designed and procured on a building-by-building or sub-system by sub-system basis, a process that in the past has often resulted in multiple proprietary systems that will not interoperate with each other. In the absence of specifications and criteria for Open systems, Government procurement rules that require competitive bidding make it extremely difficult if not impossible to procure new DDC systems that are interoperable with existing ones while also being compatible with a base-wide or campus-wide supervisory system.

The introduction of "LonTalk®" and "BACnet®" Open control protocols in the early 1990's allowed for the procurement of Open and interoperable DDC systems.

1-1.1 History.

In 2004, Unified Facilities Guide Specifications (UFGS) 23 09 23 specifying Open building control systems based on LonWorks technology and a UFGS 25 10 10 specifying a LonWorks-based utility monitoring and control system (UMCS) were released. These specifications covered the use of LonWorks® technology to specify and procure an Open building automation system. In 2010, HR2647, the National Defense Authorization Act of 2010 (NDAA 2010) was passed. Section 2841 of this legislation called for "adoption of an open protocol energy monitoring and utility control system specification" by the Department of Defense. The specification was further required to cover seven different types of systems:

- Utilities and energy usage, including electricity, gas, steam and water usage
- Indoor environments, including temperature and humidity levels
- Heating, ventilating, and cooling components
- Central plant equipment
- Renewable energy generation systems
- Lighting systems
- Power distribution networks

Some of these systems are traditionally considered part of the building automation system (BAS) while others are generally considered to be utility control systems. In order to meet these NDAA 2010 requirements, this UFC and UFGS 25 10 10 -

previously LonWorks only - was revised to incorporate support for BACnet®, Modbus®, DNP®, Niagara Framework® and OPC®.

1-1.2 Field Control System Types.

Generally speaking, there are two basic categories of field control system (FCS): building control systems (BCS) and utility control systems (UCS). BCS systems are generally considered "commercial grade" and are used for applications such as heating and air conditioning, metering, or lighting control. UCS systems are generally considered "industrial grade" and are used for applications where a higher level of reliability and performance (e.g. response time) can justify a higher cost, such as for industrial processes or power distribution. BACnet and “LonTalk” are primarily BCS protocols, Modbus and DNP are primarily UCS protocols and OPC is used for integration of UCS or BCS systems but is not generally considered a “field protocol”. While the Niagara Framework is focused at the UMCS front end, it also provides support for field devices and field protocols within BCSs and UCSs using a variety of protocols.

1-1.3 Monitoring and Control Software Protocol Support.

Note there is no front end monitoring and control (M&C) software that natively (without some 3rd party hardware device) supports both BACnet and DNP, or both LonWorks and DNP. Because UFGS 25 10 10 must address the integration of HVAC systems using BACnet or LonWorks, there is no option to select DNP as a protocol supported by the front end. As described later in this UFC, DNP systems will be supported through the use of gateways. Of the seven systems required by NDAA 2010, renewable energy generation systems and power distribution networks are expected to use UCS protocols. Central plant equipment and utility metering may use either UCS or BCS protocols, and the remaining systems are expected to use BCS protocols.

1-1.4 Open System Definition and Considerations.

Generally, an Open system is one where there is no future dependence on any one contractor or controls vendor:

- It’s One system - Multiple field systems with controls installed by multiple vendors are integrated into one system

- There is one common front-end that provides users with the capability to interface with all field systems (monitoring, supervisory control, etc.)

- There are a minimum number of vendor-proprietary (software) tools (ideally zero, in practice, a small number) which are required to operate, maintain and modify the system.

- There is no future need for the original (installing) contractor or any particular device manufacturer to perform work on the system

- There is no need for coordination between the installer of the field system and the installer or (or integrator to) the front-end. As long as each contractor follows the appropriate specification the systems will interoperate.

It's important to note, however, that Openness is not black or white. There is no such thing as a 100% open control system, but UFG 25 10 10 and this UFC, in concert with the building level UFC and specifications (UFC 3-410-02, UFGS 23 09 00, UFGS 23 09 23.01, and UFGS 23 09 23.02) are intended to procure the most open system practical. Further, an Open system can contain some proprietary components and can have fees, provided the components are a small part of the system and the fees are reasonable

1-1.4.1 Open Building Control Systems.

For building control systems, a flat (one protocol at all levels of the system) single multi-vendor system from the front-end down to the field device can be achieved using LonWorks or BACnet, and UFGS 25 10 10 includes requirements for "top-to-bottom" Openness using these protocols. This includes requirements in the UMCS specification that need complementary requirements in the building control system specification. For example:

- To integrate with a UMCS (front end) based on LonWorks, the building control system has to use only SNVTs and provide an LNS Database.

- To integrate with a UMCS (front end) based on BACnet, the building control system must use only standard BACnet Services and must support a number of BIBBs to allow for configuration of scheduling, alarming and trending functionality from the UMCS.

Niagara Framework does not provide a flat system since the Niagara Framework Supervisory Gateways[1] used in the field control systems act as gateways, but it can provide a single multi-vendor system. To integrate with a UMCS (front end) based on the Niagara Framework, a building control system should ideally be installed using the Niagara Framework components. All Niagara components must use an open license which allows multiple vendors to interoperate freely with Niagara components from other vendors.

1-1.4.2 Open Utility Control Systems.

For UCS, Openness from the UMCS all the way to the field controller is not as achievable, and may not be not desirable in some cases. Instead UCS systems are often integrated as distinct "complete systems" (with their own front-end) and use UMCS as a common supervisory front-end. UFGS 25 10 10 can accommodate using the UMCS as the primary front-end for UCS, but the general assumption is that it will serve as a supervisory system in most cases. This is due to many factors, including the increased reliability requirements of the UCS, difference in cybersecurity requirements

[1] This device is more commonly known as a "JACE", which is the name for a specific version of this device. The term "Niagara Framework Supervisory Gateway" is used to remain vendor-neutral.

for the UCS and the UMCS, and because the UCS are often operated by a different organization or group at the garrison than the BCS. In addition, integration of the field control system (with no front-end) to a UMCS is more difficult with utility control systems than with building control systems since the UCS protocols lack data exchange standards compared to LonWorks or BACnet.

1-2 PURPOSE AND SCOPE.

This document describes the design of an Open UMCS Front End and the integration of field control systems into the UMCS, both in accordance with UFGS 25 10 10. This includes hardware, software and, in some cases, networking for the UMCS Front End. With few exceptions, requirements for field control systems, including controllers, networking, and sequences of operation, are not included in this criteria or UFGS 25 10 10 and are addressed by the relevant field control system criteria and specifications.

The UMCS front end required by this criteria and specified in UFGS 25 10 10 will openly interoperate with systems and subsystems installed in accordance with the building control system specifications (UFGS 23 09 00 Instrumentation and Control for HVAC, UFGS 23 09 23.01 LonWorks® Direct Digital Control for HVAC and UFGS 23 09 23.02, BACnet Direct Digital Control for HVAC). UFGS 23 09 23.01 contains specific requirements, such as the use of LonWorks Network Services (LNS), which provide for open integration to a UMCS installed using the complementary options contained in UFGS 25 10 10. UFGS 23 09 23.02 contains similar specific requirements for a BACnet-based system. Both UFGS 23 09 23.01 and UFGS 23 09 23.02 contain options for use of the Niagara Framework.

1-3 APPLICABILITY.

This UFC and accompanying UFGS 25 10 10 'Utility Monitoring and Control System Front End and Integration' are for use on all Department of Defense projects. At the discretion of and with approval from the assigning government agency (such as the responsible Corps of Engineers District), the design of the UMCS may deviate from the standards defined in this UFC. When deviating from the guidance, systems based on an Open communications protocol are recommended and proprietary procurement or single-vendor systems are discouraged. Without this specific approval, use of both this UFC and the accompanying guidance in UFGS 25 10 10 is mandatory.

UFGS 25 10 10, and the Division 23 controls specifications referenced within, have been adopted in accordance with 10 USC 2867, and exceptions to the requirement for use of these specifications require a waiver from the Secretary of the relevant Service.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety.

Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 REFERENCES.

APPENDIX A contains a list of references used in this document.

1-6 GLOSSARY.

APPENDIX C contains acronyms, abbreviations, and terms.

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CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 USE OF UFGS 25 10 10.

The implementation of a UMCS Front End and the successful integration of field control systems requires highly specific and prescriptive specifications. UFGS 25 10 10 incorporates these requirements, and makes use of SpecsIntact Tailoring Options and designer options (bracketed text with notes) to allow for project-specific editing.

Unless specifically indicated in this UFC or with specific written permission from the authority having jurisdiction, the design of a UMCS front end and the specification of integration of field control systems into a UMCS front end must use UFGS 25 10 10 without edits beyond the use of the included tailoring options and designer options.

2-2 TAILORING OPTIONS AND DESIGNER OPTIONS IN UFGS 25 10 10.

The use of tailoring options and designer options in UFGS 25 10 10 must be in accordance with this UFC.

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CHAPTER 3 UMCS ARCHITECTURE

3-1 GENERAL.

As illustrated in Figure 3-1, a basewide UMCS consists of a UMCS front end (specified by UFGS 25 10 10) connected to one or more field control systems. These field control systems (FCS) may be building control systems (BCS) – which are generally DDC systems for the control of HVAC, lighting and other building systems - or utility control systems – which vary in composition from “smart relays” to DDC controls to programmable logic controllers (PLC) for control of power distribution or other “industrial” systems. The network architecture consists of a base-wide IP network connected to one or more field control networks. In general, field control networks themselves may use a wide variety of media and protocols, but building control networks for systems based on LonWorks should be a combination of IP, TP/FT-10, and possibly TP/XF-1250. Building control networks for systems based on BACnet should be IP and/or MS/TP. In each case a field point of connection (FPOC) provides an interface between the UMCS IP network and the field control network (FCN).

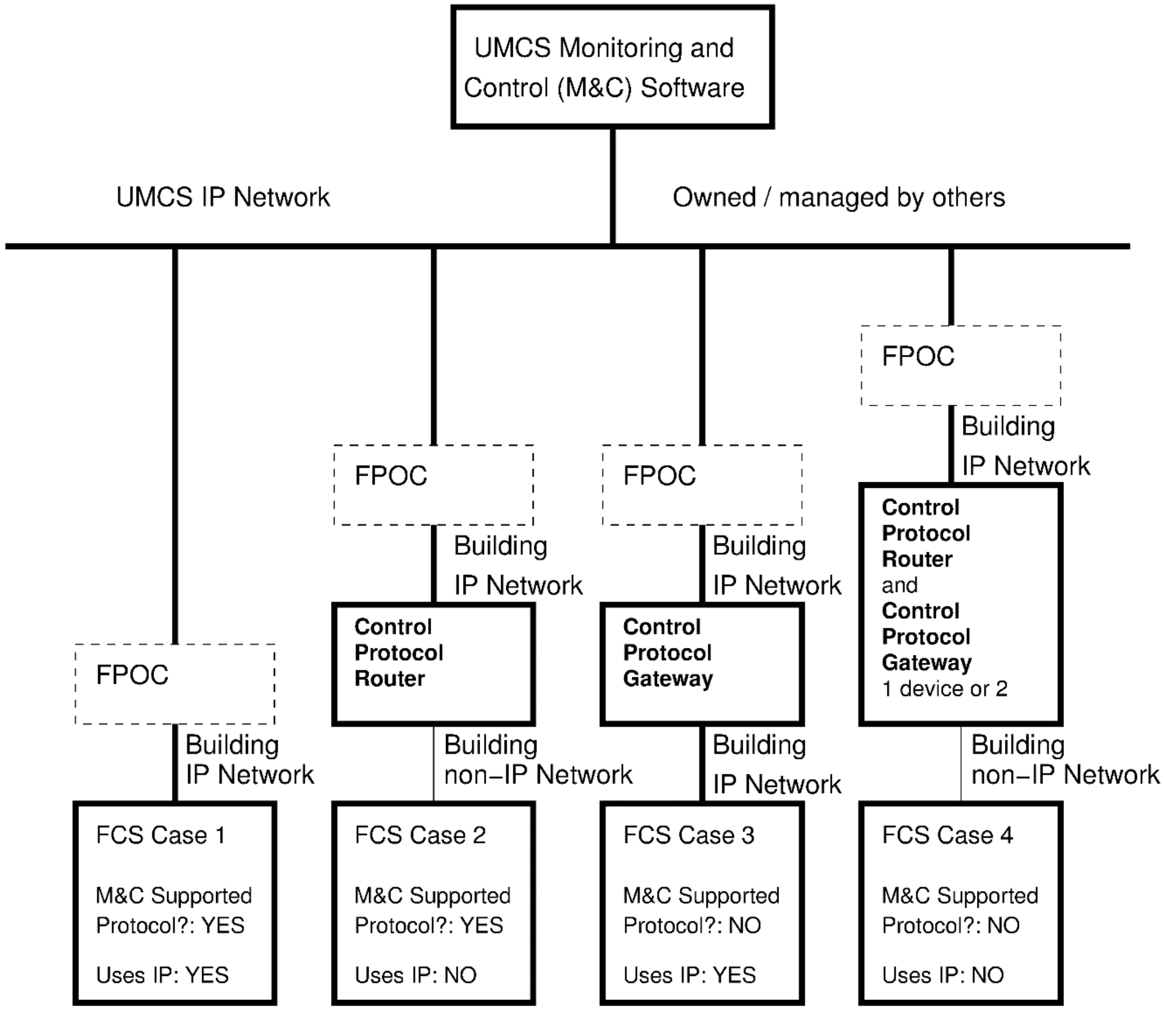
Generally, the UMCS will be a base-wide system, but it may initially consist of very few, or even only one, field control systems. The UMCS may later be expanded to include additional field control systems. A single UMCS is expected to connect to many field control systems from several or many different vendors, where the field control systems are procured separately and then integrated into the UMCS front end.

3-2 UMCS IP NETWORK.

As specified by UFGS 25 10 10 and as illustrated in Figure 3-1, the UMCS uses a base-wide IP network to support inter-building communication and to serve as the communications link between the field control system(s) and the UMCS computers.

Although this UMCS IP network could be contractor-installed, it will generally be Government Furnished, and this UFC and UFGS 25 10 10 assume the latter. Note that coordination with the installation IT group is critical to ensure that the IP network usage is approved and that cybersecurity for the UMCS has been addressed.

Figure 3-1 UMCS Architecture



Notes:
1) All FCS may have a non–IP network in addtion to any IP network
2) All buildings installed under UFC 3–410–02 / UFGS 23 09 23 are Case 1. Cases 2–4 should only be for legacy
3) M&C Protocols include those selected via tailoring options in UFGS 25 10 10 and others that may be supported by that vendor's M&C software.
4) Note that in Cases 2 – 4, the UMCS integrator may need to install Control Protocol Router and/or Gateway and also install/extend the building IP and/or non–IP networks.

3-3 KEY REQUIREMENTS FOR INTEGRATION.

A successful connection between the FCS and the UMCS front end requires two things:

- The UMCS and FCS must use the same protocol (e.g. BACnet, "LonTalk", other)
- The UMCS and FCS must use the same media. While this is often associated with the protocol (e.g. TP/FT-10 is a LonWorks media type), they are not the same. BACnet uses both IP and MS/TP, and a successful connection requires that both sides use one or the other. Similarly, many incompatible protocols use (can be carried over) IP, so although IP is a protocol, the relevant question isn't

"use of IP", but rather "what protocol is being carried over IP". IP is treated as simply another media type in UFGS 25 10 10 and this UFC.

3-4 FIELD CONTROL SYSTEM CONNECTION TO UMCS FRONT END.

Depending on the FCS, the connection between the FPOC and the FCS may be made via many different means. The primary means of connection are shown in Figure 3-1 and described in the following sub-paragraphs, but there are other, less common possibilities which are not described in this UFC. In addition, there may be additional complexities within the building, additional gateways and control protocol routers. These details are also not described here – the focus here is how the FCS presents itself to the UMCS.

In some cases, specific hardware may be required for the connection. This hardware may be provided as part of the FCS (case 1, sometimes case 2), otherwise it must be procured as part of integration of the FCS to the UMCS (cases 3 and 4, sometimes case 2). As part of UMCS design, the location and source of this hardware must be determined and shown on the drawings, as well as whether or not the hardware must be provided as part of integration.

3-4.1 Direct Connection (Figure 3-1 Case 1).

When the field control network uses IP (as a media type) and the field control system protocol is supported by the UMCS M&C software, no additional hardware is required and the two systems can be directly connected together.

Strictly speaking, a Niagara building could be considered to be as Case 3 or 4, as the Niagara Framework Supervisory Gateway converts between the building protocol and the UMCS protocol. However, since the Niagara Framework Supervisory Gateway is furnished as part of the building, this detail can be ignored from the perspective of the UMCS, and a Niagara FCS is integrated as in Case 1.

3-4.2 Control protocol router (Figure 3-1, Case 2).

When the field control system protocol is supported by the UMCS M&C software but the field control network does not use IP, a control protocol router (**not** an IP router) is required to convert the media from the field control network media to IP.

3-4.3 Control protocol gateway (Figure 3-1, Case 3).

When the field control system uses IP but its protocol is not supported by the UMCS M&C software, a gateway is required to convert the FCN protocol to one supported by the UMCS M&C Software.

3-4.4 Control protocol gateway (Figure 3-1, Case 4).

When the field control system does not use IP and its protocol is not supported by the UMCS M&C software, a gateway is required to convert the FCN protocol to one supported by the UMCS M&C Software.

- (Single Device) If a gateway is available that can connect to the field control network media, then a single device may convert both the protocol and the media.

- (Two Devices) If there is no gateway available that can connect to the field control network media, then both a gateway and a control protocol router must be used.

3-5 FIELD POINT OF CONNECTION (FPOC).

A key point in the overall system architecture is the Field Point Of Connection (FPOC), which is the connection point between the portion of the network that is physically dedicated to the control system and the portion of the network that is shared with other applications. The FPOC is important because it:

- Serves as a demarcation point between field-installed network and the UMCS IP network. In many cases, this is also the demarcation point between network owned/managed by the organization operating the facility (Army DPW or other equivalent organization) and the installation IT staff.

- Is a device that, in order to meet cybersecurity requirements, should be secured to limit traffic between the two network pieces.

The FPOC is typically a switch owned and managed by the installation IT staff. As such, it is largely transparent to the UMCS; it is part of the IP network provided by the installation IT staff. It is included here because of its important role in cybersecurity for the system.

3-6 FIELD CONTROL SYSTEM.

A Field Control System (FCS) is a networked system of controllers operating to control a building, a portion of a building, or a utility system. The terms Field Control System and Field Control Network refer to both Building Control Systems/Networks and Utility Control Systems/Networks. A FCS is generally installed as a single project and is intended to provide a complete stand-alone solution for the control of the underlying equipment, though it may lack a full-featured operator interface. From the perspective of integration to the UMCS front end, the underlying details of the FCS are not important; the integration of a FCS into the UMCS will be accomplished using one of the cases discussed above and shown in Figure 3-1.

3-6.1 Building Control Systems.

Building control systems installed in accordance with UFGS 23 09 00 (and UFGS 23 09 23.01 or UFGS 23 09 23.02) are described in those specifications and in UFC 3-410-02.

3-6.2 Other Field Control Systems.

Other field control systems, whether they are building control systems using other protocols or utility control systems, will generally not result in a flat network. In these cases it is generally expected that the connection between the UMCS and FCS will be through a gateway or through a supervisory controller/interface provided as part of the field control system. For Niagara Framework based UMCS, it is expected that these control systems will be integrated through the use of Niagara Framework Supervisory Gateways. Ideally, the gateways are installed as part of the FCS project, otherwise they must be installed during integration.

Note that for some systems, the connection between the FCS and UMCS may be via a FCS local front-end; for example, a FCS which uses a protocol not supported by the UMCS front end may have a FCS front end that has a software driver for BACnet, LonTalk, or OPC.

3-7 BASEWIDE UMCS IP NETWORK.

3-7.1 Cybersecurity.

Cybersecurity is an ever-changing area, and the guidance provided here may no longer be current or applicable. Further, the different Services have different approaches to cybersecurity for UMCS and it's vital to coordinate cybersecurity requirements with the respective Service or agency for each project. UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems* provides guidance on incorporating cybersecurity into the design of UMCS. For the Army, UMCS design, including cybersecurity, should be coordinated with the UMCS Mandatory Center of Expertise (MCX) at Huntsville.

In general, the UMCS front end will not be considered a mission critical system to the installation. Individual controls within a building control system are designed to run stand-alone without intervention from a UMCS front end. Guidance on handling critical systems as part of a UMCS is in UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*.

3-7.1.1 [Army] Certificates of Networthiness.

Army regulations require that any application or system connected to the basewide network have a Certificate of Networthiness (CoN). Installations may reference a pre-existing Networthiness certificate developed by another installation as long as the application is the same (vendor and release) and the existing certificate is not of the "limited" type and therefore can be used Army-wide. UFGS 25 10 10 includes a requirement for the contractor to either provide a valid CoN or submit a completed CoN application for use by the installation in obtaining a CoN. Further information is available at the Networthiness website[2] at: https://army.deps.mil/netcom/sites/nw/CoNApproval/Lists/Networthiness%20Data/NWPublicView.aspx.

[2] This website requires CAC authentication.

The UMCS Mandatory Center of Expertise (MCX) at Huntsville can assist with addressing CoN and should be contacted for advice and support during UMCS design.

3-7.2 IT Group Coordination.

Coordination with the IT Group is critical to address cybersecurity as well as other aspects of UMCS operation. Some key points of coordination are described here.

3-7.2.1 Computer Selection, Administration and Maintenance.

It may be advantageous (or in some cases required) for the IT group to manage day-to-day operation of UMCS computer servers including backups, account management, operating system and security updates, and other administration tasks. At the very least, the IT group will likely have specific requirements for computers connected to the basewide network

Some UMCS software, the M&C Software in particular, will have specific requirements for the configuration of the computers it operates and may also have certain requirements or limitation on the upgrades and patches that can be applied to the operating system without also updating the software. In addition, there may be certain patches or updates that cause the web browser based client to fail when they are applied to client machines. Coordination with the IT group to ensure that computers vital to the operation of the UMCS aren't patched or updated without coordination between the organization operating the UMCS and the IT group is critical.

3-7.2.2 UMCS Network Bandwidth.

A properly designed UMCS Network will require minimal network bandwidth as compared to many IT applications and compared to the bandwidth typically available on a modern basewide IT backbone. The IT group, however, will likely require assurances of this. UFGS 25 10 10 requires that the contractor provide a network bandwidth estimate. The purpose of this estimate it to provide documentation of a "ballpark" for bandwidth use that can be provided to the IT group. The UFGS does not provide specific guidance on how to calculate this estimate and instead require the contractor to use their understanding of the M&C Software they are installing and the M&C Software licensing and performance requirements to estimate the overall bandwidth usage.

CHAPTER 4 COMPUTER SOFTWARE

4-1 MONITORING AND CONTROL SOFTWARE.

The Monitoring and Control (M&C) software uses a client-server model with web-browser based clients. The UFGS specifies M&C Software functionality. Some vendors cannot implement all of this functionality in their standard server-based software, and the UFGS permits some functionality – specifically point calculations and demand limiting – to be performed by controller hardware. The software operating on the controller hardware to perform these functions is still considered M&C Software and is included in all M&C Software requirements such as licensing. In addition, any software required to set up this controller hardware must be provided.

4-1.1 M&C Software Protocol Requirements

UFGS 25 10 10 makes use of SpecsIntact Tailoring Options which allow for customization by the designer of requirements for protocol support by the Monitoring and Control (M&C) Software. Including a tailoring option – BACnet, LonWorks, Modbus, OPC, or Niagara Framework - will require support for that protocol or technology by the UMCS M&C Software. Careful consideration must be used in determining which tailoring options to include:

- Selection of a specific protocol will require that the M&C software support that protocol and that integration of buildings supporting that protocol be via that protocol (there could be cases where there are multiple options for integration).
- Any protocol (whether selected or not) may always be integrated, either by direct support of that protocol by the M&C software (e.g. integration of a Modbus FCS where the front end was required to support LonWorks but also provided a Modbus driver) or through the use of a hardware gateway.

Careful selection of appropriate tailoring options is critical to avoid creating conflicting, confusing or impossible to meet requirements. Additional guidance on the selection of tailoring options can be found in 0 *This Page Intentionally Left Blank*

UMCS DESIGN AND IMPLEMENTATION.

4-1.2 M&C Software Licensing Requirements

M&C software packages have upper capacity limits on the number of points, alarms, etc. that the package can accommodate. In addition, many packages have licenses that further limit the capacity to less than the maximum supported by the software. The designer must specify the number of network points and number of alarms, trends, and occupancy schedules required for the installation. These requirements are determined by two factors:

- The number of points, alarms, trends, and schedules required for a specific system or sequence of operation and

- The number of systems to be ultimately integrated into the UMCS

The former number can be calculated quite accurately (e.g. "this AHU needs 37 points"), however this is seldom worth the effort given the large uncertainties in the ultimate size of the UMCS (e.g. will the UMCS contain 200 AHUs, or 2000?).

4-1.2.1 Number of Points

Table 4-1 provides very rough estimates of the number of points and long-term trends for typical HVAC systems.

Table 4-1 Number of Points and Trends in Typical HVAC Systems

System	Points	Trends
Terminal unit (fan coil, VAV box, etc.)	5 - 15	1 - 5
Small packaged AHU	20 -30	4 - 8
Medium built-up AHU	25 – 50	10 - 15
Large complex AHU	30 – 60	15 - 20
Small package chiller or boiler	10 – 20	5 – 15
Large central plant chiller	30 – 60	20 – 30
Large central plant boiler	20 – 40	15 - 25
Hydronic pumping system	15 – 25	5 - 10

More accurate numbers could be obtained from sequence specific point schedules, but effort should be focused on determining the actual number of systems as that will drive the licensing requirements.

4-1.2.2 Number of schedules

If the only protocol tailoring option selected is BACnet or Niagara Framework there is no need for a requirement in the UFGS relating to number of schedules since scheduling occurs within the building control system. Similarly, if only the LonWorks tailoring option is used and the UMCS is connecting only to new building control systems installed in accordance with UFGS 23 09 00 and UFGS 23 09 23.01, scheduling will be performed within the building control system and there is no need to require that the UMCS front end perform scheduling.

When using other tailoring options (or when using LonWorks to connect to older building control systems which do not use the “Simple Scheduler” functional profile), specify the required number of schedules. A very conservative estimate would be one schedule per system (AHU, or AHU and its associated VAV boxes) and one schedule per X number of stand-alone terminal units which can operate on a common schedule, where X is determined from the design. In practice, though, it is expected that multiple systems (in multiple buildings) will operate from a common schedule so the total required number of schedules should be much less than this conservative estimate. Coordinate with the site to determine their approach to scheduling. If the site indicates they operate systems according to common schedules, the “default” recommendation in the guide spec should be more than sufficient.

4-1.2.3 Number of clients

An important decision that the designer must make in coordination with the installation (customer) is the number of client seats desired. Most M&C software will be licensed as a single server but with varying numbers of client (these may be referred to as client “seats”). UFGS 25 10 10 requires web-browser based clients, so the limit on the number of clients is the total number of simultaneous clients.

4-1.3 System display graphics requirement.

The term Graphical User Interface (GUI) is somewhat a misnomer. An operator thinks of a GUI as providing a graphical representation of systems (i.e. pictures) whereas vendors use the term GUI in the same sense that Microsoft® describes Excel®, as providing a GUI for a spreadsheet (tool bars, pull down menus, mouse driven, etc.). This can potentially lead to a Contractor providing a GUI without graphics. Most vendors offer some level of graphical representation of systems; whether these graphics are included in the base-level product offering depends on the vendor. Most vendors also offer animation, 3-D graphics, links to AutoCAD or PDF documents, and links to GIS (Geographical Information Systems).

4-1.3.1 System display graphics detail level.

UFGS 25 10 10 requires a moderate level of graphics including building floor plans and either one-line or 3-D representation of HVAC systems. These requirements must be edited in accordance with the specific site requirements. It’s important to consider the effect that detailed graphics have on the performance of the user interface; the more complex the graphic, particularly interactive graphics, the longer it will take for the page to load.

4-1.3.2 Cybersecurity issues related to graphics.

It is important to note that many vendors make extensive use of Java, JavaScript, Flash, Shockwave, Silverlight, and ActiveX controls; all of these technologies have important IA ramifications. UFGS 25 10 10 requires that the system function using only Java, Shockwave, Silverlight, Flash, and specifically prohibits use of ActiveX. These issues should be carefully coordinated with site cybersecurity personnel and with the requirements of UFC 4-010-06 and UFGS 25 05 11.

4-1.4 Standard reports.

UFGS 25 10 10 requires an extensive list of reports. Coordinate with the installation and edit these requirements as needed.

4-1.5 Demand limiting.

UFGS 25 10 10 requires that the M&C Software be capable of performing electrical demand limiting. While the installation may not implement demand limiting immediately, trends in energy pricing and government energy targets make its eventual use likely.

The UFGS includes a designer option to require the use of real time pricing data for demand limiting. While most vendors provide some demand limiting functionality, it may be difficult to get demand limiting incorporating real time pricing at this time. In addition, the use of real time pricing requires a connection to an external server (via the Internet), which introduces vulnerabilities into the system and makes meeting cybersecurity requirements more difficult. Unless specifically required by the site, it is recommended that the requirement for real time pricing ***not*** be included.

4-1.6 User account management for M&C software.

UFGS 25 10 10 requires that the M&C Software includes the ability to create and manage user accounts for itself. In addition, it includes a requirement that the M&C Software support a Common Access Card (CAC) login, although implementation of this may not be required for all projects.

4-2 USER ACCOUNT MANAGEMENT FOR OTHER COMPUTER SOFTWARE.

While other computer software required by UFGS 25 10 10 may have user accounts and privileges similar to the M&C software, more often the full capabilities of the software will be available to anyone with access to the software (i.e. there may not be a specific login screen within the software package). For example, an in general, anyone who can run the LNS Network Configuration Tool or ASHRAE-135 Network Browser will be able to perform any operation allowed by that software. For this reason, care should be taken when assigning Microsoft® Windows® user accounts to machines that contain this software to prevent an unauthorized user from being able to damage the system.

4-3 LNS NETWORK CONFIGURATION TOOL (LONWORKS).

The LNS network configuration tool is used to configure communication between controllers and to set device configuration properties such as PID loop settings and setpoints. So that the installation can become proficient with one tool and to avoid multiple tools, UFGS 25 10 10 requires the tool be provided as a part of UMCS contract rather than asking for a tool from each building control system contractor.

Coordinate with the site to determine how many copies of the LNS Network Configuration Tool are required and where they are to be installed. In general, one copy of the LNS Network Configuration Tool should always be installed on the M&C Software Server, but additional installation on laptops may be needed by the maintenance staff. Show these requirements on the UMCS Equipment Schedule.

4-4 BACNET NETWORK BROWSER (BACNET)

The BACnet Network Browser provides the capability to look at, read values from and write values to a BACnet network. While the M&C Software will also have this functionality, the BACnet Network Browser can be installed on a laptop and used by maintenance staff in the field even when the building control system is not connected to the UMCS IP network, or when a local interface is beneficial.

Coordinate with the site to determine how many copies of the BACnet Network Browser are required and where they are to be installed. Show these requirements on the UMCS Equipment Schedule.

4-5 NIAGARA FRAMEWORK ENGINEERING TOOL

The Niagara Framework engineering tool is software used to program and configure all aspects of the Niagara Framework including both Niagara Framework Supervisory Gateways and the Niagara Framework M&C software. It also provides network management and device configuration capabilities for Niagara Framework devices. It is available from multiple vendors, but requires additional licensing requirements for an open implementation (to ensure a tool from one vendor will function with Niagara Framework components from a different vendor). The tool, along with the specific licensing requirements, is specified in UFGS 25 10 10, as well as UFGS 23 09 23.01 and UFGS 23 09 23.02 (though it will typically be procured under UFGS 25 10 10).

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CHAPTER 5 DRAWINGS

5-1 UMCS DRAWINGS OVERVIEW.

This chapter describes typical UMCS design drawing requirements and how to edit them to be project-specific. CHAPTER 6 UMCS DESIGN AND IMPLEMENTATION provides an overview of the project-specific drawing requirements detailed in this chapter. Example drawings in Microsoft Excel format can be found at the “UFGS Forms, Graphics and Tables” page of the Whole Building Design Guide (WBDG) website: http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-graphics-tables

5-1.1 CONTRACT DRAWING SET.

5-1.1.1 Contract drawing set contents.

A set of Contract drawings must include:

- Points Schedule(s)
- Points Schedule - Contractor Instructions
- Alarm Contact Schedule
- Alarm Routing Group Schedule
- UMCS Equipment Schedule
- Demand Limiting Schedule (if demand limiting is implemented)
- Occupancy Schedules

5-1.1.2 Editing contract drawings.

As part of the editing process to make the sample drawings project-specific, the sample drawings use the following conventions:

- Entries required of the designer are shown bracketed as: [___]
- Entries required of the UMCS Contractor are shown bracketed as: < ___ >
- Spaces where no entry is ordinarily required contains a tilde: “ ~ “ (equivalent to an “n/a” or null value)

The bracketed ([__]) designer entries in the sample drawings are provided as a guide to the designer, and must be verified or changed during design. When editing the drawings, delete the brackets after verifying/providing the entry. Contract drawings must contain no designer brackets [___]; entries requiring information from the contractor are shown in “<___>” brackets. When appropriate, designer brackets may be replaced with contractor brackets during design. Do not leave cells blank. Instead, show the tilde ("~") to indicate a null value or that no further entry is required.

5-2 POINTS SCHEDULE.

The most common task to be performed under UFGS 25 10 10 is integration of one or more field control systems into a UMCS (new or existing), and the designer must include Points Schedule drawing(s) in the UMCS contract package to specify integration requirements. Whenever possible, these Points Schedules should be obtained from the as-built submittals of completed field control system projects, particularly when UFGS 23 09 23.01 or UFGS 23 09 23.02 was used.

Detailed point schedule instructions are in UFC 3 410 02 Direct Digital Control for HVAC and Other Local Building Systems.

5-2.1 ALARM CONTACT AND ALARM ROUTING GROUP SCHEDULES.

The M&C software will route alarms according to the alarm routing group shown on the Points Schedule. The alarm routing group is defined by the use of two separate schedules: an Alarm Contact Schedule that lists information on specific individuals and an Alarm Routing Group Schedule that defines the actions to be taken for each “route”.

5-2.2 Alarm contact schedule.

The Alarm Contact Schedule, shown in Table 5-1, defines alarm recipient information. The designer must either complete this schedule or specify that the Contractor must complete this schedule. In either case, customer input is required to identify appropriate entries.

Table 5-1 Alarm Contact Schedule

PERSONS NAME	EMAIL ADDRESS	TEXT MESSAGE ADDRESS	DESCRIPTION
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]

5-2.3 Alarm routing group schedule.

The Alarm Routing Group Schedule (shown in Table 5-2), defines actions to be taken for an alarm based on alarm routing groups. Each alarm routing group specifies the destinations for the alarm message and is some combination of the following:

- Pop-up a message on all open clients
- Send as email to one or more individuals
- Send a text message via email to one or more individuals
- Print to one or more printers

The designer must either complete this schedule or specify that the Contractor must complete this schedule. In either case, input from the project site is required to identify appropriate entries. Each row in this schedule specifies a unique alarm routing group, and each group may be used by multiple alarms. Individual cells may have multiple entries (e.g. one routing group may email to multiple individuals). Alarms are assigned to routing groups in the M&C Routing column of the Points Schedule.

Table 5-2 Alarm Contact Schedule

ROUTING NAME	EMAIL TO	TEXT MESSAGE TO	POP-UP	PRINT TO PRINTERS
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]
[_____]	[_____]	[_____]	[_____]	[_____]

5-3 UMCS EQUIPMENT SCHEDULE.

The UMCS Equipment Schedule, Table 5-3, shows requirements for UMCS equipment such as FPOCs (routers, gateways), Control Protocol Network Hardware, computer servers, computer workstations and printers. The schedule contains the following information (by column heading):

- Reference: Complete this field by entering an equipment identifier.
- Hardware: Complete this field for each piece of hardware furnished by the Government or required of the Contractor.
    - Computer: List each Server and each Workstation (Desktop or Laptop).

  - Printer: List each printer by type - Alarm (continuous feed is default), Laser (B&W), or Color.
  - FPOC: List each Control Protocol Router and each Gateway.
  - The Contractor will add entries for other hardware such as each M&C Software Controller Hardware and each BACnet Supervisory Controller Hardware.

- Hardware Provided By: Complete this field to indicate whether the hardware is contractor-provided or Government-furnished.
- Hardware Location: Show the location the hardware is installed or must be installed in.
- Network Name: The Contractor completes this field.
- IP Address: The Contractor completes this field.
- Media Size or Monitor Size: Show the display monitor size for computers or non-standard media size for printers. UFGS 25 10 10 requires all printers be able to print on 8.5 inch by 11 inch portrait mode media. List any other media sizes required here.
- Note that the following three columns are protocol specific – their use must be coordinated with tailoring options in UFGS 25 10 10.
  - Install LNS Network Configuration Tool: Designate each workstation that must be provided with LNS network configuration tool (NCT) software.
  - Install BACnet Network Browser: Designate each workstation that must be provided with BACnet Network Browser software.
  - Install Niagara Framework Engineering Tool: Designate each workstation that must be provided with Niagara Framework Engineering Tool software.
- Reference Sheet Number: The Contractor completes this field. If there is a UMCS riser diagram, this may be used to indicate a reference to the sheet number (of that riser diagram) on which the equipment is shown.

Table 5-3 UMCS Equipment Schedule

REFERENCE	HARDWARE	HARDWARE PROVIDED BY	HARDWARE LOCATION (BLDG & RM)	NETWORK NAME	IP ADDRESS	MEDIA SIZE OR MONITOR SIZE	LNS NETWORK CONFIGURATION TOOL	BACNET NETWORK BROWSER	REFERENCE SHEET No.
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>
[____]	[____]	[____]	[____]	<____>	<____>	[____]	[____]	[____]	<____>

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CHAPTER 6 UMCS DESIGN AND IMPLEMENTATION

6-1 INTRODUCTION

This chapter describes the planning and design of a UMCS project and is largely constrained to the case where a new UMCS is being designed, including integration of an initial set of field control systems. In addition to the guidance contained in this UFC the design should be based on site-specific planning documents. Designs must be accomplished in accordance with the customer's site specific requirements, such as those in the Installation Design Guide (IDG) for an Army garrison, Master Planning documents, and a UMCS/DDC Implementation Plan. To help obtain maximum benefit of Open DDC systems, designers should encourage their customers to develop a UMCS/DDC Implementation Plan as described in ERDC/CERL Technical report TR-08-12 'IMCOM LonWorks® Building Automation Systems Implementation Strategy' available at: http://dtic.mil/dtic/tr/fulltext/u2/a492015.pdf.

Note that while this report may be outdated, it still contains useful information on how best to obtain an Open DDC system.

6-2 UMCS DESIGN CONSIDERATIONS.

6-2.1 Protocol advantages and disadvantages.

Each of the three protocol options – BACnet, LonWorks and the Niagara Framework protocol - has its own strengths and weaknesses. None of them stand head and shoulders above the others; as discussed below, the decision of which protocol to require should be driven by other factors.

6-2.1.1 BACnet.

BACnet has good support for Scheduling, Alarming, and Trending in an Open standard way at the building. On the other hand, BACnet lacks a system-wide network database, and requires more proprietary software tools for device configuration. While buildings can be competed openly, the front end is generally proprietary.

6-2.1.2 LonWorks (LNS-based).

LonWorks (LNS-based) has an open system-wide database standard allowing the use of a single tool for network management and device configuration. Widespread use of ASCs reduces the need for proprietary programming tools. Scheduling, Alarming, and Trending are not supported in a standard manner, requiring custom solutions. While buildings can be competed openly, the front end is generally proprietary.

6-2.1.3 Niagara Framework.

Niagara Framework has good support for Scheduling, Alarming, and Trending in a standard way at the building. The Niagara Framework toolset and system database is more standard than BACnet, but less standard than LonWorks. Building competition is somewhat less open than for LonWorks or BACnet. The front end is non-proprietary (supported by multiple vendors), but has a larger footprint due to the common approach of installing Niagara Framework Supervisory Gateways in buildings. The biggest single downside of the Niagara Framework is that, while it meets the government procurement definition of non-proprietary, it is not an Open technology, but is wholly owned and licensed by Tridium (a subsidiary of Honeywell). Unlike BACnet and LonWorks, in theory there is no guarantee that support for the technology will continue into the future.

6-2.1.3.1 Niagara Framework as LonWorks or BACnet front end.

Note that a Niagara vendor can meet the UFGS 25 10 10 requirements for either a LonWorks or BACnet front end (even in the case where Niagara Framework was not selected). This is not the "standard" installation of that product and is not desired.

6-2.1.3.2 Standardization of building control system protocol for Niagara Framework UMCS.

When implementing the Niagara Framework it is strongly recommended to standardize on either LonWorks or BACnet for building control systems. This will help provide a more maintainable system for the installation operation and maintenance staff as they will not have to understand both protocols and can reduce the number of software tools the installation has to maintain.

6-2.1.4 Other protocols.

Note that most vendors have a great deal of flexibility in integration and that most field control protocols (for example, DNP, JCI N2, or IEC-61850) can be integrated to most front end via ***some*** method – the real issue is "how easy and seamless is the integration". Even when protocols are different, a gateway is generally available that will allow for integration (Figure 3-1, case 3 or case 4). This is often a reasonable approach towards integrating UCS which generally have their own dedicated front end and where the integration requirements are not as stringent.

6-2.2 Determine the BCS protocol requirements.

In order to support the procurement of open building control systems, the UMCS must support at least one of BACnet, LonWorks, or the Niagara Framework. In general, do ***not*** require support for more than one. The only possible exception would be an installation with a large established base of both Niagara Framework and BACnet buildings and the installation wishes to continue to add both Niagara and BACnet buildings and wishes to have a ***single*** UMCS (an installation wishing to support multiple protocols could simply have multiple UMCS).

6-2.3 Determine the UCS protocol requirements.

The primary driver behind protocol selection must be the needs of the BCS. Only if there are a large number of UCS to be integrated and they use a common protocol should the UCS requirements impact the overall choice of protocol. Even then, BCS protocol compatibility should not be sacrificed for UCS protocol compatibility. Most BCS vendors make hardware gateways that support Modbus, some BCS vendor's front end support Modbus and/or OPC.

6-2.4 Selection of UMCS protocol.

Some key considerations in making this decision are:

- Availability of local vendor support. This is the number one concern; the best protocol and software in the world will not make up for poorly trained installers and contractors. To some extent, this also depends on level of complexity in the specification and level of enforcement – both the LonWorks and BACnet specifications tend to push vendors out of their comfort zone. Selecting the Niagara Framework option will result in a somewhat more "normal" installation.

- The extent and type of existing legacy systems. This is important, but for most installations, no single legacy system has a clear majority of buildings when compared to the eventual size of a site-wide BAS. However, the existence of a large quantity of a specific legacy system is generally an indicator of local vendor support.

- The particular strengths and weaknesses of each option should be considered where there is no clear preference between LonWorks, BACnet, or Niagara Framework based on local support or existing legacy buildings.

- The need to support large numbers of Modbus and/or OPC UCS systems, which might eliminate some BACnet vendors from consideration since many BACnet vendor's front ends do not support Modbus and/or OPC.

This selection of Niagara Framework, LonWorks, or BACnet is a difficult choice, and must be carefully considered and closely coordinated with the installation. There is a lot of information available to help with this decision – unfortunately while some of it is good, much of it is not so good and a surprising amount of it is just plain wrong. Before proceeding, coordinate with the project site. For Army projects, also coordinate with the UMCS MCX at Huntsville. **It is strongly recommended that a) only one of Niagara Framework, LonWorks, or BACnet be selected and b) if BACnet is selected, do NOT select Modbus or OPC.**

6-2.5 Services tailoring option recommendations.

In addition to the protocol tailoring options, UFGS 25 10 10 contains tailoring options for the different services, with "Air Force", "Army", "Navy" and "Service Generic" tailoring options. When designing a project for the Air Force, Army or Navy use the appropriate tailoring option. Otherwise use the "Service Generic" tailoring option

6-3 UMCS DESIGN IMPLEMENTATION.

The designer is responsible for designing the UMCS using the guidance in this UFC and according to the requirements in UFGS 25 10 10. This design responsibility requires producing a design package consisting of a specification and a set of drawings. Although many implementation details are left to the Contractor, the designer must not depend on the UMCS Contractor or vendor for the preparation of the contract package.

The resultant project-specific specifications will require the UMCS Contractor to produce shop drawings, schedules, test plans, test procedures, and other documents showing the application of products to implement the UMCS design. The specification further requires the Contractor to define and install the interface to the field control network in a manner that is consistent with performance requirements defined in the specification and that the Contractor conducts a performance verification test of the UMCS to show that the UMCS functions as designed.

6-3.1 Design package requirements.

The UMCS design must include a tailored specification and contract drawings. All bracketed options in the UFGS must be addressed - included, removed or edited - as required by this UFC, the UFGS designer notes and the needs of the project. The contract drawing package must include the following drawings:

- Points Schedule(s): Points Schedules for the UMCS should derive from the As-Built Points Schedules for the FCS to be integrated. When FCS as-builts are not available, create Points Schedules for the FCS to show the UMCS integration requirements such as graphic display, overrides, and alarming.
- Points Schedule - Contractor Instructions
- Alarm Contact Schedule
- Alarm Routing Group Schedule
- Computer Equipment Schedule
- System Occupancy Schedule: The system occupancy schedule should be based on the FCS as-built drawings. If as-built drawings are not available for the FCS create a system occupancy schedule to show the required operation schedule for each system.
- Demand Limit Schedule (when demand limiting is used)

All drawings must be complete, with all information provided or shown as requiring a contractor entry.

6-3.2 Contracting mechanisms.

While procurement of building level controls is relatively straightforward, procurement of a UMCS is more complex. There are two main issues to be considered:

- UMCS work is an ongoing process. While the UMCS Front End is procured once, building integration to the UMCS is a process that can span many years. The question of how to accomplish future integration work should be addressed prior to initial procurement. As an extreme example, there are “mom-and-pop” shops that can install a custom UMCS that they have developed themselves. However, use of such a UMCS essentially guarantees that future integration work will have to be performed by the “mom-and-pop” shop.

- Contractually, it might be easiest to procure the initial UMCS Front End from a building level DDC Contractor as part of a building level DDC controls project. The danger in this approach is that allowing the same Contractor to install both requires extra vigilance on the part of the government to ensure that the interface between the UMCS Front End and the building is fully compliant with UMCS UFGS 25 10 10. As an extreme case, the Contractor might install a UMCS that works fine with the Contractor’s controls, but will not work with other building control systems that are compliant with the DDC specification.

There are a number of contracting mechanisms that can be used, including (a) IDIQ or services contract, (b) As part of a building level DDC contract, and (c) As a separate contract for either UMCS procurement or integration services. A detailed discussion of contracting methods and the pros and cons of each can be found in ERDC/CERL Technical Report TR-08-12 'IMCOM LonWorks® Building Automation Systems Implementation Strategy' available at: http://dtic.mil/dtic/tr/fulltext/u2/a492015.pdf.

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APPENDIX A REFERENCES

ENGINEER RESEARCH AND DEVELOPMENT CENTER

ERDC/CERL Technical Report TR-08-12, *IMCOM LonWorks® Building Automation Systems Implementation Strategy*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *DoD Building Code (General Building Requirements)*

UFC 3-410-02, *Direct Digital Control for HVAC and Other Building Control Systems*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs

UFGS 23 09 00, *Instrumentation and Control For HVAC*

UFGS 23 09 23.01, *LonWorks Direct Digital Control for HVAC and Other Building Control Systems*

UFGS 23 09 23.02, *BACnet Direct Digital Control for HVAC and Other Building Control Systems*

UFGS 25 05 11, *Cybersecurity for Facility-Related Control Systems*

UFGS 25 10 10, *Utility Monitoring and Control System (UMCS) Front End and Integration*

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APPENDIX B EXAMPLE POINTS SCHEDULES

Figure B-1 Example Points Schedule for LNS-Based LonWorks

FUNCTION	POINT NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	HOA REQ'D	CONFIG. TYPE	M&C VIEW AND OVRD	LDP VIEW AND OVRD	TREND REQ'D	ALARMING: ALARM CONDITION (SEE NOTES)	ALARMING: ALARM PRIORITY	ALARMING: M&C ROUTING	PRIMARY POINT INFORMATION: SNVT NAME	PRIMARY POINT INFORMATION: SNVT TYPE	OVERRIDES: SNVT NAME	OVERRIDES: SNVT TYPE	CONFIGURATION INFORMATION
PROOFS & SAFETIES	SF-S	SUPPLY FAN STATUS			ON/OFF	BI			V	[V]	[~]	SUPPLY FAN PROOF FAILED	[info] [crit]	[___]	<___>	<___>			
	RF-S	RETURN FAN STATUS			ON/OFF	BI			V	[V]	[~]	RETURN FAN PROOF FAILED	[info] [crit]	[___]	<___>	<___>			
	SA-SMK	SUPPLY AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[___]	<___>	<___>			
	RA-SMK	RETURN AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[___]	<___>	<___>			
	CLG-DA-T-LL	COOLING COIL DISCHARGE AIR TEMP LOW LIMIT		39 DEG F	ALM/NORMAL	BI		H	V	[~]		ALM	[info] [crit]	[___]	<___>	<___>			
	SA-P-HL	SUPPLY AIR PRESSURE HIGH LIMIT		[___ IWC]	ALM/NORMAL	BI		H				ALM	[info] [crit]	[___]	<___>	<___>			
	RST-BUT	SYSTEM RESET BUTTON (FOR SAFETIES)				[NET-IN][BI]									[<___>][~]	[<___>][~]			
SCHEDULING	SYS-OCC-SCHED	SYSTEM OCCUPANCY SCHEDULE		SEE OCCUPANCY SCHEDULE DRAWING		<NET-OUT>		OC	V	[~]									<___>
START/STOP	UNIT STATUS	UNIT STATUS (HTG AND/OR CLG REQUEST) (SEE NOTES)				NET-OUT			[V]	[~]	[~]	~	~	~	<___>	<___>			
	SYS-OCC-C	OCCUPANCY COMMAND			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<NET-IN>			VO	[~]	[~]				<___>	<SNVT_OCCUPANCY> <SNVT_TOD_EVENT>			
	SYS-OCC	SYSTEM OCCUPANCY (ACTUAL)			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<~><NET-OUT>			V	[V]	X				<___>	SNVT_OCCUPANCY			
	SF-SS	SUPPLY FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]				<___>	<___>			
	RF-SS	RETURN FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]				<___>	<___>			
	BLDG-T	BUILDING TEMPERATURE (NIGHT STAT)			<___>	<AI><NET-IN>			V	[~]	[~]	BLDG-T LESS THAN BLDG-T-LL	[info] [crit]	[___]	<___>	<___>			
	BLDG-T-LL	BUILDING TEMPERATURE LOW LIMIT		[55 DEG F]				C	VO	[~]									<___>
SUPPLY FAN CAPACITY CONTROL	SF-C	SUPPLY FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]				<___>	<___>			
	SA-P	SUPPLY AIR PRESSURE			<___>	AI, NET-OUT			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-P IS MORE THAN 20% ABOVE OR BELOW SA-P-SP	[info] [crit]	<___>	<___>	<___>			
	SA-P-SP	SUPPLY AIR PRESSURE SETPOINT		<___>				C	VO	[~]					<___>	<___>			
	SUPPLY FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT																	
		INTEGRAL CONSTANT																	
		BIAS																	
		MAXIMUM OUTPUT																	
		MINIMUM OUTPUT																	
		<___>																	
RETURN FAN CAPACITY CONTROL	SA-F	SUPPLY AIR FLOW			[0 - ___ CFM]	NET-IN			V	[V]	[~]	[~]	~	[___]	<___>	<___>			
	RA-F	RETURN AIR FLOW			[0 - ___ CFM]	AI			V	[V]	[~]	[~]	~	[___]	<___>	<___>			
	RF-C	RETURN FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]				<___>	<___>			
	F-DIFF-SP	FLOW DIFFERENCE SETPOINT		[___ CFM]				OC	VO	[~]					<___>	<___>			<___>
	RETURN FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT						C											<___>
		INTEGRAL CONSTANT						C											<___>
		BIAS						C											<___>
		MAXIMUM OUTPUT						C											<___>
		MINIMUM OUTPUT						C											<___>
		<___>						C											<___>
MINIMUM OUTSIDE AIR	MINOA-F	MINIMUM OUTSIDE AIR FLOW			[0 - ___ CFM]	AI			V	[V]	X	MINOA-F LESS THAN 80% OF MINOA-F-SP	[info] [crit]	[___]	<___>	<___>			
	MINOA-D-C	MINIMUM OUTSIDE AIR DAMPER COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]				<___>	<___>			
	MINOA RESET SCHEDULE FOR DCV	CO2 MAXIMUM VALUE		[___ PPM]				C											
		CO2 MINIMUM VALUE		[___ PPM]				C											
		MINOA FLOW MINIMIM VALUE (AT CO2 MINIMUM VALUE)		[___ CFM]				C											
		MINOA FLOW MAXIMUM VALUE (AT CO2 MAXIMUM VALUE)		[___ CFM]				C											
	MINOA-F-SP	MINIMUM OUTSIDE AIR FLOW SETPOINT (SETTING)		[___ CFM]				C	VO	[~]					<___>	<___>			<___>
	MINIMIM OUTSIDE AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT		<___>				C											<___>
		INTEGRAL CONSTANT		<___>				C											<___>
		BIAS		<___>				C											<___>
		MAXIMUM OUTPUT		<___>				C											<___>
		MINIMUM OUTPUT		<___>				C											<___>
		<___>		<___>				C											<___>
MIXED AIR TEMPERATURE CONTROL WITH ECONOMIZER	OA-T	OUTSIDE AIR TEMPERATURE			<___>	AI			V	[V]	X	[~]	~	[~]	<___>	<___>			
	MA-T	MIXED AIR TEMPERATURE			<___>	AI			V	[V]	X	[~]	~	[~]	<___>	<___>			
	MA-D-C	MIXED AIR DAMPER COMMAND			0-100% OPEN	AO	[~]		VO	[V]	[~]				<___>	<___>			
	ECO-HL-SP	ECONOMIZER HIGH LIMIT SETPOINT		[___]				C	[~]	[V]					<___>	<___>			<___>
	ECO-LL-SP	ECONOMIZER LOW LIMIT SETPOINT		[___]				C	VO	[V]					<___>	<___>			<___>
	MA-T-SP	MIXED AIR TEMPERATURE SETPOINT		[___]				C	VO	[~]					<___>	<___>			<___>
	MIXED AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<___>				C											<___>
		INTEGRAL CONSTANT		<___>				C											<___>
		BIAS		<___>				C											<___>
		MAXIMUM OUTPUT		<___>				C											<___>
		MINIMUM OUTPUT		<___>				C											<___>
		<ALL OTHER CONFIG SETTINGS - ADD ROWS AS NEEDED>		<___>				C											<___>
SUPPLY AIR TEMPERATURE	SA-T	SUPPLY AIR TEMPERATURE			<___>	AI			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-T MORE THAN 10 DEG F ABOVE OR BELOW SETPOINT	[info] [crit]	[___]	<___>	<___>			
	CLG-V-C	COOLING VALVE COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]				<___>	<___>			
	SA-T-SP	SUPPLY AIR TEMPERATURE SETPOINT		[55 DEG F]				OC	VO	[V]					<___>	<___>			<___>
	COOLING VALVE CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<___>				C											<___>
		INTEGRAL CONSTANT		<___>				C											<___>
		BIAS		<___>				C											<___>
		MAXIMUM OUTPUT		<___>				C											<___>
		MINIMUM OUTPUT		<___>				C											<___>
		<___>		<___>				C											<___>
OTHER POINTS	RA-T	RETURN AIR TEMPERATURE			<___>	AI			V	[~]	[~]	[~]	~	[___]	<___>	<___>			
	MA-FLT-P-HL	MIXED AIR FILTER PRESSURE HIGH LIMIT SWITCH		<___>	ALM/NORMAL	BI		H	~	[~]		ALM	[info] [crit]	[___]	<___>	<___>			
	OA-FLT-P	OUTSIDE AIR FILTER PRESSURE			<___>	AI			V	[~]		OA-FLT-P LESS THAN OA-FLT-P-LL	[info] [crit]	[___]	<___>	<___>			
	OA-FLT-P-LL	OUTSIDE AIR FILTER PRESSURE LOW LIMIT		<___>				C	~	[~]									

Figure B-2 Example Points Schedule for BACnet

												ALARMING			PRIMARY POINT INFORMATION	NETWORK DATA EXCHANGE		OVERRIDES		ALARM INFORMATION			
FUNCTION	POINT NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	HOA REQ'D	CONFIG. TYPE	M&C VIEW AND OVRD	LDP VIEW AND OVRD	TREND REQ'D	ALARM CONDITION (SEE NOTES)	ALARM PRIORITY	M&C ROUTING	OBJECT TYPE AND INSTANCE NUMBER (AND PROPERTY ID)	DATA FROM	DATA TO	OBJECT TYPE & INSTANCE NUMBER OR COMMANDABLE	TREND OBJECT LOCATION (L OR R), TYPE AND INSTANCE NUMBER (PROVIDE DDC ID FOR REMOTE IN NOTES)	ALARM TYPE (PROVIDE DDC ID FOR REMOTE IN NOTES)	NOTIFICATION CLASS OBJECT INSTANCE NUMBER	EVENT ENROLLMENT OBJECT INSTANCE NUMBER	CONFIGURATION INFORMATION
PROOFS & SAFETIES	SF-S	SUPPLY FAN STATUS			ON/OFF	BI			V	[V]	[~]	SUPPLY FAN PROOF FAILED	[info] [crit]	[___]						<INTRINSIC><REMOTE ALGORITHMIC><LOCAL ALGORITHMIC><NIAGARA FRAMEWORK>			
	RF-S	RETURN FAN STATUS			ON/OFF	BI			V	[V]	[~]	RETURN FAN PROOF FAILED	[info] [crit]	[___]									
	SA-SMK	SUPPLY AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[___]									
	RA-SMK	RETURN AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[___]									
	CLG-DA-T-LL	COOLING COIL DISCHARGE AIR TEMP LOW LIMIT		39 DEG F	ALM/NORMAL	BI		H	V	[~]		ALM	[info] [crit]	[___]									
	SA-P-HL	SUPPLY AIR PRESSURE HIGH LIMIT		[IWC]	ALM/NORMAL	BI		H				ALM	[info] [crit]	[___]									
	RST-BUT	SYSTEM RESET BUTTON (FOR SAFETIES)				[NET-IN][BI]																	
SCHEDULING	SYS-OCC-SCHED	SYSTEM OCCUPANCY SCHEDULE		SEE OCCUPANCY SCHEDULE DRAWING		<NET-OUT>		OC	V	[~]					SCHEDULE OBJECT <___>								<___>
START/STOP	UNIT STATUS	UNIT STATUS (HTG AND/OR CLG REQUEST) (SEE NOTES)				NET-OUT			[V]	[~]	[~]	~	~	~									
	SYS-OCC-C	OCCUPANCY COMMAND			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<NET-IN>			VO	[~]	[~]				MSV <___>								
	SYS-OCC	SYSTEM OCCUPANCY (ACTUAL)			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<~><NET-OUT>			V	[V]	X				MSV <___>								
	SF-SS	SUPPLY FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]												
	RF-SS	RETURN FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]												
	BLDG-T	BUILDING TEMPERATURE (NIGHT STAT)			<___>	<AI><NET-IN>			V	[~]	[~]	BLDG-T LESS THAN BLDG-T-LL	[info] [crit]	[___]									
	BLDG-T-LL	BUILDING TEMPERATURE LOW LIMIT		[55 DEG F]				C	VO	[~]													<___>
SUPPLY FAN CAPACITY CONTROL	SF-C	SUPPLY FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]												
	SA-P	SUPPLY AIR PRESSURE			<___>	AI, NET-OUT			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-P IS MORE THAN 20% ABOVE OR BELOW SA-P-SP	[info] [crit]	<___>			DDC #17, DDC #18, DDC #19						
	SA-P-SP	SUPPLY AIR PRESSURE SETPOINT		<___>				C	VO	[~]													
	SUPPLY FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT																					
		INTEGRAL CONSTANT																					
		BIAS																					
		MAXIMUM OUTPUT																					
		MINIMUM OUTPUT																					
		<___>																					
RETURN FAN CAPACITY CONTROL	SA-F	SUPPLY AIR FLOW			[0 - ___ CFM]	NET-IN			V	[V]	[~]	[~]	~	[___]		DDC#12							
	RA-F	RETURN AIR FLOW			[0 - ___ CFM]	AI			V	[V]	[~]	[~]	~	[___]									
	RF-C	RETURN FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]												
	F-DIFF-SP	FLOW DIFFERENCE SETPOINT		[___ CFM]				OC	VO	[~]													<___>
	RETURN FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT						C															<___>
		INTEGRAL CONSTANT						C															<___>
		BIAS						C															<___>
		MAXIMUM OUTPUT						C															<___>
		MINIMUM OUTPUT						C															<___>
		<___>						C															<___>
MINIMUM OUTSIDE AIR	MINOA-F	MINIMUM OUTSIDE AIR FLOW			[0 - ___ CFM]	AI			V	[V]	X	MINOA-F LESS THAN 80% OF MINOA-F-SP	[info] [crit]	[___]									
	MINOA-D-C	MINIMUM OUTSIDE AIR DAMPER COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]												
	MINOA RESET SCHEDULE FOR DCV	CO2 MAXIMUM VALUE		[___ PPM]				C															
		CO2 MINIMUM VALUE		[___ PPM]				C															
		MINOA FLOW MINIMIM VALUE (AT CO2 MINIMUM VALUE)		[___ CFM]				C															
		MINOA FLOW MAXIMUM VALUE (AT CO2 MAXIMUM VALUE)		[___ CFM]				C															
	MINOA-F-SP	MINIMUM OUTSIDE AIR FLOW SETPOINT (SETTING)		[___ CFM]				C	VO	[~]													<___>
	MINIMIM OUTSIDE AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT		<___>				C															<___>
		INTEGRAL CONSTANT		<___>				C															<___>
		BIAS		<___>				C															<___>
		MAXIMUM OUTPUT		<___>				C															<___>
		MINIMUM OUTPUT		<___>				C															<___>
		<___>		<___>				C															<___>
MIXED AIR TEMPERATURE CONTROL WITH ECONOMIZER	OA-T	OUTSIDE AIR TEMPERATURE			<___>	AI			V	[V]	X	[~]	~	[~]									
	MA-T	MIXED AIR TEMPERATURE			<___>	AI			V	[V]	X	[~]	~	[~]									
	MA-D-C	MIXED AIR DAMPER COMMAND			0-100% OPEN	AO	[~]		VO	[V]	[~]												
	ECO-HL-SP	ECONOMIZER HIGH LIMIT SETPOINT		[___]				C	[~]	[V]													<___>
	ECO-LL-SP	ECONOMIZER LOW LIMIT SETPOINT		[___]				C	VO	[V]													<___>
	MA-T-SP	MIXED AIR TEMPERATURE SETPOINT		[___]				C	VO	[~]													<___>
	MIXED AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<___>				C															<___>
		INTEGRAL CONSTANT		<___>				C															<___>
		BIAS		<___>				C															<___>
		MAXIMUM OUTPUT		<___>				C															<___>
		MINIMUM OUTPUT		<___>				C															<___>
		<ALL OTHER CONFIG SETTINGS - ADD ROWS AS NEEDED>		<___>				C															<___>
SUPPLY AIR TEMPERATURE	SA-T	SUPPLY AIR TEMPERATURE			<___>	AI			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-T MORE THAN 10 DEG F ABOVE OR BELOW SETPOINT	[info] [crit]	[___]									
	CLG-V-C	COOLING VALVE COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]												
	SA-T-SP	SUPPLY AIR TEMPERATURE SETPOINT		[55 DEG F]				OC	VO	[V]													<___>
	COOLING VALVE CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<___>				C															<___>
		INTEGRAL CONSTANT		<___>				C															<___>
		BIAS		<___>				C															<___>
		MAXIMUM OUTPUT		<___>				C															<___>
		MINIMUM OUTPUT		<___>				C															<___>
		<___>		<___>				C															<___>
OTHER POINTS	RA-T	RETURN AIR TEMPERATURE			<___>	AI			V	[~]	[~]	[~]	~	[___]									
	MA-FLT-P-HL	MIXED AIR FILTER PRESSURE HIGH LIMIT SWITCH		<___>	ALM/NORMAL	BI		H	~	[~]		ALM	[info] [crit]	[___]									
	OA-FLT-P	OUTSIDE AIR FILTER PRESSURE			<___>	AI			V	[~]		OA-FLT-P LESS THAN OA-FLT-P-LL	[info] [crit]	[___]									
	OA-FLT-P-LL	OUTSIDE AIR FILTER PRESSURE LOW LIMIT		<___>				C	~	[~]													

Notes:

1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS INDICATED IN THE SPECIFICATION AND IN ACCORDANCE WITH THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) UNIT STATUS: SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END) AND AS A HEATING/COOLING REQUEST TO THE BOILER, HEAT EXCHANGER, AND/OR CHILLER SERVING THIS SYSTEM.
4) DDC HW ID FOR DEVICE CONTAINING TREND OBJECT FOR REMOTE TRENDING FOR THIS SYSTEM: <_____>
5) DDC HW ID FOR DEVICE CONTAINING EVENT ENROLLMENT OBJECT FOR REMOTE ALARMING FOR THIS SYSTEM: <_____>

Figure B-3 Example Points Schedule for LonWorks with Niagara Framework

FUNCTION	POINT NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	HOA REQ'D	CONFIG. TYPE	M&C VIEW AND OVRD	LDP VIEW AND OVRD	TREND REQ'D	ALARMING: ALARM CONDITION (SEE NOTES)	ALARMING: ALARM PRIORITY	ALARMING: M&C ROUTING	PRIMARY POINT INFORMATION: SNVT NAME	PRIMARY POINT INFORMATION: SNVT TYPE	PRIMARY POINT INFORMATION: NIAGARA ID	OVERRIDES: SNVT NAME	OVERRIDES: SNVT TYPE	CONFIGURATION INFORMATION
PROOFS & SAFETIES	SF-S	SUPPLY FAN STATUS			ON/OFF	BI			V	[V]	[~]	SUPPLY FAN PROOF FAILED	[info] [crit]	[__]	<__>	<__>				
	RF-S	RETURN FAN STATUS			ON/OFF	BI			V	[V]	[~]	RETURN FAN PROOF FAILED	[info] [crit]	[__]	<__>	<__>				
	SA-SMK	SUPPLY AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[__]	<__>	<__>				
	RA-SMK	RETURN AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[__]	<__>	<__>				
	CLG-DA-T-LL	COOLING COIL DISCHARGE AIR TEMP LOW LIMIT		39 DEG F	ALM/NORMAL	BI		H	V	[~]		ALM	[info] [crit]	[__]	<__>	<__>				
	SA-P-HL	SUPPLY AIR PRESSURE HIGH LIMIT		[__ IWC]	ALM/NORMAL	BI		H				ALM	[info] [crit]	[__]	<__>	<__>				
	RST-BUT	SYSTEM RESET BUTTON (FOR SAFETIES)				[NET-IN][BI]									[<__>][~]	[<__>][~]				
SCHEDULING	SYS-OCC-SCHED	SYSTEM OCCUPANCY SCHEDULE		SEE OCCUPANCY SCHEDULE DRAWING		<NET-OUT>		OC	V	[~]										<__>
START/STOP	UNIT STATUS	UNIT STATUS (HTG AND/OR CLG REQUEST) (SEE NOTES)				NET-OUT			[V]	[~]	[~]	~	~	~	<__>	<__>				
	SYS-OCC-C	OCCUPANCY COMMAND			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<NET-IN>			VO	[~]	[~]				<__>	<SNVT_OCCUPANCY> <SNVT_TOD_EVENT>				
	SYS-OCC	SYSTEM OCCUPANCY (ACTUAL)			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<~><NET-OUT>			V	[V]	X				<__>	SNVT_OCCUPANCY				
	SF-SS	SUPPLY FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]				<__>	<__>				
	RF-SS	RETURN FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]				<__>	<__>				
	BLDG-T	BUILDING TEMPERATURE (NIGHT STAT)			<__>	<AI><NET-IN>			V	[~]	[~]	BLDG-T LESS THAN BLDG-T-LL	[info] [crit]	[__]	<__>	<__>				
	BLDG-T-LL	BUILDING TEMPERATURE LOW LIMIT		[55 DEG F]				C	VO	[~]										<__>
SUPPLY FAN CAPACITY CONTROL	SF-C	SUPPLY FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]				<__>	<__>				
	SA-P	SUPPLY AIR PRESSURE			<__>	AI, NET-OUT			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-P IS MORE THAN 20% ABOVE OR BELOW SA-P-SP	[info] [crit]	<__>	<__>	<__>				
	SA-P-SP	SUPPLY AIR PRESSURE SETPOINT		<__>				C	VO	[~]					<__>	<__>				
	SUPPLY FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT																		
		INTEGRAL CONSTANT																		
		BIAS																		
		MAXIMUM OUTPUT																		
		MINIMUM OUTPUT																		
		<__>																		
RETURN FAN CAPACITY CONTROL	SA-F	SUPPLY AIR FLOW			[0 - ___ CFM]	NET-IN			V	[V]	[~]	[~]	~	[__]	<__>	<__>				
	RA-F	RETURN AIR FLOW			[0 - ___ CFM]	AI			V	[V]	[~]	[~]	~	[__]	<__>	<__>				
	RF-C	RETURN FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]				<__>	<__>				
	F-DIFF-SP	FLOW DIFFERENCE SETPOINT		[___ CFM]				OC	VO	[~]					<__>	<__>				<__>
	RETURN FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT						C												<__>
		INTEGRAL CONSTANT						C												<__>
		BIAS						C												<__>
		MAXIMUM OUTPUT						C												<__>
		MINIMUM OUTPUT						C												<__>
		<__>						C												<__>
MINIMUM OUTSIDE AIR	MINOA-F	MINIMUM OUTSIDE AIR FLOW			[0 - ___ CFM]	AI			V	[V]	X	MINOA-F LESS THAN 80% OF MINOA-F-SP	[info] [crit]	[__]	<__>	<__>				
	MINOA-D-C	MINIMUM OUTSIDE AIR DAMPER COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]				<__>	<__>				
	MINOA RESET SCHEDULE FOR DCV	CO2 MAXIMUM VALUE		[___ PPM]				C												
		CO2 MINIMUM VALUE		[___ PPM]				C												
		MINOA FLOW MINIMIM VALUE (AT CO2 MINIMUM VALUE)		[___ CFM]				C												
		MINOA FLOW MAXIMUM VALUE (AT CO2 MAXIMUM VALUE)		[___ CFM]				C												
	MINOA-F-SP	MINIMUM OUTSIDE AIR FLOW SETPOINT (SETTING)		[___ CFM]				C	VO	[~]					<__>	<__>				<__>
	MINIMIM OUTSIDE AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT		<__>				C												<__>
		INTEGRAL CONSTANT		<__>				C												<__>
		BIAS		<__>				C												<__>
		MAXIMUM OUTPUT		<__>				C												<__>
		MINIMUM OUTPUT		<__>				C												<__>
		<__>		<__>				C												<__>
MIXED AIR TEMPERATURE CONTROL WITH ECONOMIZER	OA-T	OUTSIDE AIR TEMPERATURE			<__>	AI			V	[V]	X	[~]	~	[~]	<__>	<__>				
	MA-T	MIXED AIR TEMPERATURE			<__>	AI			V	[V]	X	[~]	~	[~]	<__>	<__>				
	MA-D-C	MIXED AIR DAMPER COMMAND			0-100% OPEN	AO	[~]		VO	[V]	[~]				<__>	<__>				
	ECO-HL-SP	ECONOMIZER HIGH LIMIT SETPOINT		[__]				C	[~]	[V]					<__>	<__>				<__>
	ECO-LL-SP	ECONOMIZER LOW LIMIT SETPOINT		[__]				C	VO	[V]					<__>	<__>				<__>
	MA-T-SP	MIXED AIR TEMPERATURE SETPOINT		[__]				C	VO	[~]					<__>	<__>				<__>
	MIXED AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<__>				C												<__>
		INTEGRAL CONSTANT		<__>				C												<__>
		BIAS		<__>				C												<__>
		MAXIMUM OUTPUT		<__>				C												<__>
		MINIMUM OUTPUT		<__>				C												<__>
		<ALL OTHER CONFIG SETTINGS - ADD ROWS AS NEEDED>		<__>				C												<__>
SUPPLY AIR TEMPERATURE	SA-T	SUPPLY AIR TEMPERATURE			<__>	AI			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-T MORE THAN 10 DEG F ABOVE OR BELOW SA-T SETPOINT	[info] [crit]	[__]	<__>	<__>				
	CLG-V-C	COOLING VALVE COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]				<__>	<__>				
	SA-T-SP	SUPPLY AIR TEMPERATURE SETPOINT		[55 DEG F]				OC	VO	[V]					<__>	<__>				<__>
	COOLING VALVE CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<__>				C												<__>
		INTEGRAL CONSTANT		<__>				C												<__>
		BIAS		<__>				C												<__>
		MAXIMUM OUTPUT		<__>				C												<__>
		MINIMUM OUTPUT		<__>				C												<__>
		<__>		<__>				C												<__>
OTHER POINTS	RA-T	RETURN AIR TEMPERATURE			<__>	AI			V	[~]	[~]	[~]	~	[__]	<__>	<__>				
	MA-FLT-P-HL	MIXED AIR FILTER PRESSURE HIGH LIMIT SWITCH		<__>	ALM/NORMAL	BI		H	~	[~]		ALM	[info] [crit]	[__]	<__>	<__>				
	OA-FLT-P	OUTSIDE AIR FILTER PRESSURE			<__>	AI			V	[~]		OA-FLT-P LESS THAN OA-FLT-P-LL	[info] [crit]	[__]	<__>	<__>				
	OA-FLT-P-LL	OUTSIDE AIR FILTER PRESSURE LOW LIMIT		<__>				C	~	[~]										

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS INDICATED IN THE SPECIFICATION AND IN ACCORDANCE WITH THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) UNIT STATUS: SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END) AND AS A HEATING/COOLING REQUEST TO THE BOILER, HEAT EXCHANGER, AND/OR CHILLER SERVING THIS SYSTEM.

Figure B-4 Example Points Schedule for BACnet with Niagara Framework

												ALARMING			PRIMARY POINT INFORMATION		NETWORK DATA EXCHANGE		OVERRIDES	ALARM INFORMATION		
FUNCTION	POINT NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	HOA REQ'D	CONFIG. TYPE	M&C VIEW AND OVRD	LDP VIEW AND OVRD	TREND REQ'D	ALARM CONDITION (SEE NOTES)	ALARM PRIORITY	M&C ROUTING	OBJECT TYPE AND INSTANCE NUMBER (AND PROPERTY ID)	NIAGARA ID	DATA FROM	DATA TO	OBJECT TYPE & INSTANCE NUMBER OR COMMANDABLE	ALARM TYPE (PROVIDE DDC ID FOR REMOTE IN NOTES)	NOTIFICATION CLASS OBJECT INSTANCE NUMBER	CONFIGURATION INFORMATION
PROOFS & SAFETIES	SF-S	SUPPLY FAN STATUS			ON/OFF	BI			V	[V]	[~]	SUPPLY FAN PROOF FAILED	[info] [crit]	[__]						<INTRINSIC><REMOTE ALGORITHMIC><LOCAL ALGORITHMIC><NIAGARA FRAMEWORK>		
	RF-S	RETURN FAN STATUS			ON/OFF	BI			V	[V]	[~]	RETURN FAN PROOF FAILED	[info] [crit]	[ ]								
	SA-SMK	SUPPLY AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[ ]								
	RA-SMK	RETURN AIR SMOKE			ALM/NORMAL	BI						ALM	[info] [crit]	[ ]								
	CLG-DA-T-LL	COOLING COIL DISCHARGE AIR TEMP LOW LIMIT		39 DEG F	ALM/NORMAL	BI		H	V	[~]		ALM	[info] [crit]	[ ]								
	SA-P-HL	SUPPLY AIR PRESSURE HIGH LIMIT		[IWC]	ALM/NORMAL	BI		H				ALM	[info] [crit]	[ ]								
	RST-BUT	SYSTEM RESET BUTTON (FOR SAFETIES)				[NET-IN][BI]																
SCHEDULING	SYS-OCC-SCHED	SYSTEM OCCUPANCY SCHEDULE		SEE OCCUPANCY SCHEDULE DRAWING		<NET-OUT>		OC	V	[~]					SCHEDULE OBJECT <___>							<___>
START/STOP	UNIT STATUS	UNIT STATUS (HTG AND/OR CLG REQUEST) (SEE NOTES)				NET-OUT			[V]	[~]	[~]	~	~	~								
	SYS-OCC-C	OCCUPANCY COMMAND			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<NET-IN>			VO	[~]	[~]				MSV <___>							
	SYS-OCC	SYSTEM OCCUPANCY (ACTUAL)			OCCUPIED(1)/WUCD(2)/UNOCCUPIED(3)	<~><NET-OUT>			V	[V]	X				MSV <___>							
	SF-SS	SUPPLY FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]											
	RF-SS	RETURN FAN START/STOP			ON/OFF	BO	[~]		VO	[V]	[~]											
	BLDG-T	BUILDING TEMPERATURE (NIGHT STAT)			<___>	<AI><NET-IN>			V	[~]	[~]	BLDG-T LESS THAN BLDG-T-LL	[info] [crit]	[___]								
	BLDG-T-LL	BUILDING TEMPERATURE LOW LIMIT		[55 DEG F]				C	VO	[~]												<___>
SUPPLY FAN CAPACITY CONTROL	SF-C	SUPPLY FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]											
	SA-P	SUPPLY AIR PRESSURE			<___>	AI, NET-OUT			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-P IS MORE THAN 20% ABOVE OR BELOW SA-P-SP	[info] [crit]	<___>				DDC #17, DDC #18, DDC #19				
	SA-P-SP	SUPPLY AIR PRESSURE SETPOINT		<___>				C	VO	[~]												
	SUPPLY FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT																				
		INTEGRAL CONSTANT																				
		BIAS																				
		MAXIMUM OUTPUT																				
		MINIMUM OUTPUT																				
		< >																				
RETURN FAN CAPACITY CONTROL	SA-F	SUPPLY AIR FLOW			[0 - CFM]	NET-IN			V	[V]	[~]	[~]	~	[ ]			DDC#12					
	RA-F	RETURN AIR FLOW			[0 - CFM]	AI			V	[V]	[~]	[~]	~	[ ]								
	RF-C	RETURN FAN COMMAND			0-100%	AO	[~]		VO	[~]	[~]											
	F-DIFF-SP	FLOW DIFFERENCE SETPOINT		[CFM]				OC	VO	[~]												< >
	RETURN FAN CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT						C														< >
		INTEGRAL CONSTANT						C														< >
		BIAS						C														< >
		MAXIMUM OUTPUT						C														< >
		MINIMUM OUTPUT						C														< >
		<___>						C														<___>
MINIMUM OUTSIDE AIR	MINOA-F	MINIMUM OUTSIDE AIR FLOW			[0 - ___ CFM]	AI			V	[V]	X	MINOA-F LESS THAN 80% OF MINOA-F-SP	[info] [crit]	[___]								
	MINOA-D-C	MINIMUM OUTSIDE AIR DAMPER COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]											
	MINOA RESET SCHEDULE FOR DCV	CO2 MAXIMUM VALUE		[PPM]				C														
		CO2 MINIMUM VALUE		[PPM]				C														
		MINOA FLOW MINIMIM VALUE (AT CO2 MINIMUM VALUE)		[CFM]				C														
		MINOA FLOW MAXIMUM VALUE (AT CO2 MAXIMUM VALUE)		[CFM]				C														
	MINOA-F-SP	MINIMUM OUTSIDE AIR FLOW SETPOINT (SETTING)		[CFM]				C	VO	[~]												< >
	MINIMIM OUTSIDE AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	PROPORTIONAL CONSTANT		< >				C														< >
		INTEGRAL CONSTANT		< >				C														< >
		BIAS		< >				C														< >
		MAXIMUM OUTPUT		< >				C														< >
		MINIMUM OUTPUT		< >				C														< >
		< >		< >				C														< >
MIXED AIR TEMPERATURE CONTROL WITH ECONOMIZER	OA-T	OUTSIDE AIR TEMPERATURE			< >	AI			V	[V]	X	[~]	~	[~]								
	MA-T	MIXED AIR TEMPERATURE			< >	AI			V	[V]	X	[~]	~	[~]								
	MA-D-C	MIXED AIR DAMPER COMMAND			0-100% OPEN	AO	[~]		VO	[V]	[~]											
	ECO-HL-SP	ECONOMIZER HIGH LIMIT SETPOINT		[ ]				C	[~]	[V]												< >
	ECO-LL-SP	ECONOMIZER LOW LIMIT SETPOINT		[ ]				C	VO	[V]												< >
	MA-T-SP	MIXED AIR TEMPERATURE SETPOINT		[ ]				C	VO	[~]												< >
	MIXED AIR DAMPER CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		< >				C														< >
		INTEGRAL CONSTANT		< >				C														< >
		BIAS		< >				C														< >
		MAXIMUM OUTPUT		< >				C														< >
		MINIMUM OUTPUT		< >				C														< >
		<ALL OTHER CONFIG SETTINGS - ADD ROWS AS NEEDED>		< >				C														< >
SUPPLY AIR TEMPERATURE	SA-T	SUPPLY AIR TEMPERATURE			<___>	AI			V	[V]	X	SYSTEM HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES AND SA-T MORE THAN 10 DEG F ABOVE OR BELOW SETPOINT	[info] [crit]	[___]								
	CLG-V-C	COOLING VALVE COMMAND			<0-100% OPEN>	AO	[~]		VO	[V]	[~]											
	SA-T-SP	SUPPLY AIR TEMPERATURE SETPOINT		[55 DEG F]				OC	VO	[V]												<___>
	COOLING VALVE CONTROL LOOP CONFIGURATION SETTINGS	<THROTTLING RANGE><PROPORTIONAL GAIN>		<___>				C														<___>
		INTEGRAL CONSTANT		<___>				C														<___>
		BIAS		<___>				C														<___>
		MAXIMUM OUTPUT		<___>				C														<___>
		MINIMUM OUTPUT		<___>				C														<___>
		<___>		<___>				C														<___>
OTHER POINTS	RA-T	RETURN AIR TEMPERATURE			<___>	AI			V	[~]	[~]	[~]	~	[___]								
	MA-FLT-P-HL	MIXED AIR FILTER PRESSURE HIGH LIMIT SWITCH		<___>	ALM/NORMAL	BI		H	~	[~]		ALM	[info] [crit]	[___]								
	OA-FLT-P	OUTSIDE AIR FILTER PRESSURE			<___>	AI			V	[~]		OA-FLT-P LESS THAN OA-FLT-P-LL	[info] [crit]	[___]								
	OA-FLT-P-LL	OUTSIDE AIR FILTER PRESSURE LOW LIMIT		<___>				C	~	[~]												

Notes:

1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS INDICATED IN THE SPECIFICATION AND IN ACCORDANCE WITH THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) UNIT STATUS: SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END) AND AS A HEATING/COOLING REQUEST TO THE BOILER, HEAT EXCHANGER, AND/OR CHILLER SERVING THIS SYSTEM.

Figure B-5 Example Points Schedule for Modbus Gateway

[SYSTEM NAME]

DEVICE ADDRESS: <___>

GENERAL POINT INFORMATION				POINT REGISTER INFORMATION		M&C SOFTWARE FUNCTIONS						OVERRIDE REGISTER INFORMATION (SEE NOTE 4)	
									ALARM INFORMATION				
FUNCTION	NAME	DESCRIPTION	UNITS	REGISTER NUMBERS	DATA TYPE (SEE NOTE 5)	DISPLAY REQUIRED	TREND REQUIRED	OVERRIDE REQUIRED	ALARM CONDITION	ALARM PRIORITY	ALARM ROUTING	REGISTER NUMBERS	DATA TYPE
EXAMPLE POINTS		GENERIC POINT	<___>	<___>	<DISCRETE INPUT> <COIL> <HOLDING REGISTER> <INPUT REGISTER> <CHARACTER> <FLOATING POINT> <INTEGER DATE> <CHARACTER DATE> <OTHER:<___>>	[X][~}	[X][~}	[X][~}	[___][~]	[CRIT][INFO][~]	[___][~]	<___>	<DISCRETE INPUT> <COIL> <HOLDING REGISTER> <INPUT REGISTER> <CHARACTER> <FLOATING POINT> <INTEGER DATE> <CHARACTER DATE> <OTHER:<___>>
	GEN-OIL-P	GENERATOR OIL PRESSURE	PSI	6,7	FLOATING POINT	X	X	~	GEN-OIL-P LESS THAN 50 PSI	CRIT	GEN_MAINT	~	~
	BKR-5-S	BREAKER 5 STATUS	OPEN/CLOSED	53	DISCRETE INPUT	X	X	~	CLOSED	INFO	LOG	~	~

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS SPECIFIED AND AS DESCRIBED IN THE POINTS SCHEDULE INSTRUCTIONS DRAWING
2) ALARM CONDITIONS MARKED WITH A SINGLE ASTERISK (*) SHALL BE ACTIVE ONLY WHEN THE SYSTEM IS IN OCCUPIED MODE AND HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES.
3) UNIT STATUS SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END).
4) PROVIDE OVERRIDE REGISTER INFORMATION FOR ALL POINTS REQUIRING AN OVERRIDE. IF OVERRIDE IS ACCOMPLISHED VIA WRITING TO THE POINT REGISTER, INDICATE "SAME AS POINT REGISTER"
5) FOR ALL DATA TYPES EXCEPT "OTHER" THE DATA TYPE IS SPECIFIED IN UFGS 25 10 10.
FOR ALL DATA TYPES INDICATED AS "OTHER", PROVIDE A NAME FOR THE DATA TYPE IN THE SPACE PROVIDED AND DEFINE THE DATA TYPE IN THE TABLE BELOW.
ADD ROWS TO THE TABLE BELOW AS NEEDED TO DEFINE ALL DATA TYPES USED.

DATA TYPE NAME	DATA TYPE DEFINITION
<___>	<___>
<___>	<___>
<___>	<___>
<___>	<___>

Figure B-6 Example Points Schedule for OPC Gateway

[SYSTEM NAME]

DEVICE ADDRESS: <___>

GENERAL POINT INFORMATION				POINT OPC TAG	M&C SOFTWARE FUNCTIONS						OVERRIDE OPC TAG (SEE NOTE 4)
								ALARM INFORMATION			
FUNCTION	NAME	DESCRIPTION	UNITS		DISPLAY REQUIRED	TREND REQUIRED	OVERRIDE REQUIRED	ALARM CONDITION	ALARM PRIORITY	ALARM ROUTING	
EXAMPLE POINTS		GENERIC POINT	< >	< >	[X][~}	[X][~}	[X][~}	[ ][~]	[CRIT][INFO][~]	[ ][~]	< >
	AHU1-SA-P	AIR HANDLER 1 SUPPLY AIR PRESSURE	IWC	< >	X	X	~	AHU1-SA-P LESS THAN 0.8 IWC	CRIT	HVAC_SHOP	~
	AHU5-SA-T-SP	AHU 5 SUPPLY AIR TEMPERATURE SETPOINT	DEGREES F	< >	X	X	X	~	~	~	< >

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS SPECIFIED AND AS DESCRIBED IN THE POINTS SCHEDULE INSTRUCTIONS DRAWING
2) ALARM CONDITIONS MARKED WITH A SINGLE ASTERISK (*) SHALL BE ACTIVE ONLY WHEN THE SYSTEM IS IN OCCUPIED MODE AND HAS BEEN IN OCCUPIED MODE FOR MORE THAN 5 MINUTES.
3) UNIT STATUS SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END).
4) PROVIDE OVERRIDE OPC TAG INFORMATION FOR ALL POINTS REQUIRING AN OVERRIDE. IF OVERRIDE IS ACCOMPLISHED VIA WRITING TO THE POINT OPC TAG, INDICATE "SAME AS POINT TAG"

APPENDIX C GLOSSARY

C-1 ACRONYMS

BCN	Building Control Network
BCS	Building Control System
CAC	Common Access Card
CCR	Criteria Change Request
CoN	Certificate of Networthiness
DDC	Direct Digital Control
FCS	Field Control System
FPOC	Field Point of Connection
GIS	Geographical Information Systems
GUI	Graphical User Interface
HVAC	Heating Ventilating and Air Conditioning
IDG	Installation Design Guide
IDIQ	Indefinite Delivery Indefinite Quantity
IP	Internet Protocol
IT	Information Technology
LNS	LonWorks Network Services
M&C	Monitoring and Control
MCX	Mandatory Center of Expertise
NCT	Network Configuration Tool
NDAA	National Defense Authorization Act
O&M	Operations and Maintenance
PDF	Portable Document Format
PID	Proportional, Integral, Derivative
SCADA	Supervisory Control And Data Acquisition
UCN	Utility Control Network
UCS	Utility Control System
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification

UMCS	Utility Monitoring and Control System
USACE	U.S. Army Corps of Engineers
VAV	Variable Air Volume

C-2 DEFINITION OF TERMS

Several terms are defined in this appendix for ease of reference, but UFC 4-010-06 contains a more extensive, and definitive, list of terms. Should the definitions provide here and in UFC 4-010-06 conflict, the definitions in UFC 4-0101-06 should be used, and a Criteria Change Request (CCR) should be submitted to update the definitions in this UFC.

C-2.1 Field Control System (FCS) and Field Control Network (FCN).

A Building Control System or Utility Control System. The network used by the field control system is called the field control network (FCN).

C-2.1.1 Building Automation System (BAS).

The system consisting of the UMCS Front-End and connected building control systems which provides for control of the building electrical and mechanical systems as well as a user interface and supervisory capability (i.e. the portion of the UMCS for building control and excluding any connected UCS).

C-2.1.2 Building Control System (BCS) and Building Control Network (BCN).

One type of Field Control System. A control system primarily for building electrical and mechanical systems, typically HVAC (including central plants) and lighting. Building Control Systems are generally composed of direct digital controls (DDC) and do not have a full-featured user interface. They may have some local user interface such as “local display panels” but rely on the UMCS for the full user interface functionality. The network used by the building control system is called the building control network (BCN).

C-2.1.3 Utility Control System (UCS) and Utility Control Network(UCN).

One type of Field Control System. Used for control of utility systems such as an electrical substation, sanitary sewer lift station, water pump station, etc. Building controls are excluded from a UCS, however it is possible to have a Utility Control System and a Building Control System in the same facility, and for those systems to share components such as the Field Point of Connection (FPOC). A UCS may include its own local front-end.

C-2.2 Field Point of Connection (FPOC).

The connection point between the field control network (installed by the controls contractor) and the UMCS network (generally owned and installed by the installation IT staff). The FPOC device is typically on the IP network – usually a managed switch, owned and managed by the installation IT staff, and a focal point for Cybersecurity. Note that this definition has evolved over time and may be at variance with older usage of the term.

C-2.3 Industrial Control System (ICS).

One type of control system. Most specifically a control system which controls an industrial (manufacturing) process. Sometimes also used to refer to other types of control systems, particularly utility control systems such as electrical, gas, or water distribution systems.

Note than ICS is at times used to mean “all control systems”, so care must be taken to interpret the term in the appropriate context.

C-2.4 Utility Monitoring and Control System (UMCS)

The system consisting of one or more field control systems connected to a UMCS Front-End which provides for control of the electrical and mechanical systems as well as a user interface and supervisory capability. (i.e. the complete system consisting of the UMCS Front-End with all connected BCS and UCS systems). Note that in the past the term “UMCS” has sometimes been used to mean just “the UMCS front end”, but is no longer used in this manner.

C-2.5 Utility Monitoring and Control System (UMCS) Front End

The portion of the UMCS consisting primarily of computers running software to provide a full-featured user interface. In addition to providing a full user interface, this system performs functions such as alarming, scheduling, data logging, electrical demand limiting and report generation. The front end does not directly control physical systems; it interacts with them only through field control systems.

C-2.6 Utility Monitoring and Control System (UMCS) IP Network

The IP network used by the UMCS Front End for communication between Field Control Systems. This includes the IP infrastructure components only. The UMCS IP network is often also referred to as the “platform enclave” for cybersecurity purposes.

C-3 TERMS SPECIFICALLY NOT USED BY THIS UFC

The term SCADA (Supervisory Control And Data Acquisition) is not used as the definition can vary depending on context. In general usage, however, “SCADA” can be taken to mean “UCS”.

NDAA 2010 uses the term Energy Monitoring and Utility Control System to refer to a Utility Monitoring and Control System (UMCS). This term is not a standard term used by the controls industry, so this UFC and UFGS 25 10 10 do not use this term.

C-4 OTHER TERMINOLOGY

Other terminology related to control systems is defined in UFGS 25 10 10 and in the field control system specifications (e.g. UFGS 23 09 00, UFGS 23 09.01, and UFGS 23 09.02).

UFC 3-490-06
8 June 2018
Change 1, 13 January 2021

UNIFIED FACILITIES CRITERIA (UFC)

ELEVATORS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

ELEVATORS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	13 JAN 2020	Numerous clarifications, corrections, additions, and deletions throughout the document in response to Criteria Change Requests (CCRs) and Tri-Service reviews.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
SUMMARY SHEET

Document: UFC 3-490-06: *Elevators*

Superseding: NAVFAC ITG 2013-01, NAVFAC Elevator Design Criteria

Description: This UFC 3-490-06 incorporates tri-service requirements into one unified document and provides design and construction requirements for elevators in DOD facilities.

Reasons for Document:

- References industry standards to meet DOD requirements.
- Identifies consistent and uniform design and methodology to be used for effective compliance with National Building and Safety Codes that apply to elevator installations.
- Provides direction for the most effective application of standard elevator types to the majority of typical DOD facility sizes and configurations.

Impact:

- Design requirements presented herein will reduce design costs by providing standard design requirements utilizing industry standards. Requirements for design and construction of elevators support competition and capture energy savings over the lifecycle of the elevator systems.

Unification Issues: None.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Non-Governmental building and safety codes identify absolute minimum design and operational requirements for elevator systems and for the building systems that interface with the elevator microprocessor controllers. The performance language used in the codes results in a multitude of different, and often conflicting, interpretations. This UFC was developed to provide the authority having jurisdiction (AHJ) with consistent and uniform methods to be used to comply with the performance language used in the building and safety codes.

While safety codes are designed to achieve safe operation and usage, they do not address reliability and sustainability. The NAVFAC ITG 2013-01, Elevator Design Guide, was originally developed to ensure safety, sustainment, and effective elevator performance. This concept was endorsed by USACE and ITG 2013-01 was adopted by USACE in October 2014. This UFC builds on the holistic design criteria approach and establishes uniform quality and performance requirements for specific elevator components and systems, to ensure safety code compliance, effective performance, sustainability, energy efficiency, and optimum life-cycle costs.

1-2 PURPOSE AND SCOPE.

This UFC provides minimum technical requirements and guidance for new construction and modernization of elevator systems, and their supporting structure, building systems, and components.

1-3 APPLICABILITY.

This UFC applies to all planning, design and construction, modernization, repair, maintenance and operation, and equipment installation in new and existing buildings, regardless of funding source. Certain specialized facilities, such as health facilities, may have more stringent requirements. Project conditions and geographic locations may dictate the need for designs that exceed these requirements.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, DoD Building Code (General Building Requirements). UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 CYBER SECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

1-6 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise stated, the latest available issuance of the reference is used. References to other publications, standards, and technical data referenced herein form a part of the UFC requirements to the extent referenced.

1-7 ADDITIONAL REQUIREMENTS.

When performing work within the U.S., verify if there are additional State requirements that apply to elevator design and operation. Confirm with the DOD Service agency as to the applicability of any state requirements.

1-8 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

CHAPTER 2 PLANNING AND DESIGN REQUIREMENTS

2-1 PLANNING AND PRELIMINARY DESIGN.

Coordinate elevator planning and design with facility operational requirements, DOD policy, UFCs and requirements referenced herein. The project planning and preliminary design process must determine the need for elevators based on facility operational requirements as well as DOD Policy and UFC compliance. Requirements and considerations addressing the need for elevators include the following:

- Operational requirements
- ABA Accessibility Standard for Department of Defense Facilities
- DEPSECDEF Memo: Access for People with Disabilities
- UFC or FC addressing facility type design requirements

2-2 CLIENT SURVEY AND TRAFFIC STUDY.

To determine the elevator types, service, size, capacity, speed, quantity, and operational systems necessary for effective elevator service, the preliminary design process must include a client survey and traffic study of the proposed facility design.

2-2.1 Traffic study factors.

For facilities not covered by a UFC or FC specific to a facility type where elevator requirements have been predetermined, obtain the services of an elevator consultant to conduct a traffic study. Utilize the following factors in the traffic analysis:

- Type and Use of Building
- Size and Height of Building
- Building Population
- Exterior Personnel Traffic Considerations
- Anticipated Personnel Traffic Flow

2-2.2 Passenger or freight classification.

The two categories of service that are recognized by ASME A17.1, Safety Code for Elevators and Escalators, are Passenger and Freight. For each elevator, the designer and client must decide whether the elevator will be designated as a passenger elevator or freight elevator, based on the anticipated usage of the elevator. An elevator that will be used for the movement of personnel must be designed as a passenger elevator, and must comply with DEPSECDEF Memo "Access for People with Disabilities" dated October 31, 2008. An elevator that will be used exclusively for the movement of material may be classified and designed as a freight elevator.

2-2.2.1 Platform Loading.

Passenger elevators may be utilized for movement of furniture, office equipment, and other material. A passenger elevator that will be used to transport material that exceeds 25% of the capacity of the elevator must be designed with a minimum of ASME A17.1 Class C-3 loading.

2-2.3 Emergency Medical Services (EMS) Elevator.

Where elevators are provided in a building, design a minimum of one passenger elevator to accommodate EMS access to all floors of the building. Design elevator to accommodate a 24-inch by 84-inch (610mm by 2134mm) ambulance stretcher **1**\ with not less than 5-inch (127 mm) radius corners, /**1**/ in the horizontal, open position. Identify the elevator with the international symbol for emergency medical services (star of life). Design facility to ensure EMS access from EMS response area to the EMS-designated elevator.

1\ Note: Existing building elevator modernizations are exempt if reusing the existing hoistways/shafts. However, if a new elevator shaft/hoistway is part of the renovation project, then it must comply with this requirement. /**1**/

2-3 BUILDING SYSTEMS INTERFACE.

Building utility systems that interface with elevator design and control systems include electrical, mechanical, communication, fire protection, and fire alarm. For modernization projects, verify that existing building systems are compliant with current safety code requirements and are compatible with proposed elevator systems.

2-3.1 Firefighters' Emergency Operation (FEO).

All elevators with a travel distance greater than 80 **1**\ inches /**1**/ must be designed with Firefighters' Emergency Operation (FEO). For modernization projects, verify existing building fire alarm system is compatible with elevator operational controller and compliant with current safety and building codes.

2-3.2 Emergency Power.

For new construction and modernization of buildings equipped with an emergency power generator, the emergency power system must provide, at a minimum, the capability for the normal operation of the EMS elevator on emergency **1**\ standby /**1**/ power. **1**\ All elevators in the same control group as the EMS elevator must be capable to operate on standby power. /**1**/ In addition, the designer must determine if the client requires additional elevators to be powered by the facility emergency power generator.

2-3.2.1 Emergency Power Design Considerations.

The design of elevator emergency power operation must address the following:

- Identify the number of elevators to run simultaneously.
- Identify elevators and elevator groups to be designed with sequential return operation.

2-3.2.2 Auxiliary Power Operation.

Elevators not designed for building emergency power generator operation must be equipped with an auxiliary power operating system that provides the following operation:

- Electric Traction elevators must run to the next available landing, open **\1\ /1/** the doors, and be removed from service.
- Hydraulic elevators must lower to the FEO Designated Landing, open and close the doors, and be removed from service. If elevator is below the FEO Designated Landing when normal power fails, elevator must open and close the doors at first available landing and be removed from service.

2-3.3 Energy Efficiency.

Energy-efficient technologies are available for new construction and modernization of elevator installations and can be effective in buildings with 10 stories or greater. “Regenerative Drive” motor control systems have been developed for use with gearless traction elevators. This motor control system uses the energy that is developed when the elevator is running in an overhauling load condition. The drive converts the mechanical energy into electrical energy and feeds it back to the facility power grid. The use of gearless traction machines and regenerative drive motor control should be considered for **\1** mid-rise **/1/** and high-rise elevator installations.

2-3.4 Telephone and Communication Systems.

The elevator emergency communication phone line must provide the capability for the elevator cab automated communication system to connect to an emergency response desk that is manned 24 hours a day by authorized personnel. **\1** The phone line must provide the elevator cab communication system to automatically identify the location of the elevator, elevator number and provide the capability for voice communication between the elevator passenger and authorized personnel. The phone line must be capable to provide two-way voice communication between the elevator machine room/control room and the elevator cab. **/1/**

2-3.4.1 Secondary Call Capability.

The emergency communication line must provide the capability for the elevator cab communication device to accomplish the elevator safety code required secondary phone call in the event that the initial call is not answered within 45 seconds.

2-4 ELEVATOR TYPES AND USAGE.

2-4.1 Hydraulic Elevators.

Direct Plunger Hydraulic Elevators may be used for 2 to 4 stories. Roped hydraulic elevators may be used for specific, approved applications, as incorporated into DoD UFC Criteria for approved building types and designs. Telescopic plunger, and inverted cylinder/plunger elevator designs are not permitted in DOD facilities.

2-4.1.1 Speed and Travel Requirements.

- In-ground Direct Plunger: For an elevator travel distance of **1**\ less than 16 feet (4.9 m), rated speed must be 125 feet per minute (fpm) (38.1 m/min). For a travel distance between 16 feet (4.9 m) and 44 feet (13.4 m), the rated speed must be 150 fpm (45.7 m/min). Do not exceed a travel length of 44 feet (13.4 m) or a maximum of four floors for this type of elevator. Do not exceed rated speed of 150 feet per minute (45.7 m/min). /**1**/
- Hole-less Direct Plunger: Rated speed must be 125 fpm (38.1 m/min) for this type of elevator. Elevator travel distance is limited by the depth of the hoistway pit and the overhead clearance in the top of the hoistway.
- Roped-hydraulic: A roped-hydraulic elevator is allowed for Air Traffic Control Towers (ATCT). When used for ATCT facilities, elevator travel distance must not exceed 48 feet (14.6 m). This is intended to equate to an ATCT tower cab floor elevation of 60 ft (18.3m) or less as the elevator stops at the floor below the tower cab. **1**\ For rated speed, follow speed requirements of "In-ground Direct Plunger" paragraph above. /**1**/ See section 2-5 Exceptions for other uses of roped-hydraulic elevators.

  1\ NOTE: An overspeed valve is not to be used on a Roped-hydraulic system. /**1**/

2-4.1.2 Unified Facilities Guide Specifications (UFGS).

Hydraulic elevator equipment requirements are specified in the following UFGS:

- UFGS 14 24 13: Hydraulic Freight Elevators
- UFGS 14 24 23: Hydraulic Passenger Elevators

2-4.2 Electric Traction Elevators.

1\ Provide in the design of the hoistway, a minimum of 18 inches of counterweight runby to allow for rope stretch and adjustability. /**1**/

2-4.2.1 Minimum Travel and Speed Requirements.

- Geared Traction Machine: This type of elevator may be used for **1**\ elevators with a travel of 100 feet or less. For a travel distance of less than 16 feet (4.9 m), the rated speed must be a minimum of 125 fpm (38.1 m/min). For a travel distance of 16 feet (4.9 m) to 24 feet (7.31 m), the rated speed must be a minimum of 150 fpm. For a travel distance of greater than 24 feet (7.3 m), up to 44 feet (13.4 m), the rated speed must be a minimum of 200 fpm (61 m/min). For a travel distance of 44 feet (13.4 m) /**1**/ - 100 feet (30.5 m), the rated speed must be a minimum of 350 fpm (106.7 m/min).
- Gearless Traction Machine: This type of electric traction elevator may be used for all applications and must be used for **1**\ elevators with a travel of greater than 100 feet (30.5 m). For a travel distance of less than 16 feet (4.9 m), rated speed must be a minimum of 125 fpm (38.1 m/min). For a travel distance of 16 feet (4.9 m) to 24 feet (7.3 m), the rated speed must be a minimum of 150 fpm. For a travel distance of greater than 24 feet (7.3 m), up to 44 feet (13.4 m), rated speed must be a minimum of 200 fpm (61 m/min). For a travel distance of 44 feet (13.4 m) - 100 feet (30.5 m), rated speed must be a minimum of 350 fpm (106.7 m/min). For a travel distance of greater than 100 feet (30.5 m), rated speed must be a minimum of 500 fpm (152.4 m/min). For elevators with a travel distance of greater than 200 feet (61 m), utilize elevator traffic study to determine appropriate speed. /**1**/

2-4.2.2 Unified Facilities Guide Specifications (UFGS).

Electric Traction elevator equipment requirements are specified in the following UFGS:

- UFGS 14 21 13: Electric Traction Freight Elevators
- UFGS 14 21 23: Electric Traction Passenger Elevators

Table 2-1 Elevator Types and Usage

Elevator Type	\1\ Approximate Number of /1/ Landings	Travel	Minimum Speed
Hydraulic Traction Geared Traction Gearless	2	Up to 15’	125 ft/min
1\ Hydraulic	2 - 4	16’ - 44’	150 ft/min /**1**/

\1\ /1/ Traction Geared Traction Gearless	2 - 4	16’ - **\1** 24’ **/1/**	150 ft/min
Traction Geared Traction Gearless	2 - 5	24’ - 44’	200 ft/min
Traction Geared Traction Gearless	**\1** 2 **/1/** - 10	45’ - 100’	350 ft/min
Traction Gearless	> 10	> 100’	500 ft/min

2-5 EXCEPTIONS.

Submit written UFC exception requests to the responsible Service elevator program SME. For an individual project design, the SME is authorized to grant an exception for the following conditions:

- Use of a roped-hydraulic elevator for a new construction or modernization project (except as allowed for ATCT)
- elevator speed and travel requirements for special purpose, special application, and high capacity freight elevator installations

CHAPTER 3 ARCHITECTURE

3-1 ELEVATOR MACHINE ROOM.

For building design with elevator machine room, provide one elevator machine room (MR) for each elevator or elevator group. Locate the elevator machine and elevator controller in the machine room.

3-1.1 Machine Room Size.

For a single electric traction elevator, provide a minimum machine room (MR) size of 120 sq. ft., with a minimum interior wall length of 10 feet. For a single hydraulic elevator, provide a minimum MR size of 72 sq. ft., with a minimum wall length of 8'-0". For MR with multiple elevators, increase MR size to accommodate elevator and elevator utilization equipment and to comply with all applicable codes and standards.

3-1.2 Machine Room Location.

Locate elevator MR directly adjacent to the elevator hoistway. For electric traction elevator installations, locate MR directly above hoistway or directly beside the elevator hoistway. Locate hydraulic elevator MR on the lowest landing served by the elevator, except as noted in Paragraph "Flood Zone Restrictions".

3-1.2.1 Flood Zone Restrictions.

For all elevators, design elevator system, and all related components, in accordance with the Elevator Section in the current edition of ASCE 24, Flood Resistant Design and Construction.

3-1.3 Machine Room Plans.

Provide the following:

- a. Design building and elevator systems so that access panels are not installed in walls or ceiling of the MR.
- b. Provide maximum ceiling height of 15 feet (4.6 m).
- c. For overhead traction elevator, provide interior width of elevator MR a minimum of 16 inches wider than the interior width of the elevator hoistway **1**\\ for clearance to service and test governor /**1**/.
- d. Provide minimum clearance of 18 inches (450 mm) between any building component and a traction elevator drive machine.
- e. Provide minimum clearance of 10 inches (254 mm) between over-speed governor and any building component.
- f. Provide minimum clearance of 10 inches (254 mm) between any building component and a hydraulic elevator pump unit.

g. Provide minimum 3 feet wide X 6 feet 8inches high MR entry door.

h. Provide **1**\ an out-swing, /**1**/ self-closing MR door with lever handle on MR side of door equipped with a self-locking spring-type lock arranged to permit the door to be opened from inside the MR without a key.

i. **1**\ Provide 84 inches of unobstructed vertical clearance. (headroom) /**1**/

3-1.4 Machine Room Sound Transmission Limits.

Provide elevator MR with a sound transmission coefficient design to not exceed 65 decibels of audible elevator machine room equipment noise, measured at any location outside of the elevator MR.

3-1.5 Machine Room Access.

Provide a permanent and unobstructed personnel and material access route from building entrance to the elevator MR door. The access route must have a continuous minimum width of 3 feet (914 mm) and minimum height of 7 feet (2133 mm).

3-1.5.1 Stairway Access.

When the floor level of the access route is greater than 8" above or below the floor of the MR, provide a stairway **1**\ that is IBC compliant, minimum inclination of 30 degrees and maximum inclination of 50 degrees. Vertical ladders, ships ladders, and alternating step tread designs are not permitted for MR access. Provide maximum riser height of 7 inches (178 mm) and a minimum step tread depth of 11 inches (279 mm) /**1**/, as measured from each adjoining step, nose to nose. Provide maximum height of the access stairs 12 feet (3.6 m) without an intermediate landing.

1\ Exception: For building stair designs that cannot comply with IBC, this UFC allows designers to use OSHA requirements for step riser height of 7 ½ inches and minimum step tread of 10 inches. /**1**/

3-2 ELEVATOR CONTROL ROOM AND ELEVATOR MACHINERY SPACE.

For building design that does not have an elevator machine room, provide an elevator Control Room (CR) for the elevator controller and an elevator machinery space (MS) for the elevator drive machine and speed governor. For building design with elevator CR and MS, provide one CR and one MS for each elevator or elevator group. Design CR and MS for full bodily entry. Locate elevator controller in CR and elevator drive machine in MS.

3-2.1 Control Room Location and Size.

Locate elevator CR directly adjacent to, and outside of, the elevator hoistway. For a single elevator, provide a minimum CR size of 40 sq. ft., with a minimum of one interior wall length of 7 feet. For CR with multiple elevators, increase CR size to accommodate elevator controls, elevator utilization equipment, hydraulic MS access panel, maintenance and service, and all applicable codes and standards.

1\ [C] 3-2.1 The elevator CR provides a dedicated space to facilitate maintenance associated with the elevator controller while minimizing disruption to building users (elevator operation and access to common areas). /**1**/

3-2.2 Machinery Space Location and Size.

For electric traction elevator, locate MS directly above the hoistway, directly adjacent to the side of the hoistway, or in the top of the hoistway. For a single elevator, provide a minimum MS size of 36 sq. ft. For MS with multiple elevators, increase MS size to accommodate elevator equipment, maintenance and service, and all applicable codes and standards. For hydraulic elevator, locate MS in the elevator hoistway pit or directly adjacent to the hoistway on the lowest landing served by the elevator, except as required by ASCE 24, Flood Resistant Design and construction.

1\ [C] 3-2.2 The elevator MS provides a dedicated, fixed space to facilitate ease of maintenance and testing associated with the elevator mechanical equipment. /**1**/

3-2.2.1 Flood Zone Restrictions.

For all elevators, design elevator and all related components in accordance with the Elevator Section in the current edition of ASCE 24, Flood Resistant Design and Construction.

3-2.3 Control Room Plans.

Provide the following:

a. Design building and elevator systems so that access panels are not installed in walls or ceiling of the CR. Exception: Hydraulic elevators with MS in the elevator hoistway.

b. For hydraulic elevator with MS in the elevator hoistway, provide access panel in CR that provides all necessary access to the elevator pump unit and drive machine for maintenance, service, inspection, and testing of the elevator. Maximum allowable height of access panel is 6’ above finished CR floor.

c. Provide maximum ceiling height of 12 feet (3.6 m).

d. Provide minimum clearance of 10 inches (254 mm) between over-speed governor and any building component.

e. Provide minimum 3 feet wide X 6 feet 8 inches high CR entry door.

f. Provide **1**\ an out-swing, /**1**/ self-closing CR door with lever handle on CR side of door equipped with a self-locking spring-type lock arranged to permit the door to be opened from inside the CR without a key.

3-2.4 Machinery Space Plans.

Provide the following:

a. Design building and elevator systems so that access panels are not installed in walls or ceiling of the MS.
b. Provide minimum headroom clearance of 78 inches (1981 mm) in the MS.

c. Provide minimum clearance of 18 inches (450 mm) between any building component and a traction elevator drive machine.

d. Provide minimum clearance of 10 inches (254 mm) between over-speed governor and any building component.

e. Provide minimum clearance of 10 inches (254 mm) between any building component and a hydraulic elevator pump unit located in a MS outside of the elevator hoistway.

f. Provide minimum 3 feet wide X 6 feet high MS entry door.

g. Provide self-closing MS door with lever handle on MS side of door equipped with a self-locking spring-type lock arranged to permit the door to be opened from inside the MS without a key.

h. Where MS is located in the top of the hoistway, provide solid flooring, excluding holes required for hoist and governor ropes.

3-2.5 Machinery Space Sound Transmission Limits.

Provide elevator MS with a sound transmission coefficient design to not exceed 65 decibels of audible elevator machine room equipment noise, measured at any location outside of the elevator MS, including all building interior areas and the interior of the elevator cab.

3-2.6 Control Room and Machinery Space Access.

Provide a permanent and unobstructed personnel and material access route from building entrance to the elevator CR and MS door. The access route must have a continuous minimum width of 3 feet (914 mm) and minimum height of 7 feet (2133 mm).

3-2.6.1 Stairway Access.

When the floor level of the access route is greater than 8 inches above or below the **1**\ floor of CR or MS, provide a stairway that is IBC compliant, minimum inclination of 30 degrees and maximum inclination of 50 degrees. Vertical ladders, ships ladders, and alternating step tread designs are not permitted for CR or MS access. Provide maximum riser height of 7 inches (178 mm) and a minimum step tread depth of 11 inches (279 mm) /**1**/, as measured from each adjoining step, nose to nose. Provide maximum height of the access stairs 12 feet (3.6 m) without an intermediate landing.

1\ Exception: For building stair designs that cannot comply with IBC, this UFC allows designers to use OSHA requirements for step riser height of 7 ½ inches and minimum step tread of 10 inches. /**1**/

3-3 ELEVATOR HOISTWAY.

3-3.1 Hoistway Pit Entrapment Protection.

Provide a minimum horizontal clearance of 20 inches (508 mm) between the side of the elevator platform/cab and any one wall of the elevator hoistway. A horizontal clearance of 20 inches (508 mm) wide X 36 inches long (915 mm) must be maintained for the entire height of the hoistway. Elevator and building components must not encroach on the minimum clearances or block personnel passage from the elevator pit to the **1**\ pit entrapment area.

A secondary push-to-stop pit stop switch must be provided within the hoistway pit entrapment protection egress area, at a height between 50 inches (1270 mm) and 60 inches (1524 mm) above the pit floor. /**1**/

NOTE: For the restoration or modernization of an elevator with an existing hoistway, comply with this requirement if practicable.

3-3.2 Elevator Hoistway Plans.

Develop detailed plan and section drawings for elevator hoistway. Provide all layout drawing information required by ASME A17.1. Comply with the following:

a. Elevator hoistway layout and dimensions must take into consideration the size and configuration of the elevator landing entrances.

b. Locate only access panels or doors in the walls or ceiling that are necessary for the operation, maintenance, service, inspection, and testing of the elevator.

c. Provide plumb hoistway walls with flush surfaces on the hoistway side.

d. For hoistway pit with a depth exceeding 35 inches (889 mm), provide fixed ladder on the hoistway side closest to the hoistway entrance.

e. Provide only mechanical equipment and systems directly related to the installation, operation and maintenance of the elevator. Pipes, ducts, and conduit not related to the elevator system must not penetrate the hoistway.

f. **1**\ Provide in the design of the hoistway, a minimum of 18 inches of counterweight runby to allow for rope stretch and adjustability. /**1**/

3-4 ELEVATOR HOISTWAY PIT.

3-4.1 Hoistway Pit Waterproofing.

Provide water stops in the walls and waterproofing for elevator pit floor and walls.

1\ NOTE: Waterproofing to be white or gray in color. Clear finish is not allowed. /**1**/

3-4.2 Sump and Sump Pump.

Provide elevator hoistway with a sump pit, submersible sump pump, and permanent discharge piping to a point outside of the elevator hoistway and MR. Coordinate discharge location with installation environmental department and local laws and statutes. Comply with the following:

a. Provide sump pit with fully supported and removable sump pit grate cover, with top of grate flush with pit floor.

b. Provide sump pit large enough to fully enclose submersible sump pump and control sensors below the bottom of the sump pit grate cover.

NOTE: For existing facilities that are not equipped with a sump pit, the sump pit is not required. All other requirements of **1**\ 3-4.2 /**1**/ must be met.

3-5 ELEVATOR LANDING.

Fill elevator landing doorway entrance frames **1**\ completely /**1**/ with grout to a height of 60 inches (1524 mm). Design interface between elevator landing doorway entrance frame and elevator hoistway wall to facilitate effective installation of grout in the door frame.

3-5.1 Emergency Lock Box.

For each individual elevator or for each elevator group, a keyed lockbox must be provided at the FEO Designated Landing. The lockbox must be flush mounted in the wall, adjacent to and within 20 inches (508 mm) of the hoistway entrance assembly. Locate lockbox recess in the elevator lobby wall, at a height of 60 inches (1524 mm) above the landing sill. The lockbox must have a minimum size of 6 inches (152 mm) W X 8 inches (203 mm) H X 1.25 inches (32 mm) D. The locking mechanism must utilize the ASME A17.1 FEO key.

3-5.2 Exterior Elevator Lobby Enclosure.

For exterior elevator landing entrances, provide elevator lobby enclosure or vestibule to protect elevator entrance, elevator hoistway, and elevator equipment from snow, ice, and wind driven rain.

3-6 \1\ CORROSION PROTECTION. /1/

1\ All ferrous metal elevator equipment and building components in the elevator hoistway, machine room, and machinery spaces must be painted with a minimum of one coat of enamel paint. /**1**/

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CHAPTER 4 STRUCTURAL

4-1 ELEVATOR MACHINE ROOM AND ELEVATOR MACHINERY SPACE.

Design elevator machine beams, sheave beams, **1**\ lifting beams, /**1**/ floor, and supporting structure in accordance with the concentrated load and live load requirements of ASME A17.1. Do not support elevator **1**\ machine beams or /**1**/ machine room floors located over elevator hoistway with cast-in-place or post installed anchors loaded in shear. Instead, design **1**\ all /**1**/ said **1**\ systems /**1**/ to be supported by direct bearing on hoistway walls or on structural beams pocketed in hoistway walls.

4-2 ELEVATOR HOISTWAY.

Design elevator hoistway to provide adequate support for the elevator guide rail and rail bracket connection to the building structure. For hydraulic elevators, design hoistway pit floor in accordance with the concentrated load and live load requirements of ASME A17.1.

4-2.1 Hoistway Wall Construction.

1\ All hoistway walls must comply with UFC 3-301-01. /**1**/ This applies to both load bearing and non-load bearing conditions. Additionally, elevator guide rails, rail brackets, hoist beams, and load reaction points must be supported and backed with fully grouted and reinforced cells. Do not use clay tile or brick for the construction of elevator hoistway walls.

4-3 MACHINE ROOM, MACHINERY SPACE, AND HOISTWAY PLANS.

Develop detailed plan and section drawings for elevator MR, MS, and hoistway. Show location of all support beams in the MR, MS, and hoistway. For multiple elevators in the same hoistway, provide divider beams for guide rail support brackets. Provide all layout drawing information required by ASME A17.1.

4-3.1 Structural Design Submittal.

Elevator design submittal must include a design analysis with calculations for the total static loads, impact loads, and horizontal and vertical reaction loads that will be transmitted to machine beams, sheave beams, supports, floors, walls, and foundations.

4-3.2 Lifting Beam.

For hydraulic elevator installations, provide a lifting beam at the top of the hoistway for installation of elevator equipment. The bottom of lifting beam must **1**\ not encroach on any code required clearances. /**1**/

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CHAPTER 5 MECHANICAL

5-1 ELEVATOR MACHINE ROOM, CONTROL ROOM, AND MACHINERY SPACE.

5-1.1 Elevator MR, CR, AND MS Temperature and Humidity Control.

For each elevator MR, CR, and MS, provide an independent, dedicated **1**\ Heating and Cooling system. Design Heating and Cooling system to maintain MR or CR temperature between 70 and 90 degrees F (21 to 32 degrees C) and relative humidity between 35% and 60% at all times and in all weather conditions. Design /**1**/ system to include the BTU heat load generated by operation of the elevator equipment.

5-1.2 Mechanical Equipment Installation.

Comply with the following:

a. Provide **1**\ 84 inches of unobstructed vertical clearance (headroom) where installed mechanical and electrical system components are located. /**1**/

b. Do not locate HVAC equipment above elevator equipment.

c. Provide a minimum of 18 inches (450 mm) horizontal clearance between elevator drive machine and any mechanical or electrical equipment in the elevator MR.

d. Drain AC condensate to a location outside of elevator MR and hoistway.

5-1.3 Machine Room and Machinery Space Sound Level.

Limit maximum acoustic output to 85 dBA at any point in the MR and MS.

5-2 ELEVATOR HOISTWAY PIT.

5-2.1 Hoistway Pit Sump and Sump Pump.

Provide sump pump, automatic sump pump controls, and permanent discharge piping that complies with the following:

a. Provide sump pump discharge capacity of 50 gallons per minute (189 lit/min), per elevator. Sump pump and piping must be sized to accomplish this output, regardless of head pressure or piping run.

b. Discharge to an approved location, outside of the elevator hoistway, MR, CR, and MS, that will accommodate full pump output and comply with all applicable discharge permits, regulations, and statutes.

c. Coordinate sump pump size with Architect to ensure that the sump pump and control sensors will fit completely within the sump.

d. Coordinate power requirements with electrical engineer.

5-2.1.1 Hydraulic Elevator Requirement.

For hydraulic elevator, in addition to the requirements of 5-3.1, provide a sump pump oil sensing control system designed to allow water to be pumped out of the sump without pumping oil/hydraulic fluid from the elevator hoistway pit. The sump pump control system must include an audible alarm and visual indicators for water and oil. Install alarm indicators and controls in the elevator MR **1**\ or CR. The system must alarm with high water level and the presence of oil in the sump. /**1**/

5-3 HYDRAULIC ELEVATOR CYLINDER PIPING.

5-3.1 In-Ground Cylinder Well Casing.

A dry, plumb, steel well casing must be provided for every in-ground cylinder assembly. The well casing must be located according to the elevator manufacturer's design. The well casing must have a minimum ¼ inch (6 mm) thick wall and a welded 1/2 inch (13 mm) thick steel bottom.

5-3.2 Hydraulic Oil Supply Piping.

Hydraulic oil lines must remain in or under conditioned space from end to end and remain within the building footprint. For all buried hydraulic lines between hoistway and MR or MS, provide straight pipe run in PVC pipe sleeves. Inside diameter of the PVC must be a minimum of 4 inches (102 mm) larger than the outside diameter of the supply line fittings.

CHAPTER 6 ELECTRICAL

6-1 ELEVATOR MACHINE ROOM, CONTROL ROOM, AND MACHINERY SPACE.

6-1.1 Elevator Power Supply.

For each elevator group, provide electrical power service from the main building electrical distribution panel to the elevator machine room. Designer must consider type of elevator drive specified and design accordingly. Coordinate with Designer of Record for elevator power requirements.

6-1.2 Elevator Disconnecting Means.

Provide elevator disconnecting means on the wall inside the MR and CR, on the strike jam side of the entrance door, within sight of the elevator equipment it controls.

6-1.2.1 Shunt Trip Disconnect.

For elevators with fire protection sprinklers in the elevator MR, CR, MS, or top of hoistway, provide a shunt trip circuit breaker in the elevator MR or CR for each individual elevator main power, and emergency power if provided. Shunt trip breaker design must comply with the following:

a. Shunt trip breaker must be designed to be operated by actuation of the sprinkler flow switch(s) designed to automatically open the power supply to the elevator. Power must be restored manually.

b. Breaker enclosure must include a safety-switch type handle for manual operation of the breaker.

c. Breaker handle must be capable of being locked in the open position only.

6-1.2.2 Sprinkler Line Flow Switch.

Provide sprinkler line flow switches as required by Chapter 7, Fire Protection. Provide an electrical circuit for actuation of the elevator main-line shunt trip disconnect. The sprinkler line flow switch control circuit must be monitored for the presence of operation voltage. Loss of voltage must cause actuation of a supervisory signal **\1** **/1/** at the building fire protection panel.

6-1.2.3 Auxiliary Contact.

Hydraulic elevators that are not designed for building emergency power generator operation must be designed and equipped with auxiliary power lowering operation for the purpose of lowering the car in the case of failure of the main power supply. When an elevator is equipped with auxiliary power lowering operation, the main line disconnect must be designed with an auxiliary contact to prevent automatic lowering operation when the main line disconnect is in the open position.

6-1.3 MR, CR, and MS Lighting and Receptacles.

Provide a separate 120 VAC branch circuit for each elevator MR, CR, and MS lighting and receptacles. Provide a minimum of two 2-light, 4 feet (1.2 m) long fluorescent, LED, or equivalent energy efficient lighting fixtures for illumination. Provide lighting fixture housings that are dust tight and rated for damp locations. Lighting must provide a minimum of 19 fc at floor level, in all areas of the MR, CR, and MS. The lighting must not be equipped with automatic controls or be fed from the load side of a GFCI circuit.

6-1.4 Dedicated Branch Circuits.

For each of the following circuits, provide a separate, dedicated branch circuit with a fused disconnect or breaker in the elevator MR or CR. Disconnects and breakers must be designed to be lockable in the open position only.

a. Elevator 120 VAC circuit for elevator cab lighting and receptacles.

b. Elevator cab HVAC equipment circuit **1**\ (if provided)

c. Elevator hoistway pit sump pump power and control system.

d. Elevator door controller (if provided)

e. Pit & hoistway lighting

f. MR, CR, or MS lighting

g. Pit GFCI receptacles

h. MR, CR, or MS GFCI receptacles

i. MR or CR Heating and Cooling system

j. Oil Cooler

k. Oil Heater /**1**/

6-1.5 Emergency Power.

Design power and control circuits to accomplish automatic transfer of power from normal building power to emergency power operation for elevators that will operate on emergency power. Coordinate elevator emergency power design with designer of record and the results of the client survey, as detailed in Par 2-4.2. Design requirements include the following:

a. Design electrical power circuit from emergency buss to elevator mainline disconnect(s) for all elevators that will operate on emergency power.

b. Determine which elevators will operate simultaneously on emergency power. Design emergency power system capacity to operate these elevator(s), simultaneously, at rated speed with rated load.

c. Coordinate design of the Automatic Transfer Switch (ATS) electrical control circuit with the elevator controller manufacturer's requirements.

d. Verify location of elevator MRs and CRs for potential control wiring interconnections for sequential elevator return operation.

e. Provide manual selector switch in main elevator lobby area(s) to allow emergency personnel to override the automatic emergency power selection.

f. Provide emergency power for MR, CR, and MS lighting and HVAC equipment.

g. Provide emergency power for Cab lighting and Cab HVAC equipment.

h. Provide emergency power for hoistway pit sump pump operation.

6-1.6 Emergency Communication Systems.

For elevator emergency phone in the elevator cab, provide a dedicated elevator communication service line for each **1**\ group that enables emergency response personnel to call back to any one of the individual elevators in the group and identify their location. /**1**/ Locate elevator communication line outlet adjacent to each elevator controller. Indicate outlets on telephone riser.

6-1.6.1 Fire Command Center.

For all elevators with a travel of 60 feet (18.3 m) or greater, provide emergency communication between the elevator cab and the building Fire Command Center.

6-1.7 Firefighters' Emergency Operation (FEO).

Design building fire detection and alarm system for an effective interface with the elevator controller for actuation of Fire Fighter's Emergency Operation (FEO). For FEO actuation, detail ceiling mounted fire alarm initiating devices in elevator lobbies, elevator MR or CR, and elevator hoistway where required, in conformance with UFC 3-600-01. Indicate devices on electrical drawings unless there are separate fire protection drawings. Coordinate with Fire Protection Engineer.

6-1.7.1 FEO Relay Modules.

Mount FEO operation modules on the wall inside the elevator MR or CR. Coordinate with Designer of Record for identification of FEO Designated and Alternate Landings.

\1\ /**1**/

6-2 ELEVATOR HOISTWAY.

\1\ /1/

6-2.1 \1\ Hoistway and Pit Lighting. /1/

Design hoistway **\1** and **/1/** pit lighting to provide a minimum of 10 fc at the pit floor in all areas of the pit. Hoistway lighting design must include a minimum of two lighting fixtures for lighting of the elevator hoistway pit. The fixtures must have a one piece, molded, high-impact clear acrylic diffuser with a secure seal against dust and moisture. A similar fixture must be provided at a minimum of every 10 feet (3 m) vertically up the hoistway. The fixture at the top of the hoistway must be mounted on the ceiling. For control of the hoistway lighting circuit, provide two 3-way switches inside the elevator hoistway, at a height of 4 feet (1.2 m) above the top and bottom elevator landings. Mount the switches on the hoistway wall, adjacent to the hoistway entrance strike jamb. The lower level lighting switch must be located adjacent to the hoistway pit access ladder.

6-3 ELEVATOR HOISTWAY PIT.

6-3.1 Sump Pump Receptacles.

Provide a separate branch circuit supplying power to the hoistway pit sump pump. Provide a dedicated simplex receptacle, **\1\ /1/** to supply the permanently installed sump pump. Mount sump pump receptacle 5 feet (1524 mm) above elevator pit floor. Provide LED indicator light to verify circuit is energized. For hydraulic elevators, provide an additional GFCI duplex receptacle in the elevator MR, CR, or MS to supply power to the sump pump control system.

6-3.2 Hoistway Pit GFCI Receptacles.

Provide a separate branch circuit supplying the hoistway pit **\1** receptacles with **/1/** a minimum of two duplex GFCI receptacles in the pit. Locate one receptacle on each side wall of the hoistway, at 3 feet (915 mm) above pit floor. For hydraulic elevators, provide one additional receptacle on the rear wall of the hoistway at a height of 3 feet (915 mm) above the pit floor for elevator oil-scavenger-pump power.

6-3.3 NEMA 4 Electrical Enclosures.

Provide NEMA Type 4 electrical enclosures per NEMA ICS6 for all electrical equipment located less than 4 feet (1219 mm) above the pit floor. Electrical enclosures must be water-tight, dust-tight, and identified for use in wet locations in accordance with the requirements in NFPA 70. Hydraulic elevator scavenger pump receptacle must be provided with an in-use cover.

6-4 \1\ GENERAL WIRING REQUIREMENTS.

Only electric wiring, raceways, and cables used directly in connection with the elevator are permitted inside the elevator MR, CR, Hoistway, and MS. All conductors and optical fibers except traveling cables must be in conduits.

6-4.1 Allowable electrical wiring and cables.

Allowable wiring includes wiring for elevator power control and operation, elevator communication, fire alarm and fire protection signals, lighting, receptacles, sump pump, and elevator MR, CR, and MS heating and cooling systems.

6-4.2 Separate raceways and conduits.

Provide separate electrical raceways and/or conduits for each building trade discipline; separate electrical raceways and/or conduits must be provided for:

a) Elevator contractor’s power and control wiring for operation of elevator system.

b) Fire alarm and fire protection signals and controls for the interface with the elevator system.

c) Electrical contractors power and control wiring for the lighting, receptacles, heating and cooling, and sump pump power in the MR, CR, MS, and Hoistway. /**1**/

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CHAPTER 7 FIRE PROTECTION

7-1 FIRE ALARM SYSTEM.

Design all elevator installations with Firefighters' Emergency Operation (FEO). Provide fire alarm detection and alarm system for actuation of elevator FEO and automatic elevator operational response to fire alarm initiating devices located in the elevator machine room, elevator lobbies, and elevator hoistway, as required by UFC 3-600-01 Fire Protection.

7-1.1 Elevator Controller Interface.

Utilize FEO operation relay modules for the interface between the building fire alarm panel and the elevator controller. Indicate fire alarm initiating devices, FEO relay modules, and connections on fire protection drawings or on electrical drawings if fire protection drawings are not provided. Coordinate with Electrical Engineer.

7-1.2 FEO Designated and Alternate Landings.

Determine FEO designated and alternate landings during the facility design process and identify same in the design submittal package. Coordinate FEO landing designations with the base or local fire department that will respond to a fire alarm at the facility.

7-2 FIRE PROTECTION SYSTEM.

In buildings protected with an automatic sprinkler system, comply with UFC 3-600-01, applicable codes, and the following.

7-2.1 Machine Room and Hoistway Sprinkler Protection.

For elevator MR and hoistway sprinklers located more than 2 feet (610 mm) above the pit floor, design for a supervised shut-off valve, check valve, flow switch, and test valve in the dedicated sprinkler line feeding the elevator MR and/or hoistway. Locate these items outside of and adjacent to the MR and/or hoistway. Actuation of the flow switch must remove power to the elevator by shunt trip breaker operation. Shunt trip actuation must be instantaneous; the flow switch must not have time delay capability.

7-2.2 Hoistway Pit Sprinkler Protection.

In buildings protected with an automatic sprinkler system, provide sprinkler in the pit for hydraulic elevators (except in Italy). Locate sprinkler head no more than 2 feet (609 mm) above the pit floor. Actuation of a pit sprinkler within 24 inches (610mm) of the pit floor must not remove power to the elevator.

7-2.3 Machine Room Fire Extinguisher.

On MR drawings, indicate fire extinguisher on the wall, inside the elevator machine room, on the strike-jam side of the MR door.

APPENDIX A REFERENCES

AMERICAN SOCIETY OF CIVIL ENGINEERS

http://www.asce.org

ASCE/SEI 24-0514, Flood Resistant Design and Construction

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

http://www.asce.org

ASME A17.1, Safety Code for Elevators and Escalators

ASME A17.3, Safety Code for Existing Elevators and Escalators

INTERNATIONAL CODE COUNCIL

http://www.iccsafe.org

International Building Code **1**\

International Plumbing Code

NATIONAL FIRE PROTECTION ASSOCIATION

http://www.nfpa.org

NFPA 70, National Electric Code /**1**/

UNITED STATES DEPARTMENT OF DEFENSE

http://www.dtic.mil/whs/directives/

ABA Accessibility Standard for Department of Defense Facilities

https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-aba-standards/aba-standards

http://www.lrl.usace.army.mil/Portals/64/docs/Engineering/Design_AF/aba.pdf

DEPSECDEF Memorandum, Subject: Access for People with Disabilities, 31 October 2008:

https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-aba-standards/background/dod-memorandum

DODI 8500.01, Cybersecurity, 14 March 2014DODI 8510.01, Risk Management Framework (RMF) For DOD Information Technology (IT), 12 March 2014

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, DOD Building Code (General Building Requirements)

UFC 3-101-01, Architecture

UFC 3-301-01, Structural Engineering

UFC 3-310-04, Seismic Design for Buildings

UFC 3-401-01, Mechanical Engineering

UFC 3-501-01, Electrical Engineering

UFC 3-600-01, Fire Protection Engineering for Facilities

UFC 4-510-01, Design: Medical Military Facilities

APPENDIX B BEST PRACTICES

This appendix identifies and describes standard elevator systems that are available in the elevator industry and best practices associated with each type of elevator. The best practices represent design concepts adopted by the DOD to address typical facility types, proven facility solutions, lessons learned, facility system safety, and total ownership cost.

B-1 ELEVATOR MACHINE ROOM.

The elevator Machine Room is the most critical building component of an elevator installation. The elevator machine room is the one functional area in the building that is designed and designated for the safe and effective maintenance, service, repair, and safety code mandated inspection and testing of the elevator system. During diagnostic evaluation and testing of the elevator, the certified elevator technician must operate the elevator from the elevator controller and simultaneously observe and evaluate the operation of the elevator drive machine. In addition, the certified elevator inspector is required to observe the operation of the elevator drive machine and overspeed governor during safety code mandated annual performance tests of the elevator car speed, safeties, hoist ropes, drive sheave, and overspeed governor. Performance of service, repair, inspection, and testing is more effective and more efficient when the elevator controller, the elevator drive machine, and the overspeed governor are all located in the same functional area, the elevator MR. For DoD facilities, elevator systems with a machine room for each elevator or elevator group, and the elevator controller and drive machine in the MR, are the preferred design approach.

B-1.1 Safety.

Elevator systems are comprised of complex and sophisticated mechanical, electrical, hydraulic, and electronic systems that require diagnostic evaluation, maintenance, service, repair, inspection, and testing. Elevator service personnel utilize mechanical tools and electronic equipment to perform the repair, and replacement of elevator components, including the microprocessor controller, drive machine, drive motor, over-speed governor, safeties, rope-gripper, hoist ropes, traction drive sheave, machine brake, and hydraulic elevator control valve. In addition, elevator safety code officials conduct periodic inspection and testing of the elevator system. The elevator machine room is the one functional area in the building that provides a suitable area for the staging of personnel, components, service manuals, tools, and equipment and for the safe and effective performance of these critical functions.

The elevator controller, electric motor, and motor drive, are powered by electrical power circuits that range from 30 VAC to 480 VAC. During elevator service, repair, and testing, elevator personnel are exposed to electrical safety hazards that include both electric shock and arc flash. Safety hazard exposure to any other occupants of the building is minimized by locating the elevator controller, electric motor, and motor drive in the machine room vice public space areas of the facility.

B-1.2 Clearances.

Elevator machine room minimum clearances, between elevator equipment and the MR building components, are provided to facilitate maintenance, replacement, inspection, and testing of elevator components within the machine room. While these clearances may slightly exceed the ASME A17.1 code requirements, they are designed to maximize effective lifecycle sustainment of the elevator system by DOD maintenance personnel and/or contracted services.

B-1.3 \1\ Hoistway Pit Entrapment Area.

The ASME A17.1 provides a minimum standard for refuge area and accepts the potential temporary entrapment of elevator personnel under a car in the pit. Should elevator personnel become trapped and this occurs concurrently with fire sprinkler discharge and/or catastrophic hydraulic fluid line rupture in the hoistway, entrapped personnel would be at risk of drowning.

This UFC provides egress from the pit in this scenario by requiring a hoistway pit entrapment area. DoD considers the benefit of providing egress from the pit in this scenario to outweigh its additional cost. The purpose of this area is that if an entrapment occurs emergency personnel could lower a ladder in the entrapment area to rescue trapped personnel. If the pit starts flooding before emergency personnel arrives at the scene, the entrapped personnel will have an area to self-rescue by floating up the side of the elevator. /**1**/

B-2 MACHINE-ROOM-LESS ELEVATOR DESIGN.

ASME A17.1 requires an elevator drive machine to be located in either an elevator Machine Room (MR) or an elevator Machinery Space (MS). When the elevator drive machine is not located in the machine room, the elevator is referred to as a Machine-Room-Less (MRL) elevator.

B-2.1 Location and Access.

In an MRL elevator design, the elevator drive machine is relocated from the elevator machine room (MR) to the elevator hoistway. For MRL electric traction elevators, the MRL machine is typically located in the top of the hoistway. For hydraulic elevators, the hydraulic pump unit is relocated to a position along the side wall of the hoistway pit. For both types, the elevator operation controller will be located in what is then referred to as the Control Room (CR).

Machine-Room-Less (MRL) elevator design may be utilized in the design and construction of DoD Facilities. ASME A17.1 requires elevators to be designed and constructed with an accessible machinery space whenever the elevator drive machine is located within the elevator hoistway. This UFC provides specific direction for the location and access to the MS and for clearances around mechanical and electrical equipment in the MS. These safety code and criteria design requirements are intended to facilitate the safety code mandated safe and effective maintenance, service, repair, and safety code certification inspection and testing of the elevator system.

B-2.2 Construction Cost and Leasable Space.

The construction cost and leasable space benefit of using an MRL design is that the size of the elevator equipment room can be reduced since it no longer contains the elevator drive machine. Instead of having a 72 sq ft MR, the elevator equipment room can be reduced to a 40 sq ft Control Room.

However, this perceived advantage is offset by the fact that the building must also be designed with an additional mechanical area, the machinery space described in Par B-2 and B-2.1, above. For an electric traction elevator, a typical machinery space will require approximately 36 sq ft. In developing the building design, and determining the associated costs, designers must take into consideration the duplicate electrical, mechanical, and fire protection utility systems that are required for both the CR and the MS. Building and safety codes require both the CR and the MS to be equipped with lighting, electrical disconnects, fire alarm and fire protection systems, and independent HVAC systems for each area. For electric traction elevators, electrical design considerations must also include the additional run of electrical power conductors from the CR to the MS in the top of the elevator hoistway.

B-2.3 \1\ Sustainment (maintenance) Costs.

Although often costing more initially than MRL designs, machine room designs can realize lower maintenance costs over an expected building service life when considering operating costs, preventative maintenance, testing, repair, and modernization. These avoided costs can make machine-room designs life-cycle cost effective over a building service life in most applications. /**1**/

B-3 HYDRAULIC ELEVATORS.

The conventional hydraulic elevator consists of an elevator machine room (MR) located adjacent to elevator hoistway, with the elevator operation controller and hydraulic pump unit located in the elevator MR. The hydraulic pump unit consists of a hydraulic fluid reservoir, an electric motor and hydraulic pump, and control valves that regulate the movement of hydraulic fluid in and out of the pump unit. The hydraulic cylinder/plunger assembly is located in the elevator hoistway and is fully supported by the pit floor. Hydraulic fluid supply piping is installed from the pump unit to the hydraulic cylinder/plunger assembly in the elevator hoistway. When the pump unit supplies hydraulic fluid to the cylinder, the hydraulic plunger is forced up and out of the cylinder, driving the elevator up the hoistway. Downward movement of the elevator is powered by gravity and controlled by the elevator control valve in the pump unit. Current hydraulic elevator control valve technology that controls elevator acceleration, deceleration, and leveling, limits effective hydraulic elevator speed to a maximum of 150 fpm. At higher speeds, excessive slowdown and leveling time and travel distances are required for acceleration and deceleration.

B-3.1 Restricted Designs and Technology.

Roped hydraulic elevators and hydraulic elevators with a telescopic cylinder/plunger assembly (jack) are available in the elevator industry to allow the use of hydraulic elevator systems for higher rise applications. However, the acquisition and sustainment cost of these systems, including cost of equipment, installation, maintenance, and service, is comparable to electric traction elevators without the benefits of greater speed, efficiency, and performance offered by electric traction elevators. There are some, limited, applications where a roped hydraulic elevator can be the best choice, including Air Traffic Control Tower (ATCT) installations and modernizations of existing buildings that cannot support an electric traction elevator.

A non-standard, inverted hydraulic cylinder/plunger design is also available from a limited number of hydraulic cylinder manufacturers. In this design, the hydraulic cylinder is attached to the elevator cab in an upside-down configuration. The plunger protrudes from the bottom of the cylinder and presses against the pit floor. There is no inherent cost or performance benefit to this design and the sustainment cost is much greater than for a standard hydraulic cylinder design.

B-4 ELECTRIC TRACTION ELEVATORS.

Electric traction elevators may be used for all buildings. The traditional overhead-traction elevator consists of an elevator machine room (MR) located above the elevator hoistway. The elevator operation controller and drive machine are located in the elevator MR. Steel hoist ropes (cables) are suspended on the elevator machine drive sheave and the ends of the hoist ropes hang down into the elevator hoistway. In the hoistway, the elevator cab is fastened to one end of the hoist ropes and the elevator counterweight is fastened to the other end of the hoist ropes. The counterweight is used to counterbalance the weight of the elevator cab and the load in the cab, thereby reducing required motor torque and increasing energy efficiency. Alternative roping configurations are also used (e.g. 2:1) for greater energy efficiency and to allow a smaller drive machine to support a higher capacity load than it could otherwise. As identified in Section 2-4, speed limitations are directly related to the height of the building and the number of landings served by the elevator.

B-4.1 Drive Machines.

There are two types of electric traction hoist machines, geared and gearless. Elevator travel and car speed typically determine the most effective application of each type.

- Geared Traction Machine: The elevator drive motor drives a worm and ring gear assembly in the elevator drive machine. The ring gear turns the drive sheave, which moves the hoist ropes that raise and lower the elevator cab in the hoistway.
- Gearless Traction Machine: The gearless drive machine consists of an electric motor that connects directly to the elevator drive sheave; there is no gear reduction unit. Gearless machines are available with a

conventional asynchronous induction AC motor with electrically excited fields or with the more energy efficient AC Permanent Magnet (PM) motor. Rapid advances in AC PM motor and machine technology have made this a standard option for electric traction elevator drive machines. The PMAC motor, drive, and machine technology provides the same energy efficiency whether it is located in the elevator machine room or in a machinery space in the top of the elevator hoistway.

B-4.2 Energy Efficiency.

Electric motor and motor-drive energy-efficient technologies are available in the elevator industry for electric traction elevators. High-efficiency alternating current (AC) permanent magnet (PM) gearless machines have been incorporated into elevator design in the elevator industry and can provide up to 30 - 40% efficiency gains over standard geared traction drive machines. The machine utilizes an electric motor design with permanent magnets, in lieu of electrically energized field coils, to increase energy efficiency of the drive machine. In addition, “Regenerative Drive” motor control systems have been developed for use with the AC PM motor drives. This motor control system uses the energy that is developed when the elevator is running in an overhauling load condition and converts the mechanical energy into electrical energy which is fed back to the building power grid.

Electric motor and motor-drive energy-efficient technologies should be considered for all buildings. However, the current AC PM motor and drive technology provides a service life of only 35% - 60% of the standard geared traction machine. Prior to providing direction for use of regenerative elevator motor drives, additional research and cost analysis is required, with regard to a comparison of motor drive energy savings versus excessive cost of replacement of elevator motor and motor drive systems.

B-4.3 Suspension Means.

Elevator traction-steel wire rope is the industry standard for elevator suspension means (hoist ropes). Non-coated steel hoist ropes are specified for use in UFGS 14 21 13: Electric Traction Freight Elevators and UFGS 14 21 23: Electric Traction Passenger Elevators. Elevator certifying officials are required to verify safety code compliance with minimum hoist rope diameters and maximum allowable number of broken wires in the strands of the rope. The use of non-coated steel hoist ropes provides for the effective application of elevator safety code inspection and certification requirements related to hoist rope wear and fatigue. In addition, in the event that the elevator runs past a terminal landing and bottoms out on the car or counterweight buffer, non-coated steel wire rope can slip traction with the drive sheave without damaging the wire rope.

B-4.4 Cost, Performance, and Safety.

Electric Traction vs Hydraulic

Section 2-4 of this UFC provides direction for the application of elevator types to building design, based on the length of travel and number of landings served by the elevator. These limitations are driven by several factors, including effective elevator performance, cost of the elevator system, and safety of the elevator occupants.

When an electric traction elevator is included in the design of a building, building design and construction is more expensive than for buildings with hydraulic elevators. The primary reason is that, for electric traction elevators, the building structure must be designed and constructed to support the weight of the elevator equipment, the elevator capacity, and the vertical and lateral reaction loads associated with elevator operation. In addition, the costs for the electric traction elevator equipment, installation, and sustainment are greater than the associated costs for hydraulic elevators.

B-4.4.1 Application.

For lower rise buildings, hydraulic elevators were developed as an economic alternative to electric traction elevators. By using a hydraulic elevator, cost savings are realized in the design and construction of the building since the building structure does not have to support the weight of the elevator equipment, the elevator capacity, and vertical reaction loads associated with elevator operation. The elevator is supported by the hydraulic cylinder/plunger (jack) which is supported by the elevator hoistway pit floor. All vertical loading is transferred directly to the pit floor. For low rise applications, the costs for the elevator equipment, installation, and sustainment **1**\ in most cases are /**1**/ lower for hydraulic elevators than the cost of these items for a comparable electric traction elevator.

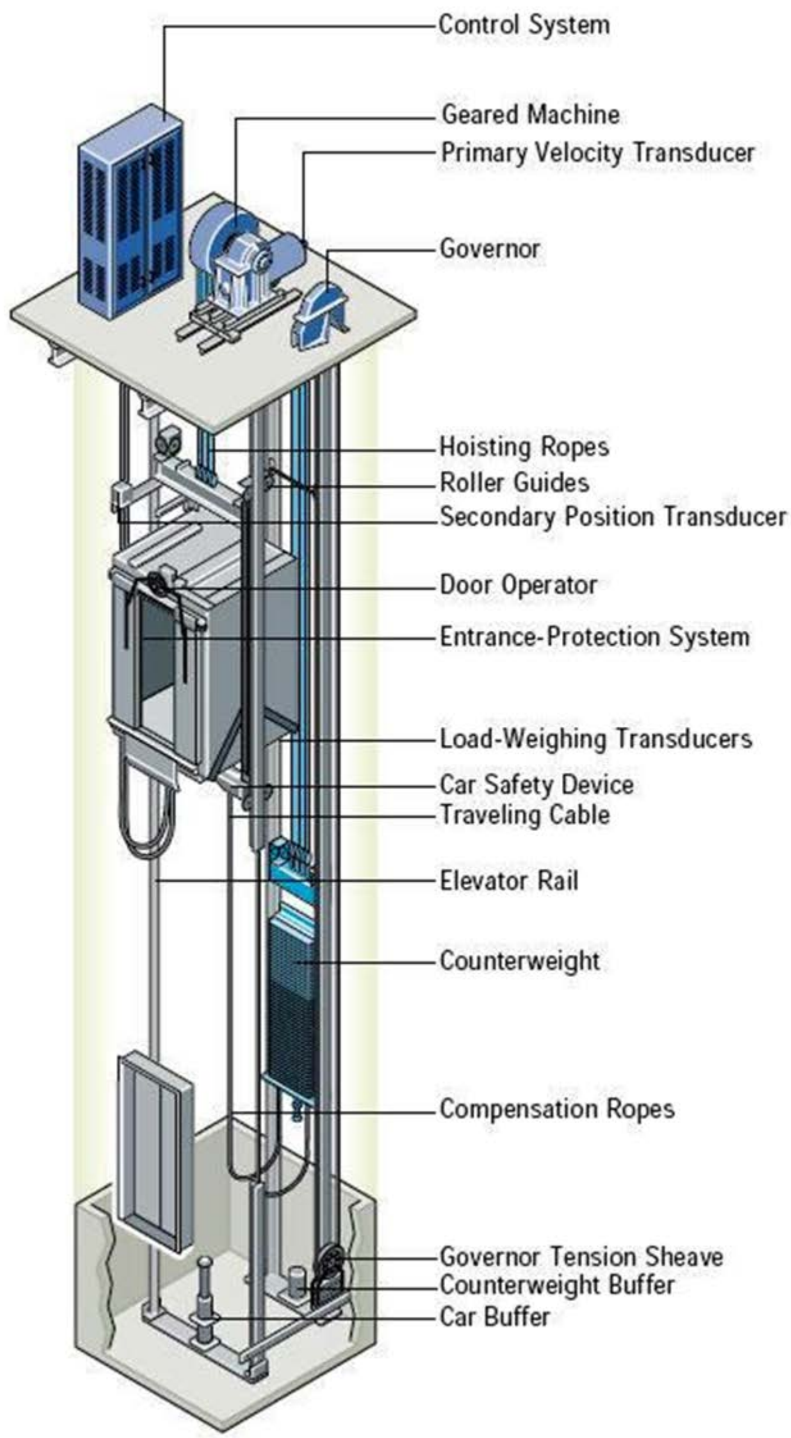
The selection of a hydraulic elevator is effective for buildings of 2 to 4 stories. For buildings of 5 stories and greater, however, the cost of the elevator equipment, the installation cost, and the cost of sustainment begin to rise substantially for hydraulic elevator systems. In addition, the speed limitations associated with hydraulic elevators has a detrimental impact on traffic flow within the building and results in excessive wait times for elevator response to hall calls and car calls. For these reasons, an electric traction elevator is the more appropriate choice for higher rise applications.

B-4.4.2 Safety.

One other critical consideration, for hydraulic elevators, has to do with safety of personnel who will be using the elevator for the life of the building. The ASME A17.1, Safety Code for Elevators & Escalators, requires all elevators suspended by wire rope to be equipped with a speed governor and elevator car safeties. The speed governor monitors the speed of the elevator and actuates elevator car safeties in the event that the elevator accelerates to an over-speed condition. These safety devices are designed to bring the elevator to a sliding stop and are effective for over-speed emergency actuation in both the up and down directions. However, ASME A17.1 does not require direct plunger hydraulic elevators to be equipped with a speed governor or safeties. The travel limitation of 44’ for hydraulic elevators serves to minimize the risk associated with catastrophic failure of the hydraulic cylinder/plunger or the hydraulic oil supply line.

Figure B-1 Electric Traction Elevator with Geared Machine

Elevator Machine Room is located Directly Over the Elevator Hoistway.



B-5 HYDRAULIC ELEVATORS.

The hydraulic drive system consists of a hydraulic fluid reservoir, hydraulic pump, and hydraulic piping from the elevator MR to the cylinder/plunger assembly located in the elevator hoistway. There are two types of cylinder/plunger configurations: direct plunger and indirect plunger.

B-5.1 Direct Plunger Hydraulic Elevator.

There are two types of direct plunger hydraulic elevators: in-ground and hole-less. The use of one or the other is governed the building design characteristics and site conditions.

B-5.1.1 In-ground Direct Plunger.

An elevator cylinder and plunger assembly is installed in the ground, below the elevator cab. The elevator cab frame is connected to the top of the plunger and moves up as hydraulic fluid is pumped into the cylinder from the hydraulic elevator pump-unit reservoir.

B-5.1.2 Hole-less Direct Plunger.

Either one or two hydraulic cylinder/plunger assemblies are installed vertically, in the elevator hoistway, with the bottom of the cylinder supported by the hoistway pit floor. The cab frame is attached to the top of the plunger and moves up as hydraulic fluid is pumped into the cylinder from a reservoir.

B-5.2 Indirect Plunger Hydraulic Elevator.

B-5.2.1 Roped Hydraulic Elevator.

The roped design is similar to the standard hole-less elevator design. The difference is that a wire rope sheave is mounted to the top of the hydraulic plunger and steel hoist ropes are attached to the cylinder base, run over the sheave, and down to the cab frame. As the cylinder runs up, the 1:2 roping moves the elevator cab twice the distance of the plunger travel. The cost of acquisition, maintenance, and service for a roped-hydraulic elevator is substantially greater than for the direct plunger types and is not permitted in DOD facilities except in the event of compelling design conditions.

Figure B-2 In-ground Direct Plunger Hydraulic Elevator

Elevator Machine Room is located Directly Adjacent to the Elevator Hoistway

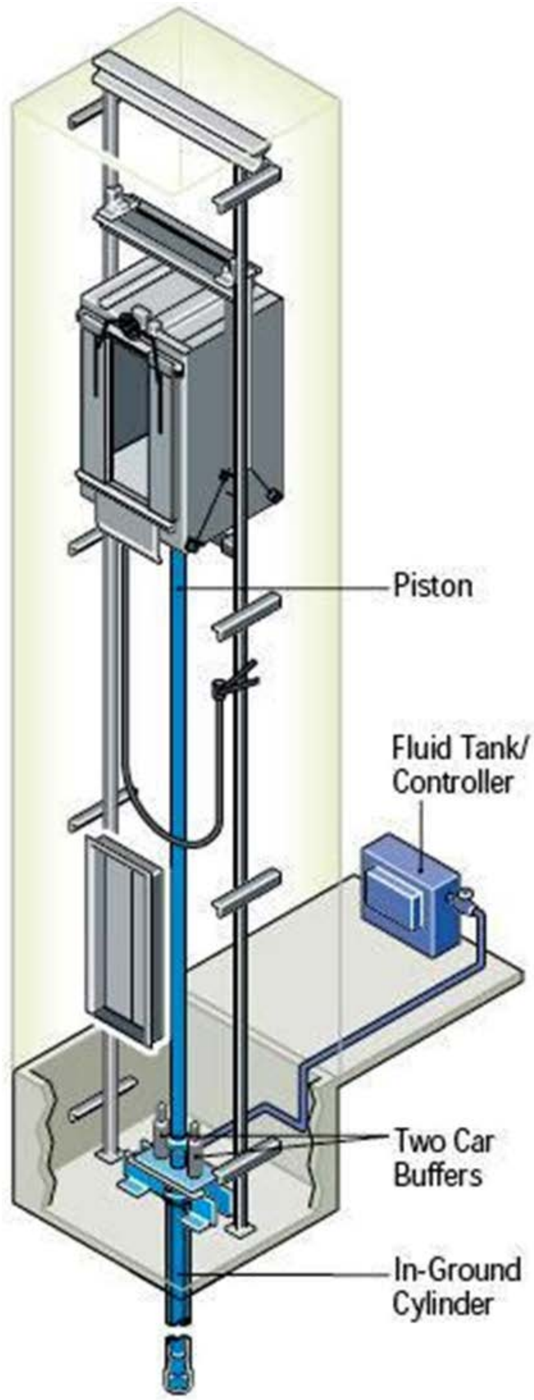
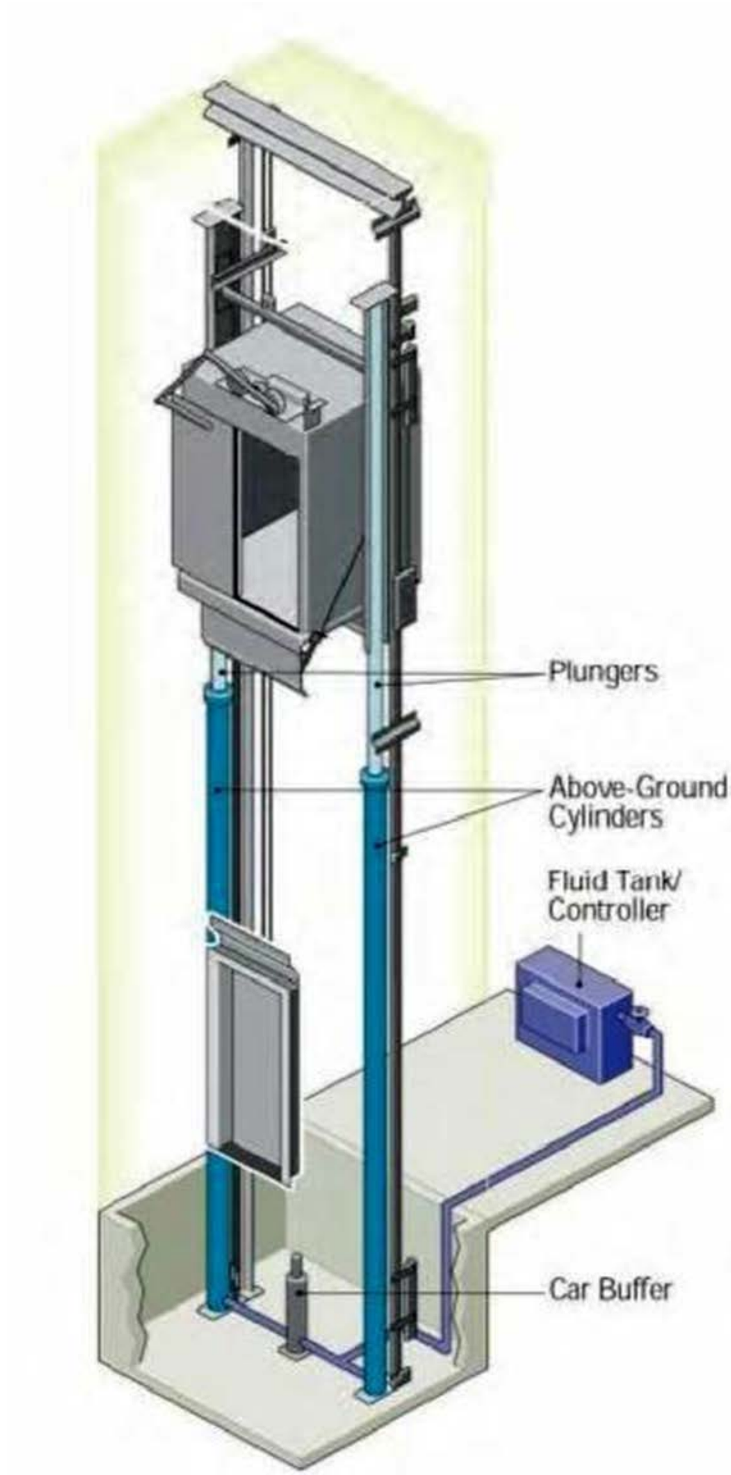


Figure B-3 Hole-less, Dual Post, Direct Plunger Hydraulic Elevator

Elevator Machine Room is located Directly Adjacent to the Elevator Hoistway.



APPENDIX C GLOSSARY

C-1 ACRONYMS

AFCEC	Air Force Civil Engineer Center
ATCT	Air Traffic Control Tower
ATS	Automatic Transfer Switch
BIA	Bilateral Infrastructure Agreement
DOD	Department of Defense
EMS	Emergency Medical Services
FEO	Firefighters' Emergency Operation
HQ USACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
MR	Machine Room
NAVFAC	Naval Facilities Engineering Command
NEI	National Elevator Industry
SME	Subject Matter Expert
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
U.S.	United States
VTE	Vertical Transportation Equipment

UFC 3-501-01
27 November 2024

UNIFIED FACILITIES CRITERIA (UFC)

ELECTRICAL ENGINEERING

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UNIFIED FACILITIES CRITERIA (UFC)

ELECTRICAL ENGINEERING

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 3-501-01, *Electrical Engineering*, dated 06 October 2015.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

The purpose of this UFC is to provide technical requirements for general aspects of the electrical design of projects. Apply the criteria provided in this UFC for the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP). It serves as the minimum electrical design requirements for design-build and design-bid-build projects. Project conditions may dictate the need for a design that exceeds these minimum requirements.

1-1.1 UFC Hierarchy.

This UFC provides the top-tier baseline requirements for electrical UFCs and is intended as a reference for all electrical work on projects. All electrical UFCs listed in Appendix E rely on this UFC for overall requirements regarding design analysis and documentation.

1-1.2 Upgrades and Modifications to Existing Systems.

Modernization of electrical systems solely for the purpose of meeting design criteria in UFCs is not required. Upgrades or modifications to electrical systems should consider the design criteria in this UFC, but it is not intended that an entire facility or system require modernization solely because of a minor modification.

For minor projects, determine if the project will affect existing electrical system calculations such as by modifying circuit breaker settings. If any electrical system calculations are affected by the modification, update the calculations, including the arc flash calculation, as part of the project.

Note: Arc flash calculation updates are necessary for electrical safety.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-501-01, *Electrical Engineering*, dated 06 October 2015.

1-3 APPLICABILITY.

This UFC applies to the planning, design, construction, sustainment, restoration, and modernization of DoD-owned facilities. It is applicable to all methods of project delivery and levels of construction as defined by UFC 1-200-01 section 1-3.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 WAIVER AND EXEMPTIONS PROCESS.

The waiver and exemption process is provided in MIL-STD 3007.

1-6 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-7 PERMITS – CONSTRUCTION, ENVIRONMENTAL, AND OTHER.

Identify the permits and fees necessary for environmental, construction, and operation of facilities.

1-8 GLOSSARY.

APPENDIX D contains acronyms, abbreviations, and terms.

1-9 REFERENCES.

APPENDIX E contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies. If dates are not indicated in the contract or in the absence or other direction, the issue/version of publication in effect at the time the design started is to be used. Designs that have been started and then delayed will need to evaluate which version is applicable and may have to update to the newer version if considerable time has gone by. This may require some redesign.

CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 GENERAL.

Design electrical systems to meet the needs of the activity and supporting facilities in accordance with this document.

Provide electrical equipment that is the manufacturer's standard catalog products, conforming to the latest published industry and technical society standards at the date of contract award. Underwriters Laboratories (UL) listing or third-party certification is required for all basic equipment. Use of shop or field fabricated electrical equipment assemblies that are not manufacturer's standard catalog products or do not conform to the industry and technical society standards are not acceptable.

2-1.1 Removal of Existing Cables and Conductors.

When a project requires disconnection of existing cables and conductors enclosed in either duct or conduit, physically remove the existing cables and conductors. Associated ducts or conduits may be abandoned in place only for the following conditions:

- They are planned for re-use.
- Removal will cause substantial facility damage.
- Conduits are inaccessible.

On duct systems between underground structures (handholes, manholes, and vaults), provide a pull wire (string or rope) for future use, and seal both ends of duct. Apply label to each end of the pull rope noting the location of the other end of the conduit.

2-1.2 Hot Caps and Removal of T-Splices Inside Manholes.

Regardless of voltage, do not hot cap conductors in a manhole or handhole as part of demolition.

If the conductor is part of a T-splice or Y-splice that is being removed, remove the splice and install an in-line splice for the remaining conductors. For the Army and Navy, if the conductor is part of a T-splice or Y-splice that is being re-used, a hot cap is allowed during construction to maintain an energized circuit.

Note: Hot caps are only allowed as a temporary method during construction to maintain an energized circuit.

2-1.3 Modification to Existing Electrical Equipment.

Uniquely identify equipment to be "Modified" or "Added to" and include the manufacturer's name and other pertinent manufacturer's identification (e.g., serial number, model number, style), if such information exists.

2-1.4 Salvaged Materials and Equipment.

Demolition projects may require equipment or material to be salvaged for, or by the Government. Uniquely identify all salvageable equipment or material. Include the manufacturer's name and other pertinent manufacturer's identification including serial number, model number, style, physical dimensions, and weight if such information exists. Indicate who is responsible for removal, storage, and transportation.

2-1.5 Scheduling and Sequencing Outages.

Designer of Record must:

- Determine and address scheduling, sequencing, and outage requirements including anticipated outage durations as a part of contract design documents. Provide a specific and detailed suggested sequence of construction. Identify any temporary requirements, including the need for emergency generators for backup power during construction-related outages.
- Require the contractor to review all identified requirements and submit outage requests for approval by the Government prior to initiating the specific work task.
- Require that all work complies with the electrical safety requirements contained in UFC 3-560-01 for government workers and EM 385-1-1 for contractor work.

Note: UFC 3-560-01 is usually more stringent than EM 385-1-1. However, it may be invoked on contractor work when desired and agreed to by the Activity. In that case, include the appropriate requirements during the design phase in the contract documents.

2-1.6 Energy Efficiency and Sustainable Design.

Comply with UFC 1-200-02.

2-1.7 Antiterrorism and Physical Security.

UFC 4-010-01 is a multidiscipline document which contains several standards that may impact electrical system design. Electrical designers must be familiar with UFC 4-010-01 and how it may affect the design of utilities, service entrance equipment, emergency backup systems, and bracing of electrical equipment. Incorporate the minimum standards into the design of all new construction and major renovations of inhabited DoD buildings. UFC 4-020-01 supports the planning of DoD facilities that include requirements for security and antiterrorism. Use in conjunction with UFC 4-010-01 to establish the security and antiterrorism design criteria that will be the basis for DoD facility designs.

2-1.8 Facility Systems Safety.

Incorporating safety into the engineering and design process is an important part of designing, constructing and maintaining safe facilities for use by U.S. Military, U.S. Government, and Contractor personnel. To the extent practicable and feasible, incorporate the safety engineering practices delineated under the Facilities Systems Safety (FASS) program as prescribed under OPNAV M-5100.23 Chapter 38 and DA PAM 385-16.

Ensure systems safety engineering related to equipment access and proper equipment clearances are addressed during a FASS review at the earliest phases of project development when remedies and solutions are more easily addressed rather than during construction or after facility turnover.

2-1.9 Corrosive and High Humidity Areas.

The special design requirements listed below apply when electrical equipment is routinely subjected to salt spray (such as installations at piers and wharves) or is installed in locations exposed to condensing humidity that has historically caused premature rusting and degradation of equipment enclosures. Coordinate with local Activity to obtain historical information and documentation to validate requirements.

- Provide an entire corrosion resistant transformer assembly, fabricated of stainless steel.
- Use stainless steel cabinets and hardware for pad-mounted switchgear, switchboards, and sectionalizing termination cabinets.

Note: When feasible, sectionalizing termination cabinets can be designed to comply with NEMA 4X non-metallic enclosure requirements instead of stainless steel if the enclosures are not subject to physical or structural integrity damage.

- Use stainless steel enclosures and hardware for exterior safety switches and other electrical equipment.
- Do not use aluminum-conductor steel-reinforced (ACSR) overhead conductors.
- Use weatherproof stainless steel or aluminum enclosures for outdoor engine generator applications.
- Use corrosion-resistant materials for other electrical components, such as conduit, conduit supports, couplings, fittings, plugs, connectors, receptacles, equipment supports, and luminaires.

2-1.10 Arc Flash Warning Labels.

Refer to UFC 3-560-01 for arc flash label requirements.

2-1.11 NFPA 70 (NEC) / IEEE C2 (NESC) Design Interface Points.

Design buildings and similar support structures such as piers, wharfs, parking structures, sewage pump stations, and fueling facilities in accordance with the general requirements of NFPA 70:

a. Services. Apply the following:

- The location for the "service point" (for clarification of the NFPA 70 Article 100 and IEEE C2 Section definitions): at the building/similar support structure service equipment which contains the main incoming overcurrent protective device.
- The demarcation between NFPA 70 and IEEE C2 for electrical power design purposes: is always the secondary terminal of the building/support structure utilization electric supply system.
- The demarcation between NFPA 70 and IEEE C2 for communication and security systems design purposes: is always the incoming service interface equipment including the five-foot raceway extension outside the building/support structure.

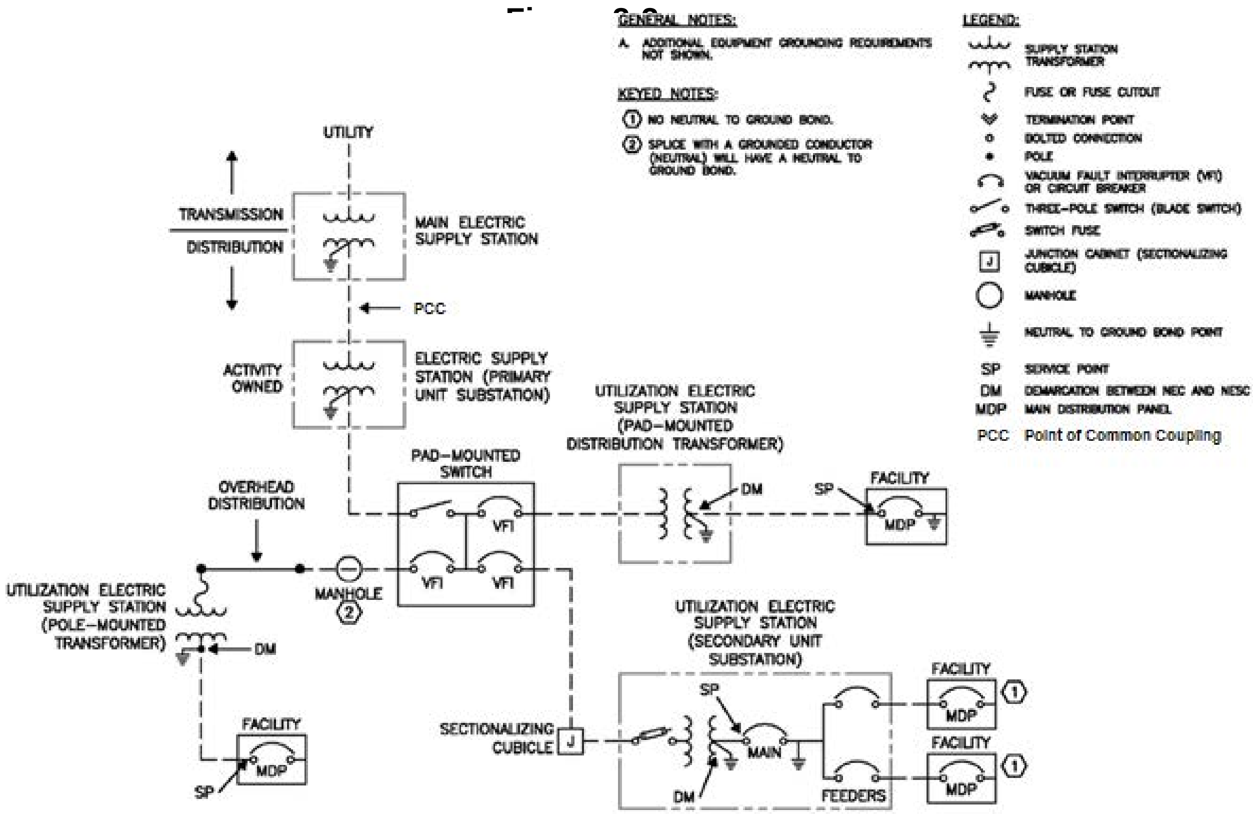
  Figure 2-1 illustrates the above in graphic form.

b. Exterior branch circuits. Design the following in accordance with the general requirements of NFPA 70:

- Exterior lighting systems (parking lot, roadway, security, and sports).
- Exterior branch or feeder circuits originating from building/support structure service equipment.
- Wiring from and connections to non-utility equipment supplying power to the wiring system of the facility or the low-voltage terminals of the medium-voltage distribution system, including engine-generator sets, photovoltaic power systems, wind turbines, and fuel cells.

c. Design all exterior underground and overhead, medium, and low voltage systems not specifically associated with a building/support structure in accordance with the general requirements of IEEE C2 except utilize the NFPA 70 ampacity and conduit fill tables for all designs.

Figure 2-1 Illustration of NFPA 70 Service Point and NFPA 70 / IEEE C2 Demarcation



2-2 SITE EXTERIOR POWER DISTRIBUTION SYSTEMS..

Provide the site utility distribution system that is compatible with the existing system and comply with UFC 3-550-01. Where the site service is derived from an existing primary feeder, the designer of record must coordinate with the government authority and receive direction regarding point of connection and concurrence that existing circuit can support the new loads.

Coordinate remote monitoring and control requirements for exterior distribution system equipment with the Activity.

2-2.1 Exterior Power Distribution Systems, Including Housing.

Comply with UFC 3-550-01.

2-2.2 Dockside Utilities for Ship Service.

Comply with UFC 4-150-02.

2-2.3 Exterior Lighting Systems.

Comply with UFC 3-530-01.

2-2.4 Airfield Lighting.

Comply with UFC 3-535-01.

2-2.5 Cathodic Protection Systems.

Comply with UFC 3-570-01

2-2.6 High-Altitude Electromagnetic Pulse (HEMP) Shielded Systems – Exterior.

Comply with MIL-STD-188-125-1A and MIL-HDBK-423. In lieu of concrete encasement for medium voltage direct buried metal conduits (ductbank), utilize a sand bed (minimum thickness of 3” (75 mm)) and topped with a minimum of 3” (75 mm) of sand. Provide a 2” (50 mm) thick concrete cap, the width of the trench atop the sand encasement. Place detectable warning tape above the concrete cap, 12” (300 mm) below finished grade to provide easy identification for future excavations.

2-2.7 Generators.

Comply with UFC 3-540-01.

2-2.8 Renewable Energy Systems.

Comply with UFC 3-540-08.

2-2.9 Microgrids.

Comply with UFC 3-550-04.

2-3 INTERIOR DISTRIBUTION SYSTEMS.

2-3.1 Interior Electrical Systems.

Comply with UFC 3-520-01.

For Army Civil Works funded projects, the requirements of NFPA 70 Article 240.2(A)(4) do not apply if all the following conditions are met.

a. The molded-case circuit breaker (MCCB) is considered mission critical.

b. A new replacement for the MCCB is not commercially available.

c. The replacement MCCB is refurbished in accordance with ANSI/PEARL Electrical Equipment Reconditioning Standard for Electrical Apparatus and Equipment used in Commercial and Industrial Applications (EERS).

d. Any equipment requiring the use of a refurbished MCCB must be prioritized for replacement.

2-3.2 Interior Lighting Systems.

Comply with UFC 3-530-01.

2-3.3 Emergency and Standby Systems.

2-3.3.1 Exit and Emergency Lighting.

Comply with UFC 3-530-01.

2-3.3.2 Fire Alarm Systems.

Comply with UFC 3-600-01.

2-3.3.3 Generators.

Comply with UFC 3-540-01.

2-3.4 Sensitive Compartmented Information Facilities (SCIF).

Comply with UFC 4-010-05.

2-3.5 Hazardous Locations.

Show boundaries of hazardous locations on the plans and identify the type of hazard by class, division, and group.

2-3.6 Stationary and Mission Batteries.

Comply with UFC 3-520-05.

2-3.7 HEMP Shielded Systems – Interior.

Comply with MIL-STD-188-125-1A and MIL-HDBK-423.

2-3.8 Renewable Energy Systems.

Comply with UFC 3-440-01.

2-3.9 Mission Critical Power, Cooling, and Control Systems.

Comply with UFC 3-520-02.

2-4 COMMUNICATIONS AND SECURITY.

2-4.1 Telecommunication Systems.

2-4.1.1 General.

Comply with UFC 3-580-01 for interior and exterior information communications technology.

2-4.1.2 Outside Plant.

Provide underground telecommunications wiring in conduit to a depth of 24 in (610 mm). Specify concrete encased conduits for telecommunications systems in accordance with UFC 3-550-01. Unless directed otherwise by the BCO, size outside category 3 copper cable for a minimum of one pair per 100 ft^2 (9 m^2) of building and provide a minimum of one 12 strand single-mode fiber optic cable for each facility. Coordinate cable selection and point of connection with the BCO and specify using RUS specifications.

Provide solid-state type primary communication circuit protectors with sneak current protection for all twisted pair media terminating inside a building from an overhead or underground outside plant.

2-4.1.3 BEQ/BOQ Housing.

Completely wire the building interior conforming to UFC 3-580-01.

2-4.1.4 Family Housing.

Provide a complete structured telecommunications system in accordance with UFC 3-580-01.

2-4.2 Television Systems.

Coordinate television system requirements with the activity.

2-4.3 Community Antenna Television (CATV) Systems.

Comply with UFC 3-580-01. Coordinate exterior cable installation with the local service provider and Base Communications Officer (BCO). Provide a conduit and pull wire from a point of connection to the base system and the main distribution equipment.

2-5 ELECTRONIC SECURITY SYSTEMS (ESS).

Comply with UFC 4-021-02.

2-6 MASS NOTIFICATION SYSTEMS.

Comply with UFC 4-021-01.

CHAPTER 3 DESIGN ANALYSIS AND DOCUMENTATION

3-1 GENERAL.

This chapter defines the minimum information to be provided at the various design submittal levels. During the design submittal process, the Designer of Record must clarify comments with the appropriate Government reviewer rather than wait until the next submittal to respond. Whenever possible, the Designer of Record is encouraged to meet with the reviewer to discuss comments.

3-2 DESIGN ANALYSIS.

The Design Analysis is a presentation of facts to demonstrate the concept of the project is fully understood and the design is based on sound engineering principles. As a minimum, include the following information in the Design Analysis.

3-2.1 Basis of Design.

Document design decisions throughout the design process. List any special features and alternatives that were considered. Provide a written narrative accurately addressing the electrical and telecommunication design. Describe the design approach to all electrical systems. Include the method used for sizing conductors, conduit, protective devices, and other equipment. Show all calculations used in determining capacities of electrical systems. When tables from industry standards are used in the design, indicate the title, source, and date of the document. Include a complete list of all design standards and references used for the design.

Update the Basis of Design for each submittal to accurately show the current state of the design. Include the information in the following sub-paragraphs as a minimum.

3-2.1.1 Exterior Primary Power Distribution Systems.

- Existing Primary Power Source – Identify the location of the point of connection into the existing primary system. Address the characteristics of this primary system, including ANSI voltage designation, phase, number of conductors, available fault current, and the circuit grounding classifications (ungrounded, uni-grounded, resistance grounded, or multi- grounded). Address the adequacy of the primary system; if inadequate, state measures proposed to correct the inadequacy.
- Estimated Electrical Project Load – Provide an estimate of total connected load (kVA) and the resulting demand load (kVA), transformer size, and service size.
- Voltage Selection – Provide basis for selection of primary and secondary voltages.
- Conductors – Include conductor size, type, number of conductors, insulation voltage rating, and insulation level.

- Standards of Design – Describe pertinent standards of design, such as voltage drop, and equipment ratings.
- Materials – Provide manufacturer's data sheets and product data for selected equipment.

3-2.1.2 Other Exterior Systems.

- Telecommunications (including voice, video and data) System – Identify point of connection into base system. Describe modifications, if required, to existing base system.
- Special Systems – Identify any special systems, such as Electronic Security Systems (ESS) or Cable Television (CATV). Describe how and where the facility will connect to the basewide Mass Notification System.
- Exterior Lighting Systems – Describe types of luminaires and illuminance values.
- Alternate Energy Sources – Describe alternate energy systems such as engine-generator sets, photovoltaic power systems, wind turbines, and fuel cells.
- Metering – Determine installation specific metering requirements as part of the electrical distribution system connection during design.
- Conductors – Include conductor type and number of conductors.
- Standards of Design – Describe pertinent standards of design, such as voltage drop and equipment ratings.
- Materials – Provide manufacturer's data sheets and product data for selected equipment.

3-2.1.3 Interior Distribution Systems.

Describe the electrical systems including the following: lighting systems; power systems; alternate energy systems, emergency lighting; emergency/standby power; grounding systems; telecommunications system; other systems such as television; physical and electronic security features such as ESS or TEMPEST. Refer to NSTISSI 7000, TEMPEST Countermeasures for Facilities, for TEMPEST criteria.

a. Electrical Characteristics – Describe the electrical system to be provided and justify its selection. Indicate ANSI voltage designation, phase, and number of conductors.

b. Switchgear and Switchboards – Provide specific design information for the following:

   - Nominal system voltage.
   - Short circuit ratings.
   - Maximum voltage ratings.

- Basic impulse level (BIL).
- Main bus ampacity.

c. Estimated Electrical Loads – Provide a breakdown, by category, of the estimated loads (kVA). Include lighting, convenience outlet, mechanical equipment, special operating equipment, user equipment, and miscellaneous load categories.

d. Wiring Methods – Indicate the type of wiring method, such as rigid conduit, electrical metallic tubing, cable tray, nonmetallic sheathed cable, and where proposed to use.

e. Conductors – Indicate the type of conductors and insulation material such as CU, AL, THW, XHHW, and where proposed to use.

f. Standards of Design – Describe the proposed standards of design, such as voltage drop, illuminance values, type of light sources, and energy conserving features.

g. ASHRAE compliance – Describe the approach for compliance with UFC 1-200-02 and its ASHRAE 90.1 requirements.

h. Special Systems – Describe the proposed type of systems. Indicate each system's function and the interrelationships between systems, when applicable. Identify government-furnished equipment, if any. Special systems include such systems as CATV, Closed Circuit Television (CCTV), Intercom, Sound, Nurse Call, Security, or Uninterruptible Power Supplies (UPS). Identify special security requirements. Identify special physical security requirements.

i. Telecommunications Systems – Identify space required for telecommunication equipment, and size of incoming duct/conduit. Include documentation concerning telecommunications room sizes, to accommodate interface equipment provisions for multi-use systems (i.e. special use systems, such as voice, video, and data).

j. Materials – Where appropriate, like for design build, provide manufacturer's data sheets and product data for selected equipment.

3-2.1.4 System Maintainability.

Design the system in a manner that facilitates safe periodic maintenance of the equipment in accordance with Section 2-1.8.

3-2.1.5 Instrumentation and Controls.

Coordinate all interfaces with instrumentation and control systems provided by other disciplines, and provide required connections, either empty conduits or power wiring as required. Normally, the designer for the discipline that is responsible for the process (such as electrical, mechanical, or civil) is also responsible for the instrumentation and controls design of that system.

3-2.2 Electrical Calculations – Overview.

The Designer of Record (DOR) is responsible for providing calculations (in accordance with the associated follow-on paragraphs) to verify proper design and operation of the facility to the point of connection to the existing electrical systems.

Note: There can be differences in how the required electrical analyses are handled, depending on whether the project is design-build or design-bid-build. Army projects might also use UFGS 26 05 73, Power System Studies, as the method for specifying requirements associated with the coordination study during the construction phase.

The DOR is also responsible for:

- Contacting and obtaining all utility data required to complete the relay coordination study from the respective Base Electric Utility Department or Private Utility Company including existing upstream protective device types and settings. The information needed for the electrical analysis depends on the point of connection to the primary distribution system and the scope of the project.
- Determining the different operational configurations. If the facility or system has various operational configurations (such as different transformer supplies, emergency generator operation, UPS bypass, or microgrid) or operational modes (such as normal parallel mode, transition-to-island mode, island mode, and reconnection mode), evaluate each possible operating configuration and each operational mode, and provide the results for each case.
- Providing analyses and calculations that are described fully, written clearly, and lead the reviewer through the design by stating all assumptions and design inputs. Computer printouts are acceptable only if accompanied by explanations to allow adequate independent review of calculation methods and results.

3-2.2.1 Electrical Analysis Software.

Most electrical-related calculations for significant projects will be completed with software tools; hand calculations are typically only acceptable for minor modifications to an existing system. For power systems analyses, coordinate with the base to determine if specific software tools are required for the analyses. Whenever software tools are used to perform analyses, provide the electronic software files with each submittal. Electronic software files must be in a format compatible with the analysis software used at the Government's facility. Before using any software tools, identify any base or service-specific limitations regarding which software packages can be used.

Note: The Navy Network is only able to utilize ETAP, SKM software modules and EasyPower for electrical analysis. If project calculations are done using any other software, they must also be provided in either ETAP, SKM or EasyPower so that they *are usable by Navy personnel on the Navy Network. The designer performing the calculations shall verify with the Navy which software package they are using at that facility and provide there database calculations to the Navy in that software database.*

Note: For the Air Force, only EasyPower is certified in accordance with AFI 33-210 for use on standard desktop systems connected to the Air Force Global Information Grid and placed on the Air Force Evaluated/Approved Products List. Other software products can be used on standard desktop systems connected to the Air Force Global Information Grid after they have been certified in accordance with AFI 33-210 and placed on the Air Force Evaluated/Approved Products List.

3-2.2.2 Electrical Calculation Summary.

Provide calculations that include a complete analysis with supporting data. Address system arrangement; voltage selection; and major equipment selections including load analysis and equipment sizing calculations. Whenever sizing electrical equipment, such as transformers, breakers, or electric cables, provide calculations to demonstrate proper facility design. Provide the following calculations unless the Basis of Design clearly explains why a particular calculation type is not applicable:

a. Load analysis.

b. Short circuit analysis, including protective device interrupting rating.

c. Protective device time-current coordination study.

d. Arc flash analysis.

e. Voltage drop.

f. Motor starting analysis.

g. Lighting.

h. Underground structure design.

i. Cable pulling tension.

j. Directional Boring

k. Sag, tension, and guying analysis.

l. Cathodic protection calculation.

m. Lightning protection analysis.

n. CATV network loss calculations.

o. ESS calculations.

p. Alternate energy system calculations.

q. Utility interactive systems and distributed resources island systems evaluation.

r. ASHRAE 90.1 calculations.

Detailed requirements for each calculation item in the list are contained in the following paragraphs.

3-2.3 Load Analysis.

3-2.3.1 Preliminary Basis of Design.

a. Load Analysis for Service Entrance Equipment, Including Feeders:

- Complete a preliminary load analysis (Basis of Design). Base calculations on NFPA 70 and use load information provided in Appendix B or ASHRAE 90.1 as applicable. Use Appendix C to apply demand and load factors when sizing the service entrance transformer only. Do not apply these factors to distribution equipment downstream of the service entrance transformer.

b. Load Analysis for Service Entrance Transformer:

- Select appropriately sized transformer based on:
  i. The standard available ratings and
  ii. The calculated demand load which is connection to each transformer.
- Apply the demand and diversity factors from Appendix C to the preliminary load analysis to determine the transformer size.
- For building designs, do not exceed a service transformer size greater than 12 VA/square foot (130 VA/square meter) of facility gross floor area or 70% of the total connected load on installations served by transformer rated 300 kVA or greater. Any design calculations exceeding these requirements must be specifically approved by the technical reviewing authority.

Note: The above check is intended to serve as a simple confirmation that the facility transformer is not oversized.

c. Load Analysis for Emergency/Standby Generator:

- Provide sizing calculations including starting kVA.
- Refer to UFC 3-540-01 for additional load analysis requirements, including the effect of UPS systems on generator sizing.

d. Load Analysis for Alternate Energy Systems:

- Provide maximum power calculations applicable to the type of alternate energy system. This includes:
  i. DC systems, including 270 VDC charging systems.
  ii. Frequency conversion equipment.
  iii. Renewable energy systems.

e. Load Analysis for Uninterruptible Power Supply (UPS):

- Provide sizing calculations in accordance with UFC 3-520-01, section entitled “Stationary Batteries and Battery Chargers”.

f. Load Analysis for utility interactive systems and distributed resource island systems (microgrids). Provide a load analysis in accordance with IEEE Std 1547.4 Clause 5. Include a system one-line diagram with system interconnection points. Evaluate historical demand profiles (real and reactive) and identify any large motor loads. Include in the load analysis a calculation of real and reactive power requirements in normal and island mode of operation.

Note: Microgrids are not included with all projects. When required by the project scope of work to install a new system or to incorporate a microgrid into an existing system, provide a complete description of the microgrid including its connection points to the system and how the system will operate.

g. ASHRAE 90.1 calculations:

- Power allowance for lighting.
- If the design methodology requires additional receptacles to satisfy the ASHRAE 90.1 automatic receptacle control criteria, identify as a line item in the system load analysis.

3-2.3.2 Follow-On Submittals.

a. Load Analysis for Service Entrance Equipment, Including Feeders:

- Complete a load analysis (Basis of Design). Base calculations on NFPA criteria.

b. Load Analysis for Service Entrance Transformer:

- Apply the demand and diversity factors from Appendix C to the final total connected load analysis to determine the transformer size. For example, Diversity Factor - A distribution feeder serves 4 buildings, each has a peak demand of 25 KW. The feeder peak demand is equal to 80 KW. The diversity is equal to 80/100 or .8. Demand Factor - a residence having 12,000W of total connected load has a maximum demand load of 9,000W. The demand factor is 9,000/12,000= 75%.
- For building designs:
    - For all transformers, do not exceed a service transformer size greater than 12 VA/square foot (130 VA/square meter) of facility gross floor area.
    - For a transformer rated 300 kVA and larger, do not exceed a service transformer size of 70% of the total connected load.

- Validate that transformer size has not been increased by the design approach taken to comply with ASHRAE 90.1.

Any design calculations exceeding these requirements must be specifically approved by the Technical Reviewing Authority.

c. Load Analysis for Emergency/Standby Generator:

- Provide sizing calculations including starting kVA.
- Refer to UFC 3-540-01 for additional load analysis requirements, including the effect of UPS systems on generator sizing.

d. Load Analysis for Alternate Energy Systems:

- Provide maximum power calculations applicable to the type of alternate energy system. Identify actual power delivered from source.

e. Load Analysis for Uninterruptible Power Supply (UPS):

- Provide sizing calculations in accordance with UFC 3-520-01, section entitled “Stationary Batteries and Battery Chargers”.

f. Load Analysis for utility interactive systems and distributed resource island systems (microgrids) in accordance with the criteria provided in Section 3-2.3.1.f.

g. ASHRAE 90.1 calculations in accordance with the criteria provided in Section 3-2.3.1.g.

3-2.3.3 Load Analysis Criteria.

Use the following additional criteria for the load analysis:

- Assign a “0%” demand factor for fire pump loads in demand calculations.
- Design underground service entrance distribution using commercially-available thermal analysis software based on Neher-McGrath or finite element methods. Assume a load factor of 100%.
- Size the service entrance conductors for a continuous load current not less than the ampacity of the main bus in the service entrance equipment. For example, provide conductors sized for 1200 amperes with 1200 ampere rated equipment which is protected with a 1000 ampere device. Listed conductor size adapters are acceptable. Design main service equipment to provide a minimum of approximately 15% combination of spare devices/space to accommodate future work. Include this 15% spare capacity in the demand load calculations for future or anticipated load growth.

Note: Consideration for spare device/space above 15% should be addressed during the scoping of the project.

- Select size of service entrance transformers based on the standard available ratings.

Note: This criterion does not apply to secondary substation transformers, dedicated site lighting transformers, etc.

For small systems 225 amps or less, or for small modifications to large systems, the load analysis can be performed manually using the above criteria. For larger systems, a load analysis using computer software tools is necessary to evaluate properly all of the possible facility modes of operation.

3-2.4 Short Circuit Analysis.

Complete a short circuit analysis in accordance with IEEE 3002.3 and include the following in the analysis:

a. Include the utility system data as well as data for the distribution system. Contact the Contracting Officer or technical reviewing authority for the utility system data and available fault current on the primary side of medium voltage equipment. When accurate data does not exist, assume that maximum available fault exists, up to a possible infinite bus on the primary side of the upstream transformer, and design the system assuming such conditions.

b. Calculate the available short circuit and ground fault currents at each bus. Incorporate any motor contribution in determining the momentary and interrupting ratings of the protective devices.

c. Use a commercially available software program designed for the type of required analysis. Incorporate pertinent data and the rationale employed in developing the calculations in the introductory remarks of the study. Comply with IEEE C37.06, IEEE C37.13.1, or UL 489 criteria, as applicable, for equipment interrupting capability evaluations.

d. Where diagrams will not fit on standard letter size paper, present the data determined by the short circuit study in a tabular format. Include the following:

    - Device identification
    - Operating voltage
    - Protective device
    - Device rating
    - Calculated short circuit current

e. Coordinate the calculated short circuit current at the service entrance with the available fault current labeling required by NFPA 70 for the service entrance equipment (switchgear, switchboard, or panelboard).

3-2.5 Protective Device Time-Current Coordination Study.

3-2.5.1 Selective Coordination.

Design the electrical system such that any fault in the system will be preferentially isolated by the selective operation of only the overcurrent protective device closest to the faulted condition. If required by the contract, perform a coordination study at the design stage to establish the basis for the system design and to enable completion of an initial arc flash analysis. Provide a final coordination study based on the as-built configuration of the system. Identify locations where selective coordination is not achievable, such as with instantaneous trips on molded case circuit breakers.

The Designer of Record is responsible for the selective coordination of overcurrent protective devices, including protective relays and medium voltage protective devices, high side transformer protection for distribution transformers, main secondary breakers, and secondary feeder protective devices. Ensure coordination between the new equipment design and the existing distribution system.

Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.

Any permanently installed backup power source required by published DoD or agency-specific criteria shall be considered a legally required standby system or emergency system.

3-2.5.2 Required Time-Current Data.

The Designer of Record is responsible for ensuring that construction contract documents require the Contractor to submit the transformers' inrush current and damage curve and the manufacturer's published time-current curves for primary fuses, relays, main secondary breakers, and secondary feeder protective devices. This information is required during the submittal process. Using the time-current curve data, perform a coordination study in accordance with the following paragraphs to ensure that protective devices are properly coordinated.

3-2.5.3 Coordination Study.

If required by the contract, provide a complete coordination study that includes a system one-line diagram, short circuit and ground fault analysis, and protective coordination plots.

The Designer of Record is responsible for providing to the Contractor settings for relays, main secondary breakers, secondary feeder protective devices, and any other protective devices in the circuit. Base the final coordination study and the specified setting information on the as-built configuration.

3-2.5.4 One-Line Diagram(s).

Show on the one-line diagram all electrical equipment and wiring to be protected by the overcurrent devices including breakers and fuses. Multiple one-line diagrams may be used if required to clearly present all the required data. Also, show on the one-line diagram the following specific information:

a. Calculated short circuit values and X/R ratios at the project utility point of connection.

b. Breaker and fuse ratings.

c. Transformer kVA and voltage ratings, percent impedance, and wiring connections.

d. Identification and voltage at each bus.

e. Identify feeder cable sizes and conduit sizes. Identify configuration such as 4-#2 AWG, 1-#4 AWG ground in 1-1/2" conduit. (Use worst case fill based on allowed materials.) Where limitations on materials and insulation are specifically required due to special environments, clearly identify this when applicable.

3-2.5.5 Coordination Curves.

Prepare the coordination curves to determine the required settings of protective devices to assure selective coordination. Graphically illustrate on a log-log scale that adequate time separation exists between series devices, including the utility company upstream devices where applicable. Plot the specific time-current characteristics of each protective device in such a manner that all applicable upstream devices will be clearly shown on one sheet. Include the following information on the coordination curves:

a. Device identification.

b. Voltage and current ratios for curves.

c. 3-phase and 1-phase ANSI damage points for transformers directly fed from the switchgear.

d. Minimum melt and total clearing curves for fuses.

e. Cable damage curves.

f. Transformer inrush points.

g. Maximum short circuit current.

3-2.5.6 Settings.

Develop a table to summarize the settings selected for each protective device. Low voltage protective devices less than 225 amperes, unless adjustable trip, are not required to be included. Address all relays and relay functions. Include in the table the following:

a. Device identification and breaker or load controlled.

b. Relay CT ratios and electronic set point equivalents for relay tap, time dial, and instantaneous pickup points.

c. Circuit breaker sensor rating.

d. Fuse rating and type.

e. Ground fault pickup and time delay.

f. Differential relay settings.

3-2.5.7 Coordination Study Report.

Include the following in each coordination study report:

a. A narrative describing the analyses performed, the methods used, and the desired method of coordinated protection of the power system.

b. Descriptive and technical data for existing devices and new protective devices. Include the manufacturers' published data, nameplate data, and definition of the fixed or adjustable features of the existing or new protective devices.

c. Documentation of the utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristic curves, current transformer ratios, and protective device settings.

d. Fully coordinated composite time-current characteristic curves to ensure coordinated power system protection between protective devices or equipment. Include recommended ratings and settings of all protective devices in tabulated form.

e. Evaluation of the total feeder inrush current with respect to relay or circuit breaker overcurrent trip settings. Power restoration following an outage should not cause a feeder trip on overcurrent.

3-2.6 Arc Flash Analysis.

Complete an arc flash evaluation in accordance with NFPA 70E, IEEE C2 and IEEE Std 1584 (including Amendments 1 and 2), and IEEE Std 1584.1 as applicable.

Note: Nominal system voltages over 15 kV must follow IEEE C2 (NESC) instead of NFPA 70E and IEEE Std 1584.

Note: Provide PPE criteria in accordance with Chapter 4 of UFC 3-560-01.

Complete an arc flash evaluation on direct current (DC) systems analysis in accordance with NFPA 70E. Include the following:

a. Description of the software used to perform the evaluation, including an explanation of software-specific user adjustable analysis settings that were used for the study.

b. Scope of analysis. When switchgear, switchboards, and panelboards are equipped with main circuit breakers, provide both “Line Side” and “Bus Side” results for each item. If the facility or system has different operational configurations, such as different transformer supplies, emergency generator operation, or UPS bypass, evaluate each possible operating configuration and provide the arc flash results for each case. When equipment design includes dual protective device settings for the purpose of equipment maintenance (non-coordinated system), provide the arc flash result for that scenario. Summarize all data and include the worst-case results in terms of arc flash levels.

c. Assumed working distance in feet. For low voltage systems, assume a working distance of 18 in. For medium voltage systems, assume a minimum working distance of 4 ft. For high voltage systems, assume a minimum working distance of 6 ft.

d. For medium voltage and high voltage systems, credit can be taken for the associated distribution feeder circuit breaker as the upstream device if:

- Existing circuit breakers – documented maintenance and testing of the circuit breaker and relay is less than five years old.
- New circuit breakers – the circuit breaker and relay commissioning process confirm functionality in accordance with NETA ATS.

e. For existing low voltage systems, credit can be taken for the main breaker as the upstream protection device if one of the following configurations apply:

- The main breaker is located remotely (separate enclosure) from the feeder breakers.
- The main breaker is located in its own sealed compartment, such as a switchgear.

f. For existing low voltage systems, an upstream circuit breaker can be credited to clear the arcing fault if:

- There is documented maintenance and testing for the circuit breaker.

Note: Maintenance confirms the functional capability and physical condition. Testing confirms that the circuit breaker can respond to and clearing an overcurrent event in accordance with its published time-current curves.

- Documented maintenance and testing is less than five years old.

g. For new low voltage systems, an upstream circuit breaker can be credited to clear the arcing fault if the circuit breaker commissioning process confirms functionality of the trip unit in accordance with NETA ATS.

h. Calculated energy in cal/cm^2 at each evaluated location. The design goal is to establish arc flash levels that result in 8 cal/cm^2 or less. Consider remote racking mechanisms to rack breakers in and out to limit personnel exposure to an arc flash event. Specifically identify locations where this energy level cannot be achieved, such as upstream of a main breaker (between the breaker and an upstream transformer) or downstream of UPS systems.

i. Specified protective device settings to achieve the arc flash results. Reconcile arc flash protective device setting recommendations with the protective device time-current coordination study.

j. List of work locations exceeding 40 cal/cm^2.

3-2.7 Voltage Drop.

The following voltage drop requirements apply to AC and DC constant voltage systems 1000V or less unless more stringent criteria apply. The following does not apply to constant current systems or distribution systems over 1000V. In situations where the voltage within a facility's distribution system is increased over this threshold, the voltage drop requirements shall restart assuming nominal voltage when transformed below the threshold.

400Hz systems must be designed for voltage drop in accordance with UFC 3-555-01N requirements.

If the phase conductor size is increased for voltage drop, increase the size of the equipment grounding conductor proportional to the circular mil increase of the phase conductor in accordance with NFPA 70 Section 250.122.

3-2.7.1 Permitted Voltage Drop.

The maximum voltage drop permitted must not exceed 5%. Unless stricter requirements apply as adopted by this or other UFCs, feeders and service conductors must be limited to 3% voltage drop and branch circuits must be limited to 3% voltage drop, with no greater than 5% total. The starting point for this calculation is defined below.

Calculation limits must be based on the cumulative amount of voltage drop seen at a given location in the distribution system from the start of calculation identified below, not on an individual basis by circuit.

3-2.7.2 General Voltage Drop Mitigation Strategies and Impacts.

Voltage drop can be mitigated through various strategies, including increasing conductor size, reducing the circuit's load, decreasing the conductor's length, decreasing conductor temperature, and improving power factor. When establishing distribution equipment placement within a facility, locate panelboards relatively central to the loads supplied to minimize circuit lengths. Likewise, routing the majority of the distribution at 480/277V and stepping down to 208/120V more locally to the loads served will yield a lower voltage drop to the end devices; this strategy needs to evaluate a balance between transformer and circuit costs, as well as requirements to submeter different load types when applicable.

Note increased conductor sizes will yield lower conductor resistances, lead to increased fault current values, and impact arc flash values at the equipment buses, potentially leading to protection coordination issues. Designers must ensure all conductor sizes are established prior to performing final fault current and arc flash calculations, and update safety calculations when modifying existing systems.

3-2.7.3 Voltage Drop Relationship with Utilization Voltage.

Voltage drop calculations focus on energy loss through conductors, and voltage drop contributes to utilization voltage for end users. However, voltage drop and utilization voltage, which is the actual voltage seen at end-use devices and equipment, are not synonymous. Devices and equipment have acceptable utilization voltage ranges within which operation can occur, the lower bound of which can be of a lower voltage than yielded by the maximum permitted voltage drop alone. Other system losses occur throughout the distribution system, most notably through transformers, and the voltage delivered by the utility service may deviate from the nominal voltage assumed in calculations. Transformer tap settings aid in providing appropriate downstream utilization voltage, however, the use of transformer taps does not negate energy losses incurred through conductor impedance voltage drop.

Design and construction personnel must remain cognizant of the utilization voltage requirements for the equipment and appliances served. Adjustments to the distribution system, such as the use of transformer taps and/or an increase in conductor sizes, must be performed accordingly to ensure proper utilization voltage is provided to the end use devices while simultaneously satisfying the voltage drop energy conservation requirements.

Practices used to boost utilization voltage at the load must not be used as a method to comply with voltage drop requirements.

3-2.7.4 Calculation Assumptions and Procedures.

3-2.7.4.1 Initial Voltage.

The use of service transformer taps must not be assumed to compensate for voltage drop on the service-entrance equipment side of the calculation start point. Calculations must assume the nominal system voltage (i.e., 208V, 240V, 480V) is present at the location described for the calculation starting point.

3-2.7.4.2 Starting Point.

Voltage drop calculations must start at the point of government ownership (i.e., transformer, disconnect switch, meter cabinet, or similar). Where the government owns the exterior distribution upstream of the service transformer, the calculation must start at the service transformer secondary lugs. Where the facility is without a service transformer and supplied by independent generator or energy storage system, the calculation must start at such power supply's output terminals.

3-2.7.4.3 Load Estimations.

3-2.7.4.3.1 Capacity.

The capacity must be 100% of a circuit breaker or fuse device's nominal rating (e.g., 100A standard (80%) devices and 100A continuous (100%) devices are both considered 100A capacity) for voltage drop calculation purposes. See UFC 3-520-01 regarding Adjustable-Trip Devices.

3-2.7.4.3.2 Feeder Loads.

Size feeders to accommodate the maximum permitted load based on the circuit ampacity. Exceptions to this are as follows:

a. **Transformer Feeders.** Per ANSI C57.96, transformers complying with the ANSI standard are designed for continuous operation at the specified temperature rise for normal life expectancy at the rated kVA. The rated kVA may be different than the nameplate or nominal kVA value based upon insulation temperature rating, ambient temperature, altitude, and other operating conditions.

   For voltage drop purposes, a transformer's secondary feeders must assume a load equivalent to the transformer's nominal output rating.

   For voltage drop purposes, a transformer's primary feeders must assume the same load as identified above for the secondary feeders PLUS 6% transformer loss load.

b. **Motor Feeders.** Motor overcurrent protection is located at the overloads and NFPA 70 categorizes the circuits from the circuit breakers to the overcurrent protection as feeders. As on transformer primary circuits, circuit breakers are sized to account for inrush. Utilize the circuit's total full-load amps (FLA) based on NFPA 70 Article 430 tables for voltage drop calculations. Additionally, this circuit must be considered a "branch circuit" for voltage drop compliance purposes only.

Fire pumps must comply with the voltage drop requirements identified in NFPA 70 Article 695 in lieu of the limits stated in this section.

c. **Air-Conditioning and Refrigerating Equipment Feeders.** The voltage drop load must be the rated-load current or full-load current marked on the nameplate as identified in NFPA 70 Article 440. Additionally, this circuit must be considered a “branch circuit” for voltage drop compliance purposes only.

d. **Variable Frequency Drives/Adjustable Speed Drive Feeders.** Feeders to variable frequency drives, adjustable speed drives, and similar must be sized for voltage drop based on the drive’s maximum input current, including any drive losses. Additionally, this circuit must be considered a “branch circuit” for voltage drop compliance purposes only.

e. **Other Feeders Directly Supplying Motor-Based Equipment.** Where NFPA 70 categorizes conductors as feeders, but the conductors supply dedicated motor-based equipment or equipment assemblies such as cranes and elevators, the voltage drop calculation load must be the total FLA. Application-specific NFPA 70 demand factors may be applied to the loads when used for voltage drop calculations. Additionally, this circuit must be considered a “branch circuit” for voltage drop compliance purposes only.

3-2.7.4.3.3 Branch Circuit Loads.

a. **Lighting Circuits.** Lighting circuits must utilize the total full load of all luminaire and non-luminaire devices connected. Where the lighting circuit contains non-luminaire components such as room controllers or power packs, ensure such loads are captured.

b. **Receptacle Circuits.** Receptacle circuits (including circuits where a dedicated receptacle is provided for a single device, appliance, or equipment) must use 80% of the circuit’s capacity for voltage drop calculations.

c. **Systems Furniture Circuits.** Systems furniture circuits must use 80% of the circuit’s capacity for voltage drop calculations.

d. **Hard-Wired Appliance and Other Non-Receptacle Circuits.** Hard-wired appliance and other non-receptacle circuits must utilize the total connected load on the circuit for voltage drop calculations.

3-2.7.4.4 Circuit Lengths.

3-2.7.4.4.1 Methods.

See UFC 3-520-01 for routing estimation instructions, and utilize the applicable method as described and assigned below.

a. **End-of-Line Method.** Loads on circuits must be at the end of the circuit for voltage drop calculations unless otherwise indicated below.

b. **Point-to-Point Method.** Calculate the load contributions to voltage drop as a function of the load experienced for a given portion of the circuit except as identified in the subsequent entries of this section. That is, the entire load on the circuit is experienced to the first device, be it a load, splicing/junction point, etc. Beyond that point, the load is diminished for the next series or parallel lengths, and only those loads contribute to the voltage dropped in the associated circuit length.

The totality of the voltage dropped on any given path must be evaluated in determining a satisfactory conductor size (i.e., the path to one end device may experience less voltage drop than the path to a different end device), and the more severe condition in a comparison of multiple paths must be used for the entire circuit size.

3-2.7.4.4.2 Feeders.

The entire feeder conductor lengths from the start of calculation described above to the last circuit breaker or fuse for a given portion of the distribution system must be used in the voltage drop calculation using the End-of-Line method.

3-2.7.4.4.3 Branch Circuits.

As with feeder conductors, the entire length of the branch circuit conductors (End-of-Line) must be used in the calculation except as follows for the purposes of the voltage drop load location:

a. **Lighting Circuits.** Lighting circuits may use the Point-to-Point Method.

Where the lighting circuit contains non-luminaire components such as room controllers, power packs, or other line-voltage control devices, ensure the lengths used and loads associated used in the voltage drop calculation capture these portions of the circuit, including travelers between three- and four-way switches.

b. **Receptacle Circuits.** The load identified above must be at the farthest receptacle (End-of-Line) as routed through other receptacles, junction boxes, control devices, etc.

c. **Systems Furniture Circuits.** The load identified above must be at the point of connection to the assembly (End-of-Line) as routed through junction boxes, control devices, etc., prior to the point of systems furniture connection.

d. **Hard-Wired Appliances and Other Non-Receptacle Circuits.** Hard-wired appliances and other non-receptacle circuits may use the Point-to-Point Method.

3-2.7.4.5 Additional Calculation Considerations.

3-2.7.4.5.1 Circuit Breakers in Series for Singular Loads or Set of Receptacles.

In situations where a circuit supplies a singular load or set of receptacles but is provided with an additional overcurrent protective device local to the load, the two portions of the distribution system may collectively be considered as part of the "branch circuit" for voltage drop calculations. For example, if an interior panelboard circuit breaker supplies an exterior pedestal-mounted receptacle with a local circuit breaker, the combined length of the circuits from the panelboard circuit breaker to the pedestal circuit breaker and from the pedestal circuit breaker to the receptacle may be sized using the branch circuit requirements for voltage drop (rather than the circuit from the panelboard circuit breaker to the pedestal circuit breaker being considered part of the feeder portion of the distribution system).

3-2.7.4.5.2 Branch Circuits Containing a Mix of Load Types.

Use the worst-case load assignment for the voltage drop calculation. Where portions of the circuit are distinguishable by load type, the worst-case voltage drop calculation may be performed for each full path from source to end device and the worst-case of the comparative results must be used.

For example, a branch circuit is routed to a junction box, where the circuit is split into separate circuit paths ('A') for a set of receptacles and ('B') for a set of luminaires. The entirety of the circuit load must be included from the source to the divergent point at the junction box; include the voltage drop to this point in the sizing for the comparative calculations. Then use the sizing results from the comparative calculations between 'A' and 'B' to establish a circuit size.

3-2.7.4.5.3 Voltage Drop through Transformers.

Voltage drop through transformers due to transformer losses for design calculation purposes must be zero. When modeling, configure transformers such that the voltage drop percentages relative to the values identified in section "Initial Voltage" above on the transformer primary and secondary buses match. That is, if the totality of the voltage dropped to the transformer primary terminations is, for example, 1.50% of the nominal system primary voltage, the calculation for the start of the conductors at the transformer secondary lugs must be at 1.50% of the nominal system secondary voltage. The aforementioned load associated with transformer losses are to be accounted for in the voltage drop calculations for the distribution system upstream of the transformer.

Voltage drop mitigation measures must be through conductor size increases only, and through strategic selection of voltage systems and locations of transformation equipment.

Transformer taps must not be used in voltage drop design calculations and must be used for field adjustments only, including to account for voltage lost through the transformer or longer conductor routing lengths than estimated in design. Note the output voltage of a transformer will drop as the load increases or the power factor decreases.

3-2.7.4.5.4 Voltage Drop Allowances Addressed by Industry Standards.

For specific applications whereby a published industry standard establishes a voltage tolerance wider than the requirements of this section, the requirements of this section will end at the point at which the facility distribution system interfaces with the specific appliance, equipment, or similar system. For example, the voltage drop limits provided by this section must be met for crane systems to the point of connection at the runway electrification system, however, the voltage drop experienced through the runway and subsequent conduction paths to the eventual loads may adhere to CMAA-70 instead.

Similarly, the additional voltage drop experienced through appliance cord and plug connections are not covered under this section's requirements, which end at the receptacle connection point.

3-2.7.4.6 Power Factor.

For applications where power factor is known or can be easily estimated based on industry standards or approved sole-source equipment, utilize such information. The following are typical power factors and must be used as estimations where the specific power factor is unknown:

	208/120V	480/277V
Fluorescent Lighting	0.95	0.95
Compact Fluorescent Lighting (hardwired)	0.90	0.90
Compact Fluorescent Lighting (GU-24)	0.50	0.30
LED Lighting	0.90	0.90
Incandescent Lighting	1.00	---
High-Intensity Discharge Lighting	0.90	0.90
HVAC Package Units	0.85	0.90
Other Motors Less than 5HP	0.80	0.80
Other Motors Greater than or Equal to 5HP	0.85	0.85
Electric Resistance Heating (including Hot Water)	1.00	1.00
Kitchen Equipment	0.90	0.90
Receptacles	0.85	0.85
Other	0.85	0.85

Table adapted from California Title 24.

Unity power factor must not be used for loads other than electric resistance heating and incandescent lighting.

3-2.8 Motor Starting.

Account for both starting and running current in motor calculations.

Refer to IEEE C37.96 for calculating motor inrush and how to place the knee point from starting to running on a Time Current Curve.

3-2.9 Lighting.

Provide calculations for interior and exterior lighting systems in accordance with UFC 3-530-01.

3-2.10 Underground Structures Design.

Provide sizing and cable bending radius calculations for underground structures (manholes and handholes) with cable sizing exceeding 500 kcmil. Verify design requirements of UFC 3-550-01 are met. Coordinate with the Activity on the naming convention for underground structure identification on the drawings.

3-2.11 Cable Pulling Tension Calculations.

Provide cable pulling tension and sidewall pressure calculations for medium voltage cable in conduit. Compare the calculations to the rating of the cable.

3-2.12 Calculations for Directional Boring.

Provide calculations in accordance with UFC 3-550-01, Appendix B.

3-2.13 Sag, Tension, and Guying Analysis.

Provide calculations in accordance with UFC 3-550-01.

Crane trolley contact conductors are exempted from this requirement due to excessive enveloping of the conductor.

3-2.14 Cathodic Protection Calculations.

Provide calculations in accordance with UFC 3-570-01.

3-2.15 Lightning Protection Calculations.

Provide a lightning risk assessment in accordance with NFPA 780 Annex L and document the required level of protection.

If lightning protection is a design requirement, provide a lightning protection system in accordance with UFC 3-575-01. Provide side flash calculations as required by NFPA 780. Provide calculations for alternative grounding methods when required by the design.

3-2.16 ESS Calculations.

Provide calculations in accordance with UFC 4-021-02.

3-2.17 Renewable Energy System Calculations.

Provide calculations for renewable energy system project requirements. As a minimum, incorporate the requirements of criteria under development in accordance with Section 2-1.8. Calculations can vary with the types of renewable energy system, but typically include:

- Predicted power generation – kW and kVAR.
- Predicted energy production – kWh per year.
- IEEE Std 1547 interface compliance.
- Voltage drop.
- Ampacity requirements.
- Site orientation and safety considerations, including glare analysis for photovoltaic systems.
- Electrical protection and coordination.

3-3 DRAWING REQUIREMENTS.

Provide adequate plans, including demolition, existing conditions, and new work, legends, details, and diagrams to clearly define the work to be accomplished. Coordinate construction drawings and specifications; show information only once to avoid conflicts. For the Navy, additionally comply with FC 1-300-09N for specific drawing requirements and drawing phases.

Utilize electrical design "Best Practices Information" located at https://www.wbdg.org/dod/supp-tech-documents to facilitate drawing requirements and related equipment detail required by the remaining paragraphs of this UFC.

Provide a General Note at the beginning of the Electrical Drawings clarifying the work to be accomplished. The following note is required unless directed or approved by the government:

"ELECTRICAL WORK AND MATERIAL IS NEW AND PROVIDED BY THE CONTRACTOR UNLESS INDICATED OTHERWISE".

a. Arrangement. Arrange the Electrical Drawings in accordance with the National CAD standards at https://www.nationalcadstandard.org/ncs6/. Provide drawings that are clear and consistent in presentation and format. Follow the NFPA 70 Metric Designations (mm) and Trade Sizes (in) for conduit.

b. Multiple Conduit/Cable Runs. To avoid misinterpretation as to the quantity of cables and conduit required in multiple conduit and cable runs, use one of the following acceptable descriptions:

- Acceptable: Two 4-inch conduits, each containing four 500 kcmil and one #2 Gnd.
- Acceptable: Two 4-inch conduits, each with four 500 kcmil and one #2 Gnd
- Acceptable: Two 4-inch conduits, with four 500 kcmil and one #2 Gnd in each conduit
- Unacceptable: Two sets of four 500 kcmil and one #2 Gnd in 4-inch conduit
- Unacceptable: Parallel Service: Four 500 kcmil and one #2 Gnd in 4-inch conduit

3-3.1 Legends and Abbreviations.

Define all symbols used in the drawings in the legend. Locate legend on the first electrical sheet using multiple legends where required and identifying the specific use of each legend. Use different legends for new and existing work. Avoid using composite legends that include all symbols but fail to indicate which symbols are to be used on which drawings.

Refer to electrical technical paper TSEWG TP-12: Appendices for typical illustrations of how to properly display legends on the contract drawings. Refer to Appendix A for more information.

3-3.2 Site Plans.

Show utility point of common coupling to the base power and telecommunications systems on the site plan. Provide explicit direction on method of entering existing manholes. Provide all details including composition of duct banks and depth and configurations of the duct banks.

3-3.2.1 Coordination with Other Utilities.

Provide Electrical Site Plans that are separate and distinct from other utility site plans. Include with the electrical drawings. Electrical and civil site plans may be combined only when the project requires minor utility work. Coordinate with the electrical engineering reviewer before combining the electrical and civil site plans.

Provide the orientation of electrical drawings consistently with the civil drawings. In addition, provide the orientation of partial building or site plans identical to the orientation of the larger plan from which the partial was taken. Indicate the exact title of each detail, partial plan or elevation as identified on the cross-referenced sheet.

3-3.2.2 Overhead Distribution.

For overhead distribution use a separate symbol for each individual circuit; define each circuit by voltage level as well as number, size, and type of conductors. Coordinate guying and conductor sag information shown on the drawings with that shown in the specifications.

3-3.2.3 Pole Details.

Indicate overhead distribution pole details on the drawings. Identify pole number assignment consistent with installation standards on the site plan and require pole identifier number to be installed on pole matching installation standard.

3-3.2.3.1 Format.

NAVFAC pole details are available in Adobe PDF format and in AutoCAD format on the WBDG website at https://www.wbdg.org/dod/ufgs/forms-graphics-tables.

Provide details in situations where an applicable pole detail has not been developed. Designer developed details must contain the same level of detail equivalent to the NAVFAC pole details and include material requirements.

Review the information contained on Details OH-1.1 through OH-1.5a for examples of how to show overhead distribution work. Do not describe proposed work by referencing sketch numbers instead of pole detail designation symbols. Do not use pole detail designation symbols to describe existing facilities to be removed. To maintain the integrity of the pole details, do not modify pole details; include any required exceptions or modifications as supplemental information with the pole detail designation symbols. When using pole details, place a note referencing the pole detail designation symbols (like the following) on the drawings:

> “XFB, 15FR3-N are pole detail designation symbols. Refer to Sketches OH-1.1 through OH-41 on Sheets [TBD] for an explanation of the use and description of equipment provided by these symbols.”

3-3.2.3.2 Conductor Sag.

Indicate conductor initial sag values. Provide initial sag values at ambient temperatures in 18 degrees F (10 degrees C) increments for a temperature range, which includes the outside summer and winter design temperature values. Clearly indicate each different calculated ruling span on the plans and provide initial sag for one span in the calculated ruling span.

3-3.2.3.3 Fusing.

Provide appropriate symbol and detail indicating the use of backup current limiting fuses with the device being protected. Indicate the fuse type and ampere rating as well as the voltage rating and current designation of the backup current limiting fuse.

3-3.2.4 Transformer Details.

Indicate transformer details on the drawings. Transformer details are available in a PDF format and an AutoCAD format on the WBDG website at https://www.wbdg.org/dod/ufgs/forms-graphics-tables.

3-3.2.4.1 Descriptive Information.

Provide the following transformer descriptive information:

- Transformer type (e.g., pad-mounted, pole mounted, station type, unit-sub)
- kVA, single or three phase
- Voltage ratings per IEEE C57.12.00 (e.g., 11.5KV – 208Y/120 volts)
- Primary and secondary connection (when using single-phase units for three-phase service; specifically indicate how the units are to be connected, i.e., connect delta-wye grounded for 208Y/120-volt secondary service)

3-3.2.4.2 Surge Arresters and Fused Cutouts.

Include the following information for surge arresters and fused cutouts:

- Surge arrester kV rating.
- Cutout kV, continuous ampere, and interrupting ampere rating.
- Fuse link type and ampere rating.

3-3.2.5 Underground Distribution.

3-3.2.5.1 Required Information.

Profiles may be required for ductbank runs. Discuss profile requirements with the electrical reviewer. Indicate structure (manhole and handhole) tops, ductbank elevations, slopes, and diameters. Coordinate structure numbers with plan sheets. Show and label all crossing utility lines, both existing and new. If depths of existing utilities are unknown, indicate the horizontal location of the utility and indicate the vertical location with a line representing the anticipated range of elevations where the utility will be found in the field. Indicate the method of new utility installation routing above or below conflicts. Notes can be used to identify parts.

Provide cable/ductbank information indicating cable identification, description, conduit size, and remarks for any special instructions. Where four or more conduits are to be installed, provide in schedule format. For smaller applications, schedule or notational conveyance is acceptable.

3-3.2.5.2 Detail Drawings.

Provide manhole foldout details or exploded views for all multiple-circuit primary systems and all primary systems requiring splices. Indicate the entrance of all conduits and the routing of all conductors in the manholes.

Manhole details are available in Adobe PDF format and in AutoCAD format on the WBDG website at https://www.wbdg.org/dod/ufgs/forms-graphics-tables.

3-3.3 Demolition Plans.

3-3.3.1 Required Information.

Provide “Demolition” plans separate and distinct from “New Work” plans, except where only minor demolition work is required. Clearly show what is to be demolished, at an appropriate scale. Indicate the beginning and ending points of circuit removals.

For modification of or additions to existing equipment, provide the manufacturer’s name and other pertinent manufacturer’s identification (e.g., serial number, model number, style, and any other manufacturer’s identifying markings).

3-3.3.2 Demolition Sequence.

Provide a sequence of demolition; if necessary, include any known requirement for continuous operation and limited shutdown requirements. Identify these in the special scheduling paragraphs of the specifications.

3-3.3.3 Lighting Demolition.

Indicate the quantity of lighting ballasts that contain PCBs and the quantity of lamps that contain mercury.

3-3.4 Lighting Plans and Details.

Do not show lighting and power on the same floor plan, unless the scale of the plan is 1:50 (¼ in = 1 ft – 0 in) or larger. "Provide a photometric layout plan as an appendix to the design analysis. The photometric layout plan may also be a for-information-only (FIO) drawing but may not be a contract drawing.

Provide luminaire (lighting fixture) details, separate luminaire schedule, controls, and control strategies for each space. Details and a luminaire schedule are available in Adobe PDF format and in AutoCAD format on the WBDG website at https://www.wbdg.org/dod/ufgs/forms-graphics-tables. To maintain the integrity of the details, do not modify details; make any required exceptions or modifications in the remark’s column of the luminaires schedule and not on the details themselves. Provide applicable luminaires type symbol(s) with each luminaire sketch/detail. When using luminaire(s) not included in the database, detail the luminaire(s) on the drawings providing the following minimum information:

- Luminaire type (e.g., high bay, fluorescent, industrial, downlight, roadway type, floodlight).
- Physical construction including housing material and fabrication method, description of lens, reflector, refractor.
- Electrical data including number of lamps, lamp type, ballast data, operating voltage.
- Mounting (surface, suspended, flush) and mounting height.
- Special characteristics such as wet label, specific hazardous classification, or air handling.

3-3.5 Power Plans.

Show all power requirements and points of connections. Specifically identify each piece of equipment including HVAC and mechanical equipment (e.g., unit heater No. 1, unit heater No. 2).

Typical illustrations showing proper methods for displaying equipment on the contract drawings are provided in a PDF format within the electrical technical paper TSEWG TP-12: Appendices. Refer to Appendix A for more information.

3-3.6 Telecommunication Plans.

Show locations of voice and data outlets in each room, closets, and equipment spaces. Detail all outlet, cable tray, backboard or distribution frames, and grounding bus bars.

Note: Power and telecommunication systems may be shown on the same drawings provided the design is small, the electrical designer and the telecommunications registered communications distribution designer (RCDD) are the same person, and combining the drawings is approved by the Contracting Officer or technical reviewing authority.

For larger designs where power and telecommunications plans are not shown on the same drawings, provide telecommunications drawings stamped by an RCDD. Refer to UFC 3-580-01 for telecommunications requirements.

3-3.7 Grounding Plan.

Provide grounding plans and details at an appropriate scale.

3-3.8 Roof Plan.

When roof mounted equipment, including HVAC equipment, cannot be adequately shown on the Power Plan, provide an appropriately scaled roof plan.

3-3.9 Lightning Protection Plan.

Provide lightning protection plan and details at an appropriate scale. Indicate locations and number of system components required. Show air terminal installation details, roof and wall penetration details, and details to show concealed components of the system.

Coordinate roof and wall penetrations with other disciplines to ensure that the integrity of the facility envelope is not compromised.

3-3.10 Hazardous Location Plan.

Provide on the drawings the boundaries and classifications of all hazardous locations in accordance with NFPA 70.

3-3.11 Power One-Line/Riser Diagrams.

Provide a power one-line (single-line) diagram for:

- Medium-voltage distribution systems, including substations and switching stations.
- Systems involving generation, either low voltage or medium voltage.
- Building switchgear, switchboards, and main distribution panels (MDPs).

3-3.11.1 Content and Format.

The one-line diagram must show all components (including metering and protective relaying). Indicate sizes of bus, feeders and conduits. Show connections of transformers, PTs, CTs, and capacitors on the one-line diagram by means of the proper symbol. Show potential and current transformer ratios. Indicate relay quantity and function (overcurrent, voltage, differential) using ANSI designation numbers.

On most facility-related projects, it is acceptable to combine the one-line diagram with a riser diagram. The one-line diagram would begin with the medium voltage system and continue through the transformer up to and including the main breaker and feeder breakers within the MDP. Sub-panels beyond the MDP may be shown in the riser diagram format.

3-3.11.2 Electrical Equipment.

Indicate kV ratings for surge arresters, and kV and ampere rating for cutouts. Indicate fuse link type and ampere rating. For capacitors indicate kVAR per unit, number of units per bank, voltage (voltage rating of units, not the system voltage), phase (e.g., three-phase or single-phase units), fuse size, and fuse type.

3-3.11.3 Transformer Information.

Show the following on the one-line diagram when a transformer is indicated, as applicable.

- Primary switches.
- Wye or delta connection.
- Loadbreak elbows.
- Lightning arresters.
- kVA rating.
- Rated voltage (primary & secondary).
- Transformer identification number.
- Industry standard impedance.
- Meter type.
- CT and PT sizes.
- Fuse sizes.

Show all pertinent transformer information on the one-line diagram as opposed to the specifications. Items that are common to all transformers can be indicated by notes on the one-line diagram if a typical detail drawing is provided.

3-3.11.4 Pad-Mounted Switchgear Information.

Show the following on the one-line diagram when pad-mounted switchgear is indicated:

- Spare ways (cubicles).
- Protective devices.
- Loadbreak elbows.
- Switch identification number.

3-3.11.5 Primary Distribution.

Show the following on the one-line diagram when a new primary is indicated:

- In-line splices in manholes.
- Normally open points.
- Number and sizes of phase, neutral and ground cables.
- Conduit sizes.

3-3.11.6 One-Line Diagram for Demolition.

If there is demolition involved or work is to be done to existing equipment, provide an existing one-line diagram showing the current arrangement of the gear and then show a new one-line diagram indicating by line weights what is existing or new.

3-3.11.7 Format.

Ensure that information shown on the one-line diagram is not duplicated elsewhere in the construction package, as this will likely cause conflicts if changes are necessary. Indicate on the electrical legend the exact nomenclature used to indicate conductor and conduit sizing. Provide a schedule for feeder runs. Provide medium voltage one-line diagrams for stations and distribution systems that have a geographic affiliation to the actual constructed distribution system.

Typical illustrations showing proper methods for displaying one-line and power riser diagrams on the contract drawings are provided in a PDF format within the electrical technical paper TSEWG TP-12: Appendices. Refer to Appendix A for more information.

3-3.12 Telecommunications Riser Diagram.

Clearly indicate service entrance cable and duct, entrance protector assemblies, and connections to existing outside cable plant. Include the following:

- Cross-connects. Indicate by notation that voice and data cables terminate in separate fields. Indicate method of cross connecting – patch panel or connector block.
- Telecommunications outlets, including room numbers.
- Cable for building backbone and horizontal distribution system.
- Pathway, including conduit and cable tray for backbone and horizontal distribution system.
- Telecommunications grounding system.

3-3.13 Intercommunication/Paging Riser Diagram.

Show power source, master station with associated equipment, speakers, and outlets. Include room numbers, wiring/conduit between components.

3-3.14 Fire Alarm Riser Diagram.

If required, fire alarm riser diagrams, including mass notification system, will be provided by the fire protection engineer.

3-3.15 Special Systems Riser Diagrams.

Provide other riser diagrams like those developed for telecommunications or intercommunication/paging.

3-3.16 Schedules and Elevations.

Provide elevations, sections, and details to clearly identify space constraints, unique conditions, design intent, or to ensure a specific method is implemented.

3-3.16.1 Panelboards.

Provide schedules for all panelboards. Provide the panelboard schedule reflecting the actual circuit breaker and bus arrangement. Include the following:

- Panelboard designation and location (i.e. room number).
- Voltage, phase, frequency, number of poles, and minimum interrupting rating.
- Main amperes indicating main breakers or lugs only.
- Surface or flush mounting.
- Circuit number, wire size, breaker trip, connected load, and identification of load associated with each branch or feeder. Provide the specific identification of load. For example, do not merely indicate “Lighting,” but rather “Lighting, Room 102” for the directory marking.
- Total connected load (calculated load) including demand factors of all circuits.
- Any special breaker requirements such as GFCI, AFCI, SWD, adjustable trip, 100% rated.

  Note: many manufacturers require minimum 400A panel frames for 100% breakers to be used.
- Neutral bus size (100% or 200%).
- See UFC 3-520-01 for additional values to be included in panelboard schedules and drawings.

Additionally, consider the following:

- Other conductor sizing factors specific to a given circuit such as anticipated ambient temperature on the assumed routing path, whether the load is nonlinear, and the number of current-carrying conductors for purposes of re-sizing should circuits be consolidated into a common raceway during construction.

Show all circuiting (identifying conduit and wiring back to specific panels but not identifying the exact routing required during construction) on the design drawings exactly as they are to be installed.

3-3.16.2 Switchboards and Switchgear.

Provide plan and elevation or isometric drawings for switchboards and switchgear, showing compartments, their intended use, and instruments, relays, and controls. Clearly show contents of all sections including whether breakers are individually, or group mounted. Indicate that switchboards and switchgear are mounted on 4 in (100 mm) elevated concrete pads. Coordinate design of pad with structural engineer.

3-3.16.3 Motor Control Centers.

Provide plan and elevation or isometric drawings for Motor Control Centers (MCCs) identifying compartments. Provide schedule listing each compartment. Include on the schedule (for each compartment) the description of load, load in amperes, load in horsepower, NEMA size and type of starter, breaker size, conductor and conduit size, control devices, and other special requirements.

- Indicate, on plans or in specifications, enclosure type, bus rating, bus material, bus bracing, NEMA class and wiring type, service voltage, control voltage and source, and top or bottom feed.
- Indicate on the drawings that MCCs are mounted on 4 in (100 mm) elevated concrete pads. Coordinate design of pad with structural engineer.
- Provide elevation of control panels, indicating front panel devices, such as indicator lights, pushbuttons, gauges, and switches.

3-3.17 Details/Diagrams.

Detail all telecommunications outlets, cable tray, and backboard/distribution frames. Provide elevations of pertinent communication room walls. Indicate additional details as required. Provide a junction box detail on the drawings showing the interface between the Systems Furniture wiring harness and the branch circuit wiring.

3-3.18 Grounding Diagrams.

Provide grounding diagrams with explicit grounding and grounded conductor requirements beginning with the medium-voltage system and continuing through the transformer up to and including the Service entrance equipment, step down transformers, sub-panels, and telecommunications systems grounding.

The service entrance grounding electrode systems and interconnections with other system grounding electrodes must be clearly shown and identified on the grounding plan. The main bonding jumper connection must be indicated and system bonding jumper connections for separately derived systems must be clearly indicated. Automatic Transfer switches must be identified indicating 3-pole design for single-phase systems and 4-pole design for three-phase systems. Coordinate this UFC with TSEWG TP-19 and clarify when ATS with unswitched neutral be used in lieu of ATS with switched neutral. Typical illustrations showing proper methods for displaying grounding diagrams on the contract drawings are provided in a PDF format within the electrical technical paper TSEWG TP-12: Appendices. Refer to Appendix A for more information.

3-3.19 Cathodic Protection Plans and Details.

Provide cathodic protection plans and details at appropriate scales. Indicate on the drawing the location of all rectifiers, anode beds, structures, elevators, and overhead cranes protected by cathodic protection system(s). Include all structures, elevators, and overhead cranes that may be affected by stray current corrosion because of cathodic protection of the specific structure within the affected area of cathodic protection. A NACE-certified Cathodic Protection Specialist must prepare or review cathodic protection design. Follow the requirements of UFC 3-570-01.

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APPENDIX A TRI-SERVICE ELECTRICAL WORKING GROUP TECHNICAL PAPERS

The Tri-Service Electrical Working Group (TSEWG) has developed technical white papers to provide additional information on certain topics. Some of these papers contain information that was provided in earlier versions of the UFCs, which was considered important to maintain for reference. The following white papers are located at https://www.wbdg.org/dod/supp-tech-documents:

- **TP-01: Electrical Calculation Examples** – provides example calculations for a variety of electrical equipment.
- **TP-02: Capacitors for Power Factor Correction** – provides information regarding capacitor application, sizing, and design.
- **TP-03: Surge Protector Performance and Evaluation Criteria** – provides information for low voltage surge protection.
- **TP-04: Stationary Battery and Charger Sizing** – provides different sizing techniques for stationary applications.
- **TP-05: Interior Transformer Ratings and Installation** – discusses transformer application, rating, and installation criteria.
- **TP-06: Low-Voltage Breaker Interrupting Ratings** – explains how low-voltage circuit breakers are rated and tested.
- **TP-07: Protection System Design** – provides electrical analysis criteria for relays, fuses, and circuit breakers.
- **TP-08: Electrical Equipment Enclosures and Hazardous Locations** – provides NEMA and NFPA guidance regarding enclosure designs and hazardous location classifications.
- **TP-09: Automatic Transfer Equipment** – provides information regarding automatic transfer switch application and design.
- **TP-10: Arc Flash Levels for Fused Voltage Inputs to Electricity Meters** – provides an arc flash analysis for arcing faults downstream of protective fuses on an electricity meter.
- **TP-11: UFC 3-500-10N Best Practices** – UFC 3-500-10N was developed by NAVFAC and was superseded by the initial issue of UFC 3-501-01. TP-11 provides the best practices information that was contained in UFC 3-500-10N.
- **TP-12: UFC 3-500-10N Appendices** – UFC 3-500-10N was developed by NAVFAC and was superseded by the initial issue of UFC 3-501-01. TP-12 provides appendices that were not included in UFC 3-501-01.
- **TP-13: UFC 3-501-03N Load Demand Analyses** – UFC 3-501-03N, Electrical Engineering Preliminary Considerations, was superseded by the initial issue of UFC 3-501-01. UFC 3-501-03N contained in its entirety MIL-HDBK 1004/1, Electrical Engineering Preliminary Design

Considerations. TP-13 was issued to retain the load demand analysis information originally contained in MIL-HDBK 1004/1.

- **TP-14**. Reserved
- **TP-15: Arc Flash Calculations and Detailed Arc Flash Warning Labels** – NFPA 70E requires a detailed arc flash warning label that specifies either the available incident energy in cal/cm^2 or the required level of personal protective equipment (PPE) that must be worn at a particular work location. TP-15 explains why detailed arc flash warning labels might be inappropriate for many military installations.

APPENDIX B DESIGN DATA TABLES

Table B-1 Typical Loading for Personal Computer Systems

Component	Measured Load
Dell Precision T5400 Desktop (Max)	2.4A
15.6", 2.6 GHz Dell Inspiron Laptop	0.75A
24" Dell Monitor	0.58A
HP LaserJet Pro P1102w printer	0.22A idle, 3A printing

Table B-2 Load Data for Preliminary Demand Calculations

Facility Type	VA/m^2	VA/ft^2
BEQ	21-64	2-6
Commissary/Exchange	75- 97	7-9
Cafe/Mess Hall	75-108	7-10
Administration Building	64-108	6-10
Craft/Hobby/Golf Pro	43-54	4-5
Shore Intermediate Maintenance Activity (SIMA)	64-108	6-10
BOQ	22-64	2-6
Warehouse/Exchange	43	4
Child Care	64	6
Chapel	54-75	5-7
Applied Instruction Building	64-108	6-10

Use the above information to aid in estimating demand for transformer sizing for preliminary calculations. As the design progresses, update demand calculations to reflect actual load of the building.

Dwelling Unit Demand Data for Electrical Calculations.

Note: These Tables are provided to aid the Designer of Record in estimating the total demand for "ALL ELECTRIC" dwelling units (including diversity). Size all distribution systems for dwellings for "ALL ELECTRIC". Use the data below for sizing distribution transformers, service lateral voltage drops and flicker calculations. These tables are not to be used for sizing the service laterals or service entrance conductors.

Table B-3 Dwelling Demand kVA per A/C Size

# of Units	HVAC Diversity	2 Tons		2.5 Tons		3 Tons		3.5 Tons		4 Tons	
		FE	Total	FE	Total	FE	Total	FE	Total	FE	Total
1	1.0	3.89	6.42	4.09	7.25	4.29	8.08	4.93	9.35	5.67	10.72
2	0.85	6.61	10.91	6.95	12.33	7.29	13.74	8.38	15.9	9.64	18.22
3	0.82	8.64	14.91	9.08	16.95	9.52	18.96	10.94	21.95	12.59	25.16
4	0.80	10.27	18.37	10.8	20.91	11.33	23.45	13.02	27.16	14.97	31.13
5	0.77	11.86	21.61	12.47	24.64	13.08	27.68	15.04	32.05	17.29	36.74
6	0.75	13.3	24.69	13.99	20.21	14.67	31.73	16.86	36.75	19.39	42.12
7	0.73	14.7	27.63	15.46	31.61	16.22	35.58	18.64	41.22	21.43	47.24
8	0.72	16.2	30.76	17.01	35.22	17.85	39.68	20.51	45.97	23.59	52.68

Table B-4 Typical A/C Size for Dwelling Units

Dwelling Type	A/C (Tons)	Typical (m^2)	Typical (ft^2)
Mobile Home, Small House	2.0	93	1000
Townhouse, House	2.5	116	1250
Townhouse, Condominium	3.0	140	1500
Condo, House	3.5	163-186	1750-2000
House	4.0	186-279	2000-3000

Table B-5 Demand for Electric Strip Heat

kW Rating of Strip	kVA Demand
5	5.0
10	8.0
15	10.5
20	14.0

FE (Full Electric) is the demand value (with diversity pre-calculated) of the load **without** a summer (air conditioning) or winter (heat strip) HVAC mechanical load included.

"Total" is the demand which **includes** a summer air conditioner load (**Total = FE + air conditioning load**). "Total" does not include the demand associated with resistive heat elements (which may drive the need for larger transformers). **HVAC diversity** = the diversity factor to use for winter HVAC unit demand calculations. It is incumbent on the electrical designer to address loads that are larger than those associated with the summer load. Size the transformer for the summer load unless the winter load calculation is more than 140% of the summer calculation.

Example: A new underground distribution system is being designed for a housing development of duplexes. Each dwelling unit is 1500 ft^2 (140 m^2) with a 3-ton heat pump and 5 kW of strip heat. "Total" load for 8 dwellings (maximum 4 duplexes per transformer – See paragraph “Housing Distribution” in UFC 3-550-01) and 3-ton units = 39.68 kVA (Table B-3). A check of the winter load = FE (Table B-3) + # of strip units x heat strip demand (Table B-5) x HVAC diversity (Table B-3). Winter load = 17.85 + 8 x 5 kW x 0.72 or 46.65 kVA. Summer to Winter load ratio = 46.65/39.68 or 1.18. Size the transformer for the summer load (39.68 kVA). Thus, each 50 kVA pad-mounted transformer must feed 4 duplexes.

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APPENDIX C ELECTRICAL ENGINEERING PRELIMINARY CONSIDERATIONS

Appendix C provides the preliminary design considerations information previously contained in UFC 3-501-03N, *Electrical Engineering Preliminary Considerations*, which has been superseded by UFC 3-550-01. UFC 3-501-03N contained MIL HDBK 1004/1, *Electrical Engineering Preliminary Design Considerations*.

C-1 PRELIMINARY DATA

C-1.1 Load Data.

Before specific electric power sources and distribution systems can be considered, realistic preliminary load data must be compiled. The expected electric power demand on intermediate substations, and on the main electric power supply, shall be calculated from the connected load by applying appropriate factors. Determine these factors by load analysis and by combining loads progressively. To combine the loads, start at the ends of the smallest feeders and work back to the electric power source. Because all loads must be on a common kilowatt (kW) or kilovolt-ampere (kVA) basis, it is necessary to convert motor horsepower ratings to input kilowatts or kilovolt- amperes before combining them with other loads already expressed in those terms. Preliminary electric power load estimates can be made by using the approximate value of one kilovolt-ampere of input per horsepower (hp) at full load. Preliminary estimates of lighting loads may be made by assuming watts per ft^2 (m^2) of building area.

C-1.2 Load Analysis.

To determine appropriate load estimating factors, using the tables and factors below as guides analyze the characteristics of each load. Consider items such as environmental conditions of weather, geographical location, and working hours, as the situation dictates. Notice that when the load densities in w/ft^2 (m^2) are used only in preliminary estimates, the demand and load factors will be used in the final designs.

C-1.3 Terminology.

Five terms are essential to the analysis of load characteristics: demand factor, coincidence factor, diversity factor, load factors and maximum demand. These terms are defined in paragraphs C-1.3.1 through C-1.3.5.

C-1.3.1 Demand Factor.

The demand factor is the ratio of maximum demand of a system to the total connected load of the system or

Equation: Demand factor = Maximum demand load / Total load connected

C-1.3.2 Coincidence Factor.

The coincidence factor is the ratio of the maximum demand of a system, or part under consideration, to the sum of the individual maximum demands of the subdivisions or

Equation: Coincidence factor = Maximum system demand / Sum of individual maximum demands

C-1.3.3 Diversity Factor.

The diversity factor is the reciprocal of the coincidence factor or

Equation: Diversity factor = Sum of individual maximum demands / Maximum system demand

C-1.3.4 Load factor.

The load factor is the ratio of the average load over a designated period, usually 1 year, to the maximum load occurring in that period or

Equation: Load factor = Average load / Maximum load

Load factors in Table C-1 are not to be used when sizing the service conductors.

C-1.3.5 Maximum Demand.

The maximum demand is the integrated demand for a specified time interval, i.e., 5 minutes, 15 minutes, 30 minutes, or other appropriate time intervals, rather than the instantaneous or peak demand.

Table C-1 Factors for Individual Facilities by Navy Category Code (See Note 1)

Navy Code	Description	Demand Factor (%)	Load Factor (%)
100	**Operational and Training Facilities:**		
121	Aircraft fueling/dispensing facility	40-60	16-20
122	Marine fuel dispensing	40-60	16-20
123 10	Filling station	40-60	13-17
125 16	Miscellaneous POL pipeline facilities	100	13-17
126	Liquid fueling and dispensing-other	40-60	3-7
131	Communications – buildings	60-65	70-75
131 40	Telephone exchange building	55-70	20-25
133 75	Air surveillance radar building	55-70	70-75
137 40	Port control office	55-70	20-25
141 11	Air passenger terminal building	65-80	28-32
141 20	Aircraft fire and rescue station	25-35	13-17
141 30	Aircraft line operations building	65-80	24-28
141 40	Aircraft operations building * EXC 141-70*	65-80	28-32
141 60	Photographic building	65-80	16-20
171 10	Academic instruction building	40-60	22-26
171 20	Applied instruction building	35-65	24-28
171 40	Drill Hall	75-85	3-7
200	**Maintenance and Production Facilities:**		
211 05	Maintenance Hangar O/H space (high bay)	45-50	28-30
211 06	Maintenance Hangar – 01 space (crew equipment)	45-50	28-30
211 07	Maintenance Hangar – 02 space (administrative)	45-50	28-30
211 10	Aircraft overhaul and repair shop (NARF)	32-38	25-30
211 12	Paint/finishing hangar	65-75	25-27
211 20	Engine overhaul shop (NARF)	32-38	20-25
211 30	Aircraft/engine accessories overhaul shop (NAR)	32-38	25-30
211 75	Parachute/survival equipment	60-65	23-28
211 81	Engine test cell (Non-NARF)	42-48	25-30
211 96	Maintenance, aircraft spares storage (Miscellaneous)	58-63	23-28
212 20	Missile equipment maintenance shop	35-40	15-20
213-10	Drydock	5-10	0.5-1
214-10	Combat vehicle maintenance shop	55-65	20-25
214-20	Automobile vehicle maintenance – noncombat	55-65	20-25
215	Maintenance – weapons/spares	70-80	20-25
216 10	Ammunition rework and overhaul shop	35-40	18-22
216 20	Rocket rework and overhaul shop	35-40	18-22

Navy Code	Description	Demand Factor (%)	Load Factor (%)
216 30	Mines and depth charge rework shop	35-40	15-20
216 40	Torpedo shop	45-55	18-22
216 50	Special weapons shop	35-40	18-22
216 60	Quality evaluation laboratory	55-65	22-27
217 10	Electronics/communications maintenance shop	35-40	20-25
218 20	Construction/weight handling equipment shop	35-45	20-25
218 40	Railroad equipment shop	35-45	15-20
218 50	Battery shop	55-65	20-25
219 10	Public works shop	32-38	18-22
221 10	Aircraft engine assembly plant	32-38	20-25
222 10	Missile assembly buildings	35-40	15-20
222 20	Missile handling launch equipment	35-40	15-20
223 10	Fabrication/assembly building	22-27	24-29
225 10	Small arms plant	15-20	22-27
225 20	Light gun (20mm/51n) plant	15-20	22-27
225 30	Heavy gun (6/161n) plant	16-21	21-26
225 50	Launcher/projector plant	15-20	22-27
226 10	Bag charge filling plant	62-67	23-28
226 15	Case filling plant	35-40	23-28
226 20	Case overhaul tank repair facility	35-40	18-22
226 35	Major-caliber projectile loading plant	35-40	18-22
226 40	Medium-caliber projectile loading plant	35-40	18-22
226 55	Cast high explosives filling plant	35-40	18-22
226 65	Propellant and related chemical facility	30-40	32-38
227 10	Radio and radar equipment plant	50-55	23-28
227 10	Sonar equipment plant	50-55	23-28
228 10	Parachute/survival equipment plant	35-40	20-25
229 10	Asphalt plant	75-80	7-12
229 20	Concrete batching plant	75-80	15-20
229 30	Rock crusher plant	75-80	15-20
229 40	Sawmill	45-55	15-20
300	**Research, Development, Test & Evaluation Facilities:**		
310 13	Chemistry and Toxicology Laboratory	70-80	22-28
310 15	Materials Laboratory	30-35	27-32
310 19	Physics Laboratory	70-80	22-28
316 10	Ammunition, explosives, and toxics laboratory	28-32	20-25
317 20	Electrical and electronics systems laboratory	20-30	3-7

Navy Code	Description	Demand Factor (%)	Load Factor (%)
400	**Supply Facilities**		
421	Ammunition storage- installation	75-80	…..
423	Ammunition storage-liquid propellant	75-80	20-25
431 10	Cold storage warehouse	70-75	20-25
441 10	General warehouse Navy	75-80	23-28
441 20	Controlled humidity warehouse	60-65	33-38
441 30	Hazardous/ flammable storehouse	75-80	20-25
441 40	Underground storage	65-70	23-28
441 70	Disposal, salvage, scrap building	35-40	25-20
500	**Hospital-Medical Facilities:**		
510 10	Hospital	38-42	45-50
530 20	Laboratory	32-37	20-25
540 10	Dental Clinic	35-40	18-23
550 10	Medical Clinic	45-50	20-23
600	**Administrative Facilities:**		
610 10	Administrative Office	50-65	20-35
620 10	Administrative facility, underground	50-65	35-40
700	**Housing and Community Facilities:**		
711	Family housing-dwellings	60-70	10-15
712	Substandard: Trailers - family housing	70-75	10-15
714 10	Detached garages	40-50	2-4
721 11	Bachelor enlisted quarters	35-40	38-42
721 12	Bachelor enlisted quarters E5/E6	35-40	38-42
721 13	Bachelor enlisted quarters E7/E9	35-40	38-42
721 30	Civilian barracks GS 01/6	35-40	38-42
721 40	Disciplinary barracks	35-40	38-42
722 10	Detached dining facilities, enlisted men	30-35	45-60
723 20	Latrine, detached	75-80	20-25
723 30	Laundry, detached	30-35	20-25
723 40	Garage, detached	40-50	2-4
724 11	UOPH, W-1/0-2	40-50	20-25
724 12	UOPH, 0-3 and above	40-50	20-25
724 22	Civilian quarters, GS-7/PLS	40-50	20-25
724 30	Dining facility (attached) commissioned personnel	35-40	30-40
730 10	Fire station	25-35	13-17
730 15	Confinement facility	60-65	33-38
730 20	Police station	48-53	20-25

Navy Code	Description	Demand Factor (%)	Load Factor (%)
730 25	Gate/sentry house	70-75	28-33
730 30	Bakery	30-35	45-60
730 35	Enlisted personnel locker room	75-80	18-23
730 40	Laundry/dry cleaning plant	30-35	20-25
730 45	Dependent school – nursery school	75-80	10-15
730 50	Dependent school – kindergarten	75-80	10-15
730 55	Dependent school – grade school	75-80	10-15
730 60	Dependent school – high school	65-70	12-17
730 65	Fallout shelter	80-85	30-35
730 67	Bus station	80-85	30-35
730 70	Decontamination facility	75-80	15-2
730 83	Chapel	65-70	5-25
730 85	Post Office	75-80	20-25
740 01	Exchange retail store	65-70	25-32
740-18	Bank	75-80	20-25
740 23	Commissary including backup storage	55-60	25-30
740 26	Installation restaurant	45-75	15-25
740 30	Exchange auto repair station	40-60	15-20
740 36	Hobby shop, art/crafts	30-40	25-30
740 40	Bowling Alley	70-75	10-15
740 43	Gymnasium	70-75	20-45
740 46	Skating rink	70-75	10-15
740 50	Field house	75-80	7-12
740 53	Indoor swimming pool	55-60	25-50
740 56	Theater	45-55	8-13
740 60	Commissioned officers' mess, open	55-60	15-20
740 63	Enlisted personnel club	55-60	18-23
740 66	Petty officers' mess, open	55-60	18-23
740 70	Mess open, E-7 through E-9	55-60	15-20
740 76	Library	75-80	30-35
740 80	Golf club house	75-80	15-20
740 86	Exchange installation warehouse	58-63	23-28
740 88	Educational services office	70-75	30-35
760 10	Museum/memorial building	75-80	30-35
800	**Utilities and Ground Improvements:**		
811 10	Electric power plant-diesel	60-65	58-63
811 25	Electric power plant-steam	60-65	58-63

Navy Code	Description	Demand Factor (%)	Load Factor (%)
811 45	Electric power plant-gas turbine	60-65	58-63
811 60	Standby generator plant	75-80	5-10
812 20	Street lighting	95-…	46-…
812 40	Perimeter/security lighting	80-85	22-27
813 20	Substation, more than 499 kV	25-30	20-25
821 12	Fossil fuel heating plant – medium	55-60	30-60
821 22	Fossil fuel heating plant – large	55-60	30-60
821 50	Non-nuclear steam plant	50-55	30-40
826 20	Chilled water plant 25/100 tons	60-70	25-30
827 20	Air conditioning-chilled water transmission/distribution system – medium (25/100 tons)	60-70	25-30
831 10	Combination sewage and industrial waste treatment plant	60-70	15-20
832 30	Sewage-industrial waste pumping station	55-60	30-35
833 22	Incinerator building and incinerator	55-60	15-20
841 10	Water treatment facilities	60-80	15-25
841 50	Wells-potable water	60-80	15-25
843 20	Fire protection pumping station	Do not include – operate for test off peak.	
890 20	Compressed air plant	45-50	25-30
890 42	Air-conditioning plant	60-70	25-30
	Miscellaneous Operational and Training Facilities:		
125 10	POL pipeline		
132 10	Antenna – communications	95-…	46-…
	Miscellaneous Facilities for Ship Repair and Shipbuilding:		
	Ship repair shops:		
213 41	Central tool shop – (06) (E)	32-37	23-28
213 42	Shipfitting shop – (11) (A)	22-27	24-29
213 43	Sheet metal ship (17) (B)	10-15	15-20
213 44	Forge and heat treatment space (23) (F)	25-30	13-18
213 49	Inside machine shop – (31) (G)	16-21	21-26
213 53	Boiler making shop – (41) (D)	12-17	14-19
213 54	Electrical shop – (51) (M)	33-38	20-25
213 55	Pipefitting shop – (56) (J)	22-27	17-22
213 56	Woodworking shop – (64) (R)	25-30	21-26
213 59	Abrasive blast facility	30-35	10-15
213 60	Paint and blasting shop – (71) (S)	50-55	23-28
213 61	Riggers shop – (72) (T)	50-55	20-25
213 62	Sail loft	35-40	20-25

Navy Code	Description	Demand Factor (%)	Load Factor (%)
213 63	Foundry – (81) (K)	35-40	22-27
213 64	Patternmaking shop – (94) (X)	28-33	12-17
213 67	Pumphouse, drydocks	75-80	0.1-0.2
	Miscellaneous Facilities for Naval Ordnance Manufacture:		
226	Ammunition components building	15-20	20-25
226	Manufacturing	30-45	17-32
226	Explosive loading	65-70	25-30
226	Miscellaneous explosives storage and handling	65-70	5-10
226	Assembly building	40-50	20-25
226	Detonator building	65-70	20-25
226	Pelleting	40-50	20-25
226	Plastic beading	55-60	18-23
226	Sewing room	35-40	25-30
226	Projective assembly breakdown	55-60	18-23
226	Machine shop	16-21	21-26
226	Phosphorous plant	35-40	25-30
226	TNT detonator (military)	35-40	15-20
226	Ammunition tank box assembly	35-40	15-20
226	Box emptying	35-40	15-20
226	Plating maintenance	35-40	18-23
226	Mixing	40-45	18-23
226	Segregation fleet return	35-40	15-20
226	Plaster load	35-40	15-20
	Fluoroscope building	45-50	18-23
	Tank building rocket	40-45	15-20
	Hydrostatic test	35-40	15-20
	Phosphorous loading	35-40	15-20
226	Vacuum and hydraulic pump building	35-40	12-17
226	Cable drive	35-40	12-17
226	Dryer building	75-80	3-8
	Miscellaneous Production Facilities:		
229 50	Printing Plant	45-55	25-30
	Miscellaneous Storage Facilities:		
750	Community Facilities – morale, welfare, and recreation – exterior	Determine by load count and time.	
750 30	Outdoor swimming pool installation	80-85	20-25
750 54	Band stand	75-80	15-25
	Miscellaneous Facilities for Utilities and Ground Improvements:		

Navy Code	Description	Demand Factor (%)	Load Factor (%)
821 09	Heating plant building (condensate)	55-60	25-40
821 09	Heating plant building (heating)	55-60	30-35
833 40	Garbage house	75-80	20-25
841	Potable water – supply/treatment/storage	Determine by load count and time.	
845 20	Pipeline nonpotable water	55-60	3-8
852 30	Pedestrian bridge	80-85	20-25
872 20	Guard and watch towers	80-	46-
890 20	Compressed air plant	60-65	20-25

Note 1: Demand factors include allowance for system loss.

C-2 ESTIMATION OF LOADS.

C-2.1 Preparation of Load Data.

Load data are generally computed in steps such as:

a. individual loads,

b. area loads, and

c. activity loads.

A particular design problem may be limited to step a), to steps a) and b), or may encompass steps a), b), and c). This section outlines each step as a separate entity, dependent only on previous steps for data. Paragraphs C-2.2 through C-2.4.4 describe the three loads.

C-2.2 Individual Loads.

Individual loads are those with one incoming service supplying utilization voltage to the premises. In general, these loads would comprise single structures. Large structures could contain more than one function: for example, aircraft operations, aircraft fire and rescue stations, and photographic buildings. Under this condition, factors that have been developed and keyed to Navy category codes (refer to Table C-1) would be used. In this case, the factors listed under Navy category Code 141 40, 141-20, and 141-60, respectively, would be combined to obtain the total load.

C-2.2.1 Lighting.

To eliminate lighting loads, divide a facility area into its significant components by function (for example, office, storage, mechanical, and corridor). Determine the average lighting level and type of light source for each area. Consider requirements for supplementary lighting (for example, floodlighting, security lighting, and special task lighting). Preliminary load estimates may be made based on applicable ASHRAE 90.1 lighting power allowances.

C-2.2.1.1 Small Appliance Loads.

Small appliance loads shall include those served by general purpose receptacles. In general, the dividing of areas by function for estimating lighting loads will serve for estimating small appliance loads. The determination of loads requires not only the knowledge of the function of an area, but to what extent its occupants use small appliances. For example, an office area demand may average about 1 W/ft^2 (10.76 W/m$^{2)}$ but could vary from a low of 0.5 W/ft^2 (5.38 W/m$^{2)}$ to a high of 1.5 W/ft^2 (16 W/m^2), depending on the specific tasks to be performed. A minimum of 0.1 W/ft^2 (1 W/m^2) for auditoriums to a maximum of 2.5 W/ft^2 (27 W/m^2) for machine shops is possible, although the upper limit would occur very rarely. Mechanical spaces in building storage areas and similar spaces in which outlets are provided but infrequently used are usually neglected in computing loads, except for special cases.

C-2.2.1.2 Electric Power Loads.

Electric power loads shall include all loads other than lighting loads and those served by general purpose receptacles. Electric power loads comprise the environmental system electric power requirements and the facility occupancy equipment electric power requirements.

C-2.2.1.3 System Loss.

A system loss of approximately 6 percent, based on calculated maximum demand, should be added to the building load.

C-2.2.2 Demand and Load Factors.

The demand and load factors for a specific facility will vary with the division of load and hours of usage. Refer to Tables C-2 and C-3 for values that can be applied to determine demand and load factors. Table C-4 is included as a guide and an aid in illustrating the method of determining loads, which are calculated for a particular type of building, such as an academic and general instruction building (Navy Code 171-10). The values given are empirical and will vary from activity to activity and may vary from one facility to another within an activity. Annual hours use of demand must be determined for each case in accordance with methods of operation and characteristics of the installation. Demand factors and load factors for individual facilities by the Navy category code given in Table C-1 are based on a survey of existing Navy facilities and past experience. Such factors should be used for quick estimating purposes and as a check when a more precise calculation is undertaken (refer to Table C-4).

C-2.2.2.1 Guides for Demand Factors.

For guides on selection of demand factors, refer to Table C-5.

C-2.2.2.2 Guides for Load Factors.

Guides for the selection of load factors indicate the need for special considerations (refer to Table C-6). Factors in the middle of the range are for the average facility at the peacetime shore establishment and should be used unless the guides in Table C-6 indicate otherwise.

Table C-2 Demand Factors for Specific Loads (See Note 1)

Types of Loads	Estimated Range of Demand Factor (%)	Quick Estimating Demand Factor (%)
Motors: General purpose, machine tool, cranes, elevators, ventilation, compressors, pumps, etc.	20–100	30
Motors: Miscellaneous, fractional, and small appliances	10–50	25
Resistance ovens, heaters, and furnaces	80–100	80
Induction furnaces	80–100	80
Lighting	65–100	75
Arc welders	25–50	30
Resistance welders	5–40	20
Air-conditioning equipment	60–100	70
Refrigeration compressors	40–100	60

Note 1: Demand factors include allowance for system loss.

Table C-3 Annual Hours of Demand Usage for Specific Loads

Types of Loads	Quick Estimating Hours of Use		
	1-Shift Operation	2-Shift Operation	3-Shift Operation
Motors: General purpose	1,200	1,600	2,000
Motors: Miscellaneous, fractional, and small appliances	1,500	1,800	2,100
Resistance ovens, heaters, and furnaces	1,000	1,300	1,600
Induction furnaces	900	1,200	1,500
Lighting	2,200	2,800	3,500
Arc welders	500	700	900
Resistance welders	500	700	900
Air-conditioning equipment			
Less than 1,500 cooling degree days	1,200	1,400	1,600
1,500 to 2,500 cooling degree days	1,600	1,800	2,000
More than 2,500 cooling degree days	2,200	2,500	2,800

Table C-4 Academic Building (Code 171-10) Demand and Load Factor Calculations (See Note 1)

		Motors				
		General	Miscellaneous Fractional & Small Appliances	Lighting	Air Conditioning	Total
1.	Watts/square foot (Watts/square meter)	1.0 (10)	1.0 (10)	2.7 (26.5)	4.5 (45)	9.2 (91.5)
2.	Connected load	100 kW	100 kW	265 kW	450 kW	915 kW
3.	Specific load demand factor	30%	10%	75%	70%	
4.	Maximum demand load (line 2 x line 3)	30 kW	10 kW	200 kW	315 kW	555 kW
5.	Annual operating (1-shift) usage	1,200 hrs.	1,500 hrs.	2,200 hrs.	1,600 hrs.	
6.	Annual usage in megawatt hours (line 4 x line 5)	36	15	440	504	995
7.	Demand factor Formula = Line 4 / Line 2 (1)	-	-	-	-	60%
8.	Load factor Formula = Line 6 / (Line 4 x 8760 hours) (4)	-	-	-	-	20%

Note 1: Calculated for a 100,000 square-foot (10,000 square meter) building. See Tables C-2 and C-3 for data used for lines 3 and 5 respectively. Load growth is included in connected load. Maximum demand load includes allowance for system loss. For this illustration, the coincidence factor occurring when individual demand loads are added is considered to be 1.00 and has not been shown.

Table C-5 Guides for Selection of Demand Factors

Select factors in upper half of range for conditions described below	Select factors in lower half of range for conditions described below
GENERAL GUIDES	
Facilities in active use and approaching maximum capacity. Loads predominantly lighting. Loads predominantly heating. Loads dominated by one or two large motors.	Facilities of intermittent use or not being fully utilized. Motor loads made up of a number of independently operated small motors. Motor loads controlled automatically unless control depends upon weather conditions.
OPERATIONAL AND TRAINING FACILITIES	
Instruction buildings with little or no electric equipment. Communications buildings with telephonic equipment only.	Large instruction buildings with electrical demonstration and training equipment.
MAINTENANCE AND PRODUCTION FACILITIES	
Shops and facilities when engaged in mass production of similar parts.	No special guides.
RESEARCH, DEVELOPMENT, AND TEST FACILITIES	
Facilities used for repetitive testing of material or equipment.	No special guides.
SUPPLY FACILITIES	
Refrigerated warehouses in South. Dehumidified warehouses in Mississippi Valley and along seacoasts. Warehouses for active storage.	Warehouses with many items of electric materials handling equipment, including cranes and elevators.
HOSPITAL AND MEDICAL FACILITIES	
No special guides.	No special guides.
ADMINISTRATIVE FACILITIES	
Large administrative buildings with mechanical ventilation and air conditioning. Note: Group large administrative buildings separately only when administration is a significant part of total activity load.	Casual offices, offices used infrequently by foremen and supervisors, or offices in which there is little prolonged desk work.
HOUSING AND COMMUNITY FACILITIES	
Enlisted barracks at training centers. Public quarters where less than 25 family units are involved. Restaurants, exchanges, cafeterias, and other food service facilities when gas or steam is primary fuel.	Food service facilities where load is primarily cooking and baking.
UTILITIES AND GROUND IMPROVEMENTS	
Central heating plants serving extended areas and buildings. Water pumping stations serving extended areas or carrying most of load of water systems. Central station compressed air plants.	No special guides.

Table C-6 Guides for Selection of Loads Factors

Select factors in upper half of range for conditions described below	Selection factors in lower half of range for conditions described below
GENERAL GUIDES	
Facilities operated on two or more shifts. Loads that are primarily fluorescent or high intensity discharge lighting. Many small independently operated motors. Electronic equipment continuously operated for immediate use. Cooling and dehumidification loads for year-round climate control in southern climates. Retail-type service loads and loads that are in active use.	Facilities used intermittently. Inactive facilities. Large motor loads when the load consists of relatively small numbers of motors. Wholesale-type service facilities.
OPERATIONAL AND TRAINING FACILITIES	
Large, permanent instruction buildings in active use.	Special-purpose instruction and training facilities not regularly used.
MAINTENANCE AND PRODUCTION FACILITIES	
Shops with battery charging equipment operated after hours. Active shops at full employment. Mass production shops.	Welding loads or loads made up primarily of welding equipment. Job-order workshops. Shops with large, heavy special function machines. Large induction or dielectric heating loads.
RESEARCH, DEVELOPMENT, AND TEST FACILITIES	
No special guides.	No special guides.
SUPPLY FACILITIES	
Refrigerated and dehumidified warehouses in South or in humid climates. Warehouses for active storage and in continuous use.	Refrigerated warehouses in North. Warehouses with large materials handling equipment loads.
HOSPITAL AND MEDICAL FACILITIES	
Clinics and wards with daily operating hours and in active use.	No special guides.
ADMINISTRATIVE FACILITIES	
Large, active, well-lighted offices with ventilation and air-conditioning equipment.	No special guides.
HOUSING AND COMMUNITY FACILITIES	
Navy exchanges with food service facilities. Gymnasiums used in connection or with physical therapy. Barracks at schools and training centers.	Restaurants and exchanges serving only one meal a day. Restaurants and exchanges with gas steam food preparation equipment. Chapels used primarily on Sundays. Subsistence buildings serving less than four meals a day. Laundries with dry cleaning plants. Exchanges operated less than 8 hrs/day Gatehouses operated less than 24 hrs/day
UTILITIES AND GROUND IMPROVEMENTS	
Heating plants that supply both heating and process steam. Water plants with little power load. Air-conditioning plants for year-round control of environment in South. Compressed air plants consisting of many banked compressors operating automatically.	Heating plants in South.

C-2.2.3 Load Growth.

Determine the requirements for load growth for anticipated usage and life expectancy with particular attention to the possibility of adding heavy loads in the form of air conditioning, electric heating, electric data processing and electronic communication equipment. Before determining the size of service and method of distribution to a facility, an economic analysis shall be made to determine the most feasible way of serving this future load. This analysis shall include the effect on the existing installation if future loads require reinforcing or rehabilitation of the service system.

C-2.2.4 Emergency Loads.

The determination of emergency electric power requirements is based on three types of loads (refer to Section 3 for types of loads to be included in each category):

- Minimum essential load,
- Emergency load for vital operations, and
- Uninterruptible (no-break) load.

When the three categories of emergency electric power requirements have been ascertained, determine where local emergency facilities are required, where loads may be grouped for centralized emergency facilities, and what loads are satisfied by the reliability of the general system. Base the above determinations on safety, reliability, and economy, in that order.

C-2.3 Area Loads.

Area loads consist of groups of individual facility loads served by a subdivision of the electric distribution system. The term “area” applies to the next larger subdivision of an overall distribution system. Demand loads for an area must be known for sizing the distribution wiring and switching, and in a large installation will be required for the design of substations serving the area. Table C-7 gives an example of how the coincident peak demand is calculated.

C-2.3.1 General Loads.

To obtain the general load, add roadway lighting, area lighting, obstruction lighting, and other loads not included in individual facility loads.

C-2.3.2 Coincidence Factor.

Determine the maximum expected demands, taking into consideration whether loads within the area peak at the same or at different times.

C-2.3.2.1 Relationships.

Figure C-1 indicates the relationship that exists between the load factor of individual facility loads and the coincidence of their peak demands with the peak demand of the group. This relationship was developed by a study of the loads of selected naval shore activities and by the application of factors developed to the formulas published by IEEE. For collateral reading on this subject, refer to IEEE Technical Paper 45-116 Coincidence-Factor Relationship of Electric Service Load Characteristics. Table C-8 is Figure C-1 in tabular form with values shown to the nearest whole dollar, except for low load factors.

C-2.3.2.2 Selection.

Areas with relatively insignificant residential type loads, where the load curve indicates that most of the electric power consumed in the area is used during the 40 normal working hours of a week, have coincidence factors at the higher end of the range.

C-2.3.2.3 Electric Power Consumption.

In general, areas where large amounts of electric power are consumed outside the usual 40 working hours a week have a coincidence factor at the lower end of the range (examples are hospitals, areas operated on two or more shifts, or large barracks type activities). The upper limit of the range is for the 40 hour per week operation; the lower limit is for a 60 hour per week operation.

C-2.3.2.4 Influencing Factors.

The number of individual loads in a group and their load factors influence the individual load coincidence factor. The coincidence factors in Table C-8 apply for groups of 100 or more individual loads. These coincidence factors can also be used for groups of as few as 30 to 50 individual loads if their load factor is 0.30 or greater. For areas of fewer individual loads, the mathematical relationship from IEEE Technical Paper 45-116 provides a basis for estimating the connected coincidence factor as shown by the following equation:

Equation: $En = Et + (1 – Et)1/n$

Where:

En = The individual load coincidence factor applied with a given number of consumers.

Et = The coincidence factor as given in Table C-8 in hundredths.

n = The number of individual loads in a group.

C-2.3.2.5 Individual loads.

The coincidence factors in Table C-8 are based on the individual loads in a group being substantially the same size. If a single load or small group of loads in an area represent a substantial percentage of overall load, the coincidence factors as given in Table C-8 will no longer apply. With an individual load, increase the coincidence factor to a value commensurate with its effect on the overall area load. This is not in addition to, but in place of, the normal coincidence factor. Determine this value by considering intergroup coincidence factors given in paragraph C-2.3.2.

An example of facility Navy Code 211-70 is presented in Table C-7.

For a small group, determine the coincidence peak load, and to this apply the appropriate intergroup coincidence factor to obtain the coincidence peak load for the area.

C-2.3.2.6 Groups of Loads or Areas.

Where groups of loads within an area, or areas within a facility are combined, an additional intergroup coincidence factor will exist. For loads of similar nature, the intergroup coincidence factor should be in the range 0.93 to 1.00. If loads of a varying nature (evening loads and daytime loads) are combined, the intergroup coincidence factor should be in the range of 0.70 to 1.00. The lower values will occur when magnitudes of the loads are nearly balanced, and the higher ones when the combined load is predominantly one type.

Table C-7 Method of Calculating Coincident Peak Demand

Navy Code		Description	Total Connected Load (kW)	Demand Factor (%)	Maximum Demand (%)	Load Factor (%)	Coincidence Factor (%)	Coincidence Peak (kW)
125	16	Fuel oil pump house						
125	16	Fuel oil pump house						
125	16	Total	0.3	100	0.3	52	52(1)	0.2
125	20	Filling station	3.0	60	1.8	18	57(1)	1.0
125	20	Filling station building	0.3	80	0.2	20	61(1)	0.1
131	35	Receiver building	2.1	65	1.4	72	79	1.1
131	50	Transmitter building						
131	50	Transmitter building						
131	50	Total	37.2	65	24.2	72	79	19.1
133	25	Tacan building	0.7	65	0.5	72	79	0.4
133	75	Radar building	1.2	70	0.8	72	79	0.6
141	20	Aircraft fire and rescue station	8.0	30	2.4	15	52(1)	1.2
141	40	Aircraft operations building	80.2	80	64.2	28	68(1)	43.6
141	60	Photographic building	10.5	70	7.4	18	57(1)	4.2
171	10	Academic instruct building						
171	10	Academic instruct building						
171	10	Academic instruct building						
171	10	Academic instruct building						
171	10	Total	47	60	28.2	22	62(1)	17.5
171	35	Operational Trainer Facility	0.1	80	0.1	15	52(1)	………
211	10	Aircraft overhaul and repair shop	7,600	38	2,890	25	95(2)	2,745
211	12	Paint/finishing hangar	127	70	89.0	26	66(1)	58.3
211	22	Engine preparation and storage shop						
211	21	Engine maintenance shop						

Navy Code		Description	Total Connected Load (kW)	Demand Factor (%)	Maximum Demand (%)	Load Factor (%)	Coincidence Factor (%)	Coincidence Peak (kW)
211	21	Engine maintenance shop						
211	21	Total	405	40	162	15	52(1)	84.2
211	83	Engine test cell	360	45	162	28	68(1)	110
212	20	Missile equipment maintenance shop	3.0	40	1.2	22	62(1)	0.7
214	20	Auto vehicle maintenance facilities						
214	20	Auto vehicle maintenance facilities						
214	20	Auto vehicle maintenance facilities						
214	20	Auto vehicle maintenance facilities						
214	20	Total	370	60	222	25	65(1)	145
730	10	Fire station	14.6	30	4.4	15	521	2.3
							Total	3,325
						System loss (6%)	194	
							Grand total	3,429

(1) The coincidence factor has been increased to allow for low load factor and number of facilities in the area. Refer to paragraph C-2.3.2.4, Influencing Factors, of this handbook.

(2) The coincidence factor has been increased because of the relative magnitude of the load. Refer to paragraph C-2.3.2.5, Individual Loads, of this handbook.

Figure C-1 Theoretical Relationship between Load Factor and Coincidence Factor at U.S. Naval Shore Establishments

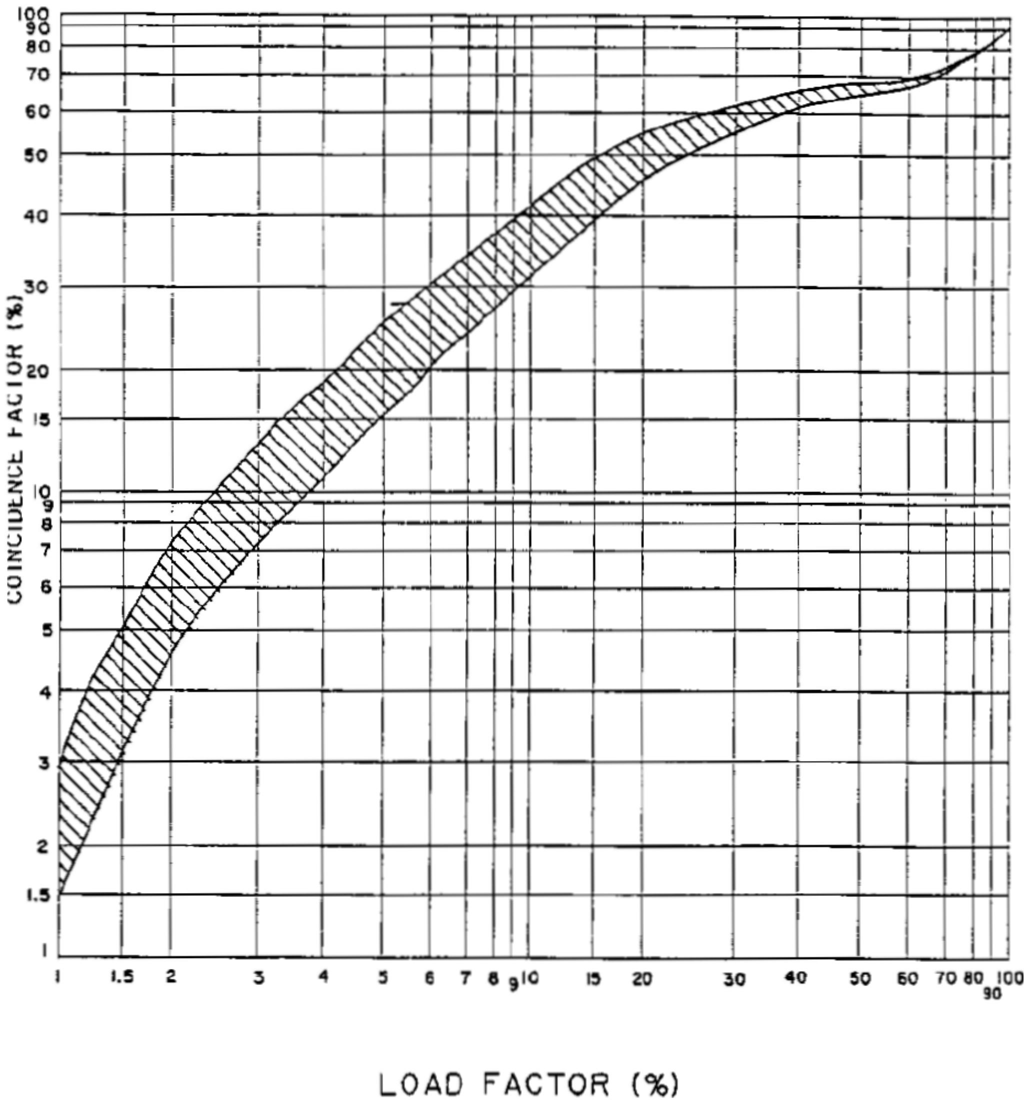

Table C-8 Relationship between Load Factor and Coincidence Factor

Load Factor (%)	Coincidence Factor (%) Loads (hr/wk)		Load Factor %	Coincidence Factor (%) Loads (hr/wk)	
	40	60		40	60
1	2.5	1.5	51	73	69
2	7.5	4.5	52	73	70
3	12	8	53	73	70
4	17	11	54	73	70
5	21	14	55	73	71
6	25	17	56	73	71
7	28	20	57	73	71
8	32	22	58	74	71
9	35	24	59	74	72
10	38	26	60	74	72
11	41	29	61	74	72
12	44	32	62	75	73
13	46	34	63	75	73
14	49	36	64	76	74
15	51	38	65	76	74
16	53	40	66	77	75
17	54	42	67	77	75
18	56	44	68	78	76
19	57	46	69	78	76
20	59	48	70	78	77
21	60	50	71	78	77
22	61	51	72	79	78
23	62	53	73	79	78
24	63	54	74	80	79
25	64	55	75	81	80
26	65	56	76	81	80
27	66	56	77	82	81
28	67	57	78	82	81
29	68	58	79	82	81
30	69	59	80	82	82
31	69	60	81	82	82
32	69	61	82	82	82
33	70	62	83	83	83
34	70	63	84	84	84
35	71	64	85	85	85
36	71	64	86	86	86
37	71	65	87	87	87
38	71	65	88	88	88
39	72	65	89	89	89
40	72	66	90	90	90
41	72	66	91	91	91
42	72	66	92	92	92
43	72	67	93	93	93
44	73	67	94	94	94
45	73	67	95	95	95
46	73	67	96	96	96
47	73	68	97	97	97
48	73	68	98	98	98
49	73	69	99	99	99
50	73	69	100	100	100

C-2.3.3 Load Growth.

In addition to planned expansion, increased application of electric equipment will generate an increase in load. When sizing components, such as transformers or feeders for the area system, consider possible load growth in addition to that included in determination of individual loads.

C-2.3.4 System Losses.

Add distribution system losses to estimated area demands. For a good approximation, use 6 percent of the calculated maximum demand.

C-2.3.5 Emergency Loads.

Review the overall emergency requirements for the area, based on criteria for the facility or as furnished by the using agency, to determine the following:

a. The emergency loads that may be combined in groups to take advantage of the coincidence factor.

b. The type of distribution system needed for reliability and to economically satisfy at least the less critical emergency load requirements. This reliability can be provided only if the source of electric power is not the determining factor.

c. Area loads that must be added to individual emergency loads, for example, security lighting and minimum roadway lighting.

C-2.3.6 Expansion.

The planned development of the area, as shown on the activity general development map, shall be considered for requirements of future expansion.

C-2.4 Activity Loads.

Activity Loads are loads that consist of two or more area loads served from a single electric power source and an integrated distribution system.

C-2.4.1 General Loads.

Follow the approach used in paragraph C-2.3 for area loads. Area loads used for determining activity coincidence demand should be the area coincident demand exclusive of allowance for load growth.

C-2.4.2 Coincidence Factor.

Refer to paragraph C-2.3.2 for the necessary approach. Where dissimilar areas, whether residential, administrative, or industrial, are part of an activity, make a careful analysis of the coincidence factor used.

C-2.4.3 Load Growth.

As for an area, components should be sized after due consideration has been given to load growth. Apply this increase to the coincident demand of the activity.

C-2.4.4 Expansion.

The planned development of the activity, as shown on its general development map, shall be considered for requirements of future expansion.

APPENDIX D GLOSSARY

D-1 ACRONYMS.

AC	Alternating Current
ACSR	Aluminum Conductor Steel-Reinforced
AFI	Air Force Instruction
AL	Aluminum
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ATS	Acceptance Test Specifications
ATS	Automatic Transfer Switch
BCO	Base Communications Officer
BEQ/BOQ	Bachelor Enlisted Quarters/Bachelor Officer Quarters
BICSI	Building Industry Consulting Services International
BIL	Basic Impulse Level
CAD	Computer Aided Drafting
cal/cm2	Calories per Centimeter Squared
CATV	Community Antenna Television
CCTV	Closed Circuit Television
CT	Current Transformer
CU	Copper
DC	Direct Current
Degrees C	Degrees Centigrade
Degrees F	Degrees Fahrenheit
DoD	Department of Defense
DOR	Designer of Record

EIA/TIA	Electronics Industries Association/Telecommunications Industry Association
ESS	Electronic Security Systems
ESS	Electric Supply Station
FASS	Facilities Systems Safety program
ft	Feet (or Foot)
ft^2	Foot Squared
GFCI	Ground Fault Circuit Interrupter
GND	Ground
HEMP	High-Altitude Electromagnetic Pulse
HID	High Intensity Discharge
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating Ventilation and Air Conditioning
hp	Horsepower
ICS	Intelligence Community Standard
IEEE	IEEE (Formerly, Institute of Electrical and Electronic Engineers)
in	Inch
kcmil	Thousand circular mils
kV	Kilovolts
kVA	Kilo-Volt-Ampere
kVAR	Kilo-Volt-Ampere-Reactive
m^2	Meter Squared
mm	Millimeter
MDP	Main Distribution Panel
MVA	Mega-Volt-Ampere
NAVFAC	Naval Facilities Engineering Systems Command

NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NETA	International Electrical Test Association
NFPA	National Fire Protection Association
NMCI	Navy and Marine Corps Intranet
O&M	Operation and Maintenance
PCBs	Polychlorinated Biphenyls
PPE	Personal Protective Equipment (Clothing)
PT	Potential Transformer
RCDD	Registered Communications Distribution Designer
RFP	Request for Proposal
RUS	Rural Utility Service
SCIF	Sensitive Compartmented Information Facility
SF6	Sulfur Hexafluoride
SWD	Switch Duty
TSEWG	Tri-Service Electrical Working Group
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
V	Volt
VA	Volt-Amp
X/R	Ratio of Reactance to Resistance

D-2 DEFINITION OF TERMS.

Activity: The end user of a base or facility.

Base Communications Officer (BCO): The person(s) responsible for the telecommunications and data infrastructure for a base or facility.

Closed Circuit Television (CCTV): A network of cables and equipment to monitor and transmit video signals throughout a facility.

Community Antenna Television System (CATV): A network of cables, headend and electronic components that process and amplify television and frequency-modulated (FM) radio signals for distribution from one central location to outlets throughout a facility.

Contractor: Person(s) doing actual construction portion of a project.

Corrosive Area: An area identified by the Technical Reviewing Authority as requiring special equipment corrosion mitigation methods.

Designer of Record: The engineer responsible for the actual preparation of the construction documents.

Distribution Device: A facility located within a dwelling unit for interconnection or cross connection of interior telecommunications wiring. Passive cross connect facilities enable the termination of cable elements and their interconnection or cross-connection by means of jumpers and patch cords.

Ductbank: Two or more conduits (or ducts) routed together in a common excavation with or without concrete encasement.

Electric Supply Station: A station that transforms the energy level (voltage) for further bulk distribution at medium voltage levels.

Hot Cap: A sealed insulated cover over the end of a bare energized conductor.

Low Voltage System: An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage System: An electrical system having a maximum RMS AC voltage of 1,000 volts to 34.5 kV. Some documents such as ANSI C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Non-Linear Loads: Loads that convert AC to DC and contain some kind of rectifier.

Service: The conductors and equipment for delivering electrical energy from the serving utility or Government-owned system to the wiring system of the premises served.

Service Point: Demarcation for the “service point” (for clarification of the NFPA 70 Article 100 definition): at the building/similar support structure service equipment line side connection.

Site Electrical Utilities: Site Electrical Utilities are the primary electric power distribution to the facilities and other electrical loads, exterior lighting not attached to the building; and telecommunication services (such as fiber optic, copper cable, CATV) required by the Facilities.

Systems Furniture: Modular prewired office furniture.

Technical Reviewing Authority: The “discipline specific” person at the DoD organization who is responsible for signing the project design documents. This is different than the authority responsible for waivers and exemptions required by Mil Std 3007.

Telecommunications Room: An enclosed space for telecommunications equipment, terminations, and cross-connect wiring for horizontal cabling.

TEMPEST: The unclassified name for the studies and investigation of compromising emanations (communications security).

Utilization Electric Supply Station: Equipment such as pole or pad-mounted transformers or secondary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use.

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APPENDIX E REFERENCES

DEPARTMENT OF DEFENSE

MIL-HDBK-423, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Facilities, Volume I: Fixed Facilities*

MIL-STD-3007 *Standard Practice Unified Facilities Criteria, Facilities Criteria And Unified Facilities Guide Specifications*

MIL-STD-188-125-1A, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions, Part 1 Fixed Facilities*

NSTISSI 7000, *TEMPEST Countermeasures for Facilities*

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 1-200-01, *DoD Building Code*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

FC 1-300-09N, *Navy and Marine Corps Design Procedures*

UFC 3-440-01, *Facility-Scale Renewable Energy Systems*

UFC 3-510-01, *Foreign Voltages and Frequencies Guide*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-520-02, *Facility Energy System Resilience and Reliability*

UFC 3-520-05, *Stationary and Mission Batteries*

UFC 3-530-01, *Interior and Exterior Lighting Systems*

UFC 3-535-01, *Visual Air Navigation Facilities*

UFC 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Applications*

UFC 3-540-08, *Utility-Scale Renewable Energy Systems*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-550-04: *Installation Microgrid Design*

UFC 3-555-01, *Aircraft Point-of-Use Power Systems*

UFC 3-560-01, *Operation and Maintenance: Electrical Safety*

UFC 3-570-01, *Cathodic Protection*

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UFC 3-580-01, *Telecommunications Interior Infrastructure Planning and Design*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

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UFC 4-010-05, *SCIF/SAPF Planning, Design, and Construction*

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UFGS 26 05 73, *Power System Studies*

AIR FORCE

AFI 33-210, *Communications and Information Cryptographic Access Program*
https://apps.dtic.mil/sti/pdfs/ADA404994.pdf

U.S. ARMY CORPS OF ENGINEERS

DA PAM 385-16, *System Safety Management Guide*

EM 385-1-1, *Safety and Health Requirements*

U.S. NAVY

OPNAV M-5100.23, *Navy Safety and Occupational Health Manual*
https://www.secnav.navy.mil/doni/SECNAV%20Manuals1/5100.23.pdf

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

https://www.ansi.org/

Note: Many ANSI documents are sponsored or co-sponsored by other organizations, such as NEMA or IEEE.

ANSI C84.1, *Electric Power Systems and Equipment—Voltage Ratings (60 Hz)*

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

https://www.ashrae.org/

ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

Note: Refer to UFC 1-200-02, for applicable publication date

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

https://www.ieee.org/

IEEE C2, *National Electrical Safety Code*

IEEE C37.06, *IEEE Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*

IEEE C37.13.1, *IEEE Standard for Definite Purpose Switching Devices for Use in Metal-Enclosed Low-Voltage*

IEEE C37.96, *IEEE Guide for AC Motor Protection*

IEEE C57.12.00, *IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std 551, *IEEE Recommended Practice for Calculating AC Short-Circuit Currents in Industrial and Commercial Power Systems*

IEEE Std 1547, *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*

IEEE Std 1547.4, *IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*

IEEE Std 551, I*EEE Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems*

IEEE Std 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations, including Amendments 1 and 2*

IEEE Std 1584.1, *IEEE Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std 1584™*

IEEE Std 3002.3TM, *IEEE Recommended Practice for Conducting Short-Circuit Studies and Analysis of Industrial and Commercial Power Systems*

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS, *Acceptance Test Specifications*

NATIONAL FIRE PROTECTION ASSOCIATION

https://www.nfpa.org/

NFPA 70, *National Electrical Code*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 780, *Standard for the Installation of Lightning Protection Systems*

PROFESSIONAL ELECTRICAL APPARATUS RECONDITIONING LEAGUE (PEARL)

ANSI/PEARL EERS, *Electrical Equipment Reconditioning Standard for Electrical Apparatus and Equipment used in Commercial and Industrial Applications*

UNDERWRITER’S LABORATORY

UL 489, *Molded-Case Circuit Breakers and Circuit-Breaker Enclosures*

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UNIFIED FACILITIES CRITERIA (UFC)

FOREIGN VOLTAGES AND FREQUENCIES GUIDE

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UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: FOREIGN VOLTAGES AND FREQUENCIES GUIDE

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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1	Jun 2006	Forward updated
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This UFC supersedes TM 5-688, dated 12 November 1999. The format of this UFC does not conform to UFC 1-300-01; however, the format will be adjusted to conform at the next revision. The body of this UFC is a document of a different number.

FOREWORD

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TECHNICAL MANUAL

FOREIGN VOLTAGES AND FREQUENCIES GUIDE

APPROVED FOR PUBLIC RELEASE DISTRIBUTION IS UNLIMITED

HEADQUARTERS, DEPARTMENT OF THE ARMY

12 NOVEMBER 1999

TECHNICAL MANUAL
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FOREIGN VOLTAGES AND FREQUENCIES GUIDE

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CHAPTER 1

INTRODUCTION

1-1. Purpose.

This manual provides guidance required to identify the voltage and frequency standards of various foreign countries for both medium and low voltage systems. It also identifies the classes of equipment that are sensitive to voltage and frequency differences. Foreign countries around the world use different electrical standards for voltage and frequency than those of the United States. Some electrical equipment will operate properly at an electrical frequency of either 50 or 60 Hz. Equipment designed for 60 Hz that will not operate properly at 50 Hz is termed "50 Hz sensitive," and equipment designed for 50 Hz that will not operate properly at 60 Hz is termed "60 Hz sensitive."

1-2. Scope.

This manual identifies the classes of electrical equipment that are sensitive to frequency and voltage variations. Appendix B covers identification of various low and medium voltage levels, along with the system frequencies, used by countries around the world. Derating factors are discussed and developed for the six generic types of equipment in chapter 3. Appendix C summarizes the derating factors presented in chapter 3 for different voltage and frequency environments.

1-3. References.

Appendix A contains a list of publications referenced in this manual.

CHAPTER 2

EQUIPMENT SENSITIVE TO FREQUENCY AND VOLTAGE LEVELS

2-1. Theoretical overview.

Equipment sensitive to frequency and or voltage is designed to operate within certain tolerances. Most equipment is sensitive to large changes in the supply voltage level because more current will flow through a device when the voltage level of the supply is increased (the current through the device is equal to the voltage across the device divided by the impedance of the device). When a larger current flows, the heat dissipated in the device increases (the heat dissipated by the device is proportional to the square of the current). Thus, doubling the voltage will typically double the current, resulting in the device dissipating four times the heat. Most devices cannot tolerate this amount of heat and cannot operate reliably with a supply voltage level more than 10 percent or so higher than their rated voltage.

a. An additional complication arises in the case of devices that use magnetic coupling. Since most electrical equipment depends on a magnetic field as the medium for transferring and converting energy, the following paragraphs discuss a basic transformer to explain how the magnetic circuit depends on the frequency and amplitude of the applied voltage.

b. A transformer enables electrical energy to be transferred with high efficiency from one voltage level to another at the same frequency. Consider a simplified view of a transformer with a sinusoidal voltage source, *v*, applied to the primary circuit and the seconday circuit open, as shown in figure 2-1. The operation of the transformer depends on several natural laws including the following—

(1) A sinusoidal, time-varying flux, Φ, linking a conducting circuit produces a voltage, *e*, in the circuit proportional to $d\Phi/dt$ (i.e., Faraday's law of induction).

(2) The algebraic sum of the voltages around any closed path in a circuit is zero (i.e., Kirchhoff's voltage law).

(3) The voltage, *v*, in a circuit induced by a changing flux is always in the direction in which current would have to flow to oppose the changing flux (i.e., Lenz's law).

c. When the sinusoidal voltage, *v*, is impressed onto the primary electrical winding of N_1 turns, it is expected that a sinusoidal current, *I*, will begin to flow in the circuit, which in turn will produce a sinusoidally varying flux, Φ. For simplicity, it is assumed that all of the flux set up by the primary circuit lies within the transformer's iron core and it therefore links with all the turns of both windings. If the flux at any instant is represented by the equation:

$$\Phi = \Phi_m \sin 2\pi ft$$

where:

Φ_m = the maximum value of the flux
f = the frequency
t = time,

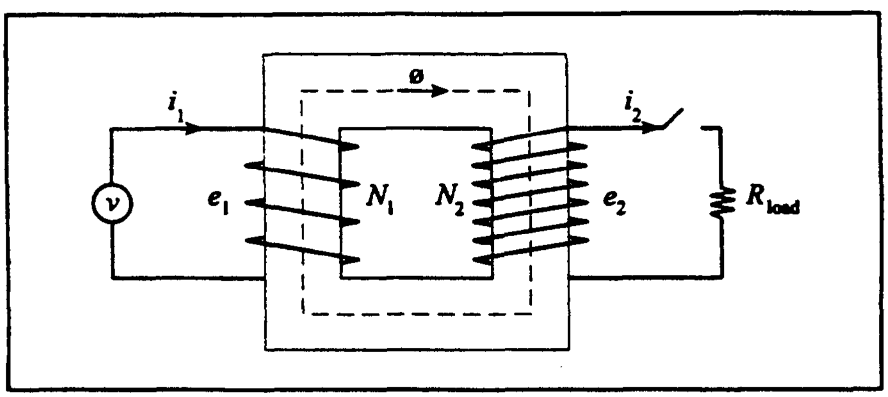

Figure 2-1 Simplified two-winding transformer

it follows from Faraday's law (i.e., $e = N\, d\Phi/dt$) that the instantaneous voltage e_1 induced in the primary winding is:

$$e_1 = 2\pi f N_1 \Phi_m \cos 2\pi f t$$

The polarity of e_1 will be according to Lenz's law, and hence will be in opposition to the impressed voltage, v (figure 2-1). The root mean square (rms) value of e_1 is

$$E_1 = (2\pi/\sqrt{2}) f N_1 \Phi_m = 4.44 f N_1 \Phi_m$$

d. Remembering Kirchhoff's voltage law, and assuming that the winding resistance is relatively small, E_1 must be approximately equal to V, where V represents the rms value of the applied voltage. One important result from this equation is that the value of the maximum flux, Φ_m, is determined by the applied voltage. In other words, for a given transformer, the maximum value of the flux is determined by the amplitude and frequency of the voltage applied to the primary winding. The same flux that caused E_1 in the primary winding will also induce a voltage across the terminals of the secondary winding. Thus, the only difference in the rms values of the two voltages will come from the difference in the number of turns. If the secondary winding has N_2 turns, the seconday voltage can be written as:

$$E_2 = 4.44 f N_2 \Phi_m$$

Dividing Equation 3 by Equation 4 gives the familiar relationship:

$$E_1/E_2 = N_1/N_2$$

e. Consider next when the transformer is loaded with a resister R_{load} by closing the switch in the secondary circuit. If the core flux is in the direction indicated (with the flux increasing), then by Lenz's law, the polarity of E_2 will be such that current I_1 will flow in the secondary winding in attempt to decrease the core flux. The amount of secondary current that will flow will depend on the value of R_{load} (that is, $I_2 = E_2/R_{load}$), and the power delivered to the load will equal $E_2 I_2$. It is important to understand the mechanism by which the power is transferred from the primary circuit to the load. Consider a situation when current is suddenly allowed to flow in the secondary winding by closing the switch. As mentioned previously, the action of this current will be to decrease the core flux. Decreasing the core flux would lower the value of E_1, which would be in violation of Kirchhoff's voltage law (KVL). Since KVL must be satisfied, more current must flow in the primary winding. The steady-state result is that the primary current will increase to the value sufficient to neutralize the demagnetizing action of the secondary current. It is important to realize that the resultant flux in the core remains the same regardless of the loading on the transformer. If the level of core flux were to vary with load, then E_1 and E_2 would also vary, which is contrary to what is observed in practice.

f. An iron core is used in transformers because it provides a good path for magnetic flux and directs the flux so it predominantly links all of the turns in each winding. However, the core has its limitations and can carry only so much flux before it becomes saturated. Core saturation occurs when all of the magnetic domains of the iron align, resulting in a condition in which no further increase in flux density over that of air can be obtained. Consider the magnetizing curve in figure 2-2, showing flux versus magnetizing current, where the magnetizing current i_m is the steady-state component of current

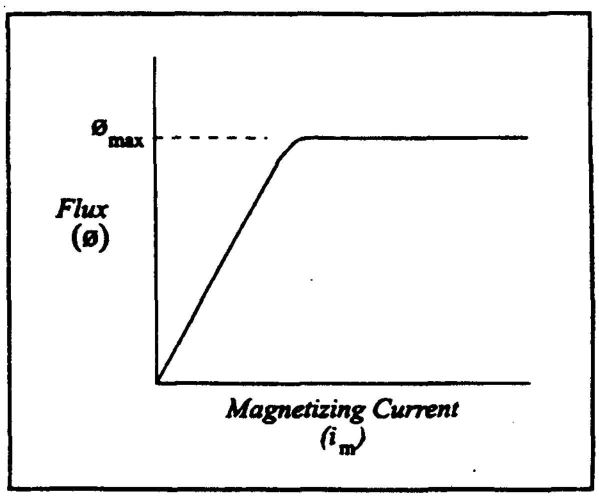

Figure 2-2. Magnetization curve for the transformer's iron core

required to establish the resultant flux level in the iron core for the transformer. It is typical for a transformer, or any other magnetic circuit, to be designed for operation close to the "knee" of this curve (i.e., Φ_{max}) to use as much of the iron core as possible. Beyond Φ_{max}, the iron saturates and it becomes extremely difficult to further increase the flux level. The curve implies that forcing the iron core into saturation can result in a significant increase in the value of the magnetizing current, and hence, can cause the windings to become overloaded and the transformer to overheat.

g. This study is concerned primarily with equipment sensitive to 50 Hz and voltage levels since the equipment will be used overseas where voltage frequencies and levels typically are different from those in the United States. This equipment could be listed by item, but a more useful format results when it is divided into classes and subclasses of equipment from which manufacturers for specific pieces of equipment can be easily selected. Following this format, listed below are the broad classes of equipment sensitive to 50 Hz and building voltage levels. Each section contains specific classes and subclasses of equipment. Additionally, each section describes why the equipment is sensitive to voltage frequency and or level. Equipment that does not readily fit into any other category is listed in paragraph 2-8.

2-2. Heating, ventilation, and air-conditioning (HVAC).

HVAC equipment includes boilers, furnaces, water chillers, humidifiers, fans, compressors, evaporators, and related equipment. Certain issues must be considered when using HVAC equipment in 50 Hz and alternate voltage environments, including the motor speed and step-down transformers for power supplies.

a. The objective of an HVAC system is to provide the necessary heating and cooling to a building according to the design specifications. Typically, alternating current (AC) motors are used in HVAC systems to drive fans, pumps, and compressors. When 60 Hz motor is run off a 50 Hz supply, the shaft speed of the motor is reduced by 5/6 since the motor speed is directly related to the frequency of the applied voltage. This speed will affect all direct-drive applications. For example, a pump that is directly coupled to the motor shaft will transfer less fluid over time if the shaft speed is reduced. Consequently, direct-drive HVAC applications must be derated to account for the reduced motor speed. However, for driven equipment that is tied to the motor through adjustable pulleys, the speed of the driven device can be increased to the necessary level.

b. Regardless of how the driven equipment is coupled to the motor, the 60 Hz motor must still operate within its rating in the 50 Hz environment. For the motor to deliver the same mechanical power at a lower speed, it must deliver more torque since output power equals torque times the shaft speed. If the motor delivers more torque, more current will flow in the motor and an overloaded condition may result. Hence, a 60 Hz motor may have to be derated to handle the extra current flow.

c. Another concern with operating a 60 Hz motor with a 50 Hz voltage source is with saturating the iron core of the motor. Like the transformer, the maximum value of flux in the core depends directly on the amplitude of the applied voltage and inversely on the frequency. Assuming that the same voltage level is applied to the 60 Hz motor in the 50 Hz environment, the reduction in frequency to 50 Hz would require an increase in core flux of 20 percent (that is, 6/5 of its 60 Hz level). If the iron core of the motor is unable to provide the extra flux, the core will saturate, and a significant increase in the stator currents can result, causing the motor to overheat.

d. Step-down transformers typically are needed to transform local voltage levels to the levels the equipment is designed for. In most cases, the equipment contains some sort of step-down transformer that typically has to be changed to convert the higher input voltage to the same output voltage. In cases where no step-down transformer is in the equipment, one must be added to avoid burning out components by subjecting them to a higher supply voltage. Determining the need for a step-down transformer and adding it to the equipment is easily accomplished, and is discussed further in chapter 3. Equipment that cannot be purchased with the precise specifications needed must be purchased in U.S. specifications and then derated as described in chapter 3.

2-3. Electrical distribution and protection.

Electrical distribution equipment includes transformers, panelboards and switchboards, generators, transfer switches, capacitors, and related equipment. Electrical protection devices include fuses, circuit breakers, relays, reclosers, and contactors. The devices have different sensitivities to supply voltage and frequency, and are discussed below.

a. Electrical distribution. As mentioned earlier, transformers are sensitive to the frequency and amplitude of the supply voltage. Using a 60 Hz transformer in a 50 Hz electrical environment can cause the core of the transformer to saturate, overheating the transformer. Other than the potential problem with saturation, the transformer should be fully capable of supplying the nameplate rated load. Most transformers are available in 50 Hz or 50/60 Hz configurations, so saturation should not be a problem.

(1) Panelboards, switchboards, and load centers are generally not sensitive to supply frequency, except when protective devices such as circuit breakers are included in them. These items can be acquired readily in a wide variety of voltage ratings; therefore, supply voltage does not pose a problem.

(2) General output voltage can be increased or decreased by using an appropriate transformer. However, since generators are typically used to supply backup power when the utility power source fails, and or are used in addition to the utility power source, it is necessary for the generator to provide a 50 Hz voltage source to match the utility supply. Therefore the user must purchase a generator configured for 50 Hz operation.

(3) Automatic source transfer switches are sensitive to supply voltage frequency and amplitude because they are electronically controlled and have power supplies that expect to operate on 60 Hz and rated voltage. Once again, supply voltage level is not a problem since transformers are available to adapt voltage levels. Supply frequency, however, may be a problem depending on the type of power supply the electronics use.

(4) Related equipment includes meter centers, and sockets or receptacles. Meter centers are sensitive to voltage level and frequency. Consequently, using a 60 Hz meter center in a 50 Hz environment may result in inaccurate readings. However, meters are readily available in a variety of voltage levels and 50 Hz configurations.

(5) Sockets or receptacles are needed when foreign consumer products are to be used with the power system. Receptacles are configured for different voltage levels, and these configurations vary in different countries. It is important that the standard receptacle style for a given voltage be used to avoid confusing the user and creating a potential safety hazard.

(6) Capacitors are used in an electrical distribution system to adjust the power factor or phase angle between the voltage and current waveforms. It is desirable to have a phase angle close to zero, or a power factor close to one so that most of the power transferred to the load is real power. Real power is the only part of the total kilovolt-amperes transferred that can do work. The balance is called reactive power and cannot do any useful work. The operation of a capacitor depends on the supply frequency, since a capacitor's impedance, X_C, is related to the capacitance and frequency of the current passing through it by the equation $X_C = 1(j2\pi f C)$, where C is the capacitance in farads and j equals the square root of -1.

b. Electrical protection. Electrical protection devices vary in their sensitivity to supply frequency. All protection devices are available in a wide range of voltage ratings so the level of the supply voltage is not a concern. The main concern with protection devices is the change in response time from 60 Hz to 50 Hz. These devices are coordinated to protect the distribution system from faults (shorts or spikes) but are connected so they do not trip when anticipated voltage spikes (that is, motor starting) occur. The power system design engineer must be sure to use the proper trip curves for the environment when coordinating protective devices. Trip curves for 50 Hz are readily available from vendors contacted in this study. The only device designed differently for 50 Hz and 60 Hz is the circuit breaker.

2-4. Medium voltage distribution equipment: 50 Hz → 60Hz.

In this section medium voltage transformers, switchgear and associated auxiliary devices will be examined with respect to frequency and voltage changes.

a. Medium voltage distribution transformers. Distribution transformers are key components in any electric power distribution system. It is important that they are properly matched to their environment. Issues related to operating a 60 Hz transformer from a 50 Hz power source were discussed earlier in this manual. The emphasis here will be on discussing issues concerning operating 50 Hz transformers in a 60 Hz environment.

(1) An important parameter to consider when operating a transformer, or other iron core-based devices, is the ratio of amplitude to frequency of the applied voltage. The ratio obtained using the nameplate rated voltage and frequency should be compared with the ratio available at the proposed site. If the ratio is less than or equal to that obtained using the nameplate quantities, magnetic saturation will not be a problem at the new site. Any time the ratio is higher than nameplate, the manufacturer should be contacted to ensure that the transformer has enough reserve available to accommodate the increase in operating magnetic flux density.

(2) For example, consider a transformer that is brought over from Germany where it was used on a 10 kV, 50 Hz distribution system. It was determined that the electrical insulation system of the transformer was rated for 15 kV. It is desired to use the transformer on a 13.8 kV, 60 Hz system. Considering the magnetic circuit, the volts-per-hertz ratio of the 50 Hz transformer is 200 (i.e., 10 kV/50 Hz). On the new supply the ration would be increased to 230 (that is, 13.8 kV/60 Hz), requiring a higher magnetic flux density in the iron core. This increase could potentially saturate the iron core and overheat the transformer. Alternatively, this

transformer could be used on a 7.2 kV/60 Hz system (120 volts-per-hertz ratio), where saturation would not be a problem.

(3) A few words should be mentioned concerning iron core loss in transformers. The two primary components of core loss are eddy-current loss and hysteresis loss. Eddy-current loss is the term used to describe the power loss associated with circulating currents that are found to exist in closed paths within the body of a iron material and cause undesirable heat production. Hysteresis loss represents the power loss associated with aligning and realigning the magnetic domains of iron in accordance with the changing magnetic flux. Both components are dependent on the frequency, as shown in the following equations:

$$P_{eddy\text{-}current} = K_e f^2 B^2_m \tau^2 v$$

$$P_{hysteresis} = K_h f B^2_m v$$

where,

K = constant value dependent upon material
f = frequency of variation of flux
B = maximum flux density
v = total volume of the material
τ= lamination thickness.

(4) It should be noted that, even though frequency increases when using 50 Hz transformers on a 60 Hz-based system, the voltage-to-frequency ratio will typically be lower, and hence, the maximum flux densities B will be lower. The result is that core-losses will generally not increase as a result of the higher frequency used.

(5) Other key parameters are voltage and current. To maintain insulation system integrity, rated voltage and/or current for the transformer should not be exceeded. A transformer can be operated on lower than rated voltage; however, its current rating must not be violated. Also, the secondary voltage must be matched to the proper voltage levels.

(6) In addition to having an iron core, windings, and insulation system, distribution transformers may include tap changers and auxiliary devices. Auxiliary devices might include fans, current transformers, pressure relief devices, and lighting arresters. Once again, attention should be focused on devices that use a magnetic field for transferring or converting energy, such as instrument transformers and small motor drives. Even if the voltage-to-frequency ratio is found to be lower, manufacturers should be contacted to make sure that all linear and rotating drive mechanisms will develop adequate force and torque to function properly.

b. Medium voltage switchgear. Switchgear is a general term covering switching and interrupting devices alone, or their combination with other associated control, metering, protective, and regulating equipment. Common switchgear components include the power bus, power circuit breaker, instrument transformers, control power transformer, meters, control switches, protective relays and ventilation equipment. The ratings of switchgear assemblies are designations of the operational limits under specific conditions of ambient temperature, altitude, frequency, duty cycle, etc. For example, the performance of some 50 Hz magnetic type circuit breakers may be altered slightly when operated on a 60 Hz power system. Switchgear manufacturers should always be consulted to identify the frequency response of circuit breakers and all auxiliary devices.

2-5. Safety and security equipment.

Safety and security equipment includes fire detection systems, burglar alarm systems, doorbells, and surveillance systems. This equipment typically operates on low voltage, either alternating current (AC) or direct current (DC), generated initially by a power supply. Acquiring the proper power supply to convert from the supply voltage to the low voltage that these systems expect (typically 6 to 12 VAC or VDC) is the key to proper operation of these systems in foreign environments. Power supplies of 50 Hz/120 VAC usually are available from vendors of these systems, and a transformer can be used to step a 240 VAC supply down to a 120 VAC foreign environment. Therefore, derating is not necessary for these items, although a transformer may be needed to step high voltage supply levels down to 120 VAC for the power supplied to these systems. Most vendors of safety and security equipment can configure their equipment to 50 Hz and a variety of voltage levels.

2-6. Communication equipment.

Communication equipment encompasses public address systems and sound systems, both of which operate on a low-voltage DC supply generated by a power supply. Power supplies are available to operate on 50 Hz and 240 V supply voltages. In cases where only 120/50 Hz supplies are available, a step-down transformer can be used to step a 240 V supply down to 120 V. The vendors contacted in this study have stated that they provide 50 Hz power supplies.

2-7. Lighting.

Lighting can be divided into incandescent, fluorescent, and high intensity discharge (HID) categories. Incandescent lighting is not frequency-sensitive, whereas fluorescent and HID lights are started by a ballast that is sensitive to voltage level and frequency.

All types of lighting are sensitive to the supply voltage level and cannot be derated for voltage. For example, subjecting a 120 V incandescent lamp to a 240 V source will result in the lamp burning twice as hot, causing rapid lamp failure. Subjecting the iron core ballast use in many HID and fluorescent fixtures to twice its rated voltage will saturate the ballast and will subject the fixture to much more than its rated current. As with transformers and motors, 60 Hz iron-core ballasts can also be saturated when operated at 50 Hz. At first thought, frequency dependence may not be os much of a problem with electronic ballasts since, in most cases, the AC voltage source is first converted back to a high frequency AC source, and therefore, the voltage source that is actually impressed across the lamp is decoupled from the 60 Hz AC source. However, the power supply used to power the electronics in these ballasts must be capable of 50 Hz operation.

2-8. Other electrical equipment.

Other electrical equipment includes motors, motor starters, computer power supplies, and clocks.

a. Typically, motor starters are sensitive to both supply voltage level and frequency. The most commonly used motor starters consisters of a coil, thermal overloads, and a set of contactors (contacts). The thermal overloads, which are essentially circuit breakers, and the contactors are rated to handle a certain amount of current. Since at 50 Hz, a motor of a given horsepower rating will draw more current than an identically-rated motor would draw at 60 Hz, the thermal overloads and the contactors must be sized accordingly.

b. Computer power supplies include voltage regulators, isolation transformers, transient voltage suppressor transformers, computer regulator transformers, and power conditioning transformers. Computer power supplies are sensitive to both frequency and voltage level.

c. Clocks are sensitive to supply frequency and voltage. Clocks rely on the frequency of the supply voltage to keep correct time, so a clock designed for 60 Hz will not keep correct time at 50 Hz. The motor that runs the clock is also sensitive to supply voltage level. Therefore, a clock must either be purchased configured for the supply voltage level, or a transformer must be used to convert the supply voltage level to the clock's rated voltage level. Clocks cannot be derated for frequency, and therefore clocks designed for 50 Hz must be purchased.

CHAPTER 3
EQUIPMENT DERATING

3-1. Derating under 50 Hz conditions.

Derating factors for 50 Hz operation are developed differently for different types of equipment. Derating factors for HVAC, electrical distribution and protection, safety and security equipment, communication equipment, lighting, and other electrical equipment are discussed below.

3-2. Heating, ventilating, and air conditioning (HVAC) for derating.

The frequency of the supply voltage affects two types of components in HVAC systems: motors and controls. From the discussion in paragraph 2-2, for the same mechanical load and voltage level, a 60 Hz motor will draw 20 percent more current when supplied from a 50 Hz voltage source. This assumes the iron core of the motor does not saturate. Therefore, a 60 Hz motor would have to be capable of handling the increase in current level. However, as was also mentioned in the previous chapter, saturation can be a serious problem when running a 60 Hz motor off a supply frequency of 50 Hz. Developing a derating factor to account for saturation is not possible, since the motor designs vary from vendor to vendor, and hence, the degree of saturation that would occur, if any, would be impossible to predict. Consequently, it is recommended that no horsepower derating be performed, and a 50 Hz motor be purchased.

a. However, if the vendor can guarantee the user that a given 60 Hz motor would not saturate at 50 Hz, then the motor would need only to be derated to handle the 20 percent increase in current level. The amount of horsepower derating required would depend on the motor's mechanical load, service factor, and thermal limit. The service factor is a measure of how much the motor can be overloaded continuously without exceeding safe temperature limits. The thermal limit is the minimum speed at which an AC motor can be operated with rated amperes, without exceeding safe temperature rise. The thermal limit is important because the motor's ability to cool itself will be reduced at lower speeds unless, of course, some sort of auxiliary cooling is used. In most cases, however, the minimum shaft speed necessary to exceed the thermal limit is much lower than 1500 revolutions per minute (RPM, for example, for a 4-pole motor), so 50 Hz operation should not be a problem, although the vendor should be contacted for verification. A 60 Hz motor with a 1.20 service factor can be operated safely while overloaded continuously by 20 percent. The same motor can be operated safely with a rated mechanical load and a 50 Hz power supply with no horsepower derating, assuming saturation is not an issue, the thermal limit of the motor is not exceeded, and the same voltage amplitude is applied. However, a 60 Hz motor, with a 1.0 service factor, driving a rated mechanical load would have to be derated for horse power by 20 percent, since it is not capable of handling greater than the rated current. In summary, the user should find out the service factor and thermal limit of the motor to determine the amount of horsepower derating required, and to ensure that the 20 percent increase in current level in the motor does not exceed the motor's rating (again, assuming saturation is not a concern].

b. Another issue to be considered when purchasing HVAC equipment for a 50 Hz environment is that the motor's shaft will spin 5/6 as fast as it would with a 60 Hz supply. For a 4-pole motor, the shaft will rotate at roughly 1500 RPM when run off a 50 Hz supply, where as with a 60 Hz voltage source it will rotate at about 18OO RPM. Consequently, equipment that is directly coupled to the shaft of the motor will rotate at 5/6 the speed it would in a 60 Hz environment. Hence, direct-drive equipment must be derated to account for the change in speed. In cases where the equipment is indirectly coupled to the motor shaft, through the use of adiustable pulleys for example, the reduction in shaft speed is not as much of a problem since the required speed of rotation can be obtained through the proper adjustment or selection of the pulleys.

c. Additionally, electronic HVAC controls that contain their own power supply may be 50 Hz sensitive. Most of the vendors contacted stated that this typically is not a problem because most controls are frequency-sensitive. If the control are 50 Hz sensitive, they must be purchased in a 50 Hz configuration. The HVAC vendor must be consulted on a case-bycase basis to determine if the controls can be used in 50 Hz environments.

3-3. Electrical distribution and protection.

In general, a 60 Hz transformer should not be used with a 50 Hz voltage source because of the potential saturation problem. As with motors, a derating factor cannot be developed to account for saturation because of the many different transformer designs on the market. It is recommended that a 50 Hz transformer be purchased for use with a 50 Hz voltage source. However, if a 60 Hz transformer vendor can ensure that a transformer will not saturate when operated at 50 Hz, the transformer should be fully capable of safely supplying its nameplate rated load (that is, no horsepower derating is required). In terms of the transformer's equivalent impedance, sometimes used for power system studies (for example, short-circuit and load-flow analysis), the 60 Hz value should be derated by 5/6 to account for the reduction in system frequency.

a. Power factor capacitors rated at 60 Hz must also be derated to 50 Hz. Capacitors do not consume any real power, but they do consume reactive power. The rating given to power factor capacitors is given in units of kilovolt-amperes reactive (KVAR), which indicates the amount of reactive power the capacitor will consume at the rated frequency. As mentioned in chapter 2, the capacitor's impedance, X_c, is inversely related to frequency. If the frequency drops from 60 to 50 Hz, the impedance will increase to 6/5 of its 50 Hz value. Since the KVAR rating equals V^2/X_c, if X_c at 50 Hz increases to 6/5 of its 60 Hz rating, the KVAR rating will decrease to 5/6 of its 60 Hz rating when the capacitor is used in a 50 Hz environment. Therefore, a 60 Hz-rated capacitor must have the KVAR rating multiplied by 5/6 to yield its 50 Hz KVAR rating.

b. Other electrical protection and distribution equipment either cannot or should not be derated. Electrical protection devices are generally able to be used at either 50 Hz or 60 Hz, but a different trip curve needs to be used by the power system designer for 50 Hz. These 50 Hz trip curves are readily available from vendors of this equipment, so no derating is necessary. The only exception is that some circuit breakers are designed differently at 50 Hz and 60 Hz.

c. Voltage, current, and power meters can be derated, but this practice is not recommended. A meter should display the true value it is supposed to measure to ensure that the readings are interpreted correctly and that no dangerous situations result. Meters, therefore, should not be derated. Automatic transfer switches use power supplies that may or may not be frequency-sensitive. Vendors must be contacted regarding 50 Hz configuration of these devices. Electrical generators must be purchased already configured to provide a 50 Hz voltage source.

3-4. Safety and security equipment for derating.

Safety and security equipment operate on a low-voltage AC or DC source that is generated by a power supply. Some power supplies are sensitive to frequency; others are not. In either case, derating is not necessary since power supplies sensitive to frequency cannot be derated, and power supplies insensitive to frequency do not need to be derated. In cases where the power supplies are sensitive to 50 Hz, vendors are able to ship the equipment with a 50 Hz-compatible power supply.

3-5. Communication equipment for derating.

Communication equipment operates on a low-voltage DC supply and does not need to be derated for frequency. Vendors will either ship the units with frequency-insensitive power supplies, or they will configure the units for 50 Hz operation before shipping.

3-6. Lighting for derating.

Incandescent lighting is not frequency-sensitive since this type of lighting consists of a resistive element (the filament), which is not frequency-sensitive. Fluorescent and high intensity discharge (HID) lighting, on the other hand, use a ballast to generate the proper lamp voltage and to limit the current flowing through the lamp. These ballasts are sensitive to frequency. Because of the numerous ballast designs and styles on the market, and the potential saturation problem, a simple derating factor cannot be developed and it is recommended that a vendor supplying 50 Hz-rated ballasts be located.

3-7. Other electrical equipment for derating.

Other electrical equipment consists of motors, motor starters, computer power supplies, and clocks. Motor derating was mentioned earlier in the HVAC section of this chapter. Motor starters are sensitive to frequency as well, but indirectly so. Since a 60 Hz motor will draw 20 percent more current when operated off a 50 Hz voltage source, assuming the same voltage amplitude is applied and there is no saturation problem, the motor starter current rating must be derated by 20 percent to account for the increase in current. Clocks and computer supply equipment are sensitive to frequency and cannot be derated. Clocks rely on the frequency of the supply to keep correct time, so a 60 Hz clock will not keep correct time at 50 Hz. Although derating factors could be developed for clocks, they would be meaningless. Computer power supply equipment cannot be derated due to the way the equipment is constructed.

3-8. Derating under alternate voltage conditions.

As appendix B shows, standard one-phase voltages around the world are either in the range of 100-127 VAC or 220-240 VAC. Voltage variations within about 10 percent of an equipment's rated voltage are acceptable, so derating for voltage will only be necessary when a piece of equipment rated for U.S. voltage (approximately 120 VAC) needs to be operated in an environment using 220-240 VAC. This would be a doubling of rated voltage. None of the equipment sensitive to voltage level is capable of surviving this increase without rapid failure. Thus, no derating factors for voltage level are offered. Instead, it is recommended that transformers be used to step the higher voltage level down to a voltage level in the range of 100-127 VAC, which U.S. equipment can tolerate. It has been found, however, that most vendors of voltage-sensitive equipment are able to configure the equipment for 220-240 VAC and corresponding threephase voltage levels.

3-9. Recommendations.

Derating factors were discussed and developed for the six generic types of equipment. Appendix C, which summarizes the discussion of derating factors presented in this chapter, is useful in identifying derating factors quickly and easily. Although this chapter presents derating factors for equipment, it is recommended that, whenever a piece of equipment is to be derated, the vendor be contacted to discuss the derating. It is always preferable to locate a vendor that will supply the equipment with the desired ratings before derating is attempted. The majority of vendors contacted are able to supply equipment rated at 50 Hz and a variety of voltage levels, so derating should be necessary in only a few cases.

3-10. Summary.

Appendix B can be used to rapidly identify the standard frequency and voltage levels in other countries. In cases where cities within a country differ in their electrical standards, the cities are listed separately. For countries in which all cities have the same electrical standards, typically only the capital city is listed. In these cases, assume that all cities in the country have the same electrical standards.

APPENDIX A

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APPENDIX B

Frequency and Single- and Three-Phase Voltage Levels by Country

This appendix covers identification of various low and medium voltage levels, along with the system frequencies, used by countries around the world.

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Afghanistan	50	1,3	220/380	3.2, 6, 10, 15, 20
Algeria	50	1,3	127/220 220/380	5.5, 6.6, 10, 30
American Samoa	60	1,3	120/240 240/480	NA
Angola	50	1,3	220/380	NA
Antigua	60	1,3	230/400	NA
Argentina	50	1,3	220/380	6.6, 13.2, 33
Australia	50	1,3	240/415	6.6, 7.6, 11, 12.7, 19, 22, 33, 66
Austria	50	1,3	220/380	3, 5, 6, 10, 20, 25, 28, 30
Azores				NA
Ponta Delgada	50	1,3	110/190 220/380	
All Others	50	1,3	220/380	
Bahamas	60	1,3	120/240 120/208	7.2, 11
Bahrain				11
Awali	60	1,3	230/400	
All Others	50	1,3	230/400	
Bangladesh	50	1,3	220/380	11, 33 (various seasonally)
Barbados	50	1,3	115/230 115/200	11,24
Belgium				6.6, 10, 15, 36, 70*
Anderlecht	50	1,3	220	
Antwerpen	50	1,3	127/220 220/380	
Brugge	50	1,3	220/380	
Brussels	50	1,3	127/220 220/380	
Charlerio	50	1,3	230/400	
Gentbrugge	50	1,3	220/380	
Hasselt	50	1,3	130/220 220/380	
Hoboken	50	1,3	127/220 220/380	
Huy	50	1,3	220	

*Voltages listed are country-inclusive, all voltages listed for the country may not be found in individual cities listed.

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Belgium *(continued)*				
Jette	50	1,3	127/220	
Leige	50	1,3	220/380	
Liege-Monsinport	50	1,3	110/220 220/380	
Lokeren	50	1,3	220/380	
Leuven	50	1,3	220/380	
Mechelen	50	1,3	220/380	
Mons	50	1,3	220/380	
Namur	50	1,3	220/380	
Oostende	50	1,3	127/220 220/380	
Ronse	50	1,3	220/380	
Seraing	50	1,3	220/280	
Turnhout	50	1,3	220	
Uccle	50	1,3	220/380	
Vilvoorde	50	1,3	120/220 220/380	
Belize				6.6, 22*
Belize City	60	1,3	110/220 220/440	
Balmopan	60	1,3	110/220 220/240	
Corozal Town	60	1,3	110/220 220/440	
Orange Walk	60	1	110/220	
San Ignacio	60	1	110/220	
Stann Creek	60	1	110/220	
Punta Gorda	60	1,3	110/220 220/440	
San Pedro	60	1	110/220	
Benin	50	1,3	220/380	15, 20
Bermuda (Island-wide)	60	1,3	120/240 120/208	NA
Bolivia				6.6, 24.9*
Calamarca	50	1,3	230/400	
Challapata	50	1,3	220/380	
Cobija	50	1,3	230/400	
Cochabamba	50	1,3	220/380	
Guayaramerin	50	1,3	230/400	
La Paz	50	1,3	???/230	
Potosi	50	1,3	220/380	
Oruro	50	1,3	110/220	
Riberalta	50	1,3	230/400	
Santa Cruz	50	1,3	220/380	
Sucre	50	1,3	220/380	
Trinidad	50	1,3	230/400	
Tupiza	50	1,3	220/380	
Viacha	50	1,3	110/220	
Villazon	50	1,3	220/380	
Bosnia/Herzogovina	NA	NA	NA	6.6, 10
Botswana	50	1,3	220/380	11, 33, 66
Brazil				6, 11.4, 13.8, 22, 25, 34.5*
Barbacena	60	1,3	110/220	
Blumenau	60	1,3	220	
Braganca	60	1,3	110/220	

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Brazil *(continued)*				
Brasilia	60	1,3	220/380	
Caxias do Sul	60	1,3	220/380	
Cel Fabriciano	60	1,3	110/220	
Corumba	60	1,3	110/220	
Florianopolis	60	1,3	220/380	
Fortaleza	60	1,3	230/400	
Goiania	60	1,3	220/380	
Goias	60	1,3	220/380	
Itajai	60	1,3	220	
Joao Pessoa	60	1,3	220	
Joinville	60	1,3	220/380	
Jundiai	60	1,3	110	
Livramento	60	1,3	220/380	
Londrina	60	1,3	127/220 110/220	
Macapa	60	1,3	110/220	
Maceio	60	1,3	220/380	
Manaus	60	1,3	120/240	
Mossoro	60	1,3	220/380	
Natal	60	1,3	220/380	
Nova Friburgo	60	1,3	220	
Olinda	60	1,3	127/220 220/380	
Paranagua	60	1,3	110/220	
Parnaiba	60	1,3	110/220	
Pelotas	60	1,3	220/380	
Petropolis	60	1,3	127/220 115/220	
Ponto Grossa	60	1,3	220	
Porto Velho	60	1,3	110/220	
Santo Andre	60	1,3	115/230	
Sao Bernaroo do Campo	60	1,3	115/230	
Sao Caetano do	60	1,3	110/220	
Sul	60	1,3	110/220	
Sao Luis	60	1,3	115/230	
Sao Paulo	60	1,3	110/220	
Teresina	60	1,3	125/216	
Volta Rendonda	60	1,3	127/220	
All Others				
Brunai	NA	NA	NA	11, 68
Bulgaria	50	1,3	220/380	NA
Burma/Myanmar	50	1,3	230/400	3.3, 6.6, 11, 33
Burundi	50	1,3	220/380	6.6, 15
Cambodia				4.4, 6.3, 15*
Phnom-Penh	50	1,3	220/380	
Sihanoukville	50	1,3	220/380	
All Others	50	1,3	120/208	
Cameroon				10, 15, 30, 33, 55*
Buea	50	1,3	230/400	
Eseka	50	1,3	127/220	
Maroua	50	1,3	127/220	
Mbalmayo	50	1,3	127/220 220/380	
Nkongsamba	50	1,3	127/220 220/380	
Sangmelima	50	1,3	127/220 220/380	

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Cameroon *(continued)*				
Victoria	50	1,3	230/400	
Yaounde	50	1,3	127/220 220/380	
All Others	50	1,3	220/380	
Canada	60	1,3	120/240	2.4, 4.16, 7.2, 8, 12.47, 13.8, 14.4, 20, 25, 34.5, 44, 49
Canary Islands	50	1,3	127/220 220/380	NA
Cape Verde (Praia)	50	1,3	220/380	6, 6.3, 13, 15, 20
Cayman Islands	60	1,3	120/240	NA
Central African Republic	50	1,3	220/380	NA
Chad	50	1,3	220/380	15
Channel Islands				11
Alderney	50	1,3	240/415	
Guernsey	50	1,3	230/400	
Jersey	50	1,3	240/415	
Chile	50	1,3	220/380	12, 13.2, 13.8, 15, 23
China	50	1,3	220/380	10, 20, 35
Colombia				4.16, 7.6, 13.2, 13.8, 33, 34.5, 44*
Bogata	60	1,3	150/240	
Duitama	60	1,3	120/208	
Honda	60	1,3	120/208	
Sogomosa	60	1,3	120/240	
All Others	60	1,3	110/220	
Congo	50	1,3	220/380	5.5, 6.6, 10, 20
Costa Rica	50	1,3	120/240	4.2, 13.2, 24.9, 34.5
Croatia	50	1,3	220/380	10,35
Cyprus	50	1,3	240/415	11
Czech Republic	50	1,3	220/380	6, 10 (urban) 22, 35 (rural)
Denmark	50	1,3	220/380	6, 10, 20, 30
Djibouti	50	1,3	220/380	NA
Dominican Republic	60	1,3	110/220	2.5, 4.16, 12.5
Ecuador				13.8, 34.5, 46, 69*
Cuenca	60	1,3	120/208	
Esmeraldas	60	1,3	120/208 120/240	
Guaranda	60	1,3	120/208 120/240	
Ibarra	60	1,3	127/220	
Latacunga	60	1,3	120/208	
Loja	60	1,3	127/220	
Machala	60	1,3	127/220	

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Ecuador *(continued)*				
Morona	60	1,3	120/208	
Portoviejo	60	1,3	127/220	
Puyo	60	1,3	127/220	
Quito	60	1,3	120/208 127/220	
Riobamba	60	1,3	110/220	
Tulcan	60	1,3	121/210 127/220	
Zamora	60	1,3	121/210 127/220	
All Others			120/208 127/220	
Egypt	50	1,3	220/380	3, 6.6, 11, 20, 33, 66
El Salvador	60	1,3	115/230	4.16, 4.4, 13.2, 23, 34.5
England (see United Kingdom)				
Equatorial Guinea	50	1	220	NA
Ethiopia	50	1,3	220/380	15
Faroe Islands	50	1,3	220/380	NA
Fiji	50	1,3	240/415	11
Finland	50	1,3	220/380	10, 20, 30, 45
France				3.3, 5.5, 10, 15, 20, 30*
l'Alpe d'Huez	50	1,3	127/220 220/380	
Alencon	50	1,3	127/220 220/380	
Amiens	50	1,3	115/220 220/380	
Angers	50	1,3	127/220 220/380	
Angouleme	50	1,3	127/220 220/380	
Annecy	50	1,3	127/220 220/380	
Arcachon	50	1,3	127/220 220/380	
Argenteuil	50	1,3	127/220 220/380	
Asnieres	50	1,3	115/200 220/380	
LaBaule	50	1,3	127/220 220/380	
Besancon	50	1,3	127/220 220/380	
Beziers	50	1,3	127/220 220/380	
Biarritz	50	1,3	127/220 220/380	
Boulogne-sur-Mer	50	1,3	127/220 220/380	
la Bourboule	50	1,3	127/220 220/380	
Bourges	50	1,3	127/220 220/380	
Bourg-En-Bresse	50	1,3	127/220 220/380	

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
France *(continued)*				
Brest	50	1,3	127/220 220/380	
Briancon	50	1,3	115/200	
Cabourg	50	1,3	127/220 220/380	
Caen	50	1,3	127/220	
Calais	50	1,3	115/220 220/380	
Cauterets	50	1,3	127/220	
Chalons	50	1,3	127/220 220/380	
Chateauroux	50	1,3	120/208 220/380	
Chaumont	50	1,3	120/208 220/380	
Cherbourg	50	1,3	127/220 220/308	
Chinon	50	1,3	127/220 220/308	
Clermont-Ferrand	50	1,3	127/220 220/308	
Collioure	50	1,3	127/220 220/380	
Courbevoie	50	1,3	115/230	
Deauville	50	1,3	127/220 220/380	
Dieppe	50	1,3	127/220 220/380	
Dijon	50	1,3	127/220 220/380	
Dinan	50	1,3	127/220 220/380	
Douai	50	1,3	127/220 220/380	
Dreux	50	1,3	127/220 220/380	
Etain	50	1,3	115/200 220/380	
Evreux	50	1,3	127/220	
Fontainbleau	50	1,3	127/220 220/380	
Frejus	50	1,3	127/220 220/380	
Grenoble	50	1,3	127/220	
LeHavre	50	1,3	110/190 127/220 220/380	
Jounge	50	1,3	127/220 220/380	
Juan-les-Pins	50	1,3	127/220	
Lens	50	1,3	127/220 220/380	
Lille	50	1,3	110/220 220/380	
Luchon	50	1,3	127/220 220/380	
Luxeuil-Bains	50	1,3	127/220 220/380	
Lyon	50	1,3	110/220 127/220 220/380	
LeMans	50	1,3	127/220 220/380	
Marly-le-Roi	50	1,3	127/220 220/380	

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
France *(continued)*				
Marseille	50	1,3	115/200 220/380	
Megev	50	1,3	127/220	
Metz	50	1,3	110/190 220/380	
Lemont-Dore	50	1,3	127/220 220/380	
Motlucon	50	1,3	127/220 220/380	
Morzine	50	1,3	127/220 220/380	
Mulhouse	50	1,3	230 220/380	
Nancy	50	1,3	127/220 220/380	
Nantes	50	1,3	110/190	
Neuilly	50	1,3	115/230 127/220 220/380	
Nice	50	1,3	127/220	
Nimes	50	1,3	220 220/380	
Orleans	50	1,3	127/220	
Paris	50	1,3	115/230	
Perpignan	50	1,3	127/220 220/380	
Roanne	50	1,3	127/220 220/380	
LaRochelle	50	1,3	115/200 127/220 220/380	
Roubaix	50	1,3	220/380	
Royan	50	1,3	127/220 220/380	
Saint-Etienne	50	1,3	115/230 127/220 220/380	
Saint-Gervais-Les-Bains	50	1,3	127/220 220/380	
Saint-Jean-de-Lux	50	1,3	380	
Saint Lo	50	1,3	127/220 220/380	
Saint Quentin	50	1,3	127/220 220/380	
Sallanches	50	1,3	127/220	
Strasbourg	50	1,3	125/220 220/380	
Tabes	50	1,3	115/200 220/380	
Toulon	50	1,3	127/220 220/380	
Tourcoing	50	1,3	110/220 220/380	
Tours	50	1,3	127/220	
Val d' Isere	50	1,3	127/220 220/380	
Valenciennes	50	1,3	127/220 220/380	
Valloire	50	1,3	127/220	
Verdun	50	1,3	127/220 220/380	
Versailles	50	1,3	127/220 220/380	
Vichy	50	1,3	127/220 220/380	
Vincennes	50	1,3	127/220 220/380	
All Others	50	1,3	220/380	

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
French Guiana	50	1,3	220/380	NA
Gabon	50	1,3	220/380	5.5, 20
Gambia	50	1,3	220/380	11, 33
Germany	50	1,3	220/380	3, 6, 10, 20, 30, 45, 60
Ghana	50	1,3	220/400	11, 33, 34.5
Gibraltar	50	1,3	240/415	NA
Greece	50	1,3	220/380	6.6, 15, 20, 22
Greenland	50	1,3	220/380	NA
Grenada	50	1,3	230/400	NA
Guadeloupe	50	1,3	220/380	20
Guam	60	1,3	110/220 120/208	4, 13.8
Guatemala	60	1,3	120/240	22, 34.5, 50
Guinea	50	1,3	220/380	5.5, 6.3, 15, 20, 30
Guinea-Bissau	50	1,3	220/380	6, 10, 20, 30
Guyana	50	1,3	110/220	2.3, 4, 11, 13.8
Haiti				2.4, 4.2, 7.2, 12.5*
Cap Haitien	60	1,3	120/208	
Gonaives	60	1,3	120/208	
All Others	50	1,3	110/220	
Honduras	60	1,3	110/220	2.4, 4.2, 13.8, 34.5, 69
Hong Kong	50	1,3	200/346	11, 33
Hungary	50	1,3	220/380	6, 10, 20, 22, 30, 35
Iceland	50	1,3	220/380	6, 11, 22, 33
India				2.2, 3.3, 6.6, 11, 15, 11*
Bombay City	50	1,3	230/400 230/460	
Madras	50	1,3	230/400 250/440	
Mussoorie	50	1,3	220/380	
Naini Tal	50	1,3	220/380	11
New Delhi	50	1,3	230/400 230/415	
Patna	50	1,3	220/380	
Simla	50	1,3	220/380	
All Others	50	1,3	230/400	
Indonesia				3-20*
Jakarta	50	1,3	220/380	
All Others	50	1,3	127/200	
Iran	50	1,3	220/380	11, 20, 33, 63, 66
Iraq	50	1,3	220/380	6.6, 11

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Ireland	50	1,3	220/380	5, 10, 20, 38
Isle of Man	50	1,3	240/415	NA
Israel Jerusalem	50 50	1,3 1,3	230/400 220/380	6.3, 12.6, 22, 33*
Italy	50	1,3	127/220 220/380	3.6, 10, 15, 20, 30, 45, 66
Ivory Coast	50	1,3	220/380	NA
Jamaica	50	1,3	110/220	6.9, 13.8, 24
Japan Chiba Hakodate Kawasaki Muroran Niigata Otaru Sapporo Sendai Tokyo Yokohama Yokosuka All Others	 50 50 50 50 50 50 50 50 50 50 50 60	 1,3 1,3 1,3 1,3 1,3 1,3 1,3 1,3 1,3 1,3 1,3 1,3	 100/200 100/200 100/200 100/200 100/200 100/200 100/200 100/200 100/200 100/200 100/200 100/200	3, 6, 6.6, 11, 20, 22, 60*
Jordan	50	1,3	220/380	6.6, 11, 33
Kenya	50	1,3	240/415	11, 33, 40, 66
Korea	60 60 60 60	1,3 1,3 1,3 1	110/220 120/208 220/380 120/240	22.9
Kuwait	50	1,3	240/415	NA
Laos	50	1,3	220/380	6.6, 22
Lebanon Tripoli Zahleh All Other	 50 50 50	 1,3 1,3 1,3	 110/190 220/380 220/380 110/190	11, 15, 33*
Lesotho	50	1,3	120/240 120/208	11, 33
Liberia	60	1,3	120/240 120/208	7.2, 12.5
Libya Barce Benghazi Darnah Al Bayda Sebha Tubruq All Other	 50 50 50 50 50 50 50	 1,3 1,3 1,3 1,3 1 1,3 1,3	 230/400 230/400 230/400 230 230 230/400 127/220	NA
Luxembourg	50	1,3	120/208 220/380	5, 15, 20, 65

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Macau	50	1,3	220/380	11
Macedonia	NA	NA	NA	6.6, 10
Madagascar				5, 20, 35*
Ambatolampy	50	1,3	220/380	
Ambatondrazaka	50	1,3	220/380	
Tulear	50	1,3	220/380	
All Others	50	1,3	127/220 220/380	
Majorco Island	50	1,3	127/220 220/380	NA
Malawi	50	1,3	230/400	3.3, 11, 33, 66
Malaysia	50	1,3	240/415	6.6, 11, 22, 33
Maldives	50	1,3	230/400	11
Mali, Republic of	50	1,3	220/380	15, 30
Malta	50	1,3	240/415	6, 11
Martinique	50	1,3	220	NA
Mauritius	50	1,3	230/400	6.5, 22
Mexico	60	1,3	127/220	6.6, 13.2, 13.8, 23, 34.5, 44, 69
Monaco	50	1,3	127/220 220/380	10, 20
Montserrat	60	1,3	230/400	NA
Morocco				5.5, 20, 22*
Agadir	50	1,3	127/220 220/380	
Beni-Mellal	50	1,3	127/220 220/380	
El-Hoceima	50	1,3	220/380	
Khemisset	50	1,3	220/380	
Khenifra	50	1,3	220/380	
Oued-Zem	50	1,3	127/220 220/380	
Sidi Kacem	50	1,3	127/220 220/380	
Sidi Slimane	50	1,3	127/220 220/380	
Souk-El-Arba Gharb	50	1,3	127/220 220/380	
All Others	50	1,3	127/220	
Mozambique	50	1,3	220/380	6.6, 11, 22, 33
Myanmar/Burma	50	1,3	230/400	3.3, 6.6, 11, 33
Nepal	50	1,3	220/440	11, 33
Netherlands				5.3, 6, 10, 12.5, 20, 25*
Amsterdam	50	1,3	220/380 220	
Delft	50	1,3	220/380 220	
All Others	50	1,3	220/380	

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Netherlands Antilles				NA
Aruba:				
Lago Colony	60	1	115/230	
Oranjestad	60	1,3	127/220	
San Nicolas	60	1,3	127/220	
Bonaire:				
Kralendijk	50	1,3	127/220	
Curacaco:				
Emmastad	50	1,3	223/380	
Willemstad	50	1,3	127/220	
St. Martin:				
Philipsburg	60	1,3	120/208	
New Caledonia	50	1,3	220/380	NA
New Zealand	50	1,3	230/400	11
Nicaragua	60	1,3	120/240	13.8, 24.9
Niger	50	1,3	220/380	5.5, 15, 20
Nigeria	50	1,3	230/415	11, 33
Norway	50	1,3	230	NA
Okinawa				NA
Military Facilities	60	1	120/240	
All Cities	60	1	100/200	
Oman	50	1,3	240/415	11, 33
Pakistan				11, 33
Hyderabad	50	1,3	220/380	
Karachi	50	1,3	220/380	
All Others	50	1,3	230/400	
Panama				11, 12, 34.5*
Colon	60	1,3	115/230	
Panama City	60	1,3	115/230 126/208	
Puerto Armuelles	60	1,3	120/240	
All Others	60	1,3	110/220	
Papua New Guinea	50	1,3	240/415	11, 22
Paraguay	50	1,3	220/380	23
Peru				5, 10, 20, 30*
Arequipa	50	1,3	220	
Talara	60	1,3	110/220	
All Others	60	1,3	220	
Philippines				2.4, 4.8, 6.24, 7.62, 13.2, 13.8, 34.5*
Manila	60	1,3	115/230 110/220	
All Others	60	1,3	110/220	
Poland	50	1,3	220/380	6, 15, 20, 30, 40, 60
Portugal	50	1,3	220/380	6, 10, 15, 30, 40, 60
Puerto Rico	60	1,3	120/240	4.16, 13.2
Qatar	50	1,3	240/415	11

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Romania	50	1,3	220/380	6, 10, 20
Russia	50	1,3	220/380	NA
Rwanda	50	1,3	220/380	6.6, 15, 30
St. Kitts and Nevis	60	1,3	230/400	NA
St. Lucia	50	1,3	240/416	11
San Marino	NA	NA	NA	15
St. Vincent	50	1,3	230/400	6.3, 11, 33
Saudi Arabia				13.8, 33, 34.5, 69*
Al Khobar	60	1,3	127/220	
Buraydah	50	1,3	220/380	
Dammam	60	1,3	127/220	
Hufuf	50	1,3	230/400	
Jiddah	60	1,3	127/220	
Mecca	50	1,3	230/400	
Medina	60	1,3	127/220	
Riyadh	60	1,3	127/220	
Taif	50	1,3	230/400	
Senegal	50	1,3	127/20	5.5, 16.6, 30
Serbia	50	1,3	220/380	10, 20, 35
Seychelles	50	1,3	240	11
Sierra Leone	50	1,3	230/400	11
Singapore	50	1,3	230/400	6.6, 22
Slova Republic	NA	NA	NA	6, 10, 22, 35
Slovenia	NA	NA	NA	6.6, 10
Somalia				3, 15*
Berbera	50	1,3	230	
Brava	50	1,3	220/440	
Chisimaio	50	1,3	220	
Hargeysa	50	1,3	220	
Marka	50	1,3	120/220	
Mogadishu	50	1,3	220/380	
South Africa/Namibia				6.6, 11, 22, 33*
Beaufort West	50	1,3	230/400	
Benoni	50	1,3	230/400	
Boksburg	50	1,3	230/400	
Cradock	50	1,3	230/400	
Germiston	50	1,3	230/400	
Grahaamstad	50	1,3	250/430	
Keetmanshoop	50	1,3	230/400	
King Williams	50	1,3	220/380 250/433	
Klerksdorp	50	1,3	230/400	
Kroonstad	50	1,3	230/400	
Paarl	50	1,3	230/400	
Port Elizabeth	50	1,3	250/433	
Pretoria	50	1,3	240/415	
Roodepoort	50	1,3	230/400	

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
South Africa/Namibia *(cont.)*				
Somerset West	50	1,3	230/400	
Springs	50	1,3	220/380	
			230/400	
Stellenbosch	50	3	220/380	
Umtata	50	1,3	230/400	
Upington	50	1,3	230/400	
Virginia	50	1,3	230/400	
Vryheid	50	1,3	230/400	
Walvis Bay	50	1,3	230/400	
Wellington	50	1,3	230/400	
Worcester	50	1,3	230/400	
All Others	50	1,3	220/380	
Spain	50	1,3	127/220	3, 6.6, 10, 11.6, 15, 20, 33
			220/380	
Sri Lanka	50	1,3	230/400	11, 33
Sudan	50	1,3	240/415	11, 33
Suriname	60	1,3	115/230	33
Swaziland	50	1,3	230/400	11, 33
Sweden	50	1,3	220/380	3, 6, 7, 10, 20, 30
Switzerland	50	1,3	220/380	1, 16, 50
Syria	50	1,3	220/380	20
Tahiti	60	1,3	127/220	4.8, 14.4, 20
Taiwan	60	1,3	110/220	2.3, 3.3, 5.9, 11.4, 22.8
Tanzania	50	1,3	230/400	11, 33
Thailand	50	1,3	220/380	3.5, 11, 12, 22, 24, 33
Togo				5.5, 20, 33*
Lome	50	1,3	127/220	
			220/380	
All Others	50	1,3	220/380	
Tonga	50	1,3	240/415	11
Trinidad and Tobago	60	1,3	115/230	6.6, 12
			230/400	
Tunisia				10, 15, 30*
Ariana	50	1,3	127/220	
			220/380	
Bardo	50	1,3	127/220	
			220/380	
Beja	50	1,3	127/220	
Bizerte	50	1,3	127/220	
Carthage	50	1,3	127/220	
Gafsa	50	1,3	127/220	
			220/380	
Hammam-Lif	50	1,3	127/220	
Kairouan	50	1,3	127/220	
La Goulette	50	1,3	127/220	
La Manouba	50	1,3	127/220	
La Marsa	50	1,3	127/220	
Mateur	50	1,3	127/220	

Table B-1. Frequency and Single and Three-Phase Voltage Levels by Country–Continued

Country/City	Frequency (Hz)	Number of Phases	Low Voltage (V)	Medium Voltage (kV)
Tunisia *(continued)*				
Menzel Bourguiba	50	1,3	127/220	
Sfax	50	1,3	127/220 220/380	
Sousse	50	1,3	127/220	
Tunis	50	1,3	127/220 220/380	
All Others	50	1,3	220/380	
Turkey				6.3, 10.5, 15, 34.5*
Istanbul	50	1,3	110/220 220/380	
All Others	50	1,3	220/380	
Uganda	50	1,3	240/415	11, 33
United Arab Emirates				6.6, 11, 33*
Abu Dhabi	50	1,3	240/415	
Ajman	50	1,3	230/400	
Dubai	50	1,3	220/380	
United Kingdom:				
England	50	1,3	240/480 240/415	3.5, 6.6, 11, 22, 33, 66
Scotland	50	1,3	240/415	6.6, 11, 22, 33
Northern Ireland	50	1,3	220/380 230/400	6.6, 11, 33
United States of America	60	1,3	120/240 120/208	2.4, 4.16, 4.8, 6.9, 8.32, 12, 12.47, 13.2, 13.8, 14.4, 19.9, 20.8, 22.86, 23, 24.94, 34.5, 46, 69
Upper Volta	50	1,3	220/380	NA
Uruguay	50	1,3	220	6, 15, 30, 60
Venezuela	60	1,3	120/240	2.4, 4.16, 4.8, 12.47, 13.8
Vietnam				6.6 (south)
Ban Me Thout	50	1,3	220/380	10 (north)
Can Tho	50	1,3	127/220 220/380	15 (middle) 35 (entire)
Dalat	50	1,3	120/208 220/380	
Da Nang	50	1,3	127/220	Note: State has plans to change to
Hue	50	1,3	127/220	22 kV for whole country.
Khanh Hung	50	1,3	220/380	
Saigon	50	1,3	120/208 220/380	
Virgin Islands	60	1,3	120/240	NA
Western Samoa	50	1,3	230/400	6.6, 22
Yemen	50	1,3	250/440	NA
Zaire	50	1,3	220/380	6.6, 15, 20, 30
Zambia	50	1,3	220/380	11, 33, 66
Zimbabwe				11, 22, 33, 66*
Bulawayo	50	1,3	230/400	
All Others	50	1,3	220/380	

APPENDIX C
Derating Factors

C-1. Heating, ventilation, and air conditioning (HVAC).

a. 50 Hz. The output of directlycoupled, motordriven equipment must be derated to account for the reduction in shaft speed to 5/6 the 60 Hz value. Otherwise, the mechanical coupling used between the motor and driven equipment should be purchased to give the required rotating speed. HVAC controls that are frequency dependent must be purchased in 50 Hz configurations.

b. Voltage. Derating for voltage is not an option.

C-2. Electrical distribution and protection for transformers.

a. 50 Hz. In general, derating for frequency is not recommended. See chapter 3 for details.

b. Voltage. Derating for voltage is not recommended. Vendors can provide almost any needed input voltage rating. Consult vendor regarding derating possibility if derating is absolutely necessary.

C-3. Electrical distribution and protection for power factor capacitors.

a. 50 Hz. Derate kilovolt-amperes reactive (KVAR) rating by multiplying 60 Hz KVAR rating by 5/6 to yield 50 Hz WAR rating.

b. Voltage. Derating for voltage is not recommended. Vendors can provide almost any needed voltage rating. Consult vendor regarding derating possibility if derating is absolutely necessary.

C-4. Electrical distribution and protection for protection equipment.

a. 50 Hz. Different trip curves may be needed. Consult vendor for these curves.

b. Voltage. Derating for voltage should not be needed. Verify with vendor since special protection equipment may need derating.

C-5. Other electrical distribution and protection.

Derating either cannot or should not be performed. Contact vendors to purchase appropriately rated equipment.

C-6. Safety and security equipment.

a. 50 Hz. Depends on type of power supply. Derating is either not necessary or not possible. Contract vendor to purchase appropriately configured power supply.

b. Voltage. Derating far voltage is not recommended. Contact vendor to purchase appropriately configured power supply, or use transformer to convert supply voltage level to power supply input level.

C-7. Communication equipment.

a. 50 Hz. Depends on type of power supply. Derating is either not necessary or not possible. Contact vendor to purchase appropriately configured power supply.

b. Voltage. Derating for voltage is not recommended. Contact vendor to purchase appropriately configured power supply, or use transformer to convert supply voltage level to power supply input level.

C-8. Incandescent lighting.

a. 50 Hz. No derating necessary. Incandescents are frequency insensitive.

b. Voltage. Not possible. Bulb life will suffer drastically. Contact vendor to purchase high voltage bulbs, or use transformer to convert supply voltage to lamp voltage.

C-9. Fluorescent and high intensity discharge (HID) lighting.

50 Hz. Derating is not recommended. Fixtures configured for 50 Hz should be purchased.

C-10. Motors.

a. 50 Hz. In general, derating a 60 Hz motor is not recommended. See chapter 3 for exceptions

b. Voltage. Derating for voltage is not recommended. Contact vendor to purchase appropriately configured equipment, or use transformer to convert supply voltage to motor's rated voltage level.

C-11. Motor Starters.

a. 50 Hz. Derate by multiplying 60 Hz horsepower rating by 4/5 to yield the 50 Hz horsepower rating.

b. Voltage. Derating for voltage is not possible. Contact vendor to purchase appropriately configured equipment, or use transformer to convert supply voltage to motor starter's rated voltage level.

C-12. Clocks.

a. 50 Hz. Derating is possible but meaningless since 60 Hz clock will not keep correct time in 50 Hz environment

b. Voltage. Derating for voltage is not recommended. Contact vendor to purchase appropriately configured clocks, or use transformer to convert supply voltage to clock's rated voltage level.

C-13. Computer power supplies.

a. 50 Hz. Derating is not possible due to equipment construction. Contact vendor to purchase 50 Hz rated equipment.

b. Voltage. Derating for voltage is not possible. Contact vendor to purchase appropriately configured equipment, or use transformer to convert supply voltage to equipment's rated voltage level.

The proponent agency of this publication is the Chief of Engineers, United States Army. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) directly to HQUSACE, (ATTN: CEMP-SP), Washington, DC 20314-1000.

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UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR ELECTRICAL SYSTEMS

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UFC 3-520-01
16 January 2025

UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR ELECTRICAL SYSTEMS

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-520-01, dated 06 October 2015.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) has been issued to provide guidance for the design of interior electrical systems. The criteria contained herein are intended to ensure economical, durable, efficient, and reliable systems and installations. Whenever unique conditions and problems are not specifically covered by this UFC, use the applicable referenced industry standards and other documents for design guidance.

UFC 3-501-01 provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-520-01 for interior electrical system requirements. Modernization of electrical systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required. Upgrades or modifications of existing facilities must apply the design criteria in this UFC, but it is not intended that an entire facility require modernization solely because of a minor modification to a part of the facility.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-520-01, dated 06 October 2015.

1-3 APPLICABILITY.

This UFC applies to planning, design, construction, sustainment, restoration, and modernization of DoD-owned facilities. It applies to all methods of project delivery and levels of construction as defined by UFC 1-200-01, Section 1-3.

1-3.1 UFC Scope.

Compliance with this UFC is mandatory for the design of interior electrical systems at all facilities and bases. This UFC typically applies up to 5 feet beyond the facility envelope. It also applies to:

- Service(s) supplying power from the utility system utilization transformer to the wiring system of the facility.
- Circuits originating from within the facility that extend beyond the facility envelope.
- Wiring and connections for supplemental grounding systems.
- Wiring from and connections to non-utility equipment supplying power to the wiring system of the facility, including engine-generator sets, photovoltaic power systems and fuel cells.

Refer to UFC 3-550-01 for exterior electrical systems.

1-3.2 Host Nation Standards.

In addition to NFPA 70 requirements, facilities located outside of the United States must also comply with the applicable host nation standards. Host nation voltage and frequency as defined in UFC 3-510-01 generally applies. Different wiring and grounding conventions usually apply in other host nations; however, follow the design principles provided in this UFC to the extent practical.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

Cybersecurity is implemented to mitigate vulnerabilities to all DoD real property facility-related control systems to a level that is acceptable to the System Owner and Authorizing Official. UFC 4-010-06 provides requirements for integrating cybersecurity into the design and construction of control systems.

1-6 DESIGN STANDARDS.

Comply with the requirements of National Fire Protection Association (NFPA) 70, National Electrical Code, and the requirements herein. Electrical safety requirements, including the types of energized work permitted, approval process for energized work, and Personal Protective Equipment (PPE), applicable to the design, installation, and operation of electrical systems are provided in UFC 3-560-01.

Note: When a project, or portion of a project, has been designated as requiring Critical Operations Power Systems (COPS) treatment as a Designated Critical Operations Area (DCOA) per NFPA 70 Article 708, those requirements identified in the Unified Facility Criteria that are more stringent than NFPA 70 requirements take precedence over NFPA requirements. This UFC does not address COPS requirements.

1-7 GLOSSARY.

APPENDIX C contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

APPENDIX D contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

References applicable to a specific topic are also listed and described in the appropriate sections of this UFC. Codes and standards are referenced throughout this UFC. Follow the guidance provided in UFC 1-200-01, Section 1-3.1 to establish the issue/version of the publication effective for the project.

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CHAPTER 2 GENERAL POWER SYSTEM CRITERIA

2-1 VOLTAGE.

Refer to UFC 3-550-01 for voltage criteria associated with the primary distribution supply voltage.

Unless there are specialty voltage requirements, base the facility system voltage on the interior load requirements as follows:

- Apply 240/120V for facilities with only single-phase loads.
- Apply three-phase, four-wire, 208Y/120V systems for lighting and power demand loads less than 150 kVA.
- Apply three-phase, four-wire, 480Y/277V systems for lighting and power demand loads greater than 150 kVA unless 208Y/120V systems are shown to be more cost-effective. Use step-down transformers inside the facility as required to obtain lower voltages.
- For facilities with demand loads less than or equal to 150 kVA in which potential voltage drop issues have been identified, evaluate the life cycle cost effectiveness of installing larger conductor sizes and/or buck-boost transformers on a 208Y/120V system against the use of a 480Y/277V service utilizing step-down transformers. If determined that the life cycle cost is effective, the use of a 480Y/277V service shall be used in lieu of a 208Y/120V service.

2-2 FREQUENCY.

Apply a frequency of 60 Hz for distribution and utilization power.

In locations in which the commercially supplied frequency is other than 60 Hz, such as 50 Hz, use the available supplied frequency to the extent practical. Where frequencies other than that locally available are required for technical purposes, frequency conversion or generation equipment can be installed. The facility user will normally provide this equipment.

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CHAPTER 3 POWER DISTRIBUTION AND UTILIZATION

3-1 TRANSFORMERS.

The transformer design criteria provided herein apply to interior applications and to dry-type transformers fed by distribution traditionally placed in/for the facility downstream of the main service. Most facilities will be supplied by an exterior utility system pad-mounted transformer.

Interior transformers shall be sized according to the NEC.

3-1.1 Low Voltage Transformers.

Specify dry-type transformers in accordance with NEMA ST 20 and the following:

- For transformers rated for 15 kVA or larger, use transformers with a 428 degrees F (220 degree C) insulation system not to exceed a 239 degrees F (115 degree C) rise capable of carrying continuously 115 percent of nameplate kVA without exceeding insulation rating at a maximum ambient temperature of 104 degrees F (40 degrees C). Provide a transformer of 80 degrees C temperature rise capable of carrying continuously 130 percent of nameplate kVA without exceeding insulation rating when additional overload capacity is required.
- Transformers rated less than 15 kVA can use a 356 degrees F (180 degree C) insulation system not to exceed an 176 degrees F (80 degree C) rise at a maximum ambient temperature of 104 degrees F (40 degrees C).
- When the transformer is located in areas where noise is a factor, specify sound levels at least 3 decibels below recommended values established by NEMA ST 20.
- Derate the transformer in accordance with the manufacturer’s guidance for locations with a maximum ambient temperature above 104 degrees F (40 degrees C) and in accordance NEMA ST 20 for altitudes higher than 3,300 feet (1,000 meters).

Include the following as part of the installation:

- Design system such that transformer vibrations are not transmitted to the surrounding structure. Small transformers can usually be solidly mounted on a reinforced concrete floor or wall. Flexible mounting will be necessary if the transformer is mounted to the structure in a normally low-ambient noise area.
- Use flexible couplings and conduit to minimize vibration transmission through the connection points.

- Locate the transformer in spaces where the sound level is not increased by sound reflection. For example, in terms of sound emission, the least desirable transformer location is in a corner near the ceiling because the walls and ceiling function as a megaphone.
- Provide adequate ventilation in transformer spaces to prevent the temperature rise from exceeding the transformer rating.

Refer to TSEWG TP-05, Interior Transformer Ratings and Installation, at https://wbdg.org/dod/supp-tech-documents for additional information regarding transformers and transformer ratings.

3-1.2 Other Transformer Types.

Do not use unless justified and documented in the design analysis. Refer to Appendix B for additional guidance for applications involving significant harmonic distortion.

3-2 SERVICE ENTRANCE AND DISTRIBUTION EQUIPMENT.

Locate service entrance equipment and other major electrical equipment in a dedicated electrical space. Provide a main breaker on each service entrance either outside of a building or structure or inside nearest the point of entrance of the service conductors in accordance with NFPA 70. Service feeders may be installed under the building only when necessary or for optimal routing. Distances shall be minimal. Locate other electrical equipment, such as electrical panels, in dedicated spaces.

Note: Identify when 100 percent rated circuit breakers are included in the design.

Size circuit breaker interrupting ratings based on the available short circuit current; however, do not select circuit breakers less than 10 kA symmetrical interrupting rating for voltages 240V and below and 14 kA symmetrical interrupting rating for 480V applications. The use of series-rated combinations of breakers to clear a fault that utilize an individual breaker rated at less than the available fault current is prohibited.

Do not use fusible overcurrent devices except when non-fusible overcurrent devices will not comply with NFPA 70 requirements for selective coordination.

3-2.1 Spare Capacity.

Provide a minimum of 15% empty space and 15% spare capacity (ampacity) for all switchgear, switchboards, panelboards, and load centers. For flush-mounted equipment, provide spare conduits extending up above the ceiling and down below raised floors when applicable. For panelboards, provide one spare conduit, minimum of ¾-inch (20 mm), for every three spare circuit breakers and for every three empty pole positions. Round up the sum of spare breakers and empty pole positions to the nearest multiple of three.

Note: Do not use spare capacity as part of the demand calculations specified in UFC 3-501-01. The overall calculations already account for this spare capacity with the 15% allowance for future load growth specified in UFC 3-501-01 load analysis calculations for the service entrance.

3-2.2 Selection.

Select equipment as follows:

- Specify metal-enclosed switchgear when the equipment is 1200A or larger, and branch and feeder circuits are above 400A or if any branch or feeder circuits is larger than 800A.
- Specify switchboards when the equipment feeds circuit breakers 800A or larger. Utilize switchboards throughout the distribution system where equipment is 1200A or larger.
- Specify distribution system type panelboards when the equipment is 800 – 1200A. Utilize panelboards up to 600A if they can be accommodated in one enclosure.

For all circuit breakers where the continuous current trip setting for the actual overcurrent device in the circuit breaker is rated for or can be adjusted is 1,200 amperes or higher, select the method used to reduce the clearing time for arc energy reduction:

- Zone-selective interlocking, or
- Differential relaying, or
- Energy-reducing maintenance switching with local status indicator, or
- Energy-reducing active arc flash mitigation system or
- An approved equivalent means.

3-2.3 Switchgear.

Design metal-enclosed switchgear per IEEE C37.20.1 and UL 1558. Provide electrically operated circuit breakers. The switchgear and circuit breakers must be the product of the same manufacturer.

Evaluate the following options as part of the switchgear design:

- Arc-resistant switchgear tested and certified to IEEE C37.20.7 to provide added protection for internal arcing faults.
- Infrared viewing windows to allow the use of an infrared camera or thermal imager direct line of site to inspect electrical connections without requiring the opening of panels and doors.
- A remote racking mechanism to allow an operator to rack a circuit breaker in or out at least 20 feet from the front of the equipment.

- Drawout compartment shutters to protect operators from accidental contact with breaker stabs when a circuit breaker is withdrawn from its cubicle.
- Evaluate medium-voltage gas-insulated switchgear (GIS) with vacuum circuit breakers when the facility owner requires more than 99.9% availability, or the switchgear must fit in a small footprint. GIS switchgear must be tested and certified per IEEE C37.20.9

3-2.4 Switchboards.

Design switchboards per NEMA PB2 and UL 891. Devices must be front accessible and must be completely isolated between sections by vertical steel barriers. Switchboards should have hinged fronts to allow safer maintenance access for electrical safety.

3-2.5 Panelboards.

3-2.5.1 Configuration.

Equip panelboards and load centers with separate ground bus bars and insulated neutral bus bars to isolate the bus bar, when required by code. Circuit breakers must be bolt-on type unless where specifically indicated otherwise for load center type panelboards. Do not use dual section panelboards.

Do not use panelboards or load centers with more than 54 poles unless any of the following conditions are met.

- All of the loads are served by a redundant source, or
- The customer accepts in writing the risk of larger outages and the AHJ approves the larger panelboard or load center.

Distribution and branch circuit panelboards should be of the wall-mounted, dead-front type, equipped with bolt-on circuit breakers. Load center style panelboards, with plug-in breakers should be used only where authorized for military family housing. Each panelboard and load center style panelboard must be fed from a dedicated circuit and circuit breaker.

3-2.5.2 Location and Design.

Place panelboards as close as possible to the center of the loads to be served. Provide panelboards with hinged fronts to allow safer maintenance access for electrical safety. Clearly fill out panelboard circuit directories indicating the specific load and location, such as “Lights, Room 102”.

Optimize equipment layout and circuit arrangement. Optimization shall include grouping together circuits going to the same space or area of the building. The phase loading on panelboards shall be balanced as much as practical by the type of loads on the panel.

Take into consideration circuit breaker frame size mismatching when arranging circuits across from each other, as well as additional pole spaces required for specialty features such as 3-pole GFCI electronics and shut trip devices.

3-2.5.3 BEQ/BOQ Facilities and Housing.

Use panelboards for service entrance equipment and electrical distribution in BEQ/BOQ facilities. Load center style panelboards, with plug-in breakers, can be used in housing units and BEQ/BOQ rooms.

3-2.5.4 Arc-Fault Circuit Interrupters.

Provide arc-fault circuit interrupter protection for branch circuits supplying 120V, single-phase,15A and 20A outlets installed in dwelling units as specifically required by NFPA 70.

3-2.6 Motor Control Centers (MCCs).

Comply with UL 845 and NEMA ICS 2.

3-2.7 Power for Fire Protection Systems.

Fire pump and fire pump controller power supply shall satisfy the requirements of NFPA 70 and UFC 3-600-01 rather than the requirements of this subpart.

Provide power for the remainder of the fire protection systems, including fire alarm and mass notification systems, suppression and containment control panels, line voltage indicator systems (such as beacons), transmitter panel, and similar monitoring, control, and reporting equipment but excluding fire pumps and fire pump controllers in accordance with NFPA 72, NFPA 70 Article 760, and as follows:

a. Distribution Configuration(s). A dedicated distribution leg (or multiple legs) shall be supplied from the main distribution equipment to support the fire protection system components described above if either of the following conditions are present:

   1. The building area exceeds 25,000 square feet.

   2. Six or more circuits are required to supply the fire protection system components on a given voltage system (i.e., 208/120V, 480/277V, etc.).

   Circuits for components directly supporting the fire protection components, such as surge protective devices and receptacles in the immediate vicinity of and whose purpose is to perform maintenance on the fire protection components, shall be permitted to be supplied from the dedicated equipment.

   In all other cases, the fire protection system components may be suppled from the portions of the distribution equipment present for other building electrical support, and such distribution components must comply with the succeeding requirements of this section.

Where multiple fire protection circuits are supplied from the same panel not dedicated exclusively to fire protection systems described above, connect the fire protection circuits to physically adjacent pole locations.

Where fire protection circuits for larger equipment (such as nitrogen generators or jockey pumps) are connected to the building main distribution equipment or the main distribution equipment for a backup power system, such circuits do not contribute toward the number of circuits in the threshold listed above. The succeeding requirements apply to the circuits connected directly to the main distribution equipment described in the paragraph.

b. Protection and Control Features. Provide lock-on circuit breakers for all feeders and branch circuits supplying fire protection system components described above. Start providing the lock-on circuit breakers from the load side of the service disconnecting means. Permanently identify in red the lock-on breakers in the branch panelboards, distribution equipment, and dedicated panelboards without obstructing manufacturer's markings on the breakers.

c. Distribution System Identification. At the distribution equipment, including panelboards, distribution panels, switchboards, switchgear, transformers, enclosed circuit breakers, disconnect switches, transfer switches, and similar equipment which are part of the electrical supply to components described above, provide a label with the following inscription in addition to the equipment nameplate: "Fire Protection/Life safety Equipment." Construct and fasten the label identical to the panelboard nameplate, except the label must be red laminated plastic with white center core. The service disconnecting means shall not require this supplemental nameplate.

d. Backup Power Sources. For facilities which are provided with emergency power supplies (i.e., engine-driven generator, energy storage system, etc.) supporting life safety functions, fire protection described above must be powered by the backup power supply system. Do not power fire protection systems from UPS systems dedicated to specific compartmentalized functions such as individual telecommunications rooms.

3-2.8 Disconnect Switches.

Fusible disconnect switches should be used only where special considerations require their use. Provide heavy duty type safety switches on systems rated for greater than 240V. Use fused switches that utilize Class R fuseholders and fuses. Use NEMA 4X stainless steel switch enclosures for switches located on building exteriors in areas where salt spray or extended high humidity is a concern.

Utilize non-fused disconnect switches as local disconnects only, properly protected by an upstream protective device.

Note: Selection of disconnect switches must be coordinated with the short circuit calculations. Non-fused disconnects are typically rated to only 10kAIC. In cases where the fault current at a disconnect location is greater than 10KAIC, provide one of the following solutions:

a. Fused disconnect.

b. Enclosed circuit breaker.

c. If NFPA 70 permits for a given application, eliminate the local disconnecting means and provide a lockable circuit breaker at the panel.

3-2.9 Circuit Lockout Requirements.

Circuit breakers, disconnect switches, and other devices that are electrical energy-isolating must be lockable in accordance with NFPA 70E and OSHA 1910.303.

3-2.10 Signage.

Place a safety sign on any cubicles containing more than one voltage source. Refer to ANSI Z535.4 for safety sign criteria.

3-2.11 Interrupting Ratings.

Refer to TSEWG TP-06, Low Voltage Breaker Interrupting Ratings, at https://wbdg.org/dod/supp-tech-documents for additional information regarding low voltage breaker interrupting ratings.

3-2.12 Load Balancing by Phase.

Arrange circuits throughout the distribution system with 5% or less design load imbalance for both single- and three-phase systems. Show load imbalance by phase as a percentage on the panel, switchboard, switchgear, and motor control center schedules. Larger facilities generally will be capable of better phase balancing than smaller facilities. Document within the design analysis the instances where phase balancing below the imbalance threshold is not possible and state the reasons, tradeoffs, and/or broader remedies.

3-2.13 Adjustable Trip Devices.

Where adjustable-trip devices are used and NFPA 70 does not permit use of the maximum trip setting, conductors must be sized with the rated capacity equal to the actual device setting. Perform arc flash calculations based on the actual device setting. In design-bid-build projects, provide contract language requiring the contractor to adjust conductor sizes at the direction of the designer of record should the trip setting on the adjustable devices deviate from the rating indicated on the plans in cases such as complying with selective coordination requirements.

Note: NFPA 70 limits the maximum trip rating for equipment such as transformers and motors. It is also possible for the circuit breaker's trip setting to exceed the bus rating.

Provide labeling on the adjustable-trip device indicating the maximum value to which the conductors are capable of safely carrying after all applicable correction and adjustment factors were applied and voltage drop calculations performed. Additionally, provide warning of the potential for different arc flash conditions should the adjustable trip rating be altered.

Size equipment grounding conductors and perform voltage drop calculations based on the respective approach used: Where the rating is based on restricted access, use the actual setting; where the rating is based on unrestricted access, use the maximum setting possible.

3-3 MOTORS AND MOTOR CONTROL CIRCUITS.

3-3.1 Basic Motor Criteria.

3-3.1.1 Efficiency.

Apply premium efficiency ratings per the Energy Policy Act of 2005 (EPACT 2005) to all motors.

3-3.1.2 Application.

Use three-phase motors if more than 0.5 horsepower rating when such service is available. If three-phase service is not available or if three-phase motor is not available, operate motors larger than 0.5 horsepower at phase-to-phase voltage rather than phase-to-neutral voltage. Motors 0.5 horsepower and smaller must be single phase.

Do not use 230V motors on 208V systems because the utilization voltage will commonly be below the -10% tolerance on the voltage rating for which the motor is designed (a 230V motor is intended for use on a nominal 240V system).

3-3.2 Motor Control Circuits.

3-3.2.1 Motor Controllers.

Provide motor controllers (starters) for motors larger than 1/8 horsepower (93.25 watts) and apply the design criteria of NEMA ICS 1 and NEMA ICS 2.

3-3.2.2 Motor Starting.

Use full voltage-type starting unless the motor starting current will result in more than a 20% transient voltage dip or if the analyzed voltage dip is otherwise determined to be unacceptable. For other than full voltage starting, apply one of the following methods for motor starting:

- Reduced Voltage Starters.
- Adjustable Speed Drives (ASDs) are also referred to as Variable Frequency Drives (VFDs). If an ASD is required for other reasons, it can also address motor starting current design needs. Refer to NEMA ICS 7 for design criteria related to the selection and design of ASDs. Appendix A provides additional information regarding the sizing and operational design of ASDs.

3-3.2.3 Manual Control.

Provide manual control capability for all installations having automatic control that operates the motor directly. Use a double-throw, three-position switch or other suitable device (marked MANUAL-OFF-AUTOMATIC) for the manual control. Confirm that all safety control devices, such as low- or high-pressure cutouts, high-temperature cutouts, and motor overload protective devices, remain connected in the motor control circuit in both the manual and automatic positions.

3-4 SURGE PROTECTIVE DEVICES (SPDS).

Provide SPDs for surge protection of sensitive or critical electronic equipment, as required by the activity or equipment manufacturer.

The design criteria provided here apply to permanently installed, hard-wired surge protectors and should not be applied to plug-in type surge protectors (Type 3). Use point-of-use (plug-in type) surge protectors to protect specific critical equipment that plugs into wall receptacles.

3-4.1 Power System Surge Protection.

Use Type 1 or Type 2 SPD and connect on the load side of a dedicated main circuit breaker of the associated equipment. Where multiple service main disconnects are used the device(s) should be placed as recommended by the manufacturer to protect the circuits. Locate as close as practical to the breaker with a maximum lead length of 3 ft (900 mm). Integral SPDs with surge counters visible from the dead front of the panelboard and manufactured by the panelboard manufacturer are permitted. The SPDs must be rated as Type 1 or Type 2 and comply with UL 1449. The SPDs must include the thermal protection measures and overcurrent protection per UL 1449.

For buildings with high concentrations of electronics equipment, employ a multi-level or cascaded system. Coordinate multiple stage surge protection.

Note: Type 1 SPDs are allowed to be installed ahead of the service entrance MCB when other equipment is required to be connected ahead of the MCB.

3-4.1.1 Service Entrance Surge Protection.

Provide the following specification requirements for SPD on the service entrance equipment

a. Use SPD to protect the electrical service entrance equipment.

b. The SPD must meet or have a voltage protection rating that is less than the UL 1449 voltage protection ratings listed below. If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

System Voltage	Protection Modes	Voltage Protection Rating
208/120 or 240/120	L-N	700
	L-G	700
	N-G	700
	L-L	1,200
480/277	L-N	1,200
	L-G	1,200
	N-G	1,200
	L-L	2,000

c. Per mode single pulse surge current rating for an 8x20 ms waveform must be no less than:

L-N 40kA

L-G 40kA

N-G 40kA

L-L 80kA

d. Protection Mode: Provide the following six modes (additional modes are permitted):

Line-to-line

Line-to-ground or line-to-neutral

Wire SPDs at grounded service entrances in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, connect the SPD elements line-to-ground (L–G).

e. MCOV for L-N and L-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% of nominal voltage above 240 volts to 480 volts.

f. Surge Life: Greater than 5000 surges of repetitive sequential IEEE C62.41 Category C3 waveforms with less than 10% degradation of measured limiting voltage.

g. Listing: The total unit as installed must be UL 1283 and UL 1449 listed, and not merely the components or modules.

h. Warranty: Not less than a 5-year warranty and include unlimited free replacements of the unit if destroyed by lightning or other transients during the warranty period.

i. Diagnostics: Visual indication unit has malfunctioned or requires replacement. Provide Form C dry contacts for remote monitoring.

3-4.1.2 Branch Panelboard Surge Protection.

Provide the following specification requirements for SPD on all the branch panelboards for facilities requiring cascaded suppression system protection.

a. Use SPD to protect the distribution branch panelboards.

b. The SPD must meet or have a voltage protection rating that is less than the UL 1449 voltage protection ratings listed below.

System Voltage	Protection Modes	Voltage Protection Rating
208/120 or 240/120	L-N L-G N-G L-L	700 700 700 1,200
480/277	L-N L-G N-G L-L	1,200 1,200 1,200 2,000

c. Per mode single pulse surge current rating for an 8x20 ms waveform must be no less than:

L-N 40kA

L-G 40kA

N-G 40kA

L-L 80kA

d. Protection Mode: Provide the following six modes (additional modes are permitted):

Line-to-line

Line-to-ground or line-to-neutral

Wire SPDs at grounded service entrances in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, connect SPD elements line-to-ground (L–G).

e. MCOV for L-N, L-G, and N-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% of nominal voltage above 240 volts to 480 volts.

f. Surge Life: Greater than 5000 surges of repetitive sequential IEEE C62.41 Category B3 waveforms with less than 10% degradation of measured limiting voltage.

g. Listing: The total unit as installed must be UL 1283 and UL 1449 listed, and not merely the components or modules.

h. Warranty: Not less than a 5-year warranty and include unlimited free replacements of the unit if destroyed by lightning or other transients during the warranty period.

i. Diagnostics: Visual indication unit has malfunctioned or requires replacement. Provide Form C dry contacts for remote monitoring.

3-4.1.3 Dwelling Unit Surge Protection.

Install as close as practical to the main breaker/lugs. All leads must be as short as possible, with no leads longer than 24 in (610 mm). Provide protection in accordance with branch panelboard surge protection criteria listed above.

3-4.2 Surge Protection for Communications and Related Systems.

3-4.2.1 Systems Requiring Protection.

Provide surge protection for the following systems, including related systems:

- Fire alarm systems.
- Telephone systems.
- Computer data circuits.
- Security systems.
- Television systems.
- Coaxial cable systems.
- Intercom systems.
- Electronic equipment data lines.

3-4.2.2 Protection Levels.

Provide surge protection equipment used for communications and related systems as follows:

- If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

- If surge protection is not required as part of a lightning protection system, provide the following protection UL Listed and tested to UL 497A, or third party verified and tested to UL 497A:
    - o Telephone communication interface circuit protection – provide a minimum surge current rating of 9,000A.
    - o Central office telephone line protection – provide multi-stage protection with a minimum surge current rating of 4,000A.
    - o Intercom circuit protection – provide a minimum surge current rating of 9,000A. Provide protection on points of entry and exit from separate buildings.
- Provide fire alarm and security alarm system loops and addressable circuits that enter or leave separate buildings, UL Listed or third-party verified and tested to UL 497B, with a minimum of 9,000A surge current rating.
- Protect coaxial lines at points of entry and exit from separate buildings.
- Single stage gas discharge protectors can be used for less critical circuits. Multistage protectors utilizing a gas discharge protector with solid-state secondary stages should be used to obtain lower let-through voltages for more critical equipment.

3-4.3 Acceptance Tests.

Perform the following installation checks:

- Inspect for physical damage and compare nameplate data with drawings and specifications.
- Verify that the surge protector rating is appropriate for the voltage.
- Inspect for proper mounting and adequate clearances.
- Verify that the installation achieves the minimum possible lead lengths. Inspect the wiring for loops or sharp bends that add to the overall inductance.
- Check tightness of connections by using a calibrated torque wrench. Refer to the manufacturer’s instructions or Table 10-1 of International Electrical Testing Association (NETA) ATS for the recommended torque.
- Check the ground lead on each device for individual attachment to the ground bus or ground electrode.
- Perform insulation resistance tests in accordance with the manufacturer’s instructions.

- For surge protectors with visual indications of proper operation (indicating lights), verify that the surge protector displays normal operating characteristics.
- Record the date of installation.

3-5 METERING.

Provide advanced metering systems (e.g., with remote reading, monitoring, or activation capabilities) in accordance with service-specific criteria and the DoD directives to comply with EPACT 2005 requirements. Coordinate meters, system components, and meter locations to be compatible with the Activity's central system.

Upon Activity request, limit housing units to meter sockets only. Sockets must be single phase, four terminal, and ring-less with manual bypass device and polycarbonate blank cover plate.

3-6 RACEWAY AND WIRING.

3-6.1 Wiring Devices.

Wiring devices and faceplate colors must match and be consistent with the interior wall types and colors. Use grounding type wiring devices. Outlet boxes must not be placed back-to-back. Provide a minimum of 12 inch (300 mm) of separation between outlet boxes located on opposite sides on common walls.

3-6.1.1 Switches.

Toggle switches must be specification grade, quiet type, and rated minimum 120/277V, 20A, totally enclosed with bodies of thermoplastic and/or thermoset plastic and mounting strap with grounding screw. Use silver-cadmium contacts and one-piece copper alloy contact arm.

When specified, pilot lights must be integrally constructed as a part of the switch's handle.

3-6.1.2 Receptacles.

Provide general purpose convenience outlets that are specification grade, 20 A, 120 V, duplex. Identify locations where split receptacles will be used with one receptacle controlled by a separate manual or automatic switching device. Provide GFI and AFCI protection in accordance with NFPA 70.

Where required by ASHRAE 90.1, all workstations and work areas must have controlled and non-controlled outlets. For non-systems furniture, duplex receptacles must be split yoke with controlled and non-controlled outlets. Duplex receptacle outlets must be fed from the same circuit. Double duplex receptacles must have controlled and non-controlled outlets fed from the same circuit, but split yoke outlets are not required. Note that GFCI receptacles typically cannot be split wired where both split wiring and GFCI are required. Provide either a GFCI device ahead of the wiring split (such as at the panelboard) or provide a double duplex arrangement where each yoke has a GFCI feature.

In addition to the location requirements specified by NFPA 70, locate general purpose, and dedicated (on an individual circuit) outlets in accordance with the following:

a. Mechanical equipment: Provide receptacle within 25 ft (7.6 m) of mechanical equipment on the interior and exterior of buildings, including roof mounted mechanical equipment.

b. Office, staff-support spaces, and other workstation locations: Minimum of two duplex receptacles, one double duplex, or one quadraplex receptacle for each workstation. Where systems furniture is not to be provided, provide double duplex receptacles a minimum of every 20-ft (5.2 m) of wall space at the floor line. Where there is less than 20-ft (5.2 m) of wall at the floor line in offices and where there are no other provisions for powering workstations (such as with systems furniture), provide a minimum of two duplex receptacles spaced appropriately to anticipate furniture relocations. Limit loads to a maximum of four (4) workstations per 20A circuit.

c. Conference rooms and training rooms: One for every 12 ft (3.6 m) of wall space at the floor line. Ensure one receptacle is located next to each voice/data outlet in all areas of the room (floor, wall, and ceiling). Provide one receptacle in the ceiling, faceplate flush with ceiling, to support video projection device, if necessary, and one receptacle in the wall to support a wall mounted monitor. Extend circuit to wall location for connection to motorized screen. When it is expected that a conference room table will be specifically dedicated to floor space in a conference room, ensure not less than one (1) floor-mounted receptacle is located under the table. This receptacle may be part of combination power/communications outlet. Ensure signal pathway exists between conference room table and wall or ceiling mounted displays.

d. Provide power outlets throughout the building to serve all proposed equipment, including government furnished equipment, and allow for future reconfiguration of equipment layout. Provide power connections to all ancillary office equipment such as printers, faxes, plotters, and shredders. Provide dedicated circuits where warranted.

e. In each telecommunications room provide a dedicated 20A circuit with a receptacle adjacent to each rack or backboard for each of the following:

   - CCTV for training systems
   - CCSTV for security systems
   - CATV

- Voice systems
- Data systems.

f. Provide receptacles supplying television monitors on circuits dedicated for such equipment and associated specialty equipment. Multiple receptacles, television monitors, and associated specialty equipment receptacles may be connected to the same circuit dedicated to this purpose provided the total connected load satisfies the limits permitted by NFPA 70 for a standard 15- or 20-amp receptacle circuit as applicable. These outlets will typically be located near the ceiling level for wall mounted television monitors.

g. Corridors: One every 50 ft (15 m) with a minimum of one per corridor.

h. Janitor’s closet and toilet rooms: One GFI receptacle per closet. Provide GFI receptacles at counter height for each counter in toilets such that there is a minimum of one outlet for each two sinks.

i. Space with counter tops: One for every 4 ft (1.2 m) of countertop, with a minimum of one outlet.

j. Building exterior: GFCI protected, weather-resistant (WR) and identified as extra-duty, within 25 ft (7.5 m) of each exterior door and near HVAC equipment in accordance with NFPA 70 requirements. An exception to the requirement for a receptacle in proximity to each exterior door is permitted for doors providing direct entrance into living units for barracks and dormitories. In such cases, one is to be provided for every 50 ft (15 m) wall length with a minimum of one per exterior wall; additionally, one is to be installed within 10 ft (3m) of each exterior door which does not provide direct entrance into a living unit.

k. Kitchen non-residential: One for each 10 ft (3 m) of wall space at the floor line.

l. Dwelling units, Child Development Centers, and other child occupied spaces (including toilets): Provide listed tamper-resistant receptacles.

m. All other rooms: One for every 25 ft (7.6 m) of wall space at the floor line. When 25 ft (7.6 m) or less of wall at the floor line exists in a room, provide a minimum of two receptacles spaced appropriately to anticipate furniture relocations.

n. Special purpose receptacles: Coordinate with the user to provide any special purpose outlets required. Provide outlets to allow connection of equipment in special use rooms.

o. Permanently installed equipment: Do not use cord and plug connections for permanently installed equipment in areas requiring GFI-protected receptacles. Provide hard-wired connections instead.

3-6.2 Cable and Raceway Criteria.

3-6.2.1 Installation.

Minimum permitted size conduit permitted is 1/2 in (15 mm). Provide an insulated green equipment grounding conductor or supply-side bonding jumper for all circuit(s) installed in raceways. Do not rely on the metallic raceway as the only boding path. Conceal raceways above ceilings and in finished areas that have finished walls or finished surfaces.

The above minimum conduit size does not apply to conduit that is part of a factory installed assembly, such as lighting fixtures.

3-6.2.2 Approved Cable and Raceway Types.

Specify cables and raceway in accordance with NFPA 70 as follows:

- The Uses Permitted are as modified by Table 3-1.
- The Uses Not Permitted are:
    - As specified in NFPA 70.
    - When restricted by other UFCs for specific types of buildings such as medical facilities.

For instances where NFPA 70 does not allow an installation based on “subject to physical damage” or “subject to severe physical damage,” refer to Appendix C-2 for baseline definitions of these conditions.

Provide a plan in the contract documents that graphically depicts the areas subject to physical damage or subject to severe physical damage along with the descriptions (such as the heights given in Appendix C-2) for installation purposes. Alternatively, as another option, provide a narrative list in the specifications indicating such descriptions in the portion of the specifications pertaining to areas subject to physical damage and subject to severe physical damage, respectively.

Table 3-1 Authorized Cable and Raceway Types

NFPA 70 Article	Raceway/Cable Type	Authorization
320	AC – Armored Cable	Prohibited for feeder circuits. Prohibited for embedded locations. Allowed for branch circuits only in the following dry locations: • New construction in exposed locations. • Renovations in exposed locations. • Concealed in renovations in existing areas where walls and ceilings are not disturbed. • Cable trays.
322	FC – Flat Cable Assemblies	Authorized.
324	FCC – Flat Conductor Cable	Authorized.
326	IGS – Integrated Gas Spacer Cable	Prohibited.
328	MV – Medium Voltage Cable	Authorized. For interior applications, MV cable must be installed in raceway or a fully enclosed cable tray. Refer to UFC 3-550-01 for additional applications.

NFPA 70 Article	Raceway/Cable Type	Authorization
330	MC – Metal-Clad Cable	Prohibited for feeder circuits other than feeder circuits for aerial messengers between buildings. Prohibited for embedded or direct buried locations. Prohibited for concealed locations, except as allowed below. Allowed for branch circuits only in the following dry locations: • New construction in exposed locations. • Renovations in exposed locations. • Concealed in renovations in existing areas where walls and ceilings are not disturbed. • Cable trays.
332	MI – Mineral-Insulated, Metal-Sheathed Cable	Authorized.
334	NM, NMC, NMS – Nonmetallic-Sheathed Cable	Allowed only in one- and two-family dwellings and their attached or detached garages, and their storage buildings.
336	TC – Power and Control Tray Cable	Authorized.
338	SE, USE – Service-Entrance Cable	Authorized.
340	UF – Underground Feeder and Branch-Circuit Cable	Prohibited.
342	IMC – Intermediate Metal Conduit	Authorized.
344	RMC – Rigid Metal Conduit	Authorized. Only threaded-type fittings are allowed for wet and damp locations.

NFPA 70 Article	Raceway/Cable Type	Authorization
348	FMC – Flexible Metal Conduit	Flexible metal conduit can be used, limited to 6 ft length, for recessed and semirecessed lighting fixtures; for equipment subject to vibration; and for motors other than pumps. Use liquidtight flexible metal conduit in damp and wet locations and for pumps.
350	LFMC – Liquidtight Flexible Metal Conduit	Use LFMC where authorized for FMC in damp and wet locations and for pumps.
352	PVC – Rigid Polyvinyl Chloride Conduit	Authorized. Minimum allowed size is PVC Schedule 40. For exterior use, comply with UFC 3-550-01.
353	HDPE – High Density Polyethylene Conduit	For exterior use only. Comply with UFC 3-550-01.
354	NUCC – Nonmetallic Underground Conduit with Conductors	Authorized only for exterior branch circuits and for feeder circuits between buildings.
355	RTRC – Reinforced Thermosetting Resin Conduit	Authorized.
356	LFNC – Liquidtight Flexible Nonmetallic Conduit	Prohibited.
358	EMT – Electrical Metallic Tubing	Specify EMT for branch circuits and feeders above suspended ceilings or exposed where not subject to severe physical damage. Only steel or stainless steel EMT may be used where subject to physical damage. Do not use EMT underground, encased in concrete, mortar or grout, in hazardous locations, where exposed to physical damage, outdoors or in fire pump rooms.
360	FMT – Flexible Metallic Tubing	Prohibited.
362	ENT – Electrical Nonmetallic Tubing	Prohibited.
366	Auxiliary Gutters	Authorized and must be listed for the application.

NFPA 70 Article	Raceway/Cable Type	Authorization
368	Busways	Authorized. For low voltage busway, provide UL 857 listed busway. For medium voltage busway, comply with IEEE C37.23.
370	Cablebus	Authorized.
372	Cellular Concrete Floor Raceways	Authorized. Requires a unique Unified Facilities Guide Specification to be developed as part of any design.
374	Cellular Metal Floor Raceways	Authorized. Requires a unique Unified Facilities Guide Specification to be developed as part of any design.
376	Metal Wireways	Authorized and must be listed for the application.
378	Nonmetallic Wireways	Authorized. *Note: The UFC definition of "subject to physical damage" prohibits the use of nonmetallic wireways for exterior applications installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.*
380	Multioutlet Assembly	Authorized for building improvements or renovations, or for applications where a variety of cord-and-plug connected equipment will be utilized in a limited space, such as in some areas of medical facilities, shops, and laboratories. Authorized for Sensitive Compartmented Information Facilities (SCIF) to limit the number of electrical penetrations through the SCIF boundary.
382	Nonmetallic Extensions	Prohibited.
384	Strut-Type Channel Raceway	Authorized.

NFPA 70 Article	Raceway/Cable Type	Authorization
386	Surface Metal Raceways	Authorized for use only for building improvements or renovations, or for applications where a variety of cord-and-plug connected equipment will be utilized in a limited space, such as in some areas of medical facilities, shops, and laboratories. Authorized for Sensitive Compartmented Information Facilities (SCIF) to limit the number of electrical penetrations through the SCIF boundary.
388	Surface Nonmetallic Raceways	Prohibited.
390	Underfloor Raceways	Authorized for listed underfloor raceways.
392	Cable Trays	Authorized. Provide and maintain a minimum of 12 inches (300 mm) access headroom above a cable tray system and a minimum of 18 inches (450 mm) side access clearance on one side of the cable tray system. The AHJ may approve side and top encroachments totaling up to 3 feet (914 mm) in a 20-foot (6096 mm) section of cable tray provided the encroachments do not prohibit access to raceways that feed into the tray.
393	Low-Voltage Suspended Ceiling Power Distribution Systems	Authorized.
394	Concealed Knob-and-Tube Wiring	Prohibited.
396	Messenger-Supported Wiring	Authorized only for exterior applications.
398	Open Wiring on Insulators	Prohibited.
399	Outdoor Overhead Conductors over 1000 Volts	Authorized.

3-6.2.3 Enclosures and Hazardous Locations.

Refer to TSEWG TP-08, Electrical Equipment Enclosures and Hazardous Locations, at https://www.wbdg.org/dod/supp-tech-documents

3-6.3 Conductors.

3-6.3.1 Baseline Requirements.

Specify conductors in accordance with NFPA 70 and the following:

- Conductors #6 AWG and smaller must be copper. Aluminum conductors of equivalent ampacity can be used instead of copper for #4 AWG and larger sizes.
- Feeder and branch circuit conductors, including power and lighting applications, will in no case be less than #12 AWG. Provide branch circuit breakers rated for 20 amperes minimum, except where lesser ratings are required for specific applications, such as fractional horsepower motor circuits.
- Circuit conductors must be sized based on the 60 degrees C ampacity for circuits rated 100 amperes or less (#12 AWG through #1 AWG) and the 75 degrees C ampacity for circuits rated over 100 amperes (larger than #1 AWG).
    - Higher temperature ampacity ratings for conductors may only be used for ampacity adjustment or correction as permitted by NFPA 70.
    - Where conductor sizing for ambient temperature correction is based on an insulation value greater than 60 degrees C for circuits rated 100 amperes or less (#12 AWG through #1 AWG) and greater than 75 degrees C ampacity for circuits rated over 100 amperes (larger than #1 AWG), explicitly indicate such in the contract documents for the circuits deviating from this convention.
    - All sizing for ampacity shall incorporate ambient temperature corrections and current-carrying conductor adjustments. Indicate whether neutral conductors are current-carrying elements.

3-6.3.2 Conductor Sizing Adjustment.

- Adjust conductor size and/or insulation type based on the ambient temperature anticipated to be encountered on the logical circuit routing path. Utilize NFPA 70 correction factors and exceptions in conductor sizing determinations. Utilize information from the Air Force Engineering Weather Data website (https://climate.af.mil/) or similar data sources such as ASHRAE for location-specific historical temperature information.

Coordinate with the HVAC designer to determine expected maximum ambient temperatures in each building space, including ceiling cavities and plenums where conductors will be routed, perimeter walls, and the building exterior. Do not assume less than 78 degrees F (25 degrees C) for ambient temperature correction factors.

Note: Recommend documenting these determinations graphically on a plan using the applicable temperature ranges for which adjustments are made in NFPA 70 Article 310 for graphical depiction. Require further adjustments to be made during construction based on the contractor exercising their routing discretion for routing not explicitly shown. Indicate on the contract documents the ambient temperature the design considered for sizing conductors and require further adjustments should the contractor's final routing path traverse an area of higher ambient temperature.

Note: Circuits are typically sized individually and consolidation of circuits into a common raceway may occur during construction, requiring further adjustments to be made during construction based on the contractor exercising their discretion to consolidate multiple circuits into a common raceway for lengths exceeding the exception threshold for adjustments and corrections in NFPA 70. Indicate on the contract documents the number of conductors the design considered to be current carrying. This information is useful when resizing conductors due to potential circuit consolidation.

- For voltage drop requirements, see UFC 3-501-01.
- For ambient temperature and voltage drop calculations, include anticipated routing of circuits in all directions (lateral and vertical). Unless explicitly identified to be installed in such a manner, do not assume underground routing will occur for conductor sizing factor purposes; overhead routing will typically require additional circuit lengths. Assume conduit routing at right angles to the building structure unless specifically shown on the plans; diagonal routing may be used for calculations only if indicated on the plans.

  Note: Routing concept adapted from the ASHRAE 90.1 User's Manual. This estimate should account for any known conditions shown on the plans including room and structure geometry.
- Where conductor size increases to mitigate voltage drop exceed the maximum permitted by a given device termination, the conductor size may be reduced to terminate properly in accordance with manufacturer requirements. Select splice kits, junctions, cable-reducing adapters, etc., to accommodate the increased wire size. Where a conductor size has been adjusted to mitigate voltage drop and conductor size reduction is required, the following restrictions will apply:

- The total length of conductor to be reduced below the size adjusted to mitigate voltage drop must not exceed 10 feet or 10 percent of the circuit length, whichever is less.
- Conductors must not be reduced below the maximum size permitted by the terminations in question.
- Conductors must not be reduced in size smaller than required by ambient temperature and current-carrying conductor ampacity corrections and adjustments; utilize increased conductor insulation as necessary.
- Alternatively, increase the equipment frame size to a class that will accommodate the termination of larger conductor sizes. This strategy may be used in combination with adapters for conductors whose size was increased to account for voltage drop, ampacity correction, or adjustment factors. Do not adjust the overcurrent protection ratings as a result of the frame size increase.

3-6.4 Wiring Annotation.

When using homerun symbols, point the homerun symbol in the general direction of the source equipment. Combine one-pole branch circuits to minimize number of homeruns.

3-7 LIGHTING.

Design lighting, including ASHRAE 90.1 criteria, in accordance with UFC 3-530-01.

3-8 GENERATORS.

Comply with UFC 3-540-01.

Coordinate with the Activity to establish marking requirements for receptacles and panelboards served by backup power systems.

3-9 AUTOMATIC TRANSFER EQUIPMENT.

Comply with UFC 3-540-01. Refer to NFPA 99 for any transfer switch applications involving medical facilities.

Refer to TSEWG TP-09, Automatic Transfer Equipment, at https://www.wbdg.org/dod/supp-tech-documents for additional information regarding ATS design and application.

3-10 UNINTERRUPTIBLE POWER SUPPLY.

Uninterruptible power supply (UPS) selection and sizing information is in TSEWG TP-19, Static Uninterruptible Power Supply, at the following site: https://www.wbdg.org/dod/supp-tech-documents

3-11 STATIONARY BATTERIES AND BATTERY CHARGERS.

3-11.1 Selection.

3-11.1.1 Vented Lead Acid Batteries.

Use vented lead acid batteries preferentially for switchgear control power and UPS applications. Batteries for switchgear or backup power applications should be rated for general purpose, switchgear, or utility use. Batteries for UPS applications should be rated for UPS or high-rate use.

3-11.1.2 Valve-Regulated Lead Acid Batteries.

As a general practice, do not use a valve-regulated lead acid (VRLA) battery if a vented lead-acid battery will satisfy the design and installation requirements. VRLA batteries have exhibited a shorter service life than vented equivalents and have shown a tendency to fail without warning. Refer to IEEE Std 1189 for additional information regarding the unique failure modes and shorter service life of this battery type. For the Air Force, refer also to AFPAM 32-1186 for additional information regarding VRLA batteries.

3-11.1.2.1 Allowed Applications.

VRLA batteries are allowed to be used in the following types of applications:

- Installations with small footprints such that a vented battery with adequate power density will not fit within the available space.
- Locations in which the consequences of electrolyte leakage cannot be allowed. UPS systems are often located in areas that necessitate the use of a VRLA battery.

3-11.1.2.2 Prohibited Applications.

Do not use VRLA batteries in the following types of applications:

- Unregulated environments that can experience abnormally high and low temperatures.
- Unmonitored locations that seldom receive periodic maintenance checks. VRLA batteries have shown a tendency to fail within only a few years after installation.

- Critical applications, unless the installation location requires the features available only in a VRLA battery.

3-11.1.3 Nickel-Cadmium Batteries.

Nickel-cadmium batteries are often more expensive than vented lead-acid batteries and should be considered primarily for extreme temperature environments or engine-starting applications. Nickel-cadmium batteries are preferred for engine starting applications because of their high-rate discharge capability and their more predictable failure modes.

3-11.1.4 Lithium Batteries.

Do not use lithium-ion, lithium metal polymer, or other lithium-based batteries for stationary applications in occupied buildings.

3-11.1.5 Battery Life for Life-Cycle Cost Analyses.

Apply the following service life for life-cycle cost comparisons of stationary batteries (small would be facility generators and large would be facility energy storage systems):

- Small VRLA batteries – 3 years.
- Large VRLA batteries – 7 years.
- Small vented lead acid batteries – 10 years.
- Large vented lead acid batteries – 15 years.
- Nickel-cadmium batteries – 15 years.

3-11.2 Battery Areas and Battery Racks.

Comply with UFC 3-520-05.

3-11.3 Installation Design.

3-11.3.1 Industry Standards.

Review the following IEEE standards, as applicable for the battery type, prior to the installation:

- IEEE Std 450—provides maintenance and test criteria for vented lead acid batteries.
- IEEE Std 484—provides installation criteria for vented lead acid batteries.
- IEEE Std 485—defines battery sizing requirements for lead acid batteries.

IEEE Std 1106—provides maintenance and test criteria for nickel cadmium batteries.

- IEEE Std 1115—defines battery sizing requirements for nickel cadmium batteries.
- IEEE Std 1184—provides application and sizing criteria for UPS applications.
- IEEE Std 1187—provides installation criteria for valve-regulated lead acid batteries.
- IEEE Std 1188—provides maintenance and test criteria for valve-regulated lead acid batteries.
- IEEE Std 1189—explains application limitations for valve-regulated lead acid batteries.

Note: the above industry standards apply to lead acid and nickel cadmium batteries. There are no industry standards available yet for the selection, specification, sizing, design, installation, maintenance, and testing of lithium-ion, lithium metal polymer, or other lithium-based batteries for stationary applications.

3-11.3.2 Design Requirements.

Size the battery in accordance with IEEE Std 485, IEEE Std 1115, or IEEE Std 1184 as appropriate for the selected battery type and application.

Refer to TSEWG TP-04, Stationary Battery and Charger Sizing, at https://www.wbdg.org/dod/supp-tech-documents for additional information regarding battery sizing principles.

3-11.3.3 Installation Requirements.

Design and install the battery in accordance with IEEE Std 484, IEEE Std 1187, or IEEE Std 1106 as appropriate for the selected battery type. Refer to the above industry standards and NETA ATS for acceptance test criteria.

3-11.3.4 Battery Chargers.

Use single-phase chargers for smaller applications. Rate single-phase battery chargers for 240V single phase, unless only 120V is available. Use three-phase chargers if the charger’s dc output current rating will be greater than 75A. Unless the battery has specific requirements to the contrary, all chargers should be of the constant voltage type.

3-11.3.5 Battery Protection.

Install a circuit breaker or fused protection device as close to the battery as possible.

Provide overcurrent protection for each string in a parallel battery system. Refer to IEEE Std 1375 for additional guidance.

3-12 GROUNDING, BONDING, AND STATIC PROTECTION.

The below requirements apply for the identified subset of acceptable techniques.

3-12.1 Ground Rods.

3-12.1.1 Design.

For ground rod composition, minimum spacing requirements and connections, conform to requirements of NFPA 70 Article 250 except that minimum ground rod dimensions are 10 feet (3.0 m) in length and ¾ inch (19 mm) diameter. Provide copper-clad steel, solid copper, or stainless steel ground rods.

3-12.1.2 Connections.

All connections to ground rods below ground level must be by exothermic weld connection or with a high compression connection using a hydraulic or electric compression tool to provide the correct circumferential pressure. Accessible connections above ground level and in test wells can be accomplished by clamping.

3-12.1.3 Spacing and Location.

Spacing for driving additional grounds must be a minimum of 10 ft (3.0 m). Bond these driven electrodes together with a minimum of 4 AWG soft drawn bare copper wire buried to a depth of at least 12 in (300 mm).

Install ground rods (and ground ring, if applicable) 3 ft to 8 ft (0.9 m to 2.4 m) beyond the perimeter of the building foundation and at least beyond the drip line for the facility. If another UFC requires the installation of one or more ground rods inside a facility, follow the requirements specified in that UFC.

3-12.2 Ground Rings.

Coordinate requirements for the ground ring of a lightning protection system with UFC 3-575-01. Provide a ground ring (counterpoise) for facilities with sensitive electronic equipment or other applications when identified by project requirements.

Provide a ground ring with at least two ground rods located diagonally at opposite corners. When required by a specific activity or facility, provide a ground rod at each change in direction of the ground ring and install test wells for at least two of the corner ground rods to allow for testing of the system. Assemble test wells with bolted connections to facilitate future testing.

3-12.3 Communication-Electronics Facilities.

Provide grounding electrode systems for Communications-Electronics (C-E) facilities in accordance with MIL-HDBK 419A when identified by project requirements.

3-12.4 Static Electricity Protection.

Comply with UFC 3-575-01 for static protection requirements.

3-12.5 Aircraft Hangars.

Refer to UFC 3-575-01 for grounding criteria for power systems and static electricity protection for aircraft hangars.

3-12.6 Ammunition and Explosive Storage Magazines.

Refer to UFC 4-420-01 and NAVSEA OP 5 for Navy project for grounding, bonding, and lightning protection criteria.

3-13 LIGHTNING PROTECTION SYSTEMS.

Provide lightning protection systems in accordance with UFC 3-575-01.

3-14 400-HERTZ DISTRIBUTION SYSTEMS.

Design 400 hertz power systems in accordance with UFC 3-555-01.

3-15 270-VOLT DC DISTRIBUTION SYSTEMS.

System requirements are specified in UFGS 26 35 44.

3-16 POWER FACTOR CORRECTION.

The power factor within a facility is normally 0.9 lagging or greater; therefore, power factor correction is not routinely required for interior electrical systems. However, if the facility design incorporates large motor applications or other specific loads that may adversely affect the power factor, provide an evaluation that includes the considerations identified in TSEWG TP-02, Capacitors for Power Factor Correction, at https://www.wbdg.org/dod/supp-tech-documents.

If the evaluation supports the need for power factor correction, contact the AHJ for authorization prior to providing power factor correction equipment.

3-17 POWER QUALITY.

Design secondary electrical systems to mitigate the harmonic effects of non-linear loads as a result of connections to electronic loads, including computer work stations, file servers, UPS, and electronic ballasts. Refer to Appendix B for power quality design criteria.

3-18 SYSTEMS FURNITURE.

3-18.1 Planning.

When systems furniture is utilized, the electrical designer, the architect, and the interior designer must coordinate during the design process. Systems furniture is typically specified and ordered when construction is nearing completion; therefore, if proper coordination has not occurred earlier in the design process, field interface problems will occur.

3-18.2 Design.

Systems furniture is pre-wired to a wiring harness. Unless specified otherwise, select a standard wiring harness that meets one of the following configurations:

- 8-wire harness consisting of 3 circuit conductors, 3 neutral conductors and 2 equipment grounding conductors.
- 10-wire harness consisting of 4 circuit conductors, 4 neutral conductors and 2 separate equipment grounding conductors.

Serve 8-wire harnesses with 2 separate circuits and 10-wire harnesses with 4 separate circuits. Provide harnesses that have a neutral conductor per phase conductor and a green ground conductor. Balance loads between circuits and phases. A single circuit must not serve more than 4 workstations under any circumstances.

3-19 ASHRAE COMPLIANCE.

Verify per UFC 1-200-02 the version of ASHRAE 90.1 that is currently used.

Provide automatic receptacle control in accordance with ASHRAE 90.1. The detailed electrical energy monitoring requirements of ASHRAE 90.1are permissible on projects when authorized in writing by the activity in order to coordinate with their existing industrial controls program.

3-20 ELECTRIC VEHICLE SUPPLY EQUIPMENT.

Provide Electric Vehicle Supply Equipment (EVSE) for Government Owned Vehicle (GOEV) for Type 1, Type 2, and Type Direct Current (dc) Fast Charging complying with requirements of NFPA 70.

3-20.1 Site and Equipment Considerations.

The following are some of the site and equipment issues that must be considered when designing for a EVSE installation.

3-20.1.1 Physical Protection of EVSE.

Provide wheel stops or bollards for physical protection in front of EVSE when curbing of sidewalks is not present.

3-20.1.2 Signage for EVSE.

Provide signage as indicated by Manual on Uniform Traffic Control Devices (MUTCD), that indicates EVSE.

3-20.1.3 Avoiding Hazards.

Cords and wires associated with EVSE should not interfere with pedestrian traffic or present tripping hazards. Charging spaces should not be located near potentially hazardous areas.

3-20.1.4 Ventilation.

When EVSE is located in an enclosed space, there must be adequate ventilation, which may include installation of fans, ducts, and air handlers. Verify the installation and ventilation requirements with the manufacturer's documentation.

3-20.1.5 Battery Temperature Limits.

Because some EV batteries have operating and charging temperature limits, EVSE may need to be located within an enclosed, climate-controlled area in extreme climates. Verify resulting installation environment is compatible with EVSE manufacturer's installation requirements.

3-20.1.6 Metering.

Separate or sub-metering for electricity used by EVSE may be a requirement so that vehicle charging can be isolated from the rest of a building or structure's energy usage. Verify if metering is a requirement with the activity.

APPENDIX A ADJUSTABLE SPEED DRIVES

A-1 ADJUSTABLE SPEED DRIVES (ASD).

A-1.1 ASD Sizing.

At the rated full load of the driven equipment, the output voltage and frequency of the ASD should be the same as the motor's rating. Note that this design requirement places limits on the motor design; the motor should not have a significantly higher full load horsepower or speed rating than the driven load. Mismatches can easily cause operational problems, including efficiency losses and increased ASD input current. In extreme cases, a mismatch can cause the ASD to trip on overcurrent during motor starting or cause the ASD input current to be substantially higher than the design without the ASD.

The ASD short term current rating should be adequate to produce the required motor starting torque, including loads with high starting torque.

A-1.2 Motor Considerations.

Specify a motor with a minimum 1.15 service factor or ensure the motor is rated well above the actual load it will carry. Verify with the manufacturer that the motor is capable of acceptable operation with an ASD. Standard motors can often operate down to 50% of rated speed, high efficiency motors can often operate down to 20% of rated speed, and "inverter duty" motors can operate below 20% of rated speed without problems in a variable load application.

A-1.3 Power Quality.

Ensure that the final installation does not create voltage or current harmonic distortion beyond acceptable limits. Take power quality field measurements after installation to confirm that the system total harmonic distortion is not degraded beyond acceptable levels. If the ASD can be provided power from a standby generator upon loss of normal commercial power, the harmonic distortion evaluation must include the system effects when powered from the standby generator.

Voltage sags can cause nuisance tripping. Ensure that the ASD either has a minimum of 3 cycle ride-through capability or automatic reset circuitry.

A-1.4 Capacitor Switching Effects.

Nearby capacitor switching can cause transient overvoltages, resulting in nuisance tripping. In this case, ensure the ASD either has input filtering to reduce the overvoltage or automatic reset circuitry.

A-1.5 Bypass Capability.

Important applications should include bypass operation capability to allow motor operation independent of the ASD.

APPENDIX B POWER QUALITY

B-1 INTRODUCTION.

Unlike other electrical design requirements, power quality design solutions are very dependent on the types of transients and disturbances that can and will occur in power systems. In many cases, it will be easier to provide protection and power quality design features to specific equipment rather than generically throughout the facility.

B-2 UNBALANCED VOLTAGES.

Evaluate the loading on each phase and balance the loads as well as possible. As part of acceptance testing, monitor the degree of unbalance and make corrections if necessary.

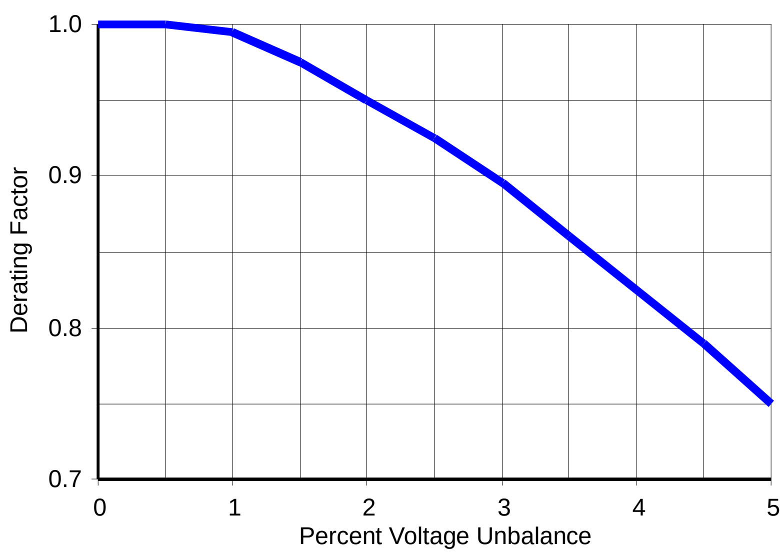
B-2.1 Calculation.

Calculate voltage unbalance as follows:

B-2.2 Effect on Motors.

The rated load capability of three-phase equipment is reduced by voltage unbalance. Figure B-1 shows a typical derating factor for three-phase induction motors as a function of voltage unbalance.

Figure B-1 Typical Derating Factor for Three-Phase Induction Motors



B-3 HARMONIC DISTORTION EVALUATION.

If a significant number of nonlinear loads are installed in the facility, perform a harmonic distortion evaluation during the facility design phase. If the effect of nonlinear loads is expected to be minor, a detailed harmonic distortion evaluation is not required.

IEEE Std 519 provides the industry-accepted method of evaluating harmonic voltages and currents. IEEE Std 519 provides system level guidance, not equipment specific guidance; harmonic distortion limits are established for the facility and the installation of any equipment should not degrade the system to beyond acceptable levels

B-4 DERATING TRANSFORMERS FOR HARMONIC CURRENT EFFECTS.

Whenever significant nonlinear loads are expected in a facility, evaluate the system in accordance with IEEE C57.110 to determine if transformer derating will be required. For transformers without a k-factor rating, derating must be used to determine the maximum fundamental load current that the transformer can maintain with the additional harmonic currents.

Note: Derating applies to the full-load capability of the transformer when applied in an environment containing significant harmonic distortion. If the transformer is not fully loaded, the derating process might have little or no practical significance unless it is expected that the transformer will eventually be fully loaded. Nationwide surveys indicate average loading levels for dry-type transformers of between 35% for commercial facilities and 50% for industrial facilities. Military facilities are commonly loaded to less than 25% of the service entrance transformer full-load capability during periods of peak demand.

If it is determined that a transformer will require derating because of harmonic distortion, perform the following additional reviews:

- Verify the expected transformer loading assumptions for a new design or actual metering data for an existing design to confirm that the transformer is fully loaded; most transformers are never fully loaded.
- Determine if the harmonic distortion environment can be improved by design changes for the most offending loads.
- If the transformer requires more than 10% derating, evaluate the feasibility of installing a new transformer designed for a harmonic distortion environment (harmonic mitigating transformer). Include delivery and replacement time scheduling as well as cost in the evaluation.
- If transformer derating is the selected option, annotate the percent derating on the applicable design drawings and install a label near the transformer nameplate indicating that the transformer has been derated. The purpose of these actions is to prevent inadvertent overloading of the transformer in the future.

B-5 NONLINEAR LOAD DESIGN CONSIDERATIONS.

Analyze planned electrical loads on new projects to determine whether or not they are considered potential nonlinear loads with high harmonic content. The following guidelines are provided if nonlinear loads are a significant portion of the total load.

- Derate transformer, motor, and generator outputs if necessary to prevent overheating or burnout. Ensure that design documents and equipment nameplates reflect the derated capability.
- If standby generators represent the only power source upon loss of normal power, the generator design must account for nonlinear loads.
- Use a single three-phase transformer with common core, delta connected primary and wye connected secondary instead of three single-phase transformers connected for three-phase service. Evaluate the use of a harmonic mitigating transformer if a standard transformer has to be derated by more than 10%.

  Note: Refer to TSEWG TP-05, Interior Transformer Ratings and Installation, at https://www.wbdg.org/dod/supp-tech-documents *for additional information regarding harmonic mitigating transformers.*

- Specify harmonic filters as necessary to minimize the localized effects of harmonics. If separate harmonic filters are installed specifically to protect against offending loads, locate each filter as close to each load as practical.
- Specify true RMS sensing meters, relays, and circuit breaker trip elements.

Analysis alone will not always adequately predict power quality problems. Refer to IEEE Std 1159 for additional information regarding power quality monitoring.

B-6 NEUTRAL CIRCUIT SIZING FOR NONLINEAR LOAD CONDITIONS.

Minimize neutral circuit overheating by specifying separate neutral conductors for line-to-neutral connected nonlinear loads with high harmonic content. Treat the neutral conductors as current carrying conductors in the design analysis. When a shared neutral conductor must be used for three-phase, four-wire systems, size the neutral conductor to have an ampacity equal to at least 1.73 times the ampacity of the phase conductors.

Two paralleled, full size neutral conductors can be used to obtain the required neutral ampacity for conductors sized #1/0 AWG and larger. Size the neutral conductor between the transformer and all downstream distribution equipment to be a minimum of 1.73 times the ampacity of the phase conductors. Select panelboards that have been rated for nonlinear loads.

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APPENDIX C GLOSSARY

C-1 ACRONYMS.

A	Amperes
AC	Alternating Current
AC	Armored Cable
AFCI	Arc Fault Current Interrupter
AFPA	Air Force Pamphlet
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ASD	Adjustable Speed Drive
ATS	Automatic Transfer Switch
AWG	American Wire Gauge
BEQ	Bachelor’s Enlisted Quarters
BOQ	Bachelor’s Officer Quarters
CCTV	Closed Circuit Television
CATV	Cable Television
CFR	Code of Federal Regulations
COPS	Critical Operations Power System
Dc	Direct Current
DCOA	Designated Critical Operations Area
EGSA	Electrical Generating Systems Association
EMT	Electrical Metallic Tubing
ENT	Electrical Non-Metallic Tubing
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment

FC	Flat Cable Assemblies
FCC	Flat Conductor Cable
FMC	Flexible Metal Conduit
FMT	Flexible Metallic Tubing
Ft	Feet
GFI	Ground Fault Circuit Interrupter
GRS	Galvanized Rigid Steel
HDPE	High Density Polyethylene Conduit
HID	High Intensity Discharge
Hz	Hertz
IEEE	formerly Institute of Electrical and Electronics Engineers
IMC	Intermediate Metal Conduit
kA	Kilo-Amperes
kVA	Kilo-Volt-Amperes
kW	Kilowatt
LFMC	Liquidtight Flexible Metal Conduit
LFNC	Liquidtight Flexible Nonmetallic Conduit
M	Meter
MCC	Motor Control Center
MCOV	Maximum Continuous Overvoltage Rating
Mm	Millimeter
MC	Metal-Clad Cable
MI	Mineral-Insulated, Metal-Sheathed Cable
MV	Medium Voltage Cable
NAVFAC	Naval Facilities Engineering Systems Command

NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NETA	International Electrical Testing Association
NFPA	National Fire Protection Association
NM, NMC, NMS	Nonmetallic-Sheathed Cable
NUCC	Nonmetallic Underground Conduit with Conductors
OSHA	Occupational Safety and Health Administration
PVC	Rigid Polyvinyl Chloride Conduit
RMC	Rigid Metal Conduit
RMS	Root-Mean-Square
RTRC	Reinforced Thermosetting Resin Conduit
SCIF	Sensitive Compartmented Information Facilities
SE, USE	Service-Entrance Cable
SPD	Surge Protective Devices
SWD	Switching Duty
TC	Power and Control Tray Cable
TSEWG	Tri-Service Electrical Working Group
UF	Underground Feeder and Branch-Circuit Cable
UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
USACE	U.S. Army Corps of Engineers
V	Volts
VFD	Variable Frequency Drive (see ASD)
VRLA	Valve-Regulated Lead Acid

C-2 DEFINITION OF TERMS

Note: The terms listed here are provided for clarification of the design criteria provided in this UFC. Refer to IEEE Std 100 for additional electrical-related definitions.

Automatic Transfer Switch (ATS): A switch designed to sense the loss of one power source and automatically transfer the load to another source of power.

Branch Circuit: The circuit conductors and components between the final overcurrent device protecting the circuit and the equipment.

Closed Transition Switch: Transfer switch that provides a momentary paralleling of both power sources during a transfer in either direction. The closed transition is possible only when the sources are properly interfaced and synchronized.

Existing Facility: A facility is existing if changes to be made are cosmetic or minor in nature.

Harmonic: A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.

Linear Load: An electrical load device that presents an essentially constant load impedance to the power source throughout the cycle of applied voltage in steady-state operation.

Listed: Applies to equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction. The organization periodically inspects production and certifies that the items meet appropriate standards or tests as suitable for a specific use.

Low Voltage System: An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage System: An electrical system having a maximum RMS AC voltage of 1,000 volts to 34.5 kV. Some documents such as ANSI C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Molded Case Circuit Breaker: A low voltage circuit breaker assembled as an integral unit in an enclosing housing of insulating material. It is designed to open and close by nonautomatic means, and to open a circuit automatically on a predetermined overcurrent, without damage to itself, when applied properly within its rating.

Motor Control Center: A piece of equipment that centralizes motor starters, associated equipment, bus and wiring in one continuous enclosed assembly.

New Construction: A facility is considered new if changes to be made are more than cosmetic or minor, such as major renovations, additions, or new facilities.

Nonlinear Load: A steady state electrical load that draws current discontinuously or has the impedance vary throughout the input ac voltage waveform cycle. Alternatively, a load that draws a nonsinusoidal current when supplied by a sinusoidal voltage source.

Power Quality: The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.

Service Voltage: Voltage at the facility service entrance location.

Short Circuit: An abnormal condition (including an arc) of relatively low impedance, whether made accidentally or intentionally, between two points of different potential.

Subject to Physical Damage (or Subject to Severe Physical Damage): Locations that are subject to physical damage or severe physical damage include:

- Exposed interior raceways installed less than 6 ft above finished floor elevation where personnel are operating mechanized equipment on a recurring basis. Mechanized equipment that might be operated on a recurring basis includes vehicles, carts, forklifts, and pallet-handling units.
- Exposed exterior raceways installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.
- Exposed raceways where personnel operate mobile or fixed-in-place hoisting equipment.

Surge Protector: A device composed of any combination of linear or nonlinear circuit elements and intended for limiting surge voltages on equipment by diverting or limiting surge current; it prevents continued flow of current and is capable of repeating these functions as specified.

Transfer Switch: A device for transferring one or more load conductor connections from one power source to another.

Uninterruptible Power Supply System: A system that converts unregulated input power to voltage and frequency controlled filtered ac power that continues without interruption even with the deterioration of the input ac power.

Utilization Voltage: The voltage at the line terminals of utilization equipment.

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APPENDIX D REFERENCES

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UFC 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Applications*

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ANSI C84.1, *Electric Power Systems Voltage Ratings (60 Hz)*

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IEEE C37.20.7, *IEEE Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*

IEEE C37.20.9, *IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems*

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UL 497A, *Standard for Secondary Protectors for Communications Circuit*

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UFC 3-520-02
27 July 2023
Change 1, 29 January 2025

UNIFIED FACILITIES CRITERIA (UFC)

FACILITY ENERGY SYSTEM RESILIENCE AND RELIABILITY

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UNIFIED FACILITIES CRITERIA (UFC)

FACILITY ENERGY SYSTEM RESILIENCE AND RELIABILITY

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	January 2025	Narrowed the applicability to existing and updated C5ISR-type facilities. Added references UFC 4-141-03 for new C5ISR-type facilities. Added references to the Component Technical Representative for certain decisions. Adds reliability requirements for communication pathways to remote monitoring and control stations. References Appendix D to obtain component reliability data.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Unified Facilities Criteria (UFC) documents provide planning, design, construction, sustainment, restoration, and modernization criteria. They also apply to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. The United States Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC) and the Office of the Air Force Civil Engineer are responsible for administration of the UFC system. This is one of those documents.

Resilience is “the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.” When applying resilience principles to the design and operation of critical facilities, it is useful to incorporate tools for evaluating the effectiveness of existing and proposed system designs or upgrades. The purpose of this document is to describe quantitative methods for evaluating the resilience of an existing or proposed designs for the electrical, Mechanical and Controls for Critical Facilities.

1-2 PURPOSE AND SCOPE.

This document summarizes current knowledge, research related to backup power system reliability, and identified best cost options in areas for R&D investment. The scope of this document is electrical systems, cooling systems (chilled water systems, condenser water systems, and all other aspects for facility cooling) and control systems.

1-3 APPLICABILITY.

This UFC follows the same applicability as UFC 1-200-01, APPLICABILITY for C5ISR facilities.

\1\ See UFC 4-141-03 for specific design requirements for new C5ISR facilities. /1/

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-6 GLOSSARY.

APPENDIX E contains acronyms, abbreviations, and terms.

1-7 REFERENCES.

APPENDIX F contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 RESILIENCE

2-1 RESILIENCE.

2-1.1 Prepare, Absorb, Recover and Adapt.

RESILIENCE is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. When applying resilience principles to the design and operation of critical facilities, it is useful to incorporate tools for evaluating the effectiveness of existing and proposed system designs or upgrades. The purpose of this chapter is to describe quantitative methods for evaluating the resilience of an existing or proposed design.

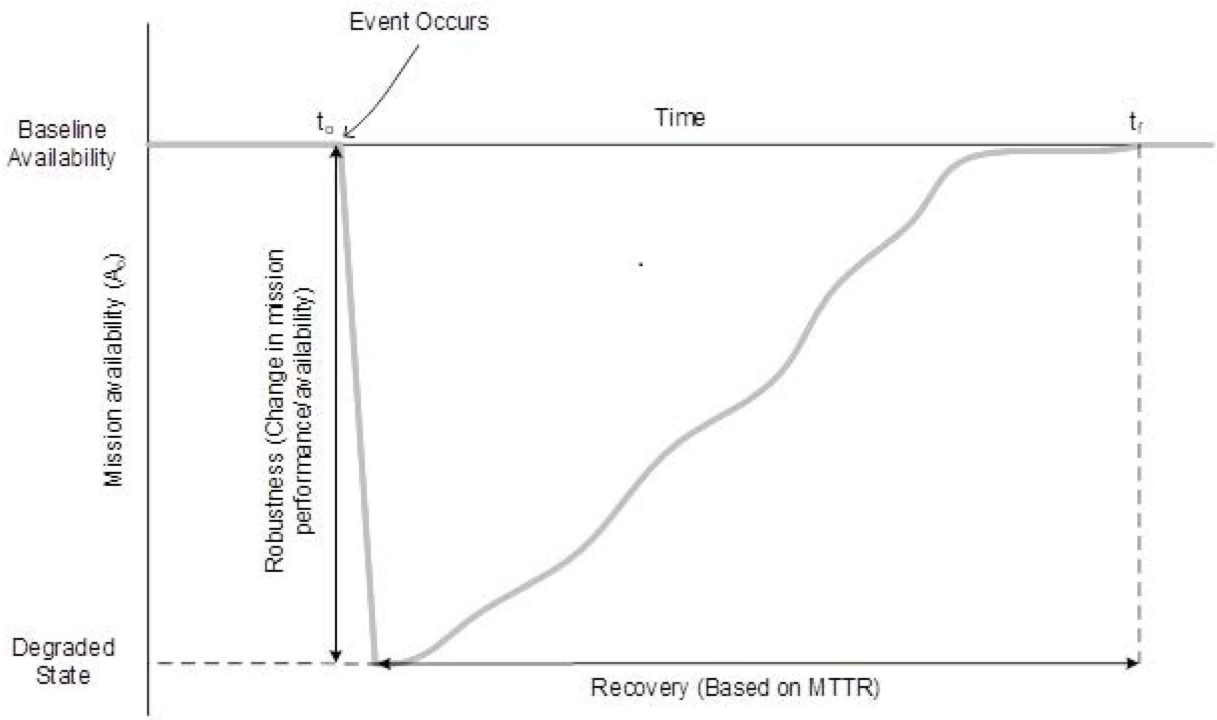
2-1.2 Considerations.

System operational considerations and the nature of events to be considered may dictate the preferred measure of availability for evaluating a given event. For example, hurricanes are often closely tracked and forecasted, allowing for several days or even weeks of advance notice prior to arrival. This can provide time for workers to delay or back out of planned maintenance tasks. In this situation, the availability of the system is more representative of its inherent availability. For disturbances which occur without warning such as seismic events, it may be more useful to consider operational availability as this is more representative of normal day-to-day operations. For the purposes of this discussion, the following examples will refer to operational availability.

2-1.3 Absorption and Recovery.

Using availability concepts, the overall resilience of a system can be quantified in two phases: absorption of the event, and recovery. Consider an event occurring as shown in Figure 2-1.

Figure 2-1 System Response to a Disruptive Event



Immediately following the event, there is a sharp drop in mission availability. The change in mission availability from the baseline to the degraded state represents the robustness of the system to that particular event. The lower the change in mission availability, the more robust the system. The time required to restore the system to its baseline state is referred to as recovery. This is based on the mean-time-to-repair (MTTR) of any assets affected by the event and may be affected by several factors including site remoteness, event severity, and environmental conditions. The overall resilience, R(t) of the system to any particular event can be quantified according to the area under the curve as shown in Equation 2-1. By this model, a perfectly resilient system would have resilience index value of zero.

Equation 2-1. Resilience

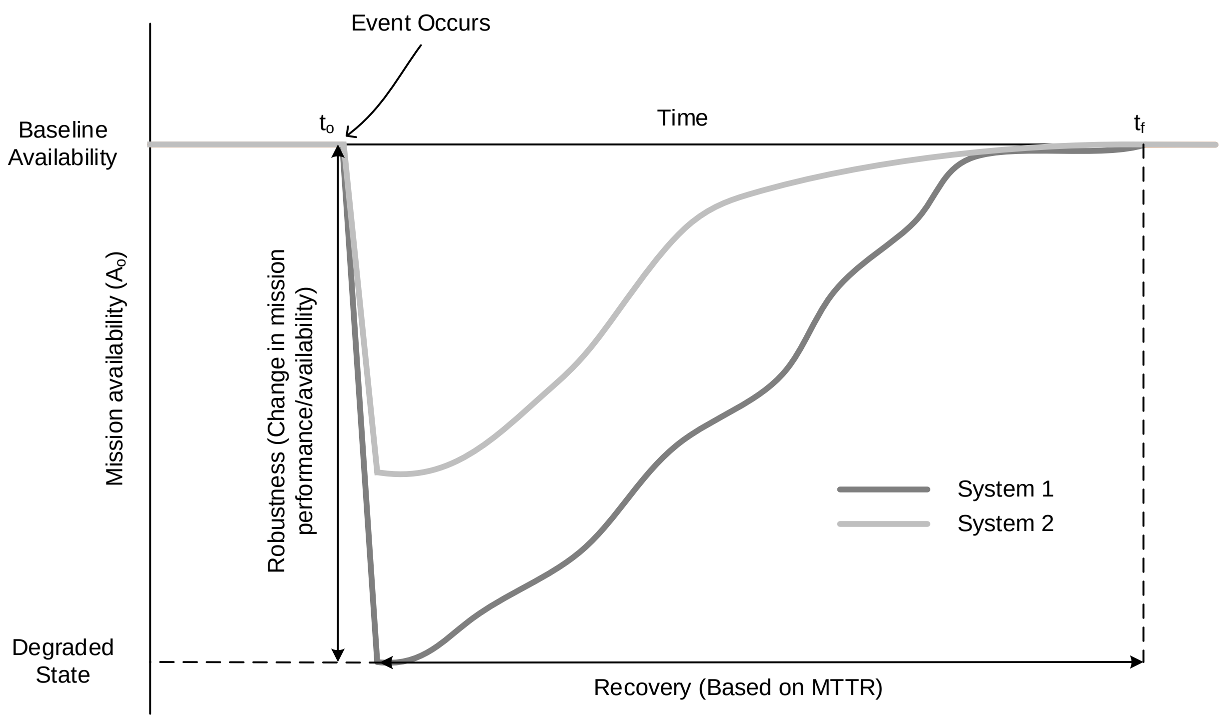
$$R(t) = \int_{t_o}^{t_f} A_o(t)dt$$

Where:
R(t) = resilience
t_f = time required to restore (hours)
t_o = time event occurs (hours)
A_o = mission availability
(t) = time (hours)
dt = downtime (hours)

2-1.4 Prioritizing Robustness or Recovery.

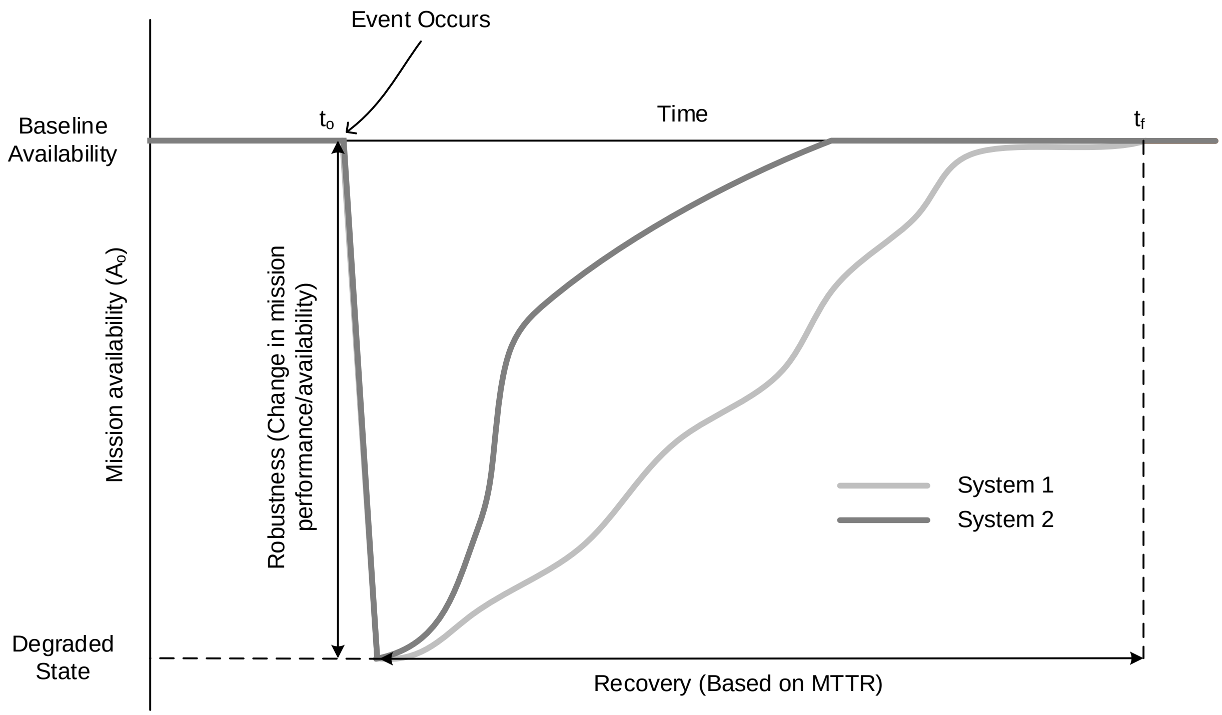
Depending on mission needs, it may be more important to prioritize either robustness or recovery. For those installations with limited availability of repair parts and personnel, consider prioritizing robustness. Where resources are more readily available, consider prioritizing recovery, provided that the minimum requirements for mission functions are satisfied. Figure 2-2 shows two systems with different levels of resilience. The two systems have the same recovery time, but System 2 has a lower initial decrease in mission availability. System 2 is more resistant to the postulated event and is more resilient than system 1 despite having the same recovery time. This may be beneficial for improving overall resilience at remote sites where recovery time is limited by the physical demand of getting replacement parts to the site.

Figure 2-2 Two System with Different Robustness



In other cases, it may be more important to prioritize recovery from an event as opposed to robustness. Figure 2-3 shows two systems with similar robustness to an event, but different recovery times. Though both systems have the same ability to absorb the shock from the event, the shorter recovery time for System 2 yields less area under the curve. Accordingly, System 2 can be said to be more resilient than System 1. The difference between the system responses shown in Figure 2-2 and Figure 2-3 demonstrate that similar improvements in overall resilience can be achieved by improving either robustness or recovery. Consider site-specific factors such as duration of backup power supplies and minimum equipment requirements when determining an optimal resilience improvement strategy.

Figure 2-3 Two Systems with Different Recovery Time



2-1.5 Availability Definitions.

Availability is defined as the percentage of time that a system is available to perform its required function(s). It is measured in a variety of ways, but it is principally a function of downtime. Availability can be used to describe a component or system, but it is most useful when describing the nature of a system of components working together. Because it is a fraction of time spent in the “available” state, the value can never exceed the bounds of $0 < A < 1$. Thus, availability will most often be written as a decimal, as in 0.99999, as a percentage, as in 99.999%, or equivalently spoken, “five nines of availability.” Chapter 5 contains a detailed discussion of availability.

2-1.5.1 Operational Availability (A_O).

Another equation for availability directly uses parameters related to the reliability and maintainability characteristics of the item as well as the support system. Equation 2-2 reflects this measure.

Equation 2-2. Operational Availability

$$A_0 = \frac{MTBM}{MDT + MTBM}$$

Where:
A_o = operational availability
MTBM = mean time between maintenance (hours)

MDT = mean downtime (hours)

2-1.5.2 Inherent Availability (A_i).

In Equation 2-2, MTBM includes all maintenance required for any reason, including repairs of actual design failures, repairs of induced failures, cases where a failure cannot be confirmed, and preventive maintenance. When only maintenance required to correct design failures are counted and the effects of the support system are ignored, the result is inherent availability, which is given by Equation 2-3.

Equation 2-3. Inherent Availability

$$A_i = \frac{MTBF}{MTTR + MTBF}$$

Where:
A_i = *inherent availability*
MTBF = mean time between failure
MTTR = mean time to repair

2-1.6 Reliability.

Reliability is concerned with the probability and frequency of failures (or more correctly, the lack of failures). A commonly used measure of reliability for repairable systems is the mean time between failures (MTBF). The equivalent measure for non-repairable items is mean time to failure (MTTF). Reliability is more accurately expressed as a probability of success over a given duration of time, cycles, etc. For example, the reliability of a power plant might be stated as 95% probability of no failure over a 1000-hour operating period while generating a certain level of power. (Note that the electrical power industry has historically not used the definitions given here for reliability. The industry defines reliability as the percentage of time that a system is available to perform its function, such as, availability. The relationship between reliability and availability is discussed in paragraph 2-1.8.)

2-1.7 Maintainability.

Maintainability is defined as the measure of the ability of an item to be restored or retained in a specified condition. Maintenance should be performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. Simply stated, maintainability is a measure of how effectively and economically failures can be prevented through preventive maintenance and how quickly system operation can be restored following a failure through corrective action. Note that maintainability is not the same as maintenance. Maintainability is a design parameter, while maintenance consists of actions to correct or prevent a failure event.

2-1.8 Relationship Among Reliability, Maintainability, and Availability.

Perfect reliability (such as, no failures, ever, during the life of the system) is difficult to achieve. Even when a "good" level of reliability is achieved, some failures are expected. The effects of failures on the availability and support costs of repairable systems can be minimized with a "good" level of maintainability. A system that is highly maintainable can be restored to full operation in a minimum of time with a minimum expenditure of resources.

2-1.8.1 Inherent Availability.

Inherent availability is when only reliability and corrective maintenance or repair (such as, design) effects are considered. This level of availability is solely a function of the inherent design characteristics of the system.

2-1.8.2 Operational Availability.

Availability is determined not only by reliability and repair, but also by other factors related to preventative maintenance and logistics. Operational availability is when the effects of preventative maintenance and logistics are included. Operational availability is a "real-world" measure of availability and accounts for delays such as those incurred when spares or maintenance personnel are not immediately at hand to support maintenance.

2-1.9 Factors Influencing Availability.

Availability of a system in actual field operations is determined by the following.

2-1.9.1 The Frequency of Occurrence of Failures.

These failures may prevent the system from performing its function (mission failures) or cause a degraded system effect. This frequency is determined by the system's level of reliability.

2-1.9.2 Restoration and Maintenance Time.

The time required restoring operations following a system failure or the time required to perform maintenance to prevent a failure. These times are determined in part by the system's level of maintainability.

2-1.9.3 Logistics Delays.

The logistics provided to support maintenance of the system. The number and availability of spares, maintenance personnel, and other logistics resources combined with the system's level of maintainability determine the total downtime following a system failure.

2-1.9.4 Reliability Impact.

Reliability is a measure of a system's performance that affects availability, mission accomplishment, and operating and support (O&S) costs. Too often performance is only thought of in terms of voltage, capacity, power, and other "normal" measures. However, high frequency of system failures can be overshadowing the importance of more typical system metrics.

2-1.9.5 Impact of Failures and Costs.

Reliability also affects the costs to own and operate a system. Using an example of a critical DoD facility, Reliability determines how often repairs are needed. The less often the facility has a failure, the less it will cost to operate over its life. The reliability of any repairable system is a significant factor in determining the long-term costs to operate and support the system. For non-repairable systems, the cost of failure is the loss of the function (for example, the missile misses its target, the fuse fails to protect a circuit, etc.). In addition, the mission plays a part in the overall operation of the facility. The objective is to run as efficient as possible while still maintaining mission requirements.

2-1.9.6 Improving Availability of Failures.

Regardless of how reliable a system may be, failures will occur. An effective maintenance program applied to a system that has been designed to be maintainable is necessary to deal with the certainty of failure. Even when several redundant items are installed to decrease the chance of a mission failure, when any one item fails, it must be repaired or replaced to retain the intended level of redundancy.

2-1.10 Improving Availability of C5ISR Facilities.

The decision on which methods to use for improving availability depends on whether the facility is being designed and developed or is already in use.

2-1.10.1 Existing C5ISR Facilities.

For a facility that is being operated, three basic methods are available for improving availability when the current level of availability is unacceptable:

- Selectively adding redundant units, such as: (e.g., generators, chillers, fuel supply, etc.) to eliminate sources of single-point-failure
- Optimizing maintenance using a reliability-centered maintenance (RCM) approach to minimize downtime
- Redesign subsystems to replace components and subsystems with higher reliability items.

2-1.10.2 New C5ISR Facilities.

The opportunity for designing high availability and reliability systems is greatest when designing a new facility. A highly available facility will result from the following: applying an effective RAM strategy, modeling, and evaluating the systems, designing for maintainability, and ensuring that manufacturing and commissioning do not negatively affect the inherent levels of reliability, availability, and maintainability. \1\ See UFC 4-141-03 for details on specific design requirements /1/. Upon completion, an RCM program should be employed to cultivate the opportunities for high RAM success. Although the primary focus of this UFC is on improving the availability of current facilities, a brief discussion of the approach used when designing a new facility is provided in the next paragraphs to give the reader an appreciation of an effective design and development program.

2-1.10.2.1 RAM Strategy.

A RAM strategy describes how an organization approaches reliability for all systems and services it develops and provides to its customers. The strategy can be considered as the basic formula for success, applicable across all types of systems and services. A reliability strategy that has proved successful in a variety of industries and in government is shown in Figure 2-4.

2-1.10.2.2 RAM Program.

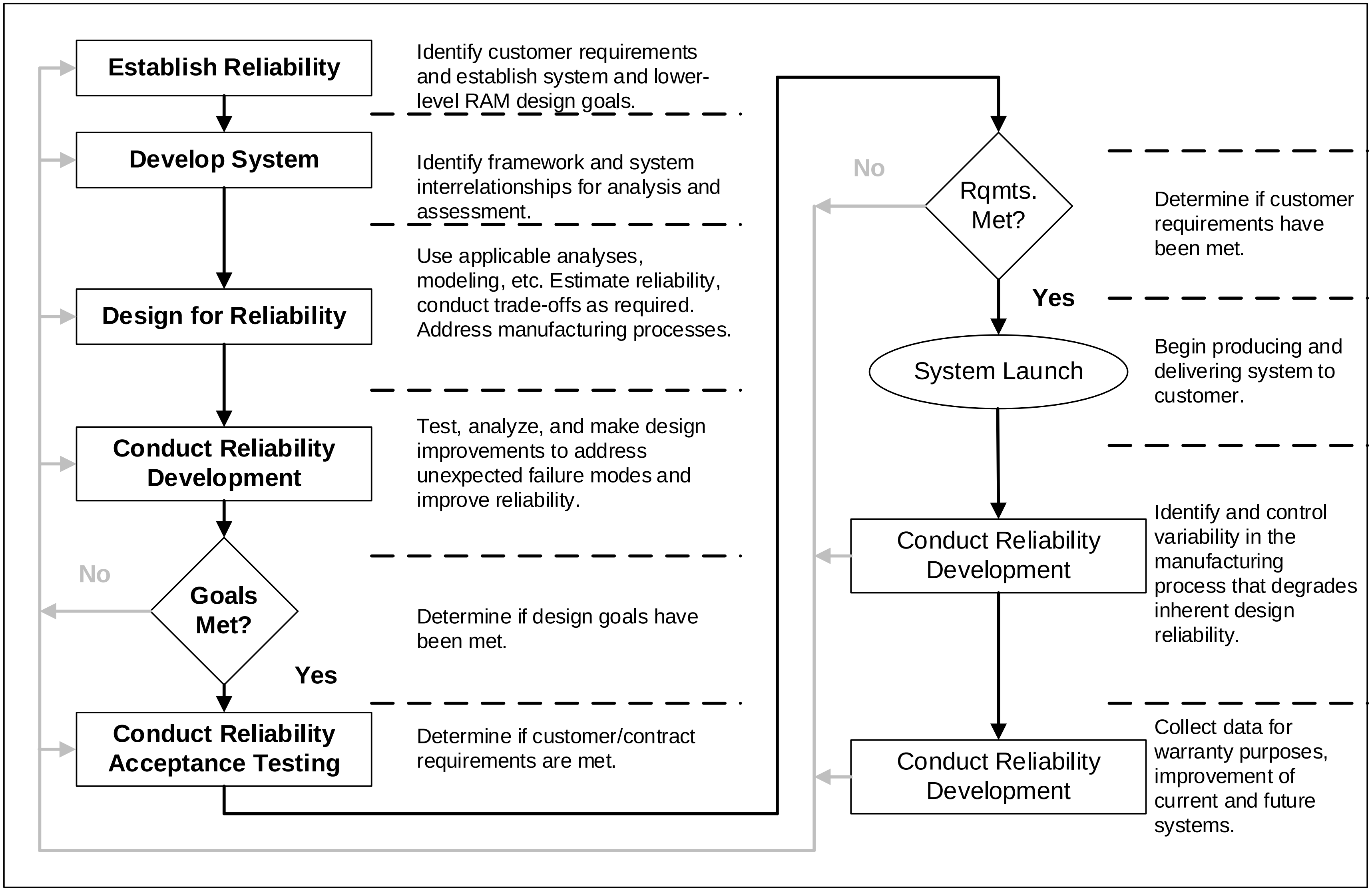
A RAM program is the application of the RAM strategy to a specific system or process. As can be inferred from Figure 2-4, each step in the strategy requires the selection and use of specific methods and tools. For example, various methods can be used to develop requirements or evaluating potential failures.

(a) Developing Requirements. Translations and analytical models can be used to derive requirements. Quality Function Deployment (QFD) is a technique for deriving more detailed, lower-level requirements from one level of indenture to another, beginning with customer needs. It was developed originally as part of the Total Quality Management movement. Translations are parametric models intended to derive design RAM criteria from operational values and vice versa. Analytical methods include:

- thermal analysis
- durability analysis
- predictions, etc.

They are used to make accommodations for special considerations to system design, such as environmental concerns.

Figure 2-4 A Sound Reliability Strategy addresses All Phases of a System's Life Cycle



(b) Evaluate possible failures. Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) are two different methods for evaluating possible failures. The reliability engineer must determine which one to use, or whether to use both. Chapters 5, 6 and 7 will address these and other methods and how to determine which are applicable to a specific situation. Selecting the specific tasks to accomplish each step of the strategy results in a tailored system program. Figure 2-5 shows some of the factors that must be considered in selecting tasks to implement the reliability strategy.

Figure 2-5 Factors Selecting Tasks for a Specific Program

Effectiveness and applicability of tasks vary depending on:

- Production runs (total population) – limits use of system-level statistical analysis
- Critical functions/cost of failure – may require exhaustive analysis
- Technology being used – may require new models
- Nature of development (such as evolutionary vs. revolutionary) experience of much less value when breaking new ground

Selection of tasks is also a function of past experience, budget, schedule, and the amount of risk commanders and facility managers are willing to accept

2-1.10.2.3 Reliability Requirements.

The entire effort of designing for reliability begins with identifying the customer's reliability requirements. These requirements are stated in a variety of ways, depending on the customer and the specific system. Table 2-1 lists some of the ways in which a variety of industries measure reliability. Note that in the case of the oil & gas and communications industries, availability is the real requirement. The reliability and maintainability requirements must then be derived based on the availability requirement.

Table 2-1 Typical Reliability-Related Measures

Customer	System	Measure of Reliability
Airline	Aircraft	On-time departure
Consumer	Automobile	Frequency of Repair
Hospital	Medical	Availability& Accuracy
Military	Weapon	Mission Success Probability
Highway Department	Bridge	Service Life
Oil & Gas	Sub-sea	Availability
Communications Organization	Utilities	Availability

2-2 PROGRAM ELEMENTS.

The essential elements of a system’s engineering program are described below. They must be considered in light of the organization’s mission and function, the availability of existing natural and manmade resources and the security necessary for a new or existing facility.

2-2.1 RAM Requirements Implementation.

The designer must implement reliability, availability, and maintainability (RAM) to achieve the required availability of the C5ISR utility systems.

2-2.2 Human Factors Engineering (HFE).

Human factors engineering (HFE) activities will ensure that reliability, availability, and safety of the C5ISR power system are not degraded through human activities during operation or maintenance. The design agency must accomplish the HFE program requirements using established standard HFE design criteria and practices based on MIL-STD-1472, Human Engineering.

2-2.3 Power System Safety Program.

The C5ISR power system safety program must ensure that the design incorporates, within program restraints, the highest attainable level of inherent safety. It must eliminate or reduce the probability of events that can cause injury or death to personnel, or damage to or loss of equipment or property. For example, pipes, lines, and tanks must be placed away from high-traffic areas. Safety documentation must be provided for safety items that require designation or may cause action during subsequent program phases. The design agency system safety program must be based on a philosophy that the most effective actions to control potential hazards are those taken early in the design process.

2-2.3.1 Special Operating Procedures.

When hazards cannot be controlled by design measures, including safety and warning devices, special operating procedures must be developed and documented. The safety program must provide support to the systems engineering (SE) program and must ensure that the applicable requirements of MIL-STD-882, System Safety, are met.

2-2.3.2 System Safety Analyses.

The systems safety program must define and address the system safety analyses that must be performed during development of design. During the early design phase, an analysis that identifies conditions that may cause injury or death to personnel and damage or loss to equipment and property must be performed. Prior to the final safety design review, the design agency must perform a second systems safety analysis to determine adherence of the design to all required safety standards and criteria, and to ensure avoidance or reduction of identified hazards. Operating and maintenance procedures must also be reviewed for compliance with all required safety standards and criteria.

2-2.3.3 Safety Hazards Identified.

The systems safety program must include procedures to ensure that safety hazards identified by the systems safety analyses are eliminated or reduced to acceptable levels of risk, and that those actions taken are fully documented.

2-2.3.4 Safety Program Documentation.

The design agency must prepare specific safety program documentation. This documentation must include, but not be limited to, safety analysis reports and the final systems safety report.

2-2.4 Consolidation Systems Test Program.

The design agency must develop a consolidated systems test program that covers all phases of testing, develops confidence in the system, and provides means for interim and final acceptance of equipment and systems. The design agency must minimize cost through elimination of testing duplication and by maximizing the collection of data for each test. Successful completion of these tests must be accomplished prior to final acceptance.

2-2.5 Standardization Program.

The design agency must develop and implement a standardization program to minimize equipment and component stockage. Redundant systems must be of the same design.

2-2.6 Configuration Management (CM) Program.

The configuration management (CM) program must maintain effective control over design from criteria development through design, construction, and installation of the equipment. The design agency should work with maintenance staff supervisor to determine maintenance capabilities and any training or funding requirements. A government configuration control procedure must be developed by the design agency for use in the C5ISR utility systems configuration control program.

2-2.7 Operations and Maintenance Planning.

Operations and maintenance (O&M) planning will be done by the design agency and must identify and recommend essential items of the program during the design phase. The design agency should work with maintenance staff supervisors to determine maintenance capabilities and any training or funding requirements. An RCM program should be implemented to identify single point failures and identify the critical systems. Basic elements of the program are as follows.

2-2.7.1 Data Requirements.

As part of the SE database, data requirements must be identified for preparation of O&M manuals. Systems functional descriptions must be developed. Requirements must be developed for data collection, including spare parts list, calibration requirements, special tools and test equipment, spare parts stockage level, and shelf-life data. Spare parts list, spare parts stockage level, test equipment, and test frequency must be provided for the using government agency. For a resilient C5ISR facility, spare parts for critical equipment are necessary to make the facility complete and usable, because they impact the required resilience of the facility design.

2-2.7.2 Complex Systems and Equipment.

Systems and equipment of high complexity or peculiarity must be identified, and special training for personnel who operate and maintain such systems and equipment must be identified.

2-2.7.3 Identify Critical Items.

The design agency must identify those items critical to accuracy and repeatability and must recommend calibration requirements. Unique calibration requirements and procedures must be provided whenever necessary.

2-2.7.4 Systems Test and Checkout.

Systems test and checkout requirements to be performed following major maintenance activities must be developed during design to ensure safe and normal operation of the system.

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CHAPTER 3 DESIGN CONSIDERATIONS

3-1 \1\ RELIABILITY/AVAILABILITY REQUIREMENTS FOR EXISTING C5ISR FACILITIES. /1/

3-1.1 Availability Requirements.

The availability will initially be set to at least 0.999 (99.9%, approximately 8 hours and 45 minutes of downtime a year). The criticality of the mission will determine if a higher availability is required but must not be required to exceed 0.999999 (99.9999%, approximately 31 seconds of downtime a year). The utility systems must be evaluated using the standard R/A analysis techniques to determine if goals are met.

3-1.2 Responsibilities for Determining Availability Requirements.

\1\ The Component Technical Representative is responsible for determining if the availability requirements for their mission and facility should be set higher than 0.999 (99.9%). Section 3-1.3 covers specific mission and facility types that have an availability requirement higher than 0.999 (99.9%). See UFC 1-200-01 for the definition of the CTR. /1/

3-1.3 Availability Requirements for Specific Facility Types.

There are some missions and facilities that are critical enough to require a higher availability requirement. \1\ If the Component Technical Representative (CTR) does not provide availability requirements, achieve the following availability levels for the listed missions and facilities. /1/

The criticality of the following missions and facilities is sufficiently high they should be designed and constructed to have a minimum availability of at least 0.99999 (99.999%, approximately five minutes of downtime a year). This availability requirement applies to any operational headquarters facility, airfield and supporting infrastructure, harbor facility supporting naval vessels, munitions production and storage facility, radar, space launch facility, or operational communications facility that is determined to be a critical mission.

The criticality of the following missions and facilities is sufficiently high they should be designed and constructed to have a minimum availability of at least 0.999999 (99.9999%, approximately 31 seconds of downtime a year). This availability requirement applies to any missile field, ballistic missile early warning radar, satellite control facility, cyber operations facility, or biological defense facility that is determined to be a critical mission.

3-2 GENERAL DESIGN REQUIREMENTS \1\ FOR UPGRADING EXISTING SYSTEMS. /1/

The design agency's role in the O&M concept is to establish the foundation for stable C5ISR utility systems that must provide continuous operation incorporating redundancy (dual systems), readiness (standby systems), flexibility (multiple modes of operations), and standardization (parts and equipment). Power plant facilities, systems, and O&M documentation must be designed to permit rapid startup and repair of equipment under emergency conditions. O&M functions must be enhanced through the application of these guidelines by the C5ISR utility systems designer.

\1\ The availability requirement for upgrade and renovation projects will initially be set to at least 0.999 (99.9%, approximately 8 hours and 45 minutes of downtime a year). The Component Technical Representative is responsible for determining if the availability requirements for their mission and facility should be set higher than 0.999 (99.9%). See section 3-1.3 for specific mission and facility types that have an availability requirement higher than 0.999 (99.9%).See UFC 1-200-01 for the definition of the CTR. /1/

3-2.1 Historical Records.

A recording device must be included in the design to provide a log of facility performance. This recorder must accept either analog or digital signals (such as input and output parameters for generators, main switchgear feeders, uninterruptible power supply (UPS) systems, power distribution units, chillers, etc.), convert them to numerical data, scale them to useful values and store them in electronic storage. The signals should be stored at intervals of 15 minutes or other specified preset time intervals. The recorder must have the capability to record critical signal values more frequently than the preset recording rate (for example, every five seconds) when prompted by a signal from the operator or operating equipment. The recorder must automatically return to its primary recording when system operation returns to normal. Records must be maintained on-site for a minimum of five years. A supervisory control and data acquisition (SCADA) system should be incorporated into the design of the systems.

3-2.2 Control Systems.

Control systems are the third major component making a C5ISR facility as reliable as possible with electrical systems being the first major component and mechanical systems being the second major component. Control systems are the brains behind the operational characteristics during normal and abnormal conditions. Control systems are commonly identified as SCADA systems and are designed to monitor conditions and react in a manner to maintain a set point. Typical SCADA systems are comprised of a series of sensors sending signals to a central command center where the signals are interpreted. A data communication protocol will be required for the signals between the central command center and the sensors to be interpreted and acted upon. \1\ To achieve maximum reliability/availability for a facility consideration should be given to the reliability/availability of the SCADA system when it participates in the control of the facility systems. If the monitoring and control station is located outside of the facility, then the reliability/availability of the communication pathways should be analyzed and improved as needed. /1/

Some examples of common data communication protocols include \1\ MIL-STD-3071, Lonworks, and BACNet. /1/ There are other data communication protocols available and the protocol providing the most robust solution should be used. Signals are sent from the command center to actuators to throttle input conditions and provide the necessary environmental condition required for the mission operations. Typical components for a SCADA system are:

- Computer access panel
- Digital drivers
- Power supplies
- Programmable Logic Controller (PLC)
- Interface devices such as control panels or circuit breakers

3-2.3 Maintenance Concepts.

The design outputs prepared by the design agency must reflect the following maintenance concepts.

3-2.3.1 Equipment Standardization Program.

The design agency must develop and implement an equipment standardization program to simplify equipment maintenance.

3-2.3.2 Modular Designed Subassemblies.

The design agency must specify modular designed subassemblies which will permit rapid repair.

3-2.3.3 Built-in Test Modules/Fault Sensors.

The design agency must specify that manufacturers provide built-in test modules/fault sensors. Selector switches that allow personnel to access and sequentially monitor operating variables within an assembly must be provided.

3-2.3.4 Equipment Tag.

The design agency must specify that a plate with an equipment tag number be attached to the equipment by the construction contractor. The design agency must specify a method for identifying and numbering wires and cables, for marking cable termination strips, and for uniformly interconnecting equipment of different manufacturers. Corresponding identity codes must be used for termination strips and wiring. The design agency must specify that if a manufacturer changes the characteristics of a purchased component for use in a composite item, the true source identity of the originally purchased part will remain intact.

3-2.4 Evaluations.

The following evaluations must be an integral part of the design process.

3-2.4.1 Operations Evaluations.

Operations evaluations must consider both user and system requirements.

(1) The design agency must evaluate user requirements to determine operating parameters and the effect that these parameters will have on system operation, output efficiency, and personnel safety. The design agency must determine if limits need to be placed on manual control and, if so, must specify those limits.

(2) The design agency must evaluate the system requirements as to the operational effects produced by changing power by switching the source of electrical power and maintenance or repair activities within the facility. System designers must identify critical mission variables subject to O&M schedules and incorporate equipment and/or operational redundancies to perform maintenance without disruption to critical operations. The design agency must specify areas in the control system that should allow automatic adjustments to system equipment to aid the operator when events occur that demand immediate operator intervention.

3-2.4.2 Evaluate User Constraints and Parameters.

The design agency must evaluate user constraints and parameters to ensure maintainability of the C5ISR utility systems.

3-2.4.3 Perform a Hazard Evaluation.

The design agency must perform a hazard evaluation to ensure adherence to Occupational Safety and Health Administration (OSHA), National Electrical Code (NEC), and other locally binding safety standards.

3-2.5 Operations and Maintenance Documentation.

The design agency must perform an O&M analysis to identify the equipment in the C5ISR utility systems that contributes significantly to the maintenance burden of the system and the O&M data required to support maintenance of this equipment by the using government agency. This analysis must be coordinated with the using government agency to determine maintenance parameters and O&M data that are available to the using government agency.

3-2.5.1 Identify O&M Data Requirements.

The design agency must identify O&M data requirements on an individual basis for all maintenance-significant equipment. Typical data requirements include the following items.

- Minimum spare parts list.
- Recommended spare parts list.

- Recommended onsite test equipment.
- Recommended O&M training.

3-2.5.2 Specify Functional Areas of Operating System.

The design agency must specify functional areas of the operating system and/or equipment where a technical representative will be furnished by the manufacturer for training, test, checkout, validation, or pre-operational exercises.

3-2.6 Verification.

A verification of O&M procedures and data manual content must be performed by the using government agency to demonstrate technical accuracy, fulfillment of intent, and applicability to the performance of O&M within the facility. A review of the verification process may necessitate that additional information be obtained from the equipment manufacturer.

3-2.6.1 Verification Process.

Verification should begin during the equipment acceptance process and continue as the using government agency applies the instructions, data, and technical manuals to the continuous routines of equipment operation and repair.

3-2.6.2 Verification Support.

The design agency must support the user's verification process by:

(1) Specifying acceptance test procedures which the contractor must be expected to fulfill during facility acceptance. The format should contain adequate sign-off routines to verify the performance of equipment in accordance with design specifications.

(2) Requiring that, for specially designed equipment that does not fit well into a standard acceptance format, the contractor must submit an acceptance plan in lieu of the designer-specified acceptance test procedures.

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CHAPTER 4 ACCEPTABLE METHOD FOR EVALUATING SYSTEM RESILIENCE

4-1 ROBUSTNESS.

Robustness is defined as "the ability to absorb shocks and continue operating." (North American Electric Reliability Corporation - NERC) For many critical facilities, there may be many mission assets which are considered uninterruptible. Since it is imperative to the mission that these assets remain on-line, any downtime or outage for such assets would be considered mission failure; the shock has not been absorbed. When evaluating missions for which any interruption is unacceptable, component failure or degradation should be considered as reducing the probability of mission success. Component failures or degradations should be considered as eliminating equipment redundancies or reducing individual component reliability. In these cases, it is appropriate to evaluate the performance of the system as the resulting operational availability for the mission. For example, if an event occurs which reduces the mission availability to 0.999, then the average expected weekly downtime of the mission is about 10 minutes. If a more resistant system is only reduced to an availability of 0.9999, the expected weekly downtime for the mission is approximately one minute. This essentially represents a 10-fold difference in system performance during the recovery period.

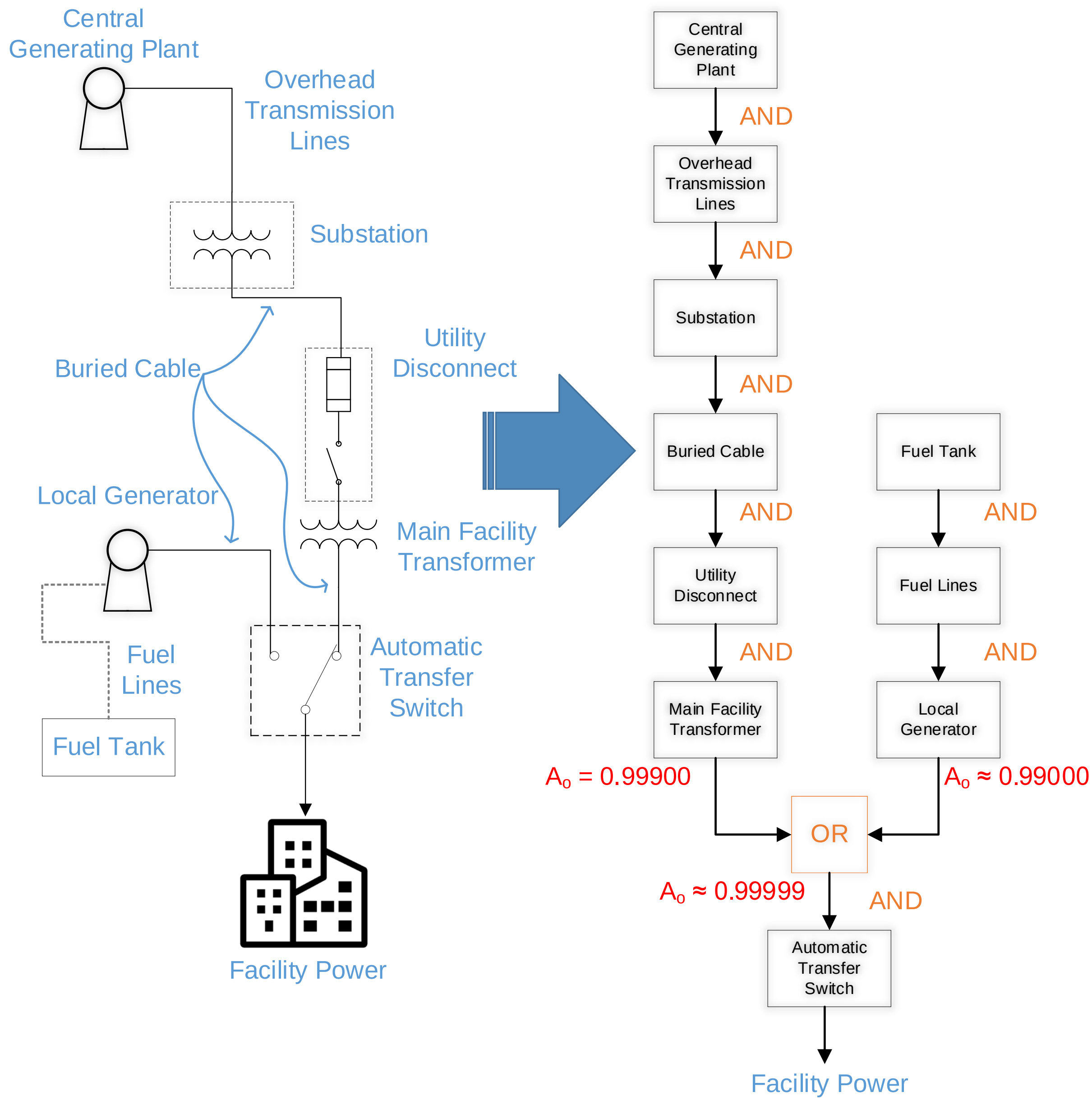
4-1.1 Evaluating Robustness.

As discussed, robustness may be quantified as a change in mission availability caused by the occurrence of a postulated event. Traditional reliability and availability analysis methods such as reliability block diagrams (RBDs), state-space modeling, or Monte Carlo simulations, may be used to evaluate mission availability during base-case and contingency operations. For the purposes of evaluating resilience, the following paragraphs will focus on the reliability RBD/Boolean algebra methodology.

4-1.1.1 Constructing an RBD.

Constructing a RBD requires translating the system topology into a set of discrete elements and logic gates. Items connected in series are typically combined with AND operators; parallel objects and strings are typically combined with OR operators. Depending on system configuration and redundancy parallel objects and strings may be combined using AND or OR operators. Each element in the block diagram has an associated availability statistic, which is derived from statistical data collected from similar components. Figure 4-1 shows an example of a typical utility system translated into an RBD. Note that combining redundant paths with an OR operator significantly increases the mission availability.

Figure 4-1 RBD for a Typical Distribution System



4-1.1.2 Contingency Event Data.

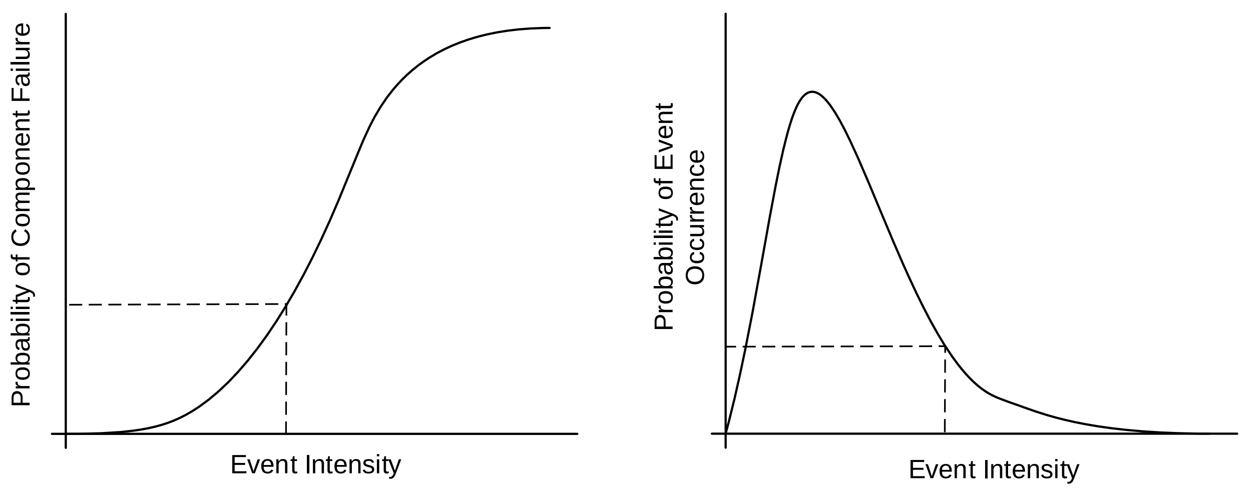
Incorporating contingency event data into availability modeling allows for a quantifiable difference in performance between base-case and contingency operations. There are two primary ways through which this is accomplished. The first, and most intuitive method, involves a deterministic approach, and is similar to traditional Failure Modes, Effects and Criticality Analysis (FMECA) analysis. This method assumes that an event of a certain magnitude has occurred and evaluates the effect that the event has on overall system availability. The following steps outline the deterministic method for Robustness evaluation:

4-1.1.2.1 Determine Events for which the Robustness of the System should be Assessed.

When applying the deterministic method, only a particular event or set of related events should be evaluated at a time. When selecting scenarios for evaluation, the probability and severity of the event should be considered. As a starting point, consider key components in the system where, as determined by baseline availability studies, failure is likely to significantly impact the performance of the system. Chapter 5 will discuss how to perform/create the baseline availability analysis.

In cases where reliable statistics exist to determine the probability that a particular event may occur, it is possible to select events based on the conditional probability of component failure given the occurrence of the event. In general, higher intensity events have a greater chance of causing component failure, but also occur less frequently. This can be seen in the two graphs in Figure 4-2. The graph on the left shows the fragility curve for a particular component; this shows the probability of component failure according to the intensity of an event. The graph on the right shows the probability density function (PDF) for a particular event based on event intensity.

Figure 4-2 Fragility Curves vs Event Probability



From these graphs, it can be see that an event of a given intensity has a corresponding probability of causing component failure (P(failure)), and an independent probability that it will occur (P(event)). Combining these two probabilities in Equation 4-1 yields the conditional probability of failure given the occurrence of the event.

Equation 4-1. Conditional Probability of Failure Given Occurrence of the Event

$$P(failure\ given\ event) = \frac{P(failure)\ \cap P(event)}{P(event)}$$

Where:

P = probability
∩ = the probability that Events A and B both occur is the probability of the intersection of A and B. The probability of the intersection of Events A and B is denoted by P(A ∩ B). If Events A and B are mutually exclusive, P(A ∩ B) = 0.

4-1.1.2.2 Conditional Probability of Failure.

The conditional probability of failure given event occurrence can be used to evaluate the relative risk associated with an event and determine whether further evaluation of that event is justified. For example, a site in Utah may not need to evaluate its response to a hurricane. If fragility data and event data indicate that event occurrence does not significantly increase the risk of component failure (such as the conditional probability of failure is within one order of magnitude of inherent failure rate), that scenario does not necessarily require further evaluation.

For other events, the severity of risk may be more subjective. For contingencies such as HEMP events, wildlife damage, cyber-attacks, or terrorist attacks, the probability of occurrence may be unknown or is subject to change. Consequently, a threshold value for conditional probability of failure may not exist, and a different means of event selection is warranted.

4-1.1.2.3 Determine what Components are likely to Fail as a Result of the Event.

All components in a system are uniquely vulnerable to a set of events. For example, exterior generators may be vulnerable to flooding, whereas SCADA controlled switchgear may be more vulnerable to cyber-attacks. If fragility curves for individual components are available, then the probability of component failure associated with an event can be incorporated into the system availability model. Consider using an analysis tool such as HAZUS, as developed by the Federal Emergency Management Agency (FEMA), to assess the overall risk of component failure due to specific events. HAZUS is an example of a risk assessment tool that utilizes both fragility and event data in its analysis. Where event and fragility data are unavailable, it may be more practical to assume certain key components as having failed due to a postulated event. This deterministic approach clearly identifies single points of failure or areas that require additional hardening measures.

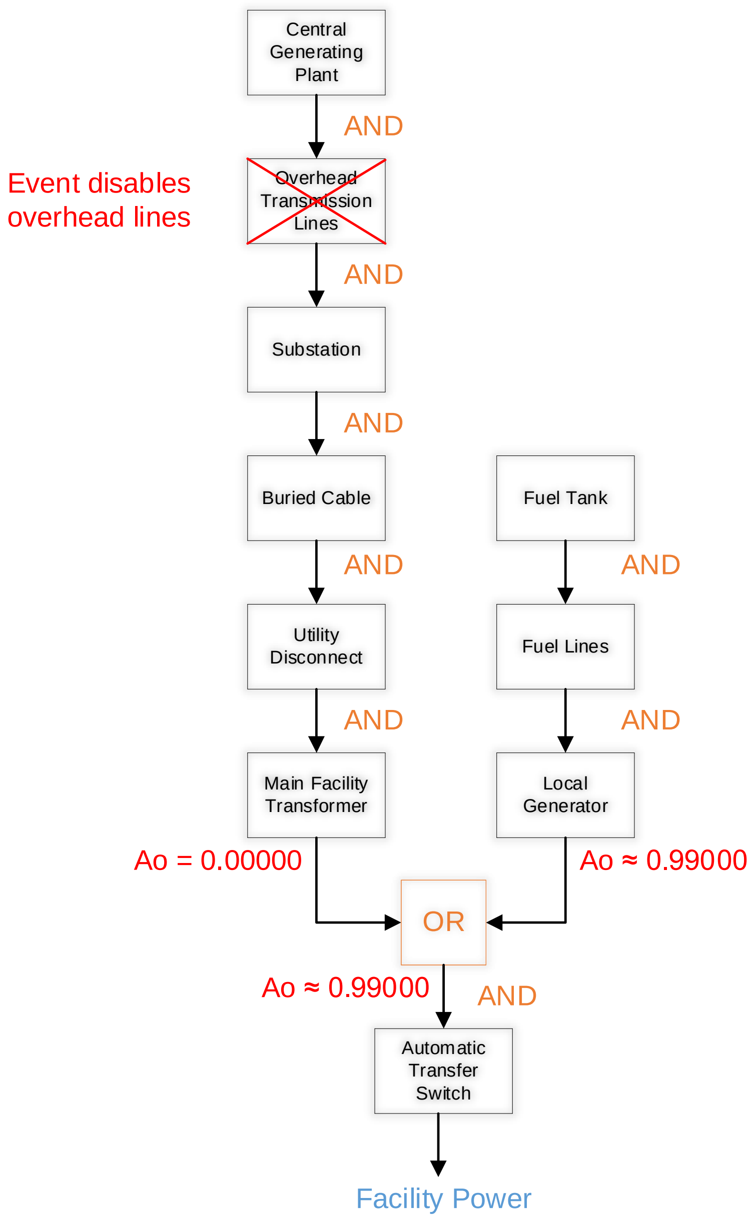
4-1.1.2.4 Analyze the Degraded System State.

As previously mentioned, functionality for critical missions that are considered uninterruptible must be maintained. In these cases, the change in system performance can be measured by the change in mission availability from the baseline state. In other words, a contingency event is considered to affect mission availability, not overall mission success. For example, in the postulated power system in Figure 4-3, a wind event disables only overhead transmission lines. Since backup power can be immediately supplied by emergency generators, mission loads can continue to operate.

However, until the transmission lines are restored, the likelihood of failure is significantly increased.

Similar methods can be used to evaluate the degraded mission availability as for the baseline case (for example RBDs, Monte Carlo, state space). More information on each of these methods is provided in Chapter 5. To evaluate the degraded state, the input data used for the analysis must be modified to reflect the impact of the event being considered. The simplest method is to consider failed components as having an availability of zero. If equipment fragility curves are available, the resulting equipment reliability can be incorporated into the existing availability model.

Figure 4-3 Distribution System Model in Degraded State



4-2 RECOVERY.

Operations in the recovery phase have stabilized, and no further damage or degradation is expected. The system may be operating in alternate or emergency modes with a reduced availability. Power may be provided to critical systems via stand-by generators, alternate utility feeds, or distributed energy resources. In this phase, the emphasis is on restoring the system to its baseline operation.

4-2.1 Recovery Time.

As previously discussed, the shorter the recovery time, the more resilient the system. Recovery time is determined by the average length of time required to return damaged components to service. In general, the availability of the system increases as assets are recovered. For large or complex systems, availability during the recovery phase may change continuously. For smaller systems, or where fewer redundant paths exist, it can be more useful to consider the change in availability during the recovery phase as a step function. That is, there are discrete step changes in availability as components or success paths are returned to service.

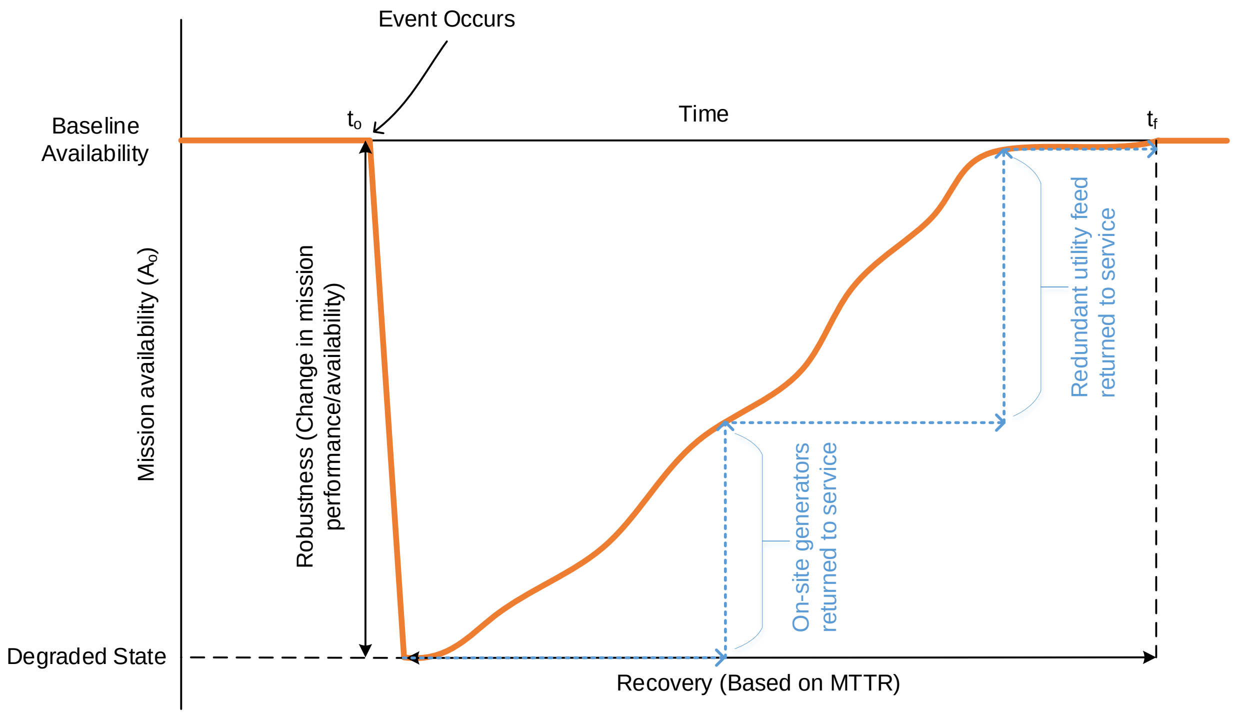
4-2.2 Stepped Recovery of Power System Assets.

Figure 4-4 provides an example of this concept. In this example, an event has disabled both the on-site generation as well as one of two redundant utility feeders. The on-site generators are quickly returned to service, resulting in a large step increase in availability. After some time, the redundant utility feed is returned to service, resulting in a second step increase in availability. It is important to note that for a single success path to be restored, all series components must be fully restored before improvements in availability are realized. For example, if an event disables a backup generator, its associated fuel tank and fuel lines, all these assets must be repaired before that feed is considered back on-line.

The step-change model in Figure 4-4 indicates the recovery time for the system can be approximated using the mean-time-to-repair (MTTR) for the various affected components. However, designers, planners, and facility managers must use caution when using MTTR to anticipate recovery time following a contingency event. MTTR data is typically based on failure modes that occur during normal operation. Contingency events may cause different failures to occur, and additional logistics delays must be considered based on the nature of the event and the location of the site. To determine the recovery time for a system, MTTR data should be used as an input to evaluate a disaster recovery plan.

Following a contingency event, the facility or site should have a plan in place to adapt to and recover quickly from its affects. Due to limitations of personnel, resources, and logistics, repairs for all components cannot occur simultaneously. It may also be required that some assets be restored in sequence. The following steps provide an outline for considerations when developing a recovery plan:

Figure 4-4 Stepped Recovery of Power System Assets



4-2.2.1 Identify the Components that are likely to have Failed.

This step may already have been completed as part of evaluating system robustness. Fragility curves and unique factors such as site geography are used to identify those components and success paths which may be inoperable following the event.

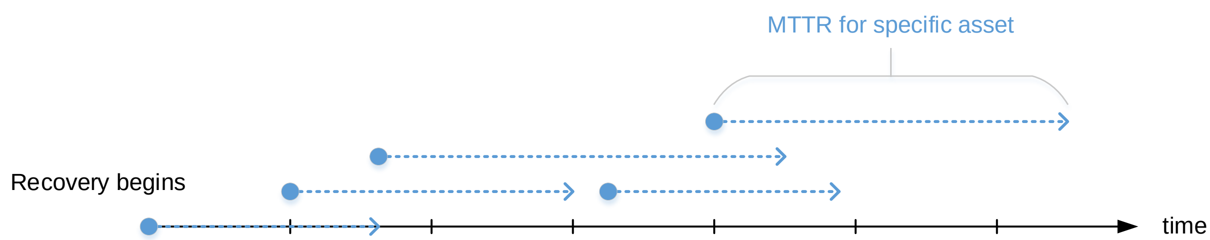
4-2.2.2 Evaluate Repair Priorities.

The RBD can be used to evaluate the effectiveness of individual repair activities based on what effect they have on mission availability and the time it takes to execute the repair. For example, when comparing two repair activities which have similar execution times, the activity which results in a larger improvement in mission availability should be prioritized. Typical MTTR values can be used as an input to evaluate the time requirements for each activity, but event-specific failure modes, and additional logistical delays should also be evaluated. In this step it is important to consider any repairs that, due to operational or resource limitations, may need to be executed in sequence.

4-2.2.3 Determine the Overall Time to Return to Baseline Operations.

Once the overall structure of the recovery plan is in place, the timeline for recovery should be evaluated. The result should be a site-specific, and event-specific number representing the required execution time for the planned series of repair activities. The result should be evaluated against operational limitations such as fuel reserves to determine whether the recovery time is adequate. Figure 4-5 shows an example of how the timeline for a typical recovery plan may look. Each arrow represents the repair time for a specific asset. Note that individual repair events are staggered to optimize personnel and equipment resources throughout the recovery phase.

Figure 4-5 Sample Recovery Timeline



4-3 DETERMINING OPERATIONAL REQUIREMENTS FOR RESILIENCE METRICS.

Requirements for resilience metrics can vary from site to site and depend on a multitude of factors. As previously discussed, certain sites may want to prioritize either robustness or recovery depending on their specific needs.

4-3.1 Evaluate the Needs of the System.

To evaluate the needs of the system, it is important to apply a realistic time scale to the baseline and degraded availability states. Typically, availability is related to equipment downtime on a yearly scale; a “six-nines” system relates to about 30 seconds of downtime per year. However, contingency scenarios are more likely measured in weeks. Table 4-1 shows the corresponding weekly downtime for various levels of availability.

Table 4-1 Average Weekly Downtime Based on Availability

Availability	Average Weekly Downtime (Minutes)
0.9	1008
0.99	100.8
0.999	10.08
0.9999	1.008
0.99999	0.1008
0.999999	0.01008

4-3.2 Availability Requirements.

There are certain mission types with specific availability requirements. These requirements come from a memorandum from the Office of the Under Secretary of Defense dated 20 May 2021. The subject of the memorandum is Metrics and Standards for Energy Resilience at Military Installations. The availability requirement for the following mission types must be 99.999% or five-9's:

- Operational Headquarters Facility
- Airfield and Supporting Infrastructure
- Harbor Facility Supporting Naval Vessels
- Munitions Production and Storage Facility
- Radar
- Space Launch Facility
- Operational Communications Facility that is determined to be a critical mission

The availability requirement for the following mission types must be 99.9999% or six-9's:

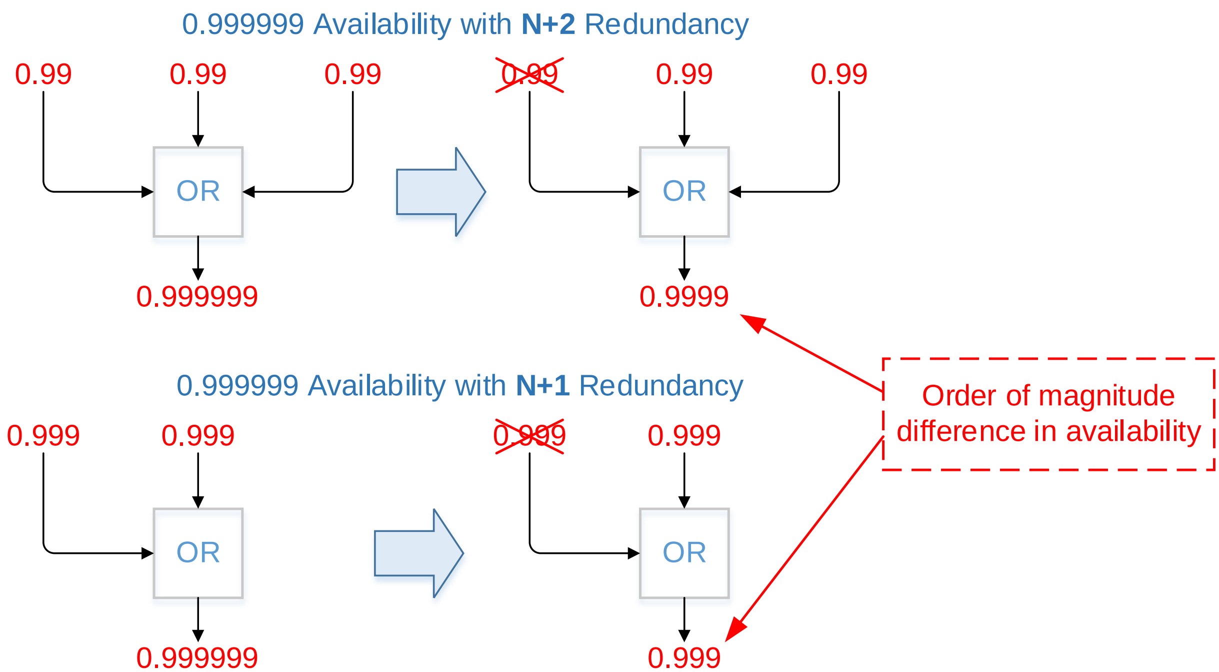
- Missile Field
- Ballistic Early Warning Radar
- Satellite Control Facility
- Cyber Operations Facility
- Biological Defense Facility that is determined to be a critical mission

A critical mission that does not fit these mission types is allowed to have an availability range from 99.9% (three-9's) to 99.9999% (six-9's) depending on the criticality of the mission.

4-3.3 Minimum Acceptable Level of Degraded State Availability.

When assessing the minimum acceptable level of degraded state availability, it is also important to consider the site-specific requirements for availability, as well as requirements for system topology. For example, a baseline availability requirement of six nines (0.999999) can be achieved using an N+2 redundant arrangement of three elements each with an availability of 0.99, or an N+1 redundant arrangement of two elements each with an availability of 0.999. If an event occurs which incapacitates only one feed, the N+2 system will have a degraded state availability a full order of magnitude higher than the N+1 system. Naturally, systems with a higher level of required redundancy should have more stringent requirements for resilience than those with less design redundancy. This is shown in Figure 4-6.

Figure 4-6 N+2 vs N+1 System Resilience



Site-specific requirements for resilience should also be decided by weighing several major factors. Ultimately, the required level of resilience is based on the level of mission criticality, the remoteness of the site, and whether the mission is duplicated and can be executed at any other sites.

4-3.3.1 Criticality.

Many DoD installations serve a range of critical missions. In a perfect world, designers would be able to protect all levels of critical missions from the effects of any possible event. However, due to funding and design constraints, some assets must be prioritized over others. Ultimately, the assets should be prioritized according to the DoD Mission-Based Critical Asset Identification Process (CAIP, DoD Inst 3020.45). To simplify the decision process for resilience planning, missions and supporting assets can also be categorized as having low, medium, or high criticality. Criticality in this context refers to the impact that incapacity or destruction of a mission would have on the physical or economic security or public health or safety.

This criticality level can be assigned based on national priorities, or within the scope of a local project. For example, when considering resilience improvements for only a single installation or facility, it may be useful to consider the low-medium-high scale as spanning the range of criticality present at that installation. In many cases, specific details related to the level of criticality of a mission may be classified.

4-3.3.2 Remoteness.

Critical facilities and other critical assets exist in a variety of locations. This can have a significant effect on recovery of a mission following an extreme event. Remoteness is primarily related to the geographical location of a facility or installation but can be further influenced by other accessibility factors. Topographic features such as bodies of water or mountainous terrain, as well as the number and condition of access roads can also impact the remoteness of a site. For example, if a site can only be accessed via a single bridge, it would be considered as more remote than a similar site with several access points.

Like the level of criticality, the remoteness of a site can be categorized in relative terms. For the purposes of resilience planning, sites should be considered to have low, medium, or high remoteness. Typically, more remote sites should prioritize the robustness phase of resilience as recovery may be limited by physical constraints. This maximizes overall resilience by prioritizing the ride-through ability for these missions.

4-3.3.3 Duplicated Missions.

Some missions can be carried out at geographically diverse sites such that a contingency event at one is unlikely to affect mission success at any of the other sites. This creates additional mission redundancy and can reduce resilience requirements at an individual site. It is important to evaluate the practical considerations in mission duplication; several questions must be answered. Will the mission be transferred to an alternate site automatically? Will personnel be available at the alternate site to process the mission? Can the mission be transferred in anticipation of a foreseen event? In the interest of simplicity, the ability of a mission to be carried out at alternate sites should be considered as a simple yes or no.

Once these three factors have been evaluated, the results can be used to determine the requirement categories for both Robustness and Recovery. As previously discussed, these two aspects of resilience should be considered independently due to the unique needs of individual sites. Using Table 4-2 below, the three factors can be applied to place a mission or asset in prioritized categories for both Robustness and Recovery. The result is a low-medium-high index for each resilience phase. For example, a mission with medium criticality, high remoteness, and no mission duplication would have a High Robustness requirement and a Medium recovery requirement.

Table 4-2 is designed to provide a simple framework to assign independent requirements for both robustness and recovery. This should be used as a tool to determine the relative need for prioritizing either phase of the system response to a given event. In some cases, a single facility may have different required levels of robustness and recovery.

Table 4-2 Determine Resilience Requirements

		Resilience Phase	
		Robustness	Recovery
Resilience Metric Requirement	Low	Criticality: **Low-Med** Remoteness: **Low** Duplicated Missions: **Yes**	Criticality: **Low** Remoteness: **Low-Med** Duplicated Missions: **Yes**
	Medium	Criticality: **Low-Med-High** Remoteness: **Med** Duplicated Missions: **Yes**	Criticality: **Low-Med** Remoteness: **Low-Med-High** Duplicated Missions: **No**
	High	Criticality: **Med-High** Remoteness: **Med-High** Duplicated Missions: **No**	Criticality: **High** Remoteness: **Low-Med-High** Duplicated Missions: **No**

CHAPTER 5 RELIABILITY/AVAILABILITY

5-1 BASIC RELIABILITY AND AVAILABILITY CONCEPTS.

5-1.1 Probability and Statistics

This chapter provides the reader with an overview of the mathematics of reliability theory. It is not presented as a complete (or mathematically rigorous) discussion of probability theory and statistics but should give the reader a reasonable understanding of how reliability is calculated. Before beginning the discussion, a key point must be made. Reliability is a design characteristic that indicates a system's ability to perform its mission over time without failure or without logistics support. In the first case, a failure can be defined as any incident that prevents the mission from being accomplished; in the second case, a failure is any incident requiring unscheduled maintenance. Reliability is achieved through sound design, the proper application of parts, and an understanding of failure mechanisms. Estimation and calculation techniques are necessary to help determine feasibility, assess progress, and provide failure probabilities and frequencies to determine spare part requirements and other analyses.

5-1.1.1 Uncertainty.

Uncertainty - at the heart of probability. The mathematics of reliability is based on probability theory. Probability theory, in turn, deals with uncertainty. The theory of probability had its origins in gambling.

(1) Simple examples of probability in gambling are the odds against rolling a six on a die, of drawing a deuce from a deck of 52 cards, or of having a tossed coin come up heads. In each case, probability can be thought of as the relative frequency with which an event will occur in the long run.

(a) Tossing an honest coin will result in heads (or tails) 50% of the time, this does not mean it will necessarily toss five heads in ten trials. It only means that in the long run, it is expected to be 50% heads and 50% tails. Another way to look at this example is to imagine a very large number of coins being tossed simultaneously; again, it is expected to be 50% heads and 50% tails.

(b) Rolling an honest die, it is expected the chance of rolling any possible outcome (one, two, three, four, five, or six) is one in six. It is possible to roll a given number, say a six, several times in a row. However, in a large number of rolls, it is expected to roll a six (or a one, or a two, or a three, or a four, or a five) only 1/6 or 16.7% of the time.

(c) Drawing from an honest deck of 52 cards, the chance of drawing a specific card (an ace, for example) is not as easily calculated as rolling a six with a die or tossing a heads with a coin. First it must be recognized that there are four suits, each with a deuce through ace (ace being high). Therefore, there are four deuces, four tens, four kings, etc. So the chance of drawing any ace is four in 52 since there are only four aces. It is instinctively known that the chance of drawing the ace of spades, for example, is less than four in 52. Indeed, it is one in 52 (only one ace of spades in a deck of 52 cards).

(2) Why is there a 50% chance of tossing a head on a given toss of a coin? It is because there are two results, or events, which can occur (assume that it is very unlikely for the coin to land on its edge) and for a balanced, honest coin, there is no reason for either event to be favored. Thus, the outcome is random, and each event is equally likely to occur. Hence, the probability of tossing a head (or tail) is one of two equally probable events occurring = 1/2 = 0.5 = 50% of the time. On the other hand, one of six equally probable events can result from rolling a die: it can be a one, two, three, four, five, or six. The result of any roll of a die (or of a toss of a coin) is called a discrete random variable. The probability that on any roll this random variable will assume a certain value, call it x, can be written as a function, f(x). The probabilities of f(x), specified for all values of x, are referred to as the values of probability function of x. For the die and coin, the function is constant. For the coin, the function is f(x) = 0.5, where x is either a head or tail. For the die, f(x) = 1/6, where x can be any of the six values on a die.

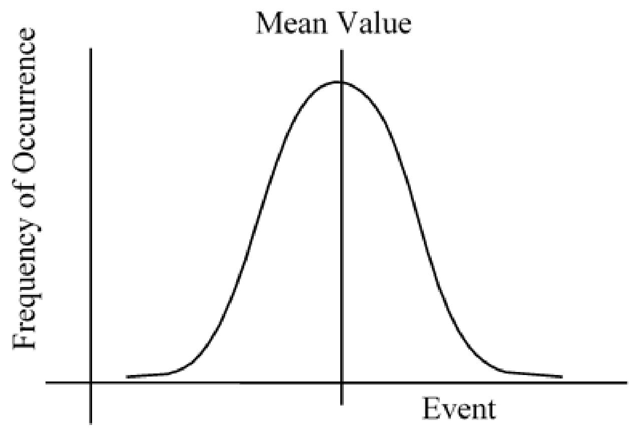
5-1.1.2 Probability Functions.

All random events have either an underlying probability function (for discrete random variables) or an underlying PDF (for a continuous random variable).

(1) The results of a toss of a coin or roll of a die are discrete random variables because only a finite number of outcomes are possible; hence these events have an underlying probability function. When the probability of each event is equal, underlying probability function is said to be uniform.

(2) The number of possible heights for American males is infinite (between 5 feet – 8 inches (1.72 meters) and 6 feet (1.83 meters), for example, there are an infinite number of possible heights) and is an example of a continuous random variable. The familiar bell-shaped curve describes most natural events, such as the height of a person, intelligence quotient of a person, errors of measurement, etc. The underlying PDF represented by the bell-shaped curve is called normal or Gaussian. Figure 5-1 shows a typical normal distribution. Note that the event corresponding to the midpoint of the curve is called the mean value. The mean value, also called the expected value, is an important property of a distribution. It is like an average and can be compared with the center of mass of an object. For the normal distribution, half the events lie below the mean value and half above. Thus, if the mean height of a sample of 100 Americans is 5 feet -9 inches (1.75 meters), it is expected that half the sample would be less than 69 inches (1.75 meters) tall, and half would be taller. It is also expected that most people would be close to the average with only a few at the extremes (very short or very tall). In other words, the probability of a certain height decreases at each extreme and is “weighted” toward the center, hence, the shape of the curve for the normal distribution is bell-shaped.

Figure 5-1 Typical Normal Distribution Curve



(3) The probability of an event can be absolutely certain (the probability of tossing either a head or a tail with an honest coin), absolutely impossible (the probability of throwing a seven with one die), or somewhere in between. Thus, a probability always can be described with Equation 5-1.

Equation 5-1. Probability of an Event

$$0 \leq P \leq 1$$

Where:
P = probability of an event

(4) Determining which distribution best describes the pattern of failures for an item is extremely important, since the choice of distributions greatly affects the calculated value of reliability. Two of the continuous distributions commonly used in reliability are shown in Table 5-1. Note that f(t) is called the probability density function (PDF). Reliability is usually concerned with the probability of an unwelcome event (failure) occurring.

Table 5-1 Commonly Used Continuous Distributions

Distribution	Probability Density Function	Most Applicable to
Exponential	$f(t) = \eta e^{-\lambda t}$	Electronic parts and complex systems
Weibull (2-parameter)	$f(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} e^{(\frac{t}{\eta})^{\beta}}$	Mechanical Parts

Where:
f(t) = probability density function
η = scale
e = the base of natural logarithms
λ = the failure rate (inverse of MTBF)

t = time (hours)

Where:
f(t) = probability density function
β = shape parameter/Weibull slope
η = scale
t = time (hours)
e = the base of natural logarithms

(a) The underlying statistical distribution of the time to failure for parts is often assumed to be exponential. A glance at the equation of the PDF explains why. It is easy to work with and has a constant mean, λ. Rather than assuming a distribution, one should determine the most appropriate one using various techniques for analyzing time-to-failure data.

(b) When the exponential distribution is applicable, the rate at which failures occur is constant and equal to λ. For other distributions, the rate at which failures occur varies with time. For these distributions, a Hazard Function is used, which is a function that describes how the rate of failures varies over time.

(c) Note that different types of parts (such as, items that fail once and then are discarded and replaced with a new item) may have different underlying statistical distributions of the time to failure. The times to failure of electronic parts, for example, often follow the exponential distribution. The times to failure for mechanical parts, such as gears and bearings, often follow the Weibull distribution. Of course, the parameters for the Weibull for a gear will most likely will be different from the parameters for a ball bearing. The applicability of a given distribution to a given part type and the parameters of that distribution are determined, in part, by the modes of failure for the part.

(d) By their very nature, systems consist of many, sometimes thousands, of parts. Since systems, unlike parts, are repairable, they may have some parts that are very old, some that are new, and many with ages in between these extremes. In addition, each part type will have a specific distribution of times to failure associated with it. The consequence of these part characteristics together within a system is that systems tend to exhibit a constant failure rate. That is, the underlying statistical distribution of the time to failure for most systems is exponential. This consequence is extremely significant because many reliability prediction models, statistical demonstration tests, and other system analysis are predicated on the exponential distribution.

5-1.1.3 Determining Failure Rate or Hazard Function.

How is the failure rate (or Hazard Function) of a specific system or component determined? Two methods are used.

(1) In the first method, use failure data for a comparable system or component already in use. This method assumes that the system in use is comparable to the new system

and that the principle of transferability applies - this principle states that failure data from one system can be used to predict the reliability of a comparable system.

(2) The other method of determining failure rate or the Hazard Function is through testing of the system or its components. Although, theoretically, this method should be the "best" one, it has two disadvantages. First, predictions are needed long before prototypes or pre-production versions of the system are available for testing. Second, the reliability of some components is so high that the cost of testing to measure the reliability in a statistically valid manner would be prohibitive. Usually, failure data from comparable systems are used in the early development phases of a new system and supplemented with test data when available.

5-1.2 Calculating Reliability.

If the time (t) over which a system must operate and the underlying distributions of failures for its constituent elements are known, then the system reliability can be calculated by taking the integral (essentially the area under the curve defined by the PDF) of the PDF from t to infinity, as shown in Equation 5-2.

Equation 5-2. Reliability

$$R(t) = \int_{t}^{\infty} f(t)\, dt$$

Where:
R(t) = reliability over time t
t = time (hours)
f(t) = probability density function
dt = downtime (hours)

5-1.2.1 Exponential Distribution.

If the underlying failure distribution is exponential, Equation 5-2 becomes Equation 5-3.

Equation 5-3. Exponential Distribution

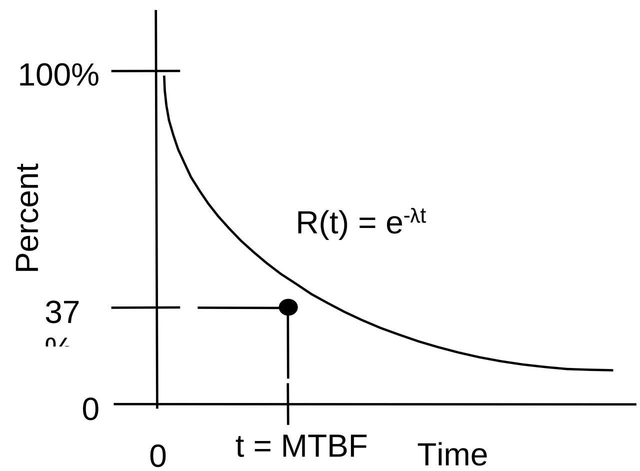
$$R(t) = e^{-\lambda t}$$

Where:
λ = the failure rate (inverse of MTBF)
t = the length of time the system must function
e = the base of natural logarithms
R(t) = reliability over time t

(1) Figure 5-2 shows the curve of Equation 5-3. The mean is not the "50-50" point, as was true for the normal distribution. Instead, it is approximately the 37-63 point. In other words, if the mean time between failures of a type of equipment is 100 hours, it is expected that only 37% (if t = MTBF = 1/λ, then $e^{-\lambda t} = e^{-1} = 0.367879$) of the population

of equipment to still be operating after 100 hours of operation. Put another way, when the time of operation equals the MTBF, the reliability is 37%.

Figure 5-2 Exponential Curve Relating Reliability and Time

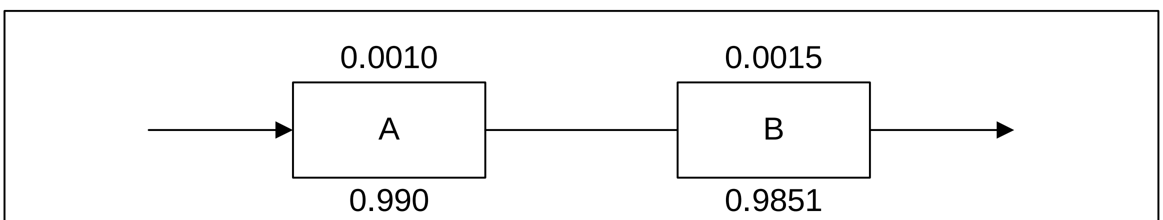


(2) If the underlying distribution for each element is exponential and the failure rates (λ_i) for each element are known, then the reliability of the system can be calculated using Equation 5-3.

5-1.2.2 Series Reliability.

Consider the system represented by the RBD in Figure 5-3.

Figure 5-3 Example RBD



1. The number above each block is the failure rate in failures per million hours.
   The inverse of the failure rate is the mean time to failure (exponential failure rate assumed).
2. The number below each block is the reliability calculated using equation 5-3 with t = 10 hours.

(1) Components A and B in Figure 5-3 are said to be in series, which means all must operate for the system to operate. Since the system can be no more reliable than the least reliable component, this configuration is often referred to as the weakest link configuration.

(2) Since the components are in series, the system reliability can be found by adding together the failure rates of the components and substituting the result as seen in

Equation 5-4. Furthermore, if the individual reliabilities are calculated (the bottom values,) the system reliability can be found by multiplying the reliabilities of the two components as shown in Equation 5-5.

Equation 5-4. System Reliability

$$R(t) = e^{-(\lambda_A+\lambda_B)t} = e^{-0.0025x10} = 0.9753$$

Where:
R(t) = system reliability
λ = the failure rate (inverse of MTBF)
t = the length of time the system must function
e = the base of natural logarithms

Equation 5-5. System Reliability

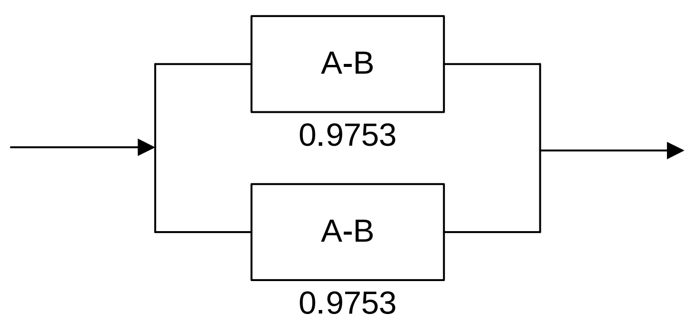
$$R(t) = R_A(t)\ x\ R_B(t) = 0.99000\ x\ 0.98510 = 0.9753$$

Where:
R(t) = system reliability
$R_A(t)$ = system A reliability
$R_B(t)$ = system B reliability

5-1.2.3 Reliability with Redundancy.

Now consider the RBD shown in Figure 5-4.

Figure 5-4 RBD of a System with Redundant Components



1. Each block represents the series configuration of components A and B.
2. The number below each block is the reliability calculated using equations 5-3 and 5-4 with t = 10 hours.

(1) The system represented by the RBD in Figure 5-4 has the same components (A and B in series denoted by one block labeled: A-B) used in Figure 5-3, but two of each component are used in a configuration referred to as redundant or parallel. Two paths of operation are possible. The paths are top A-B and bottom A-B. If either of two paths is intact, the system can operate. The reliability of the system is most easily calculated by

(Equation 5-6) finding the probability of failure (1 - R(t)) for each path, multiplying the probabilities of failure (which gives the probability of both paths failing), and then subtracting the result from 1. The reliability of each path was found in the previous example. Next, the probability of a path failing is found by subtracting its reliability from 1. Thus, the probability of either path failing is 1 - 0.9753 = 0.0247. The probability that both paths will fail is 0.0247 x 0.0247 = 0.0006. Finally, the reliability of the system is 1 - 0.0006 = 0.9994, about a 2.5% improvement over the series configured system.

Equation 5-6. System Reliability of Figure 5-4

$$R(t) = 1 - \left(1 - R_T(t)\right) x \left(1 - R_B(t)\right) = 1 - (0.0274\ x\ 0.0274) = 0.9994$$

Where:
R(t) = system reliability
R_T = the reliability of the top path
R_B = the reliability of the bottom path

(2) Two components in parallel may always be on and in operation (active redundancy) or one may be off (standby redundancy). In the latter case, failure of the primary component must be sensed to indicate that the standby module should be activated. Standby redundancy may be necessary to avoid interference between the redundant components. If the redundant component is normally off, reduces the time over which the redundant component will be used (it's only used from the time when the primary component fails). Of course, more than two components can be in parallel. Paragraph 5-2.4.1 discusses the various types of redundancy and how they can be used to improve the availability of current C5ISR facilities.

(3) Adding a component in parallel, such as, redundancy, improves the system's ability to perform its function. This aspect of reliability is called functional or mission reliability. Note, however, that in Figure 5-4 another set of components with its own failure rate has been added. To calculate the total failure rate for all components, they are add together. The result is 5000 failures per million operating hours (0.005000). The failure rate for the series-configured system in Figure 5-3 was 2500 failures per million operating hours. Although the functional reliability of the system improved, the total failure rate for all components increased. This perspective of reliability is called basic or logistics reliability. When standby redundancy is used, the sensing and switching components add to the total failure rate.

5-1.2.4 Logistics Reliability.

Whereas functional reliability only considers failures of the function(s), logistics reliability considers all failures because some maintenance action will be required. Logistics reliability can be considered as either the lack of demand placed on the logistics system by failures or the ability to operate without logistics. If standby redundancy is used with the redundant component not on, the apparent failure rate of the standby component will be less than that of its counterpart (it will likely operate less than ten hours), but the failure rate of the switching circuits must now be considered.

5-1.3 Calculating Availability.

For a system such as an electrical power system, availability is a key measure of performance. An electrical power facility must operate for very long periods of time, providing power to systems that perform critical functions, such as C5ISR. Even with the best technology and most robust design, it is economically impractical, if not technically impossible, to design power facilities that never fail over weeks or months of operation. Although forced outages are never welcome and power facilities are designed to minimize the number of forced outages, they still occur. When they do, restoring the system to operation as quickly and economically as possible is paramount. The maintainability characteristics of the system predict how quickly and economically system operation can be restored.

5-1.3.1 Reliability, Availability, and Maintenance.

Reliability and maintainability (R&M) are considered complementary characteristics. Looking at a graph of constant curves of inherent availability (A_i), one can see this complementary relationship. A_i is defined by Equation 5-7 and reflects the percent of time a system would be available if delays due to maintenance, supply, etc. are ignored.

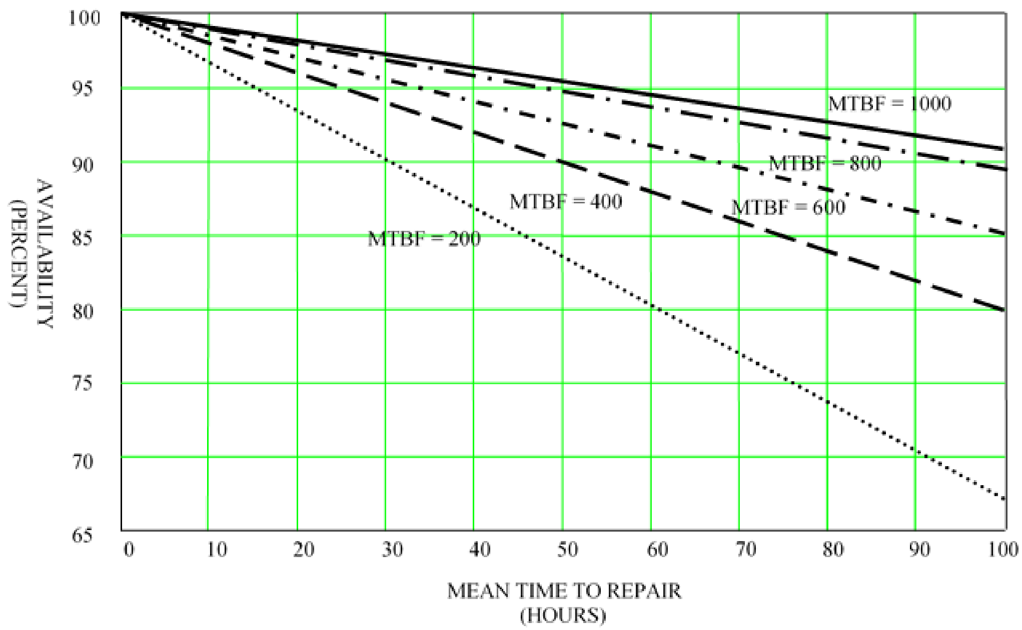
Equation 5-7. Inherent Availability

$$A_i = \frac{MTBF}{MTBF + MTTR} \; x \; 100\%$$

Where:
A_i = inherent availability
MTBF = mean time between failure
MTTR = mean time to repair

As seen in Equation 5-7, if the system never failed, the MTBF would be infinite, and A_i would be 100%. Or, if it took no time at all to repair the system, MTTR would be zero and again the availability would be 100%. Figure 5-5 is a graph showing availability as a function of reliability and maintainability (reliability is calculated using Equation 5-6). Note that the same availability with different values of R&M can be achieved. With higher reliability (MTBF), lower levels of maintainability are needed to achieve the same availability and vice versa. It is very common to limit MTBF, MTTR, or both. For example, the availability requirement might be 95% with an MTBF of at least 600 hours and a MTTR of no more than 3.5 hours.

Figure 5-5 Different Combinations of MTBF and MTTR Yield Same Availability



5-1.3.2 Other Measures of Availability

Availability is calculated through data collection by two primary methods:

(1) Operational availability includes maintenance and logistics delays and is defined using Equation 5-8:

Equation 5-8. Operational Availability

$$A_0 = \frac{MTBM}{MTBM + MDT}$$

Where:
A_o = operational availability
MTBM = mean time between all maintenance
MDT = mean downtime for each maintenance action

(2) Availability is also a function of raw uptime and downtime as seen in Equation 5-9:

Equation 5-9. Availability

$$A = \frac{Uptime}{Uptime + Downtime}$$

Where:
A = availability

where uptime is the time during which the system is available for use and downtime is the time during which the system is not available for use. Given that the sum of uptime and downtime is equal to the total system run time, this calculation is simply a ratio, indicating the percentage of the time that the system is up (or available).

(3) Note that A_o and A_i are probabilistic measures, while *A* is a deterministic measure. MTBF, MTBM, MTTR, and MDT are measures of reliability and maintainability (R&M). By designing for appropriate levels of R&M and ensuring statistically appropriate calculations, a high confidence in the availability can be obtained. However, that confidence can never be 100%. Measuring *A* is done by measuring the amount of uptime in a given total time and then calculating the observed availability using Equation 5-9. For this measure of availability, the time interval for the measurement is extremely important. Its importance can be understood by considering an availability requirement of 95% with a maximum downtime of ten hours. Table 5-2 shows the effect of varying intervals of time for measuring *A*.

Table 5-2 Effect of Measurement Interval on Observed Availability

Total Time	Actual Downtime	Actual Uptime	Measured Availability	Maximum Downtime to Meet Requirement (Using Equation 5-9)
1 hours	0.5 hours	0.5 hour	50%	0.05 hours (3 minutes)
8 hours	1 hour	7 hours	87.5%	0.4 (24 minutes)
24 hours	2 hours	22 hours	91.67%	1.2 hours
240 hours	10 hours	230 hours	95.83%	10 hours
7200 hours	10 hours	7190 hours	99.86%	10 hours

(a) Very short intervals make it increasingly difficult, if not impossible, to meet an availability requirement. It is very possible that a failure could occur in the first hour of operation. If that were the case, the system would pass the 95% availability test only if the repair could be made in 3 minutes or less. For many systems, it may be impossible to correct any failure in three minutes or less. So even if it is unlikely that a failure will occur in the first hour of operation (such as, the system is highly reliable), the probability of such a failure is not zero. If a failure occurs in the first hour and requires more than three minutes to repair, the system will have failed to meet an availability requirement of 95%. Yet, if the system is truly reliable, it may experience no more failures (and no more downtime) in the next 24 hours of operation, in which case the measured availability will be greater than the requirement.

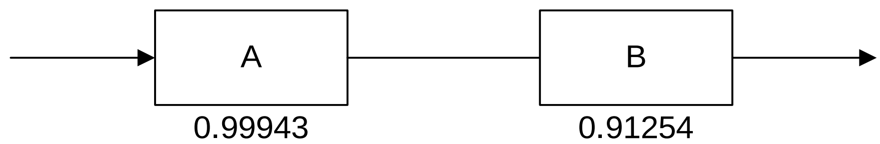
(b) Since A_o, A_i, and A are not measured in the same way, it is extremely important in contractual form to state clearly (for example, in a step-by-step, deductive manner) how availability will be measured during acceptance or qualification testing.

5-1.3.3 Calculating Simple System Availabilities.

Calculating simple system availability measures is similar to the reliability calculations in paragraphs 5.1-2.2 and 5.1-2.3.

(1) For series availability, consider the system represented by the block diagram in Figure 5-6.

Figure 5-6 Example Availability Block Diagram



1. The number below each block is availability of the component.

(a) Since the components are in series, the system availability can be found by multiplying the availabilities of the two components as shown in Equation 5-10.

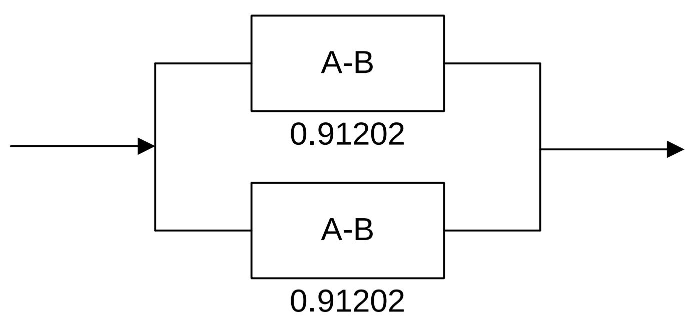
Equation 5-10. Series Availability

$$Series\ Availability = A_A\ x\ A_B = 0.99943\ x\ 0.91254 = 0.91202$$

Where:
A_A = component A availability
A_B = component B availability

(2) For parallel availability, consider the system represented by the block diagram in Figure 5-7.

Figure 5-7 Availability Block Diagram of a System with Redundant Components



1. The number below each block is the availability of the set of components.

(a) Since the components are parallel, the system availability can be found as shown in Equation 5-11.

Equation 5-11. Parallel Availability

$$\textit{Parallel Availability} = 1 - (1 - A_T)\ x\ (1 - A_B)$$

$$\textit{Parallel Availability} = 1 - (0.08798) \times (0.08798)$$

$$\textit{Parallel Availability} = 0.99226$$

Where:
A_T = *the availability of the top path*
A_B = *the availability of the bottom path*

5-1.4 Predictions and Assessments.

Predictions and assessments refer to the process of evaluating the RAM calculations, system weaknesses, and areas offering opportunities for improvement. Quantitative numbers are a usual byproduct of a prediction or assessment. Such numbers are necessary for calculating spares requirements, probability of success, and other purposes.

5-1.4.1 Reliability Predictions.

In a new development program, reliability predictions are a means of determining the feasibility of requirements, assessing progress toward achieving those requirements, and comparing the reliability impact of design alternatives. Predictions can be made through any appropriate combination of reliability models, historical data, test data, and engineering judgment. The choice of which prediction method to use depends on the availability of information. That choice can also be a function of the point of the system life cycle at which the prediction is performed. Considerations in performing predictions include that correct environmental stresses are used, the reliability model is correct, the correct part qualities are assumed, and that all operational and dormancy modes are reflected.

5-1.4.2 Reliability Assessments.

Predictions are one method of assessing the reliability of an item. At the onset of a new development program, the prediction is usually purely analytical. As the program progresses, other methods become available to improve or augment the analytical prediction. These methods include testing, design reviews, and others. For existing systems, reliability assessments include analyzing field data to determine the level of reliability being achieved and identify weaknesses in the design and opportunities for improvement.

5-1.4.2.1 Common Techniques.

Table 5-3 lists some common techniques that can be used for assessing reliability and guidance for their use. Some of these methods provide a numerical value that is representative of the system reliability at a point in time; all provide a valuable means of better understanding the design's strengths and weaknesses so that it can be changed accordingly.

5-1.4.2.2 Assessment Methods.

The assessment methods chosen should be appropriate for the system and require only a reasonable level of investment given the value of the results. The failure of some components, for example, may have little impact on either system function, or on its operating and repair costs. A relatively costly analysis may not be justified. For other systems, a thermal analysis may not be needed, given the nature of the system and its operating environment. When the consequences of failure are catastrophic, every possible effort should be made to make the system fail-safe or fault tolerant.

Table 5-3 Methods for Assessing Reliability

Method	Application
Accelerated Life Testing	Effective on parts, components, or assemblies to identify failure mechanisms and life limiting critical components.
Critical Item Control	Apply when safety margins, process procedures and new technology present risk to the production of the system.
Design of Experiments (DOE)	Use when process physical properties are known, and parameter interactions are understood. Usually done in early design phases, it can assess the progress made in improving system or process reliability.
Design Reviews	Continuing evaluation process to ensure details are not overlooked. Should include hardware and software.
Dormancy Analysis	Use for products that have “extended” periods of non-operating time or unusual non-operating environmental conditions or high cycle on and off periods.
Durability Analysis	Use to determine cycles to failure or determine wear out characteristics. Especially important for mechanical products.
Failure Modes, Effects and Criticality Analysis (FMECA)	Applicable to equipment performing critical functions (for example control systems) when the need-to-know consequences of lower-level failures is important
Failure Reporting Analysis and Corrective Action (FRACAS)	Use when iterative tests or demonstrations are conducted on breadboard, or prototype products to identify mechanisms and trends for corrective action. Use for existing systems to monitor performance.
Failure Tree Analysis (FTA)	Use for complex systems evaluations of safety and system reliability. Apply when the need to know what caused a hypothesized catastrophic event is important.
Finite Element Analysis (FEA)	Use for designs that are unproven with little prior experience/test data, use advanced/unique packaging/design concepts, or will encounter severe environmental loads.
Life Cycle Planning	Use if life limiting materials, parts or components are identified and not controlled.
Parts Obsolescence	Use to determine need for and risks of application of specific parts and lifetime buys.
Prediction	Use as a general means to develop goals, choose design approaches, select components, and evaluate stresses. Equally useful when redesigning or adding redundancy to an existing system.
Reliability Growth Test (RGT)/Test Analyze and Fix (TAAF)	Use when technology or risk of failure is critical to the success of the system. These tests are costly in comparison to alternative analytical techniques.

Sneak Circuit Analysis (SCA)	Apply to operating and safety critical functions. Important for space systems and others of extreme complexity. May be costly to apply.
Supplier Control	Apply when high volume or new technologies for parts, materials or components are expected.
Test Strategy	Use when critical technologies result in high risk of failure
Thermal Analysis (TA)	Use for products with high power dissipation, or thermally sensitive aspects of design. Typical for modern electronics, especially of densely packages products.
Worst Case Circuit Analysis (WCCA)	Use when the need exists to determine critical component parameters variation and environmental effects on circuit performance.

5-2 IMPROVING AVAILABILITY.

5-2.1 Overview of the Process.

Facility managers are faced with the responsibility of providing the proper utilities (electrical, chilled water, steam, etc.) at the needed levels (power levels, voltage, pressure, etc.) to their customers when needed to support an end mission. The steps for improving the availability of new facilities in design and facilities already in use are shown in Table 5-4. The steps for each situation will be discussed in this chapter. \1\ See UFC 4-141-03 for specific design requirements. /1/

Table 5-4 The Process for Improving Facility Availability

New Facilities Being Designed	Facilities Already in Use
1. Determine system availability requirements 2. Derive reliability and maintainability requirements from availability requirement 3. Develop one-line diagrams 4. Conduct analyses to predict availability, reliability, and maintainability and to determine weaknesses in design based on failure criteria and cost/benefit analysis 5. Conduct testing to validate analytical results 6. Update assessment of availability, reliability, and maintainability based on test results 7. Revise design as necessary based on test results 8. Construct facility and continuously assess performance and identify opportunities for improvement 9. Continuously assess performance and identify opportunities for improvement	1. Determine system availability requirements 2. Derive reliability and maintainability requirements from availability requirement 3. Develop one-line diagrams 4. Collect data for availability assessment 5. Assess availability, reliability, maintainability, and logistics performance being achieved for each system (this establishes the baseline performance) 6. Identify shortfalls (differences between required level of performance and baseline performance) 7. Perform cost-benefit analysis to prioritize improvement efforts 8. Design and develop system changes 9. Assess improvement in availability, reliability, and maintainability based on analyses and test 10. Implement design changes 11. Continuously assess performance and identify opportunities for improvement

5-2.2 New Facilities

Since reliability and maintainability, and hence availability, are predominantly affected by design, it is essential that these system characteristics be addressed in the design of a new system. It is during design, that these characteristics can be most effectively and positively influenced at the least cost.

5-2.2.1 Determine System Availability Requirements.

Establishing clear, comprehensive, and measurable requirements is the first and most important step in designing and developing systems. The design requirements must allow the user needs to be met. User needs are often stated in non-design terms. For facilities, these might include operational availability, readiness, mean time between maintenance (where maintenance includes all maintenance actions, including those to repair operator-induced failures), and total downtime (including the time to order and ship parts if necessary). Designers must have requirements that they can control. For a facility, these may include inherent availability, mean time between design failures, and mean time to repair (includes only the actual "hands on" time to make a repair). The facility availability requirement should be included in the specifications for a new facility.

5-2.2.2 Derive Reliability and Maintainability Requirements from Availability Requirement.

Based on the user need (for example, operational availability), the reliability and maintainability design requirements (for example, mean time between failure and mean time to repair) must be derived. This derivation of lower-level requirements is usually done by the design organization and continues throughout the development effort until design requirements are available at the lowest level of indenture (subsystem, assembly, subassembly, part) that makes sense.

5-2.2.3 Develop One-line Diagrams.

One-line diagrams will be instrumental in the creation of all models concerning RAM criteria and analysis. It is critical that diagrams are accurate and up to date. Paragraph 5.3-5 of this UFC demonstrates how one-line diagrams are used in modeling and calculation.

5-2.2.4 Conduct Analyses.

Conduct analyses to predict availability, reliability, and maintainability and to determine weaknesses in design and redesign based on failure criteria and cost/benefit analysis. Some of the pertinent analyses are summarized in Table 5-5.

5-2.2.5 Conduct Testing to Validate Analytical Results.

No matter how diligently the models are developed, and the analytical tools are used, all variations and factors cannot be accounted for. By testing a given design, unexpected problems will be uncovered. These problems can include new types of failures, more frequent than expected failures, different effects of failures, and so forth. Problems discovered during test provide opportunities for improving the design and models and tools.

5-2.2.6 Update Assessment of Availability, Reliability, and Maintainability Based on Results.

Based on the results of testing, the analytical assessments of reliability made earlier should be updated. Adding the results of testing provides higher confidence in the assessment than is possible using analytical results alone.

Table 5-5 Analyses Helpful in Designing for Reliability

Analysis	Purpose	Applications	When to Perform
FEA	• Computer simulation technique for predicting material response or behavior of modeled device • Determine material stresses and temperature • Determine thermal and dynamic loading	• Use for devices that: - Are unproven with little prior experience/data - Use advanced/unique packaging/design concepts - Will encounter severe environmental loads - Have critical thermal/mechanical constraints	• In design phase when candidate devices can be selected using selection criteria
TA	• Calculate junction temperatures • Calculate thermal gradients • Calculate operating temperatures	• For integrated circuits • For electronics and electrical devices	• During circuit design • Prior to design of cooling systems
Dormancy Analysis	• Calculate failure rates of devices in dormancy or storage	• Use for devices identified to have periods of dormancy	• During design
FTA	• Top-down approach to identify effects of faults on system safety or reliability • Address multiple failure	• Can be applied when FMECA too expensive • To address effects of multiple failures	• Early in design phase, in lieu of FMECA
FMECA	• Bottom-up approach to identify single failure points and their effects • To assist in the efficient design of BIT and FIT • To establish and rank critical failures • To identify interface problems	• More beneficial if performed on newly designed equipment • More applicable to equipment performing critical functions (for example, control systems)	• Early in design phase
SCA	• To identify failures not caused by part failures • To reveal unexpected logic flows that can produce undesired results • To expose design oversights that create conditions of undesired operation	• Mission and safety critical functions • Hardware with numerous interfaces • Systems with high testing complexities • Use selectively due to high testing complexities	• Later in design stage but prior to CDR
WCCA	• To evaluate circuits for tolerance to “drift” • When time dependency is involved • To evaluate the simultaneous existence of all unfavorable tolerances • Single failures	• Assesses combined effect of parts parameters variation and environmental effects on circuit performance • Not often applied • Use selectively	• Later design stage as required

LEGEND: Finite Element Analysis (FEA); Thermal Analysis; Fault Tree Analysis (FTA); Failure Modes, Effects and Criticality Analysis (FMECA); Sneak Circuit Analysis (SCA); Worst Case Circuit Analysis (WCCA); Build-in-Test (BIT); Framework for Integrated Test (FIT); Critical Design Review (CDR)

5-2.2.7 Revise Design as Necessary Based on Test Results.

If the updated assessment indicates the design is falling short of the RAM requirements, the design must be revised to improve the reliability. Even when the updated assessment indicates the design is close to meeting the requirements, design changes should be considered referencing cost-benefit considerations.

5-2.2.8 Construct Facility and Continuously Assess Performance and Identify Opportunities for Improvement.

Once the RAM requirements are satisfied by the facility design, the facility is constructed. The inherent levels of reliability must be sustained over time. To that end, data needs to be collected continuously to assess the availability performance of the facility. This operational, field data should be archived for use in designing new facilities.

5-2.3 Existing Facilities.

For facilities in use, the process for improving availability is somewhat different than that discussed for new systems. It is different for two major reasons. First, improvements must be made by modifying an existing design, which is usually more difficult than creating the original design. Second, the improvements must be made with as little disruption to the facility as possible since it is supporting an ongoing mission. Although design changes are usually the primary focus of improvement efforts, changes in procedures or policy should also be considered. Not only are such changes usually much easier and economical to make, but they may also be more effective in increasing availability.

5-2.3.1 Determine System Availability Requirements.

As was the case for a new system, the requirements must be known. For existing facilities, it may be difficult to find the original user needs or design requirements. Even when the original requirements can be determined, the current requirements may have changed due to mission changes, budget constraints, or other factors.

5-2.3.2 Derive Reliability and Maintainability Requirements from the Availability Requirement.

After the system availability requirements are determined, it is necessary to translate them into reliability and maintainability requirements.

5-2.3.3 Develop One-line Diagrams.

This step can be bypassed if original one-lines are still current.

5-2.3.4 Collect Data for Availability Assessment.

Ideally, a data collection system was implemented when the facility was first put into operation. If that is not the case, one should be developed and implemented. The data to be collected includes the category of failures, causes of failures, date and time when failures occur, mechanisms affected, and so on. A substantial byproduct of an RCM program is the generation of such unique, facility data.

5-2.3.5 Assess Performance.

Assess the availability, reliability, maintainability, and logistics performance being achieved for each system. Performing this step establishes the baseline performance for the facility.

5-2.3.6 Identify Shortfalls.

Shortfalls are the differences between the required level of performance and baseline performance.

5-2.3.7 Performance Cost-Benefit Analysis to Prioritize Improvement Efforts.

Many potential improvements will be identified throughout the life of a facility. Those that are safety-related or are essential for mission success will always be given the highest priority. Others will be prioritized based on the costs to implement compared with the projected benefits. Those that have only a small return for the investment will be given the lowest priority.

5-2.3.8 Design and Develop System Changes.

The process for improving the availability, reliability, and maintainability performance of an existing facility is essentially the same as for designing new facility.

5-2.3.9 Assess Improvement.

Assess improvement in reliability, availability, and maintainability based on analyses and tests. Before implementing any potential improvements, some effort must be made to ensure that the design changes must be validated. All too often, a change that was intended to improve the situation makes it worse. Through careful analyses and appropriate testing, one can determine that the proposed change results in some level of improvement.

5-2.3.10 Implement Design Changes.

Those design changes that are validated as improving availability must be implemented in a way that minimizes the downtime of the facility. Perhaps they can be made during scheduled maintenance periods. Or perhaps there are times of the day, month, or year when downtime is less critical to the mission than at other times. Careful planning can minimize the impact on the mission. Also, the procedures, tools, training, and materials needed for the design change must be in place and validated prior to starting the facility modification.

5-2.3.11 Monitor Performance.

Continuously assess performance and identify opportunities for improvement. Continuous improvement should be the goal of every facility manager. As the facility ages, the cost-benefits of what were low-priority improvements may change, new problems may be introduced, and new mission requirements may arise. By collecting data and maintaining a baseline of the facility availability performance, the facility manager will be able to make future improvements as they become necessary or economical.

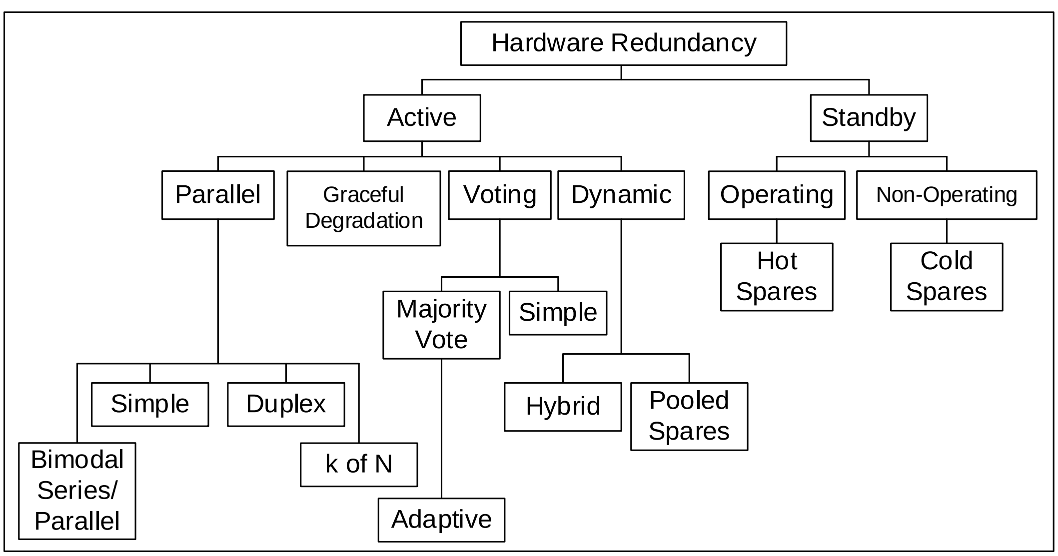
5-2.4 Improving Availability Through Addition of Redundancy.

Redundancy is a technique for increasing system reliability and availability by making the system immune to the failure of a single component. It is a form of fault tolerance – the system can tolerate one or more component failures and still perform its function(s).

5-2.4.1 Types of Redundancy.

There are essentially two kinds of redundancy techniques employed in fault tolerant designs, space redundancy and time redundancy. Space redundancy provides separate physical copies of a resource, function, or data item. Time redundancy, used primarily in digital systems, involves the process of storing information to handle transients, or encoding information that is shifted in time to check for unwanted changes. Space, or hardware, redundancy is the approach most commonly associated with fault tolerant design. Figure 5-8 provides a simplified tree-structure showing the various types of hardware redundancy that have been used or considered in the past.

Figure 5-8 Types of Redundancy



5-2.4.2 Impact on Testability.

Many of today's more sophisticated systems not only require an ability to detect faults but also to diagnose or isolate them. It may even be desirable for a system to have the ability to reconfigure itself to avoid system failure. Automated fault detection and isolation has therefore become an essential means of obtaining highly fault tolerant systems. Because of this, the design of the diagnostic system, including any built-in-test (BIT) features and the overall testability of the design are important tradeoffs that need to be made as part of the fault tolerant design process. Table 5-6 presents a sample list of hardware fault tolerant design approaches, and their impact on diagnostic approaches and BIT.

(1) No matter which technique is chosen to implement fault tolerance in a design, the ability to achieve fault tolerance is becoming increasingly dependent on the ability to detect, and isolate malfunctions as they occur or are anticipated to occur. Alternate maintainability diagnostic concepts must be carefully reviewed for effectiveness before committing to a final design approach. BIT design has become very important to achieving a fault tolerant system. When using BIT in fault tolerant system design, the BIT system must do the following:

(a) Maintain real-time status of the system's assets (on-line and off-line, or standby, equipment).

(b) Provide the operator with the status of available system assets.

(c) Maintain a record of hardware faults for post-mission evaluation and corrective maintenance.

(2) The essence of fault tolerance is that the system is able to perform its mission despite experiencing some failures. In systems where redundancy is used, this fault tolerance is achieved by one or more redundant units taking over the function previously being performed by another unit. When standby redundancy is used, the failed unit must be detected and the standby unit "brought online." In still other cases principally involving electronics, failures can be repaired by rerouting signals or functions to other units. These repairs can be done upon a failure or in anticipation of a failure. In such cases, the BIT should, in addition to the actions identified in paragraph 5-2.4.2; maintain a record of any reconfiguration events that were required for system recovery during the mission.

(3) For fault tolerant systems, it is important that the design's inherent testability provisions include the ability to detect, identify, recover, and if possible, reconfigure, and report equipment malfunctions to operational personnel. The RBDs for fault tolerant systems are complex, with non-serial connections. Fault tolerant systems often have a multitude of backups with non-zero switch-over time and imperfect fault detection, isolation, and recovery. Therefore, it is imperative that effective testability provisions be incorporated in the system design concept. If they are not, the fielded design will exhibit long troubleshooting times, high false alarm rates, and low levels of system readiness.

Table 5-6 Diagnostic Implications of Fault Tolerant Design Approaches

Fault Tolerant Design Technique	Description	Diagnostic Design Implications	BIT Implications
Active Redundancy simple parallel	All parallel units are on whenever the system is operating. K of the N units are needed, where 0<k<N. External components are not required to perform the function of detection, decision and switching when an element or path in the structure fails. Since the redundant units are always operating, they automatically pick up the load of the failed unit. An example is a multi-engine aircraft. The aircraft can continue to fly with one or more of engines out of operations	Hardware/Software is more readily available to perform multiple functions.	N/A
Active Redundancy with voting logic	Same as Active Redundancy but where a majority of units must agree (for example, when multiple computers are used)	Performance/status-monitoring function assures the operator that the equipment is working properly: failure is easily isolated to the locked-out branch by the voting logic	N/A
Stand-by redundancy (Non-operating)	The redundant units aren't operating and must be started if a failure is detected in the active unit (for example a spare radio is turned on when the primary radio fails.)	Test capability and diagnostic functions must be designed into each redundant or substitute functional path (on-line AND off-line) to determine their status.	Passive, periodic, or manually initiated BIT
Stand-by redundancy (Operating)	The redundant units are operating but not active in system operation; must be switched "in" if a failure is detected in the active unit (for example a redundant radar transmitter feeding a dummy load is switched into the antenna when the main transmitter fails)	N/A	Limited to passive BIT (such as, continuous monitoring) supplemented with periodic BIT

5-2.4.3 Role of RAM Concepts in the Fault Tolerant Design Process.

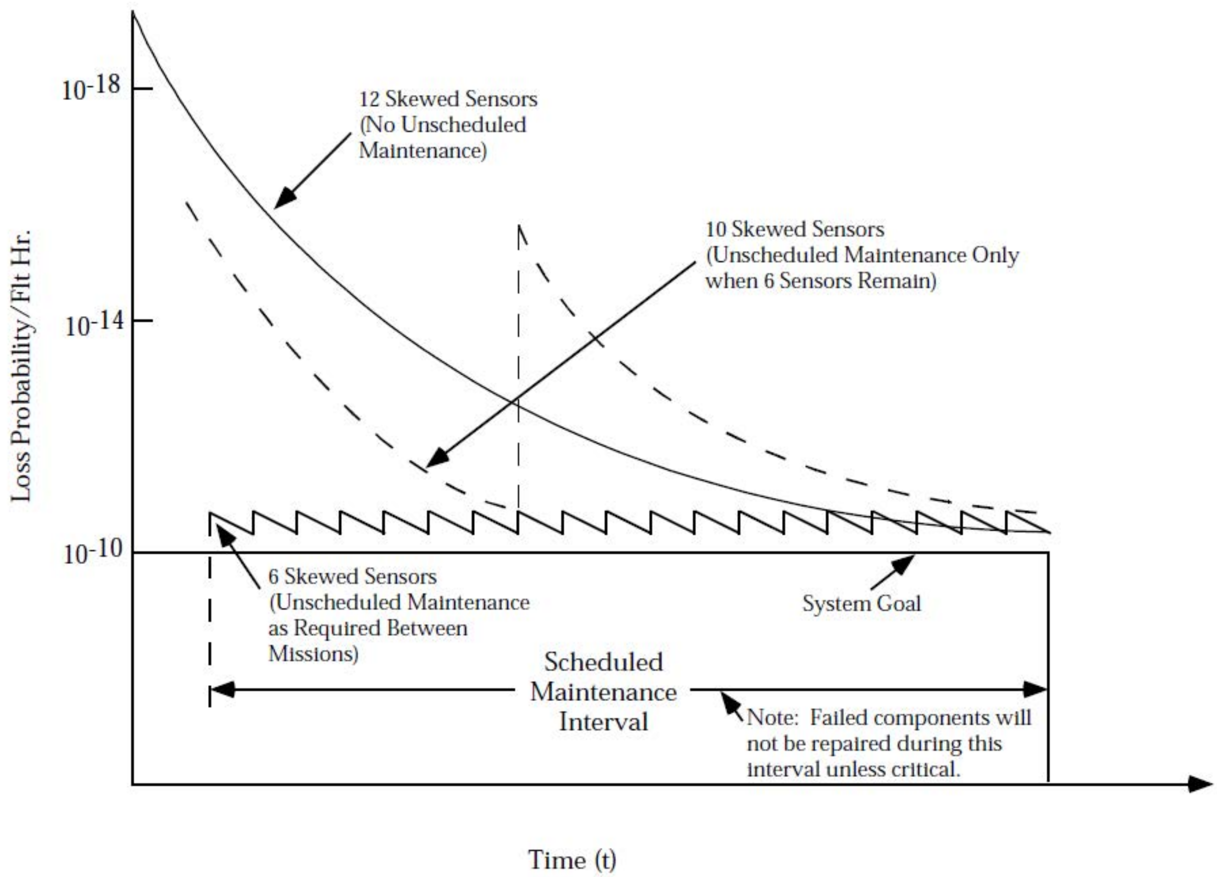
The role of the reliability engineer in regard to fault tolerant design requirements is to ensure that system RAM requirements are achievable for each of the fault tolerant design approaches being considered. Furthermore, to properly design a fault tolerant system, including a diagnostic scheme, the designer needs to understand the modes in which the system can fail, and the effects of those failure modes. This requires that a failure mode and effects analysis (FMEA) be performed, as a minimum. The FMEA will identify which faults can lead to system failure and therefore must be detected, isolated, and removed to maintain system integrity. In general, the reliability design manager must ask a series of questions, as listed below. Additionally, the RCM process helps to direct RAM concepts throughout the facility life cycle. The applicability of that process is further described in Chapter 7.

1. How do the system fault tolerance requirements impact the overall reliability, maintainability, and availability requirements?
2. Where should fault tolerant design methods be applied?
    - Which functions involve the most risk to mission success?
    - What is the effect of the operating environment?
    - What maintenance strategy/policy needs to be considered?
3. What is the effect of maintainability and testability?
4. What are the constraints that affect fault tolerance?
    - Cost
    - Size & Weight
    - Power
    - Interface Complexity
    - Diagnostic Uncertainties

5-2.4.4 Fault Tolerance and Tradeoffs.

The designer needs to consider each of the questions, listed above, and others as part of the overall fault tolerant design process. Other reliability tradeoffs to be considered involve analysis of the redundancy approaches being considered for the fault tolerant design. In addition to reliability concerns, fault tolerance also requires analysis of the impacts on maintainability and testability. As an example, consider Figure 5-9. This figure illustrates a design vs. corrective maintenance tradeoff analysis performed early in the product development phase. In particular, the figure shows the tradeoff of restoration frequency versus the number of sensors being used to meet requirements. This program requires a time period for allocating a scheduled maintenance activity and a probability of less than one in 10 billion per flight hour that a total loss of the skewed sensor function would occur. The tradeoff is made between the number of sensors and the cost of unscheduled maintenance activity associated with each approach. Other tradeoffs, such as cost, power, weight, etc. are also necessary. In general, as in any design analysis support function, an analysis of the impacts on reliability, availability, and maintainability (including support for system testing) of a chosen fault tolerant design approach must be performed.

Figure 5-9 Effect of Maintenance Concept on Level of Fault Tolerance



Note: More Frequent Restoration of Redundancy Lowers Fault Tolerance Requirements, But Results in Higher Maintenance Manhours

5-2.4.5 General Rules in Applying Redundancy.

In applying redundancy to a C5ISR facility, the following general rules should be followed:

5-2.4.5.1 Rule 1.

Determine the weak links in the system to know where to add redundancy. These weak links may be portions of the system prone to single point failures or, where redundancy is already used, the reliability is still too low to meet availability requirements.

(a) As an example of applying Rule 1, consider the simple system shown in Figure 5-10.

This system has five subsystems (lettered) with seven major components (numbered). The MTBF and MTTR for each component are shown. Using these figures, the overall system availability can be calculated using Monte Carlo simulation (see paragraph 5-3 for methods of calculating complicated system availability models). The results of a Monte Carlo simulation of the system yielded the results shown in Table 5-7. The areas of weakness from an availability perspective can be determined from simply looking at the relative contribution to system unreliability as summarized in Table 5-8 (also resultants from a Monte Carlo simulation). Note that subsystem C is the weakest link, even though it is not subject to a single point failure. Subsystem D is the next weakest link; it is subject to a single point failure. It may have been obvious that D, representing a potential single point failure, is a weak link. It may not have been as obvious that C, even though it already incorporates redundancy, is a weak point. Looking at the relative availability of component 3, we see that it is much less reliable than the other components. Even dual redundancy is insufficient to compensate for the low MTBF. As this example shows, although it may be tempting to always add redundancy to those portions of a system subject to single point failures, it is sometimes more effective to add it elsewhere.

Figure 5-10 Analyzing the Contribution to System Reliability Helps Determine Where Redundancy is Needed

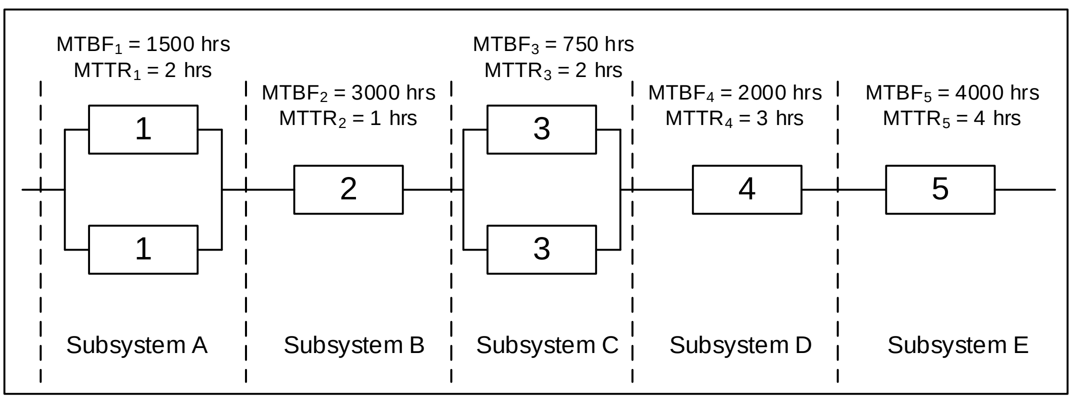


Table 5-7 Availability of System Depicted in Figure 5-10

MTBM	Mean System Failures	MTTR	Availability %
258.77	1.0658	2.5695	99.7236

Notes:

1. For ease of calculation, the times to failure and the times to repair were assumed to be distributed exponentially.
2. 10,000 simulation trials were run using an operating time of 1,000 hours.

Table 5-8 Relative Unreliability of Subsystems (Repairs Ignored)

Subsystem	Reliability in 1000 hours	Expected Failures per 1000 Hours	% Contribution to System Unreliability	Contribution to System Unreliability Ranking
A	0.7632	0.2368	14.12	4
B	0.7165	0.2835	16.90	3
C	0.4577	0.5423	32.33	1
D	0.6065	0.3935	23.46	2
E	0.7788	0.2212	13.19	5
SYSTEM	0.1182	1.6773	-	-

5-2.4.5.2 Rule 2.

Add redundancy in a way that avoids undesirable interactions. Rule 2 implies that some components cannot be used in some forms of redundancy, depending on the failure modes, application, and other factors. The type of redundancy shown in Figure 5-10 is active redundancy, in which all components are on all the time that the system is operating. In some cases, such a redundant configuration would result in undesired interactions or interference among the redundant units. As will be seen later in this chapter, certain forms of redundancy are preferable to others in a given application.

5-2.4.5.3 Rule 3.

Adding redundancy increases support requirements and costs. Rule 3 refers to the added costs incurred with redundancy. The most obvious increase is because more components must be purchased and installed. An additional cost comes from an increase in the total failures within the system. The increase in complexity results in an increase in unscheduled maintenance. If nothing is done to improve the reliability of the individual components in a system, but additional components are added to provide redundancy, the total failure rate of the components will increase. System reliability will improve but more component failures will occur. These failures will increase support requirements and costs. Redundancy also increases weight, space requirements, complexity, and time to design. Thus, safety and mission reliability are gained at the expense of adding an item(s) in the unscheduled maintenance chain.

(a) The decision to use redundant design techniques must be based on analysis of the tradeoffs involved. Redundancy may prove to be the only available method, when other techniques of improving reliability (for example, derating, simplification, better components) have been exhausted, or when methods of item improvement are shown to be more costly than duplications.

(b) When preventive maintenance is planned, the use of redundant equipment can allow for repair with no system downtime. Occasionally, situations exist in which equipment cannot be maintained. In these cases, redundant elements may be the best way to significantly prolong operating time.

5-2.4.5.4 Rule 4.

Ensure that any one redundant unit can be maintained without shutting down the other redundant units. Assume that two generators, for example, are sharing a load. If one fails and the operators must shut the other generator down to either gain access to or repair the failed generator, then there is no effective redundancy. An implicit assumption in using redundancy is that availability increases because a failed component can be repaired while the remaining redundant components continue to operate. If this assumption is violated, redundancy will not increase availability.

5-2.4.6 Design Considerations.

The FMEA is a primary reliability analysis, critical to the fault tolerant design process. The reliability engineer will use additional techniques as well for analyzing a fault tolerant design to verify that it meets reliability requirements. However, many of the evaluation tools used in the past are no longer adequate to deal with more sophisticated fault tolerant designs that include more complex fault handling capabilities. Because fault handling methods include the use of fault detection and fault recovery approaches, any evaluation tool must include the ability to properly account for the effects of imperfect fault detection and fault recovery.

5-2.4.6.1 Monte Carlo Simulation and Markov Techniques.

Monte Carlo simulation and Markov techniques continue to be used as the primary means of analyzing highly sophisticated fault tolerant designs. These approaches have been modified to incorporate situations where the sequence of failure is important, where the failure is transient or intermittent, or where the response to failure (such as, detection, isolation, recovery, and reconfiguration) is imperfect. In these situations, Markov methods continue to lead the way in evaluation methods. In general, the Markov approach, which is used to define the specific states that a system can occupy, has been used to incorporate fault handling and recovery. A major limitation to the Markov approach is that the number of system states that must be defined to comprehensively describe a large system and model the behavior of complex fault management schemes can become very large (approaching 105 system states for highly complex systems). A common solution to this problem is to partition the system into smaller systems, evaluate each partition separately, and then combine the results at the system level. However, such an approach is only exact when each partitioned subsystem's fault tolerant behavior is mutually independent of each other. If subsystem dependencies do exist, then an assumption of independence will result in only an approximate solution.

5-2.4.6.2 Other Approaches.

Other approaches that are now becoming more common involve decomposing the system into separate fault-occurrence and fault handling submodels. However, the inputs for this type of approach require knowledge of the distribution and parameter values of detection, isolation, recovery, rates, etc. The following is a list of assumptions, limitations and sources of error found in existing reliability models:

(a) Solving a fault-handling model in isolation and then reflecting its results in an aggregate model is, itself, an approximation technique. The assumptions necessary to determine a solution typically result in a lower bound (conservative) approximation of the system reliability.

(b) Separate fault-handling models have been assumed to be independent of system state. This requires that the same fault-handling model and choice of parameters be used irrespective of the system's level of degradation. This ignores the fact that for many systems the recovery process is faster if the number of active units is smaller or that the recovery process may be different, depending on the sequence of events in different subsystems.

(c) The common technique of partitioning the system into independent functional subgroups for computational ease is a potential source of error. The magnitude and direction of the error is a function of how truly independent/dependent the subgroups are of each other. If subgroups are assumed independent when in fact they are not, the effect is an overstatement of system reliability/availability. If subgroups are assumed completely dependent when some degree of independence exists, the effect is an understatement of the system's RAM capabilities.

(d) Some models assume a constant instantaneous fault-protection coverage factor in lieu of a separate fault handling model. These fail to recognize that during time spent in the intermediate fault-handling states to detect, isolate, and recover/reconfigure, a second item failure could result in system failure. Further, as with fault handling models, these times are generally not constant, but depend on the current state of the system.

(e) Most models require the assumption that the system is perfect at the mission start. Therefore, they cannot evaluate the effects of latent defects (for example, handling, manufacturing, transportation, and prior mission), nor assist in determining the testability payoff or requirements for detection and removing them before the start of the mission. Models with this limitation cannot be used to evaluate alternate maintenance concepts that include degradation between missions as an acceptable strategy.

(f) Some models require that spares be treated exactly like active units, irrespective of their actual utilization in the system mechanization. This requires that spares are assumed to be "hot" and have the same failure rates and failure modes as the active units. This assumption will cause the model to understate the system reliability in those situations where spares are "cold" or in "stand-by" and/or where their failure rates may be less that those of the active units.

(g) As indicated previously, some models require the assumption that item failure rates are constant throughout time. This will result in an overstatement of system reliability if the items have failure rates that increase with mission time. Some models remove this restriction and permit time-varying failure rates. However, the solution algorithms employed require the use of global time (as opposed to local time of entry into a state), thus precluding the use of the model for repairable systems and availability analysis.

5-3 ASSESSING RELIABILITY AND AVAILABILITY.

5-3.1 Purpose of the Assessment.

As systems become more and more complex, good methods for specifying and analyzing the systems and their sub-systems become more important. Reliability modeling (including prediction, evaluation, and control) is vital for proper design, dependable operation, and effective maintenance of systems. The popularity of designing redundancy into systems poses additional challenges to reliability professionals. For the various kinds of redundant systems, the reliability and availability are extremely sensitive to even small variations in certain parameters; thus, precise understanding and insight can be gained only by modeling.

The need to assess the reliability, availability, and maintainability of a system is becoming more important as organizations understand the potential effects of failures and downtime for the systems. Regardless of what mission is being served, or who the intended customer may be, it should be a reasonable assumption to state that the degree of product/service success is directly related to the ability of that product/service to meet or exceed customer expectations.

The eight-step process shown below should be adhered to during a reliability study. Validation is essential throughout the eight-step process.

1. **Problem Definition**: define problem and its objectives.
2. **Model Building**: description of system’s entities and their interaction.
3. **Data Collection**: quantify probability distributions for system’s entities.
4. **Program**: select programming language or software package to execute.
5. **Verification**: check that code is achieving expected results.
6. **Experimental Design**: determine initial conditions, simulation period and number of runs (must be statistically valid).
7. **Implementation**: run model and test its sensitivity to variations.

8. **Documentation**: document reliability study to verify problem definition objectives are reached (document enough for functional model in future).

5-3.2 Prediction.

There are many valid reasons for predicting reliability. One purpose for reliability prediction is to assess the reliability of a proposed design and to provide a quantitative basis for selection among competing approaches or components. In addition, prediction results can be used to rank design problem areas and assess trade study results. A combination of prediction methods should be used to assess progress in meeting design goals, identifying environmental concerns, controlling critical items, and determining end-of-life failure mechanisms. Making predictions should be an ongoing activity that starts with the initial design concept and continues through the evaluation of alternate design approaches, redesigns, and corrective actions. Each iteration of prediction should provide a better estimate of system reliability as better information on the system design approach becomes available.

5-3.3 Analytical Methodologies.

Analytical methods of evaluating systems are based on a variety of logical and mathematical principles. Some utilize logical algebraic formulas to arrive at a closed-form, exact, solution to a model of a system. Others use simulation processing to empirically arrive at model solutions. Simple systems can be calculated with pencil and paper. Those exercises grow linearly as the model grows linearly. Several techniques/software algorithms streamline the process of calculating availability for large systems.

5-3.3.1 Cut Set.

The cut-set method can be applied to systems with simple as well as complex configurations and is a very suitable technique for the reliability analysis of power distribution systems. A cut-set is a “set of components whose failure alone will cause system failure,” and a minimal cut-set has no proper subset of components whose failure alone will cause system failure. The components of a minimal cut-set are in parallel since all of them must fail to cause system failure and various minimal cut-sets are in series as any one minimal cut-set can cause system failure.

5-3.3.2 Network Reduction.

The network reduction method is useful for systems consisting of series and parallel subsystems. This method consists of successively reducing the series and parallel structures by equivalent components. Knowledge of the series and parallel reduction formulas is essential for the application of this technique.

5-3.3.3 Boolean Algebra and Block Diagrams.

One of the most useful tools in evaluation methods has been the use of a combination of block diagrams and Boolean algebra. The use of software to these analyses is critical given that the logic and algebra become immense as systems grow. The GO algorithm is one such instrumental method.

5-3.3.3.1 GO Algorithm.

The GO algorithm, a success-oriented system analysis technique, was originally developed for defense industry applications in the early 1960s. The capability of the GO methodology was drastically improved under the sponsorship of the Electric Power Research Institute (EPRI) with the development of additional analytical techniques (such as system interactions, system dependencies, and man-machine interactions) and improved computer software reliability. The popularity of the GO method can be linked to basic characteristics that fault trees do not possess. The hardware is modeled in a manner more or less the same way as in the system drawings, model modifications can be easily introduced to reflect configuration changes, and the modeling capability is extremely flexible. GO's success-oriented technique analyzes system performance through straightforward inductive logic. The GO representation of a system, or GO model, can often be constructed directly from engineering drawings, which makes GO a valuable tool for many applications, since it is relatively easy to build and review models.

5-3.3.3.2 System Model.

A system model is first constructed within the GO methodology using a top-down (forward-looking) approach to identify the functions required for successful operation following normal process flow or operational sequences. Secondly, in the GO methodology each of the systems that provide the functionality is modeled to the required level of detail. The level of detail may be at the system, subsystem, or component level depending upon the type of information required and the plant specific information available. The GO models determine all system-response modes: successes, failures, prematures, etc.

5-3.3.3.3 Go Models.

GO models consist of arrangements of GO operator symbols and represent the engineering functions of components, subsystems, and systems. The models are generally constructed from engineering (one-line) drawings by replacing engineering elements (valves, motors, switches, etc.) with one or more GO symbols that are interrelated to represent system functions, logic, and operational sequences. The GO software uses the GO model to quantify system performance. The method evaluates system reliability and availability, identifies fault sets, ranks the relative importance of the constituent elements, and places confidence bounds on the probabilities of occurrence of system events reflecting the effects of data uncertainties. Some key features of the GO method are:

- Models follow the normal process flow
- Most model elements have one-to-one correspondence with system elements
- Models accommodate component and system interactions and dependencies
- Models are compact and easy to validate
- Outputs represent all system success and failure states
- Models can be easily altered and updated
- Fault sets can be generated without altering the basic model
- System operational aspects can be incorporated
- Numerical errors due to pruning are known and can be controlled

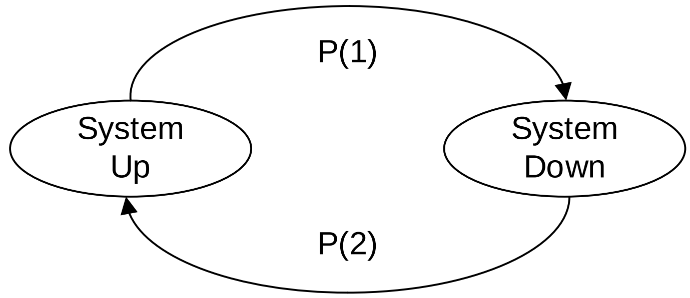
5-3.3.3.4 Go Procedure.

The GO procedure uses a set of seventeen standard logical operators to represent the logic operation, interaction, and combination of physical equipment and human actions. For example, a type 1 operator represents the logical operation of equipment which either performs, or fails to perform, its function given a proper input or stimulus. The type 2 operator performs the logical OR gate operation where a successful response is generated if any of several inputs is proper, etc. The Random variables of the GO methodology include operator inputs called stimuli (S1, S2…Sn) and outputs referred to as responses (R1, R2…, Rn). An operator, which represents equipment responses or human actions, and which may itself have associated performance probabilities, process the input random variable in a prescribed and well-defined way to generate the output random variables. These random variables are given the electrical term “signals” in the GO models.

5-3.3.4 State Space.

The State Space methodology is founded on a more general mathematical concept called Markov Chains. Markov Chains employ a modeling technique that describes a system by the possible states in which it can possess (such as State Space). For this purpose, a system essentially resides in two distinct states: up or down. The probability of transitioning from one state to the other in a given time period is the critical reliability metric used. Figure 5-11 shows this simple Markov model.

Figure 5-11 Simple Markov Model

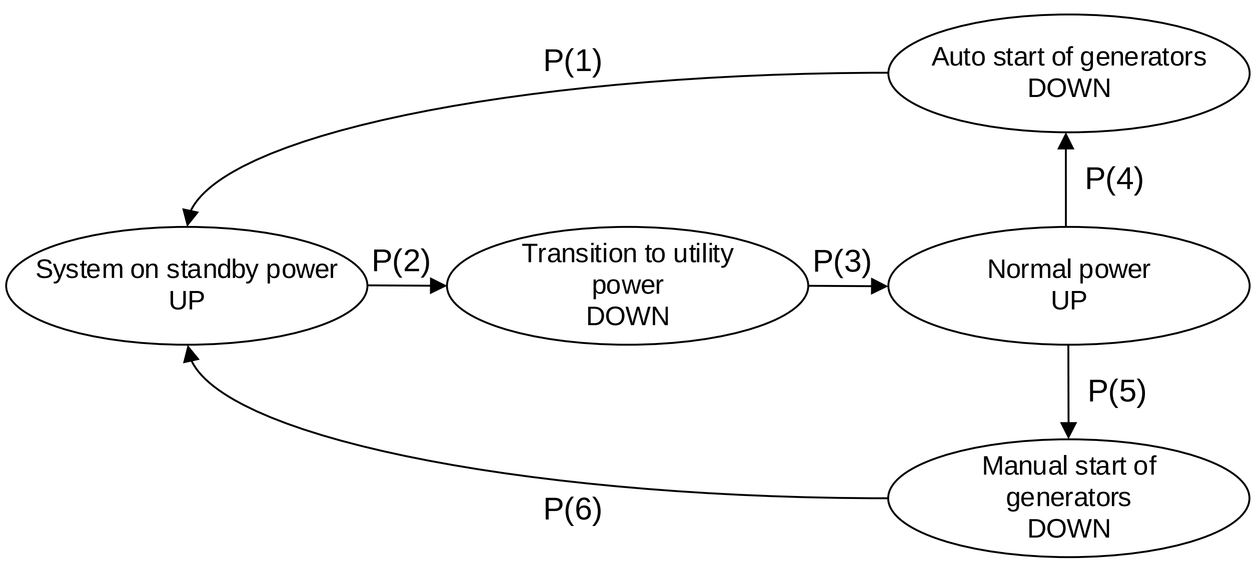


Where
P(1) is the probability of the system going down in time t
P(2) probability of the system coming up in time t

(1) However, the true goal of availability analysis is to determine the probability of being in the up state – or the time spent in the up state for an indefinite time period. To show this, consider a simple scenario including only a system with backup generation. Given loss of utility power, the generators will either start automatically or, if that functionality fails, the generators can be started manually. In those starting phases, the system is 'down.' Once started, the system is 'up.' The system will then switch to utility power once available. The system could be down during that switching.

(2) Figure 5-12 shows the associated Markov model for this system. Between each of the possible states are state transitional probabilities that must be known. The solution to the model will be the system's time spent in the up states vs. the down states.

Figure 5-12 Less Simple Markov Model



(3) Solving Markov models is simple only for very simple models, by solving a set of linear equations. The complexity solving these models grows exponentially as the sizes of the models grow linearly. Solutions can be found by using complex Numerical Analysis methods involving Linear Algebraic matrix operations, etc. Markov models can also be solved by Monte Carlo techniques described below.

5-3.3.5 Monte Carlo Simulation.

Monte Carlo Simulation is the most versatile modeling methodology available. The methodology can be implemented in many forms from simple models in a spreadsheet environment to complex models that are ‘hand crafted’ in a programming language of choice. There are also a variety of simulation software packages that provide drag-and-drop environments that can automate the creation of simulated models for the casual analyst.

(1) The Monte Carlo Simulator operates on an iterative process where each ‘iteration’ represents a description of what the system could experience through a set mission life. For instance, consider the past experience of a system, including what really failed, that experience was only one of infinite possible outcomes that depended on the failure characteristics of that system.

(2) Thus, Monte Carlo Simulation looks forward by considering possible scenarios that could occur in the future – and those scenarios, with their associated likelihoods, are dependent on the failure characteristics applied to the system components. For each iteration, failure times and the associated repair attributes are picked for each component in the system. The simulation will then implement the logical relationships of the system to determine:

(a) If a failure has occurred in the system prior to the defined mission life.

(b) If a failed component(s) takes the system down, what is the duration of downtime?

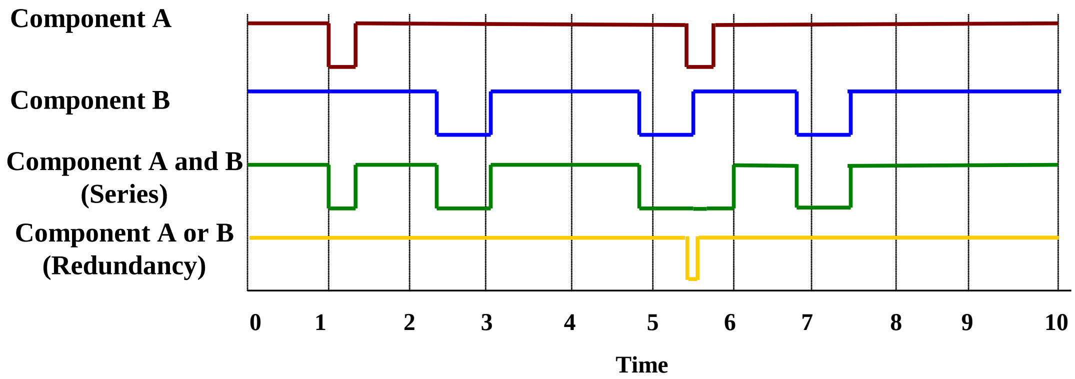
(3) With these items determined, the availability for the system in that particular iteration can be calculated. Then, as this single iteration is repeated, an average is tabulated of uptime vs. downtime, and duration of downtime. The average of all the iterations yields expected system availability.

(4) This method is extremely useful in calculating downtime based on different types of failure distributions. A component in a system may be repaired or replaced upon failure. Because many components that are replaced have failure distributions that are based on time in service, calculations must incorporate time-based failure distributions to accurately predict system availability.

(5) Figure 5-13 shows a sample timeline of the operation of two components. In this example, both components start in the available state. As the simulated time progresses, component failures are randomly generated based on that component’s

operational RAM statistics. The figure shows the difference in series and redundant component orientation. In series, downtime occurs when either component fails; with redundancy, both components are required to fail to incur downtime.

Figure 5-13 Timeline of a Monte Carlo Simulation



5-3.4 Analysis Considerations.

The results of availability analyses are extremely sensitive to factors such as underlying assumptions, techniques for calculating availability, and the data used to support the analysis. No results of an analysis should be distributed – let alone trusted – without documentation supporting those attributes. Subtle differences in those attributes can produce drastically different results – results that might be used to drive design decision making. It is the ultimate responsibility of the analyst to be aware of those sensitivities and perform and present analyses with integrity.

5-3.4.1 Modeling Limitations.

Cut set, State Space, Network Reduction and Boolean algebra are techniques that lend themselves to the casual reliability engineer to analyze small systems; primarily because they can all be accomplished with common desktop PC tools such as spreadsheets, etc. A series of studies recently performed on the IEEE Gold Book (IEEE 493-2007) standard network have shown that, provided that the assumptions are held equal, each technique produces similar results. However, model size and data sophistication make algebraic methods more complicated and therefore, more difficult to use.

5-3.4.1.1 Large Systems.

As larger systems are modeled, the sheer size of the analysis becomes burdensome for the analyst. Furthermore, ‘what-if’ sensitivity analyses also become impractical because models must be redrawn and formulas, rewritten. For the number of formulas and conditions that can be involved, peer reviews are of utmost importance to compensate for the high probability of error involved in such an extensive effort.

5-3.4.1.2

Data collection efforts have expanded the analysts' tools beyond the classical 'MTBF' analysis. MTBF relies on the exponential distribution, sometimes referred to "point estimates." These estimates give the average MTBF (such as one point). Failure distributions such as the Normal, Lognormal, Weibull, etc. are being fitted to common failure modes of many critical components in electrical and mechanical distribution networks. These distributions capture the fact that the failure rate of a component likely changes over time, capturing initial and wear-out failure modes. These distributions require more precise data collection: time-to-failure data. With point estimates, the data collector need only count operational hours and failure events for a component. For time-to-failure data, each interval of time between installation and failures, making the data collection and processing effort extremely challenging, but extremely valuable.

5-3.4.1.3 Time-To-Failure Data.

Time-to-failure data has become substantially important to system analyses. For many components such as belts, valves, and batteries, availability figures may not be specific enough to characterize the likelihood of failure. In these cases, failures are more likely to occur toward the end of a component's life – not evenly throughout its life. Simulation methods provide the means to include these considerations.

5-3.4.2 Modeling Hurdles.

There are several system attributes that are challenging to model. UPS battery life, for instance, had historically been assumed to be limitless in many analyses – whereas their contribution to power availability is not. Furthermore, data has shown that standby equipment has differing distributions from their primary counterparts. Spare parts availability, human factors, etc. are difficult to capture with the classical approaches to availability analysis.

5-3.4.3 Modeling Data.

The underlying data that supports a reliability assessment can be as important as the model itself. Data must be scrutinized to ensure that the results are realistic and defendable. There are a variety of sources of component reliability data. \1\ Appendix D of this UFC /1/ contains data collected by the US Army Corps of Engineers. This dataset was collected and summarized for the distinct \1\ purpose /1/of modeling C5ISR facilities.

5-3.4.4 Modeling Solutions.

The typical engineer can perform 'back of the envelope' analyses easily. Results from these analyses are only as good as the assumed ground rules and the data used. Experience has shown that analysts who wish to perform availability studies often and consistently should choose a software package to aid in this effort. Packages exist that perform analyses via most of the described methodologies. Once a package is selected, the user should become familiar with the package behavior, the analytical or numerical methodology used, and the underlying limitations of that package.

5-3.5 Modeling Examples.

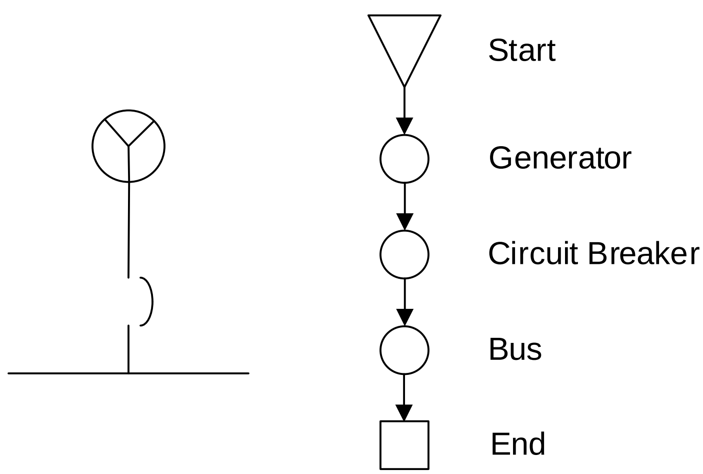
No matter what methodology is chosen for a reliability analysis, the expected results, provided that the underlying assumptions are held fixed, should be consistent across all methods. The analyst should develop a sense of the expected results of small systems and have a feel for the effects of increments changes to a system when made. Below are a series of small examples that will illustrate typical results in simple models.

5-3.5.1 Modeling Basics.

Reliability modeling generally begins with referring to a one-line drawing for the electrical, mechanical, and control systems. In addition to these resources, the analyst should have a firm understanding of the theory of operation of the system to be modeled. These sources of information will form the basis for the structure and behavior of the system that is to be modeled.

(1) For this UFC, a pseudo diagramming technique is adopted that can be applied to, or converted to, whichever modeling technique is chosen. The convention can be most accurately described as an RBD. Figure 5-14 shows a typical one-line diagram representation of a generator/bus and its corresponding RBD representation.

Figure 5-14 Simple Series Model



(2) Figure 5-14 represents a typical series diagram – the most common scenario observed in electrical and mechanical one-line drawings and can be solved simply by series calculations, such as for power to be available at the bus, the following must be available: generator, breaker, and the bus.

(3) Assume that the generator has an availability of 0.99, the breaker is 0.9999, and the bus is 0.99999. Then the series can be calculated by the following equation:

Equation 5-12. Availability for Figure 5-14

$$A = 0.99 \times 0.99999 \times 0.9999 = 0.989891$$

Where:
A = Availability

(4) Typical generator models often require an N of M calculation. If, for example a plant has three generators, of which two are required to carry the critical load, then a 2 of 3 generator availability calculation must be made. The calculation for this can be quite complex, but is reasonable for small values of M:

Equation 5-13. Availability for Typical Generator Models

$$A = \sum_{k=m}^{n} \frac{n!}{k!\,(n-k)!}(A')^{k}(1-A')^{(N-K)}$$

Where:
A = Availability
n = the total number of components
m = the required components

(5) Figure 5-15 represents a simplistic parallel-redundant system commonly found in C5ISR facilities. Note that the model consists of series calculations and parallel calculations. This model implies that there is a pure redundancy, where switching between A and B happens without risk of failure. In most cases, there are reliability considerations in the switching between redundant systems.

(6) The model described by Figure 5-15 can also be solved with simple calculations. Assume that the bus has an availability of 0.99999, the breakers are 0.9999, and the UPS is 0.999. To determine the system availability, one must reduce the network to simpler series and parallel models. The general sequence is to reduce the breaker-UPS-breaker series to one value. Then calculate the redundant OR operator followed by treating that result as a value in series with the bus. The breaker-UPS-breaker series can be computed by

Equation 5-14. Breaker-UPS-Breaker Reduction for Figure 5-15

$$A_{UPS} = 0.9999 \times 0.999 \times 0.9999 = 0.9988002$$

Where:
A_{ups} = the UPS Availability

Now, with that reduction, the model can be represented by Figure 5-16.

Figure 5-15 Simple Parallel Model

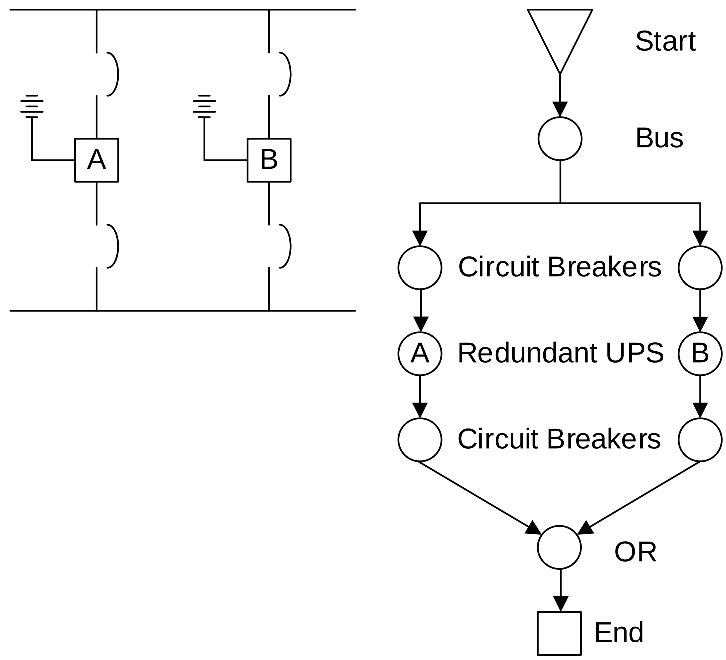
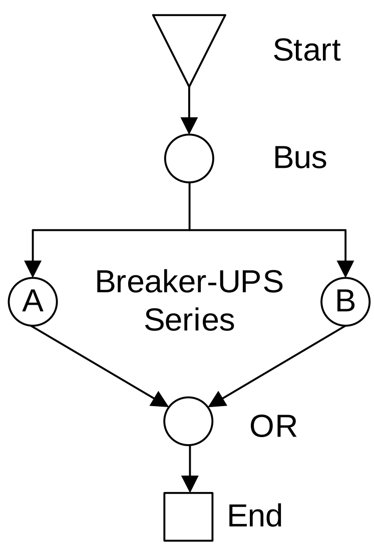


Figure 5-16 Simple Parallel Model, First Reduction



Next reduce the OR calculation to one availability value:

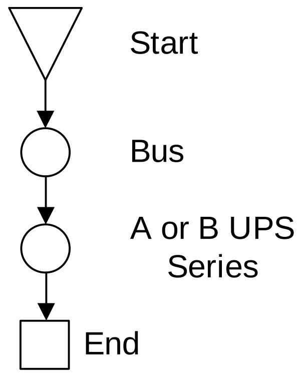
Equation 5-15. OR Availability for Figure 5-16

$$A_{OR} = 1 - [(1 - 0.9988002) \times (1 - 0.9988002)] = 0.99999856$$

Where:
A_{OR} = *OR Availability*

Figure 5-17 shows this further reduction.

Figure 5-17 Simple Parallel Model, Second Reduction



Then, this system, now reduced to a series system, can be easily calculated by

Equation 5-16. Final Availability for Figure 5-17

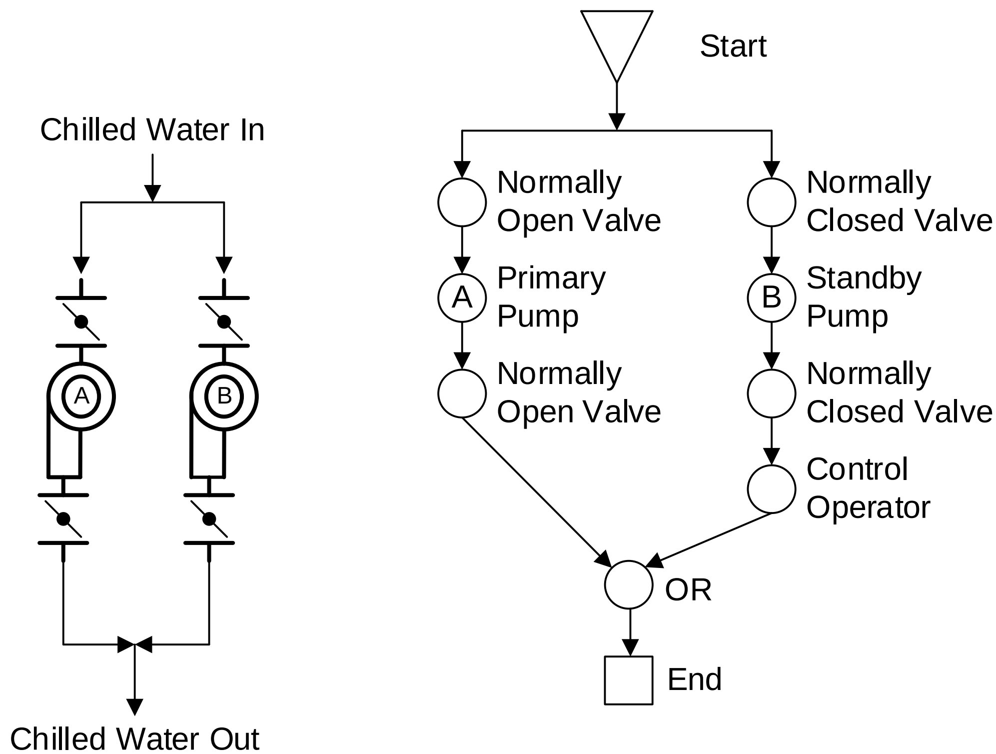
$$A_{Final} = 0.99999 \times 0.99999856 = 0.99998856$$

Where:
A_{Final} = *Final Availability*

(7) Building controls contingencies into reliability models is prudent. Often pure OR gates result in availability values that are inflated because they do not include the probability of the switching action itself. Whether the control is automatic via PLC or SCADA, or requires maintenance personnel to manually make the switch, the redundancy is limited by that switching action.

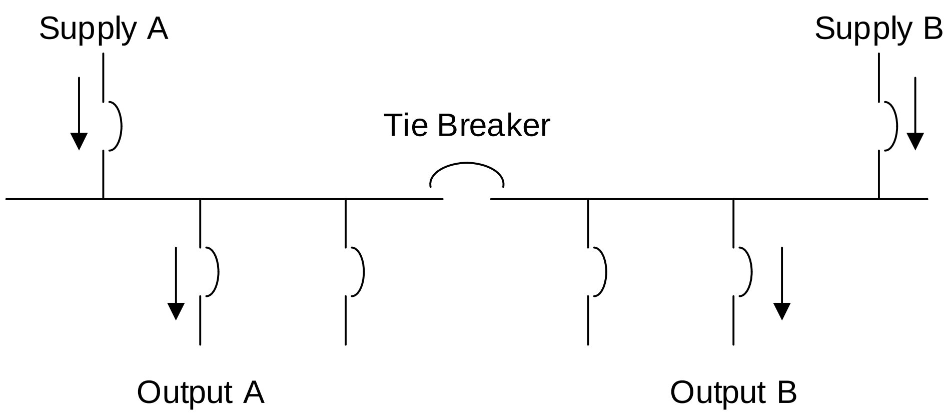
(8) Consider Figure 5-18 where a facility utilizes dual chilled water pumps. If Pump A fails (or is taken down for maintenance) the valves supporting Pump A must be closed and the valves supporting Pump B must be opened. The model shows a control node with the B series to represent the reliability of the switching. Note that the A path, the ‘normal day’ operating mode, has no controls contingency. Only when path B is required does the availability of the system need to be reduced due to the switching function.

Figure 5-18 Parallel Model with Controls Contingency



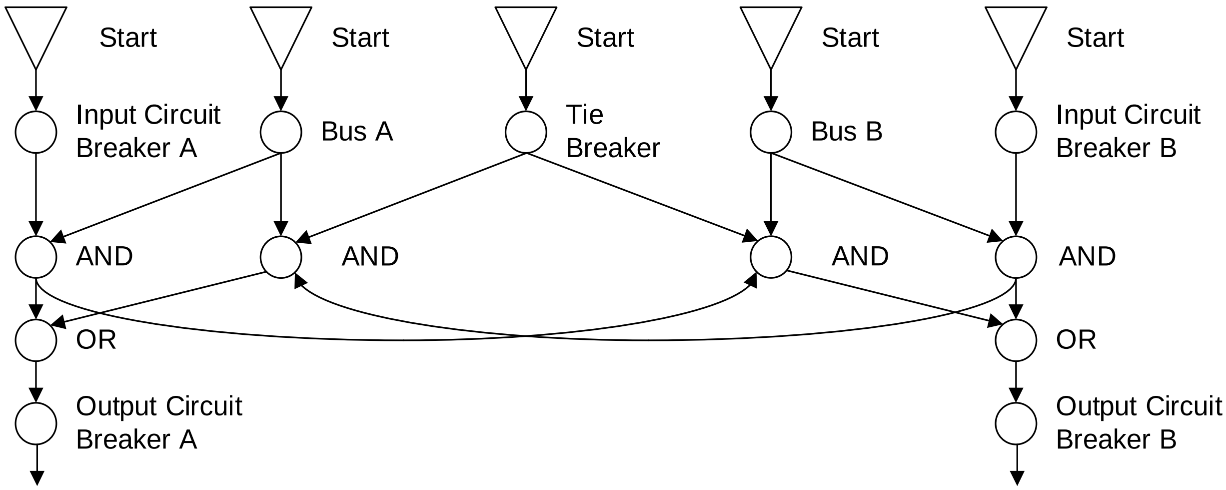
(9) Modeling becomes significantly more complicated when redundant paths are added. Even the most common scheme found in C5ISR facilities, the Double-Ended Bus with a tie, can begin to complicate modeling. Consider Figure 5-19. The gear essentially receives power from two sources and passes it through via two paths (thus retaining the redundancy). If one source is lost, then the Tie, which is normally open, closes to provide power to both output paths.

Figure 5-19 Double Ended Bus



A typical model of this system is illustrated in Figure 5-20

Figure 5-20 Model of Double Ended Bus



(10) The key to the logic lies in the fact that typical modeling cannot readily emulate that power can pass through the tie in both directions. Thus, the availabilities of the tie and the busses are created independently and used within the logic where required.

(11) If one looks at the logic behind the availability of power out of a breaker on bus A, then the critical ‘OR’ statement is joining the following two scenarios:

(a) Power available from source A

(b) Power required from source B

(12) In case (a), the only required components are the incoming breaker, (on side A) the Bus A, and the outgoing breaker A. Case (b) requires much more. In order of how the power will flow if source A is unavailable: Input Breaker B, Bus B, Tie, Bus A, output Breaker A. Figures 5-21 and 5-22 show these two cases, with the pivotal OR block shaded black.

Figure 5-21 Model of Double Ended Bus, Case 1

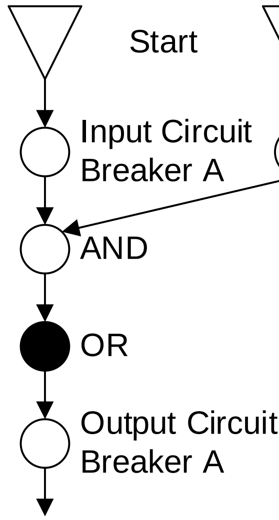
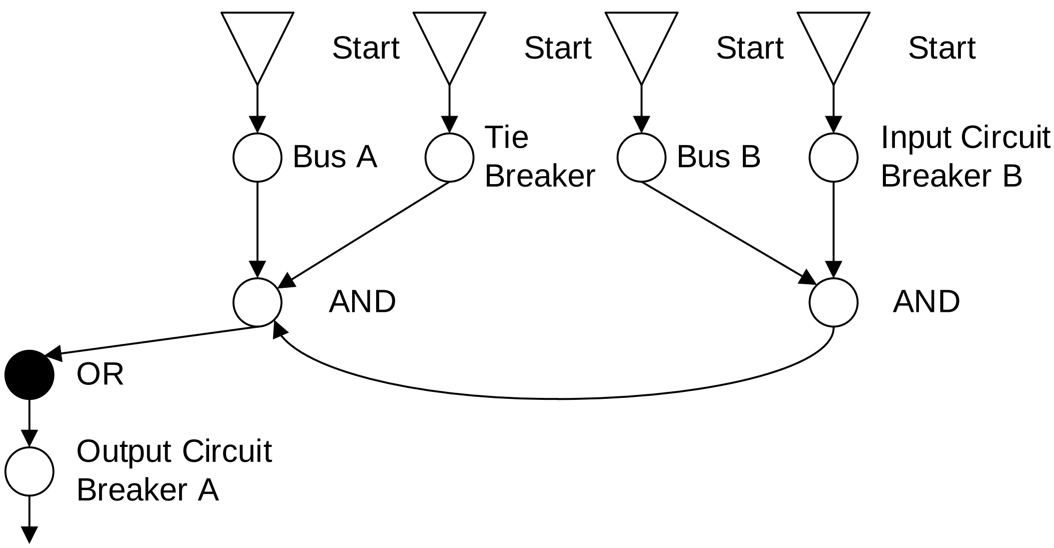


Figure 5-22 Model of Double Ended Bus, Case 2



5-3.6 Modeling Complexities.

The modeling examples discussed previously represent a top-down style of modeling and is the most common type of modeling. The model has a beginning and an end. Failures within the model interrupt the availability of downstream components. This style has a variety of advantages, one being that it loosely follows the intuitive paths of, say, power or chilled water. There are some disadvantages and limitations to top-down modeling: upstream effects of failures, loop systems, and UPS systems. In most cases, advanced simulation methods need to be employed to capture these complexities.

5-3.6.1 Effects of Unique Failure Modes.

The failure of a component in a system typically influences the remainder of the system downstream of the failure only. Unfortunately, there are some failures, or failure modes of a component, that can have effects on the system upstream. For example, if a circuit breaker fails to open on command, such as there is a downstream fault that the breaker is intended to protect against but doesn't. That fault can be passed upstream and influence a much larger portion of the entire system than just those components downstream of the fault. The sequence of Figure 5-23 shows how a downstream fault can affect other sub-systems.

5-3.6.2 Interdependencies and Loop Systems.

Interdependencies and loop systems are common in C5ISR facilities. Two scenarios often create a modeling hurdle. One instance is the interdependency between power, chilled water, and controls. The mechanical systems are dependent on power and the controls system, the power system depends on the controls system, and the control system requires power. These interdependencies are possible to model, though typically only through special means, such as Monte Carlo Analysis.

5-3.6.3 UPS Systems.

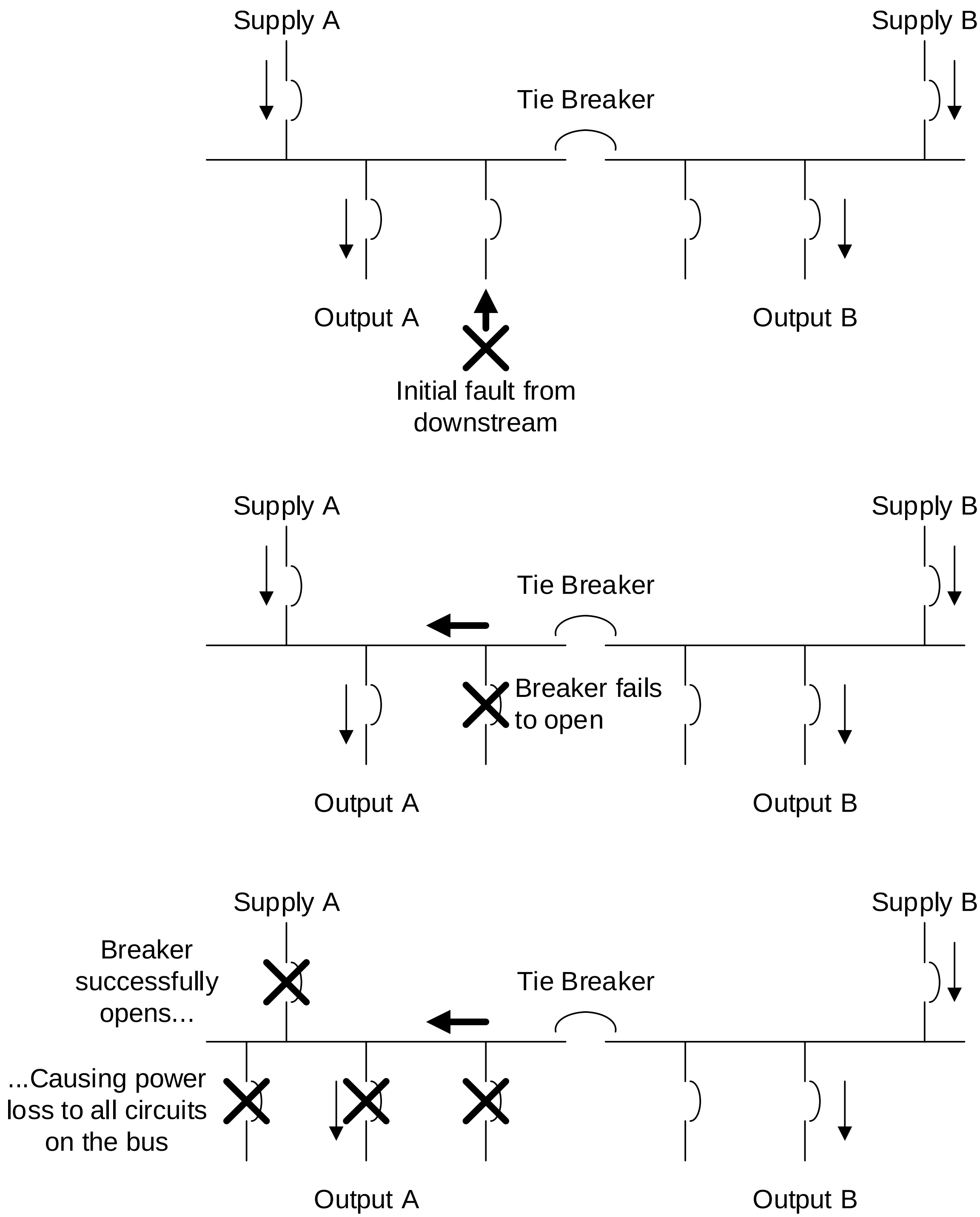
Uninterruptible power supply systems present a unique challenge to the analyst because capturing the effects on availability from the added battery backup can be difficult. The concept of operation for a UPS is limited to the fact that the battery has a limited life. If, for instance, a UPS has 45 minutes of ride-through time, then any upstream interruption less then 45 minutes will essentially be mitigated. However, if an interruption lasts longer then 45 minutes, the total interruption time is essentially shortened by 45 minutes before the downstream mission is lost. Below are two simple cases to illustrate this point.

Assume that over the course of one year, a system experiences a failure upstream of the UPS:

Case 1: the failing component is repaired within 30 minutes. In this case the UPS provides sufficient downstream power and the mission remains available. This case yields an availability of 8766/8766 = 1. Availability is retained.

Case 2: the failing component requires 24 hours to repair. In this case the UPS merely reduces the downtime of the mission to 24 hrs – 45 minutes, or 23.25 hrs. In this case the availability for the case-year is (8766-23.25)/8766 or 0.9973.

Figure 5-23 Downstream Fault



5-3.6.4 Conclusion of Complexities.

Complex modeling scenarios need complex modeling techniques. In most cases Monte Carlo methods need to be employed. Monte Carlo methods capture true operating scenarios, one iteration at a time, as set up by the analyst. Simulation allows the analyst to interject nearly any conceivable operating anomaly that might occur in a facility.

5-3.7 Conclusion.

RAM studies should be conducted with the intent of capturing the actual behavior of the facility. This goal will force the analyst to continually seek better data and better modeling techniques. Although, in design, RAM can not be perfectly captured; it is still just a prediction. Refined assessment techniques can uncover previously unforeseen contingencies that may cause a mission to be lost.

5-3.7.1 RAM Analysis.

RAM analysis must be continuously improved to converge with the behavior of a system. As systems become more complex, the methods will undoubtedly become more complex as well. The analyst should always compare their modeling assumptions and attributes captured to the actual operation of the system being modeled. New techniques must continuously be explored to see that the gap between the models and the true system narrows.

5-3.7.2 Verification.

Facility managers must verify that the model is valid – capturing their system accurately. They must also be aware of the reliability data that supports the model. The model is only as good as the data that it uses. In a sense, the data is a single-point vulnerability for the accuracy of the model. Facility managers and reliability analysts alike should always consult the most recent IEEE DOT STD 3006.8 for reliability data. Further, adoption of a continuous RAM process such as RCM will provide actual system behavior data that will continue to serve the reliability, availability, and maintainability goals over the life of the system.

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CHAPTER 6 FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS

6-1 BACKGROUND ON FMECA.

6-1.1 Define FMECA.

The FMECA is composed of two separate analyses, the Failure Mode and Effects Analysis (FMEA) and the Criticality Analysis (CA). The FMEA analyzes different failure modes and their effects on the system while the CA classifies or prioritizes their level of importance based on failure rate and severity of the effect of failure. The ranking process of the CA can be accomplished by utilizing existing failure data or by a subjective ranking procedure conducted by a team of people with an understanding of the system. Although the analysis can be applied to any type of system, this \1\ UFC /1/ will focus on applying the analysis to a C5ISR facility.

6-1.1.1 Initiating a FMECA.

The FMECA should be initiated as soon as preliminary design information is available. The FMECA is a living document that is not only beneficial when used during the design phase but also during system use. As more information on the system is available the analysis should be updated to provide the most benefit. This document will be the baseline for safety analysis, maintainability, maintenance plan analysis, and for failure detection and isolation of subsystem design. Although cost should not be the main objective of this analysis, it typically does result in an overall reduction in cost to operate and maintain the facility.

6-1.2 FMECA Benefits.

The FMECA will:

- Highlight single point failures requiring corrective action.
- Aid in developing test methods and troubleshooting techniques.
- Provide a foundation for qualitative reliability, maintainability, safety, and logistics analyses.
- Provide estimates of system critical failure rates.
- Provide a quantitative ranking of system and/or subsystem failure modes relative to mission importance; and identify parts & systems most likely to fail.

6-1.2.2 Developing a FMECA.

Developing a FMECA during the design phase of a facility, the overall costs will be minimized by identifying single point failures and other areas of concern prior to construction, or manufacturing. The FMECA will also provide a baseline or a tool for troubleshooting to be used for identifying corrective actions for a given failure. This information can then be used to perform other analyses such as a FTA or an RCM analysis.

6-1.2.3 FTA.

The FTA is a tool used for identifying multiple point failures; more than one condition to take place for a particular failure to occur. This analysis is typically conducted on areas that would cripple the mission or cause a serious injury to personnel.

6-1.2.4 RCM Analysis.

The RCM analysis is a process that is used to identify maintenance actions that will reduce the probability of failure at the least amount of cost. This includes utilizing monitoring equipment for predicting failure and for some equipment, allowing it to run to failure. This process relies on up-to-date operating performance data compiled from a computerized maintenance system. This data is then plugged into a FMECA to rank and identify the failure modes of concern.

6-1.2.5 Additional Analysis Information.

For more information regarding these types of analyses refer to the following publications:

(1) Ned H. Criscimagna, Practical Application of Reliability Centered Maintenance Report No. RCM, Reliability Analysis Center, 201 Mill Street, Rome, NY, 2001.

(2) David Mahar, James W. Wilbur, Fault Tree Analysis Application Guide, Report No. FTA, Reliability Analysis Center, 201 Mill St., Rome, NY: 1990

(3) NASA's Reliability Centered Maintenance Guide for Facilities and Collateral Equipment, February 2000.

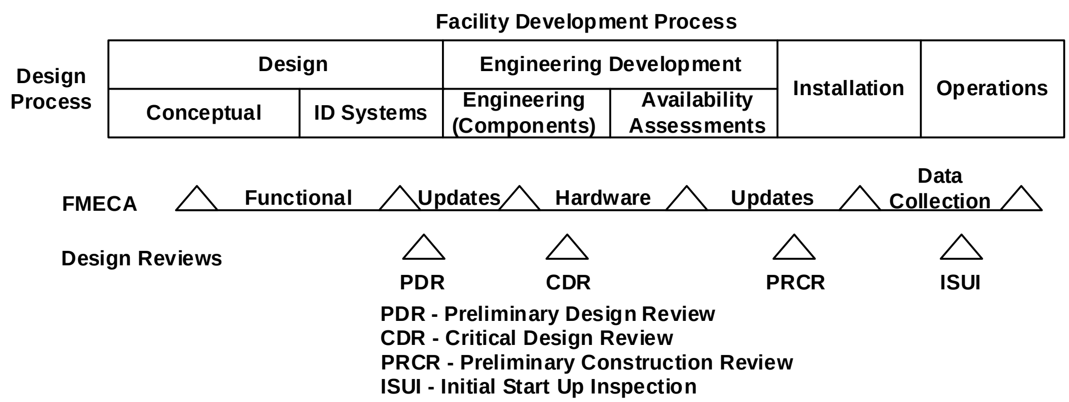
6-1.3 Team Effort.

The FMECA should be a catalyst to stimulate ideas between the design engineer, operations manager, maintenance manager, and a representative of the maintenance personnel (technician). The team members should have a thorough understanding of the systems operations and the mission's requirements. A team leader should be selected that has FMECA experience. If the leader does not have experience, then a FMECA facilitator should be sought. If the original group of team members discovers that they do not have expertise in a particular area during the FMECA then they should consult an individual who has the knowledge in the required area before moving on to the next phase. The earlier a problem in the design process is resolved, the less costly it is to correct it.

6-1.4 FMECA Characteristics.

The FMECA should be scheduled and completed concurrently as an integral part of the design process. Ideally this analysis should begin early in the conceptual phase of a design, when the design criteria, mission requirements and performance parameters are being developed. To be effective, the final design should reflect and incorporate the analysis results and recommendations. However, it is not uncommon to initiate a FMECA after the system is built to assess existing risks using this systematic approach. Figure 6-1 depicts how the FMECA process should coincide with a facility development process.

Figure 6-1 Facility Development Process



Since the FMECA is used to support maintainability, safety, and logistics analyses, it is important to coordinate the analysis to prevent duplication of effort within the same program. The FMECA is an iterative process. As the design becomes mature, the FMECA must reflect the additional detail. When changes are made to the design, the FMECA must be performed on the redesigned sections. This ensures that the potential failure modes of the revised components will be addressed. The FMECA then becomes an important continuous improvement tool for making program decisions regarding trade-offs affecting design integrity.

6-1.5 Requirements.

To perform an accurate FMECA, the team must have some basic information to get started.

a. The basic information is:

- Schematics or drawings of the system.

- Bill of materials list (for hardware only)

- Block diagram which graphically shows the operation and interrelationships between components of the system defined in the schematics.
- Knowledge of mission requirements
- An understanding of component, subsystem, & systems operations

b. Once the team has all the information available to them, the analysis can proceed. The team leader should organize a meeting place for all team members with enough space to display schematics, block diagrams or bill of materials for all members to view. Setting the ground rules and establishing the goals of the mission should be discussed at the first meeting.

6-1.6 Goals.

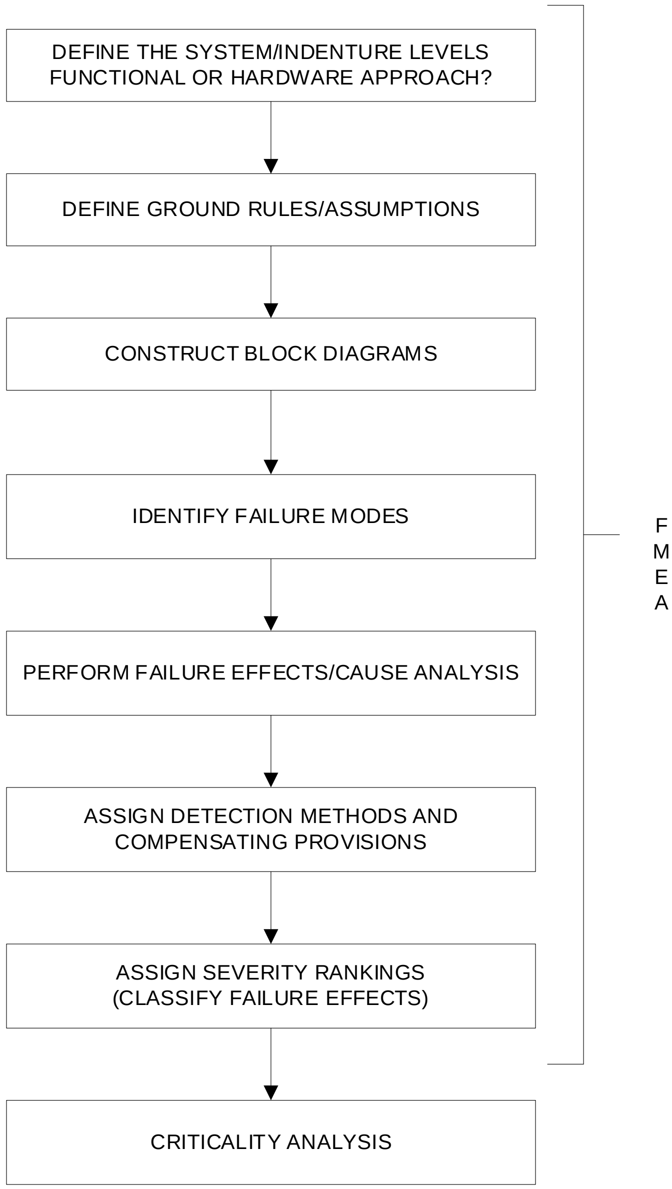
Questions from all participants should be addressed. It is essential to the analysis that all "gray" areas concerning the goal(s) of the analysis should be clarified early on. For the analysis to be successful, all team members must be cooperative and have a positive outlook regarding the goals of the analysis.

6-2 FAILURE MODES AND EFFECTS ANALYSIS (FMEA) METHODOLOGY.

6-2.1 Methodology – Foundation.

To perform a FMECA the analysts must perform a FMEA first then the CA. The FMEA will then be used as the foundation of the CA. This paragraph will discuss the process flow of a FMEA, see Figure 6-2, and explain when and how to perform a FMEA at an upper system level and lower system level approach. The FMEA will identify systems and/or components and their associated failure modes. This part of the analysis will also provide an assessment of the cause and effects of each failure mode.

Figure 6-2 Typical FMEA Flow



6-2.2 Define the System to be Analyzed (Functional/Hardware Approach)

Provide schematics and operational detail of the system. Clarify the mission of the system or the goal of the system. The mission may be to provide emergency power or maintain a certain temperature to the facility. Whatever it is, it must be identified prior to analysis. Identify failure definitions, such as conditions which constitute system failure or component failure.

6-2.2.1 System Indenture Levels.

The system indenture levels must be identified. Figure 6-3 depicts typical system indenture levels. At these system indenture levels; a functional approach is usually applied. Each system's function is known and possibly the major pieces of equipment are known. However, it is possible to conduct a hardware analysis to these levels as well. But they must begin at the lower levels and propagate them up to the higher system levels. An example of the hardware approach is shown in Figure 6-4.

Figure 6-3 Functional Method

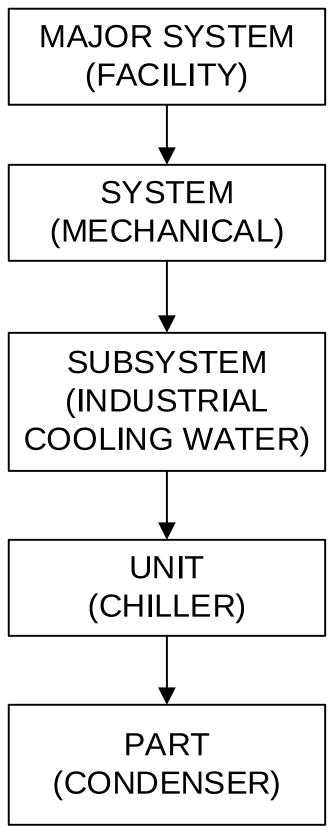
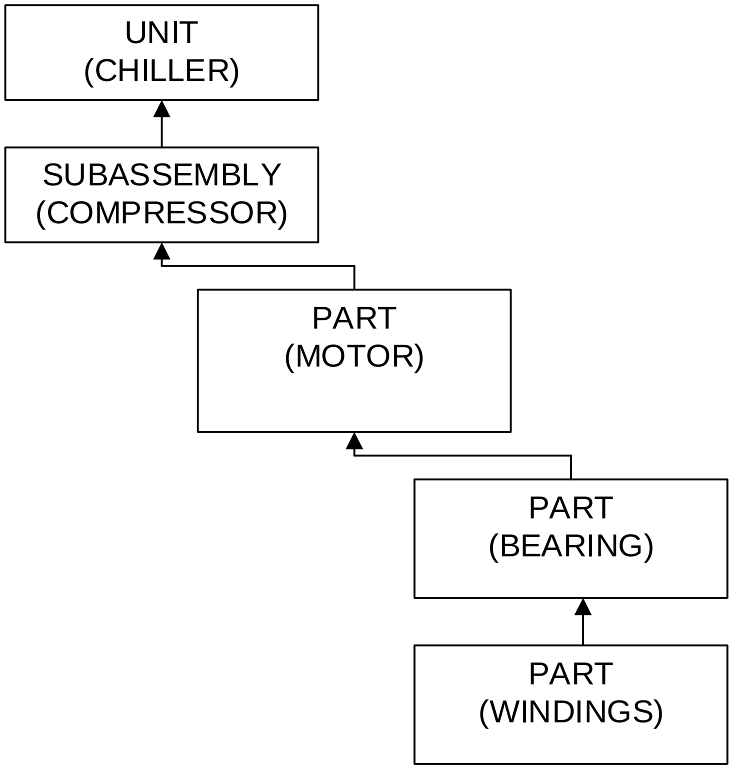


Figure 6-4 Hardware Method



6-2.2.2 Functional Approach.

Early in a design, the functional approach will be used to analyze a system's or sub-system's affects on the specified mission. This approach is performed from the upper system level down to quickly provide a general assessment of the major system's requirements to meet mission objectives. Specific parts or components are initially unknown. Once the major components are known a hardware approach can be conducted as well. This type of analysis is conducted at the indenture levels shown in Figure 6-4. To perform a functional FMEA the analyst will need:

- System definition and functional breakdown
- Block diagrams of the system
- Theory of operation
- Ground rules and assumptions including mission requirements
- Software specifications

6-2.2.3 Define and Identify.

The analyst performing a functional FMEA must be able to define and identify each system function and its associated failure modes for each functional output. Redundant components are typically not considered at the upper levels. The failure mode and effects analysis is completed by determining the potential failure modes and failure causes of each system function. For example, the possible functional failure modes of a pump are pump does not transport water; pump transports water at a rate exceeding requirements; pump transports water at a rate below requirements.

6-2.2.4 Failure Mechanisms or Causes.

The failure mechanisms or causes would be motor failure; loss of power; over voltage to motor; degraded pump; motor degraded; and, under voltage to motor.

6-2.2.5 Observing.

The functional approach should start by observing the effects of each major system, heating, ventilation, and air conditioning (HVAC) and power generation/distribution, has on each other. The next level down would analyze either just the required components within the HVAC or the required components of the power generation/distribution.

6-2.2.6 Functional FMEA.

The functional FMEA is crucial to the success of understanding the equipment and to determine the most applicable and effective maintenance. Once failure rates on each component within each system can be established, they are added up to assign a failure rate of the system. This failure rate will aid in determining where redundant components are required.

6-2.2.7 Hardware Approach.

The hardware approach is much more detailed. It lists individual hardware or component items and analyzes their possible failure modes. This approach is used when hardware items, such as what type of motors, pumps, cooling towers, or switchgear, can be uniquely identified from the design schematics and other engineering data.

6-2.2.8 Hardware Failures.

The possible hardware failure modes for a pump could be pump will not run; pump will not start; and, pump is degraded. The mechanisms would be motor windings are open; a coupling broke; starter relay is open; loss of power; impeller is worn; and, seal is leaking.

6-2.2.9 Bottom-Up.

The hardware approach is normally used in a bottom-up manner. Analysis begins at the lowest indenture level and continues upward through each successive higher indenture level of the system. This type of analysis is usually the final FMEA for the design. To perform a hardware FMEA the analyst will need:

- Complete theory or knowledge of the system
- RBDs/functional block diagrams
- Schematics
- Bill of materials/parts list
- Definitions for indenture levels
- Ground rules and assumptions including mission requirements

6-2.2.10 Utilizing Both Hardware and Functional Approaches.

Depending on the complexity of the system under analysis, it is sometimes necessary to utilize both the hardware and functional approach. The major difference between the two approaches is the amount of “parts” the component has and the descriptions of the failure modes. The failure mode description for a functional approach is a functional description whereas the hardware approach may identify a particular part that failed.

6-2.2.11

To help the reader understand the FMEA and FMECA results, the analyst must clearly document the ground rules and/or assumptions made when performing each part of the analysis. The ground rules generally apply to the system/equipment, its environment, mission, and analysis methods. Ground rules require customer approval and generally include:

a. The mission of the item being analyzed (example: Power-Electricity)

b. The phase of the mission the analysis will consider (example: Main Power Outage)

c. Operating time of the item during the mission phase (example: Run Time of Generators)

d. The severity categories used to classify the effects of failure

e. Derivation of failure mode distributions (vendor data, statistical studies, analyst's judgment)

f. Source of part failure rates when required (nonelectronic parts reliability data (NPRD), vendor data, Power Reliability Enhancement Program (PREP) data)

g. Fault detection concepts and methodologies (SCADA, alarms, warnings)

6-2.2.12 Block Diagrams.

A functional and RBD representing the operation, interrelationships, and interdependencies of functional entities of the system should be constructed. The block diagrams provide the ability to trace the failure mode effects through each level of indenture. The block diagrams illustrate the functional flow sequence as well as the series or parallel dependence or independence of functions and operations.

6-2.2.12.1 Item Input and Output.

Each input and output of an item should be shown on the diagrams and labeled. A uniform numbering system which is developed for the functional system breakdown order is essential to provide traceability through each level of indenture.

6-2.2.12.2 Functional Block Diagram.

The functional block diagram shows the operation and interrelationships between functional parts of the system as defined by the schematic drawings and engineering data. It depicts the system functional flow, the indenture level of analysis, and the present hardware indenture level. This type of diagram should be used for hardware and functional FMEAs.

6-2.2.12.3 Functional Block Diagram Subsystems.

The functional block diagram in Figure 6-5 would be used at the earliest part of a design. It indicates what subsystems a facility will need to supply a room with temperature control. These subsystems are:

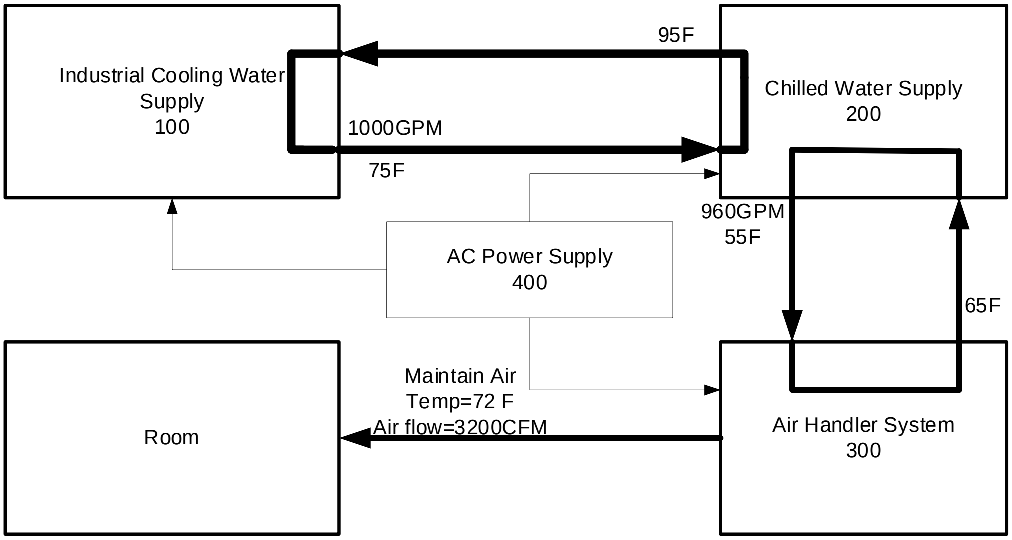
(1) The Industrial Cooling Water system; used to remove the heat generated by the chiller.

(2) The Chilled Water Supply; used to supply water at a temperature of 55°F to the Air Handling System.

(3) The Air Handling system; used to provide air flow at 3200cfm to the room and maintain a temperature of 72°F.

(4) AC Power Supply; used to provide power to each of the above subsystems.

Figure 6-5 Functional Block Diagram of System



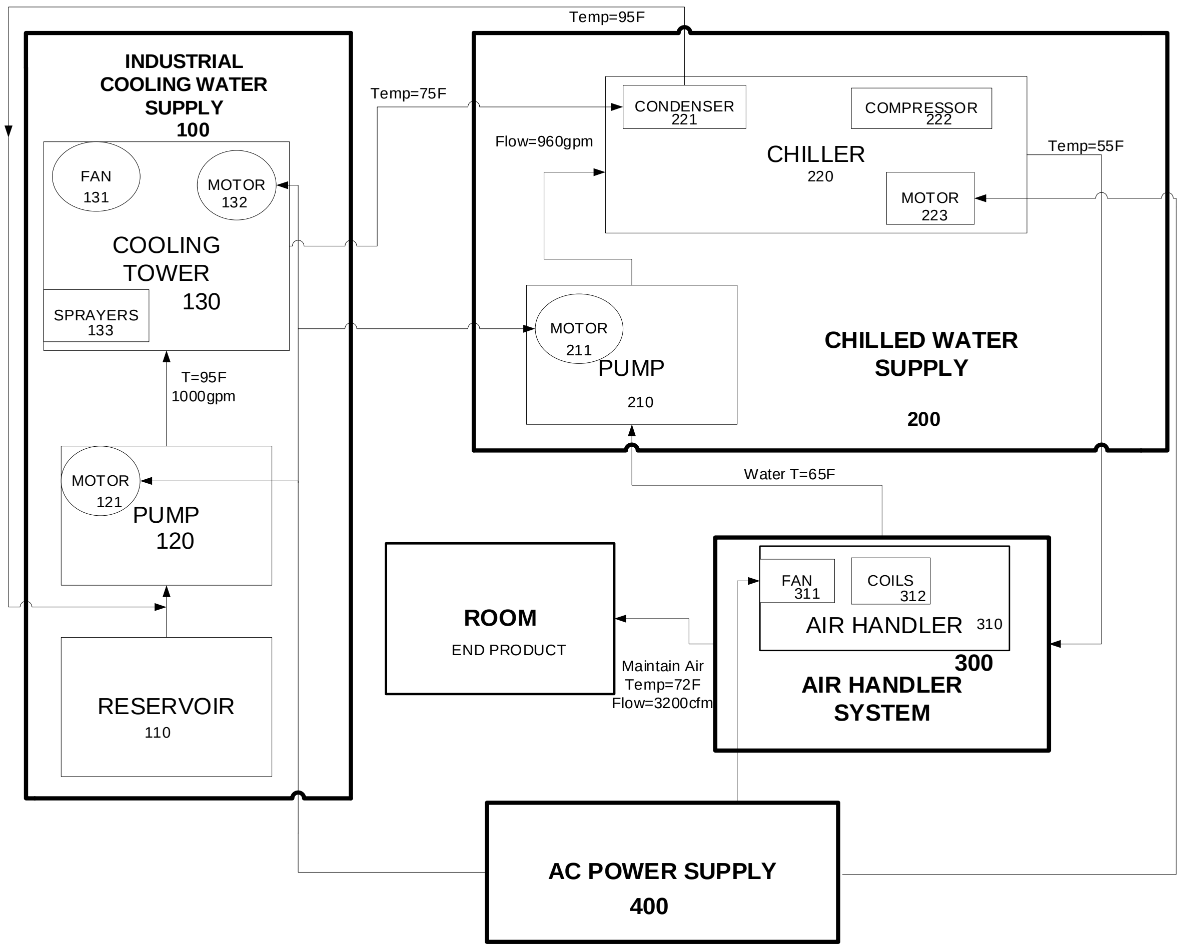
6-2.2.12.4 Functional Block Diagram Subsystem Components.

The next step is to provide a functional diagram within each sub-system indicating what types of components are required and their outputs. Figure 6-6 is an example of the same system but provides the basic components and their relationship within their system and other systems.

6-2.2.12.5 Functional or Hardware FMEA.

If a functional or hardware FMEA is to be conducted, a reliability diagram should be constructed down to the component level after the functional diagram of the system is completed. This will visually provide information to the team of any single point failures at the component level.

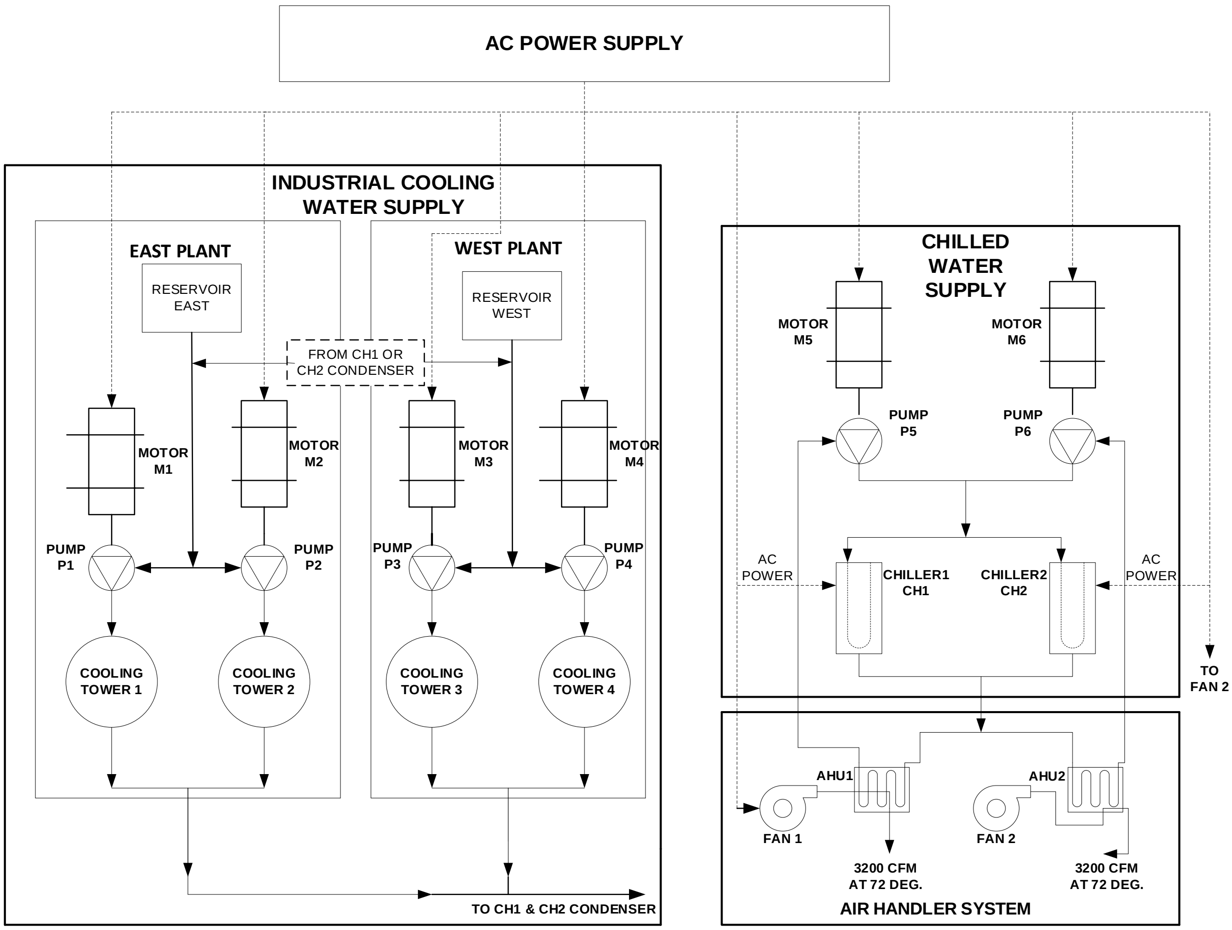
Figure 6-6 Functional Block Diagram of the Sub-Systems



6-2.2.12.6 Reliability Diagram.

The RBD of the same system is shown in Figure 6-7. It is used to illustrate the relationship of all the functions of a system or functional group. All the redundant components should be shown. This diagram should also indicate how many of the redundant components are required for the whole system to be operational. In other words, it should be stated that there may be four pumps but only two are required to accomplish the mission.

Figure 6-7 Reliability Block Diagram



6-2.2.12.7 Reliability Block Diagram Figure 6-7 Case.

In this case: one cooling tower is required from either the East or West Plant Industrial Cooling Water Supply. Either the East Plant or the West Plant is sufficient enough with one cooling tower operational for mission success.

6-2.2.12.8 Reliability Block Diagram Figure 6-7 Chilled Water and Air Handling System.

Within the Chilled Water Supply and the Air Handling System, one pump, one chiller, and one air handling unit is required to supply enough air flow and heat exchange (cooling) to the room.

6-2.2.12.9 Reliability Block Diagram Figure 6-7 AC Power Supply.

The AC Power Supply is not shown broken down for clarity reasons. This system should also be broken down similar to the “Mechanical Systems” in the HVAC. When conducting the HVAC analysis, the AC power supply should be referenced to for possible failure mechanisms.

6-2.2.12.10 Reliability Block Diagram Figure 6-7 Blocks.

The example shown provides symbols for components, but "blocks" clearly labeled are all that is necessary to be effective. There are numerous software programs available to aid in the construction of these diagrams.

6-2.2.12.11 Entering Reliability Block Diagram Information into FMEA Sheet.

From the reliability or functional block diagram, each system, component, part number and name under analysis can now be entered in the corresponding columns of the FMEA sheet (Table 6-1, DA Form 7610). Important: The FMEA should be filled out in a column-by-column manner. Never go across the sheet. Start by filling in all the item numbers and the item names/functions before identifying the failure modes. Using this method will allow the team to stay focused and consistent when assigning inputs into each category. This should be repeated across the worksheet.

6-2.2.12.12 Entering Reliability Block Diagram Information into FMEA Sheet Exception.

The only exception to this rule is when it comes time to assign item numbers for failure modes/mechanisms. Each failure mode/mechanism identified should have its own unique number that can associate it to the component. For example, if the component number is 100 then a number assigned to the mechanism should be 100.1 or 100.01 depending on how many failure modes/mechanisms are possible for the item. This is shown in Table 6-2.

6-2.2.12.13 HVAC System Components.

The components that make up the HVAC system in a typical facility are AC power; industrial cooling water; chilled water supply; and, air handling/heat exchanger.

6-2.2.12.14 Industrial Cooling Water Sample FMEA Worksheet.

A sample FMEA worksheet for just the industrial cooling water is presented in Table 6-1 to indicate the flow of the process using DA Form 7610, Failure Modes and Effects Analysis.

Table 6-1 Example of DA Form 7610 (AUG 2006), FMEA Worksheet Flow (One Column at a Time)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA) For use of this form, see TM 5-698-4; the proponent agency is USACE.											
SYSTEM: Mechanical System									DATE (YYYYMMDD): 20050819		
PART NUMBER: Industrial Water Supply									SHEET: 1 of 1		
REFERENCE DRAWINGS:									COMPLIED BY: AAA		
MISSION: Provided Temperature Control to Room									APPROVED BY: BBB		
ITEM NUMBER	**ITEM/FUNC-TIONAL ID**	**POTENTIAL FAILURE MODES**	**FAILURE MECHANISM**	**FAILURE EFFECTS**			**DETECTION METHOD**	**COMPEN-SATING PROVSION**	**SEVERITY CLASS**	**REMARKS**	
				LOCAL EFFECTS	**NEXT HIGHER LEVEL**	**END EFFECTS**					
100	Ind cool water /supply water to condenser at 75° F & 1000GPM										

Table 6-2 Example of DA Form 7610 (AUG 2006), Functional FMEA System Level

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM	FAILURE EFFECTS			DETECTION METHOD	COMPEN-SATING PROVSION	SEVERITY CLASS	REMARKS
				LOCAL EFFECTS	NEXT HIGHER LEVEL	END EFFECTS				
100.0	Ind cool water /supply water to condenser at 75° F & 1000GPM	Provide water greater than 75° F	Cooling tower malfunction, pump degraded, fan will not start							
100.1		Provide water less than 75° F	Fan will not turn off							
100.2		Provide water less than 1000GPM	Degraded pump							
100.3		Provide no water	Broken pipe							
100.4			Blockage in pipe or pump failure							

6-2.3 Failure Mode Identification.

The failure mode is the manner that a failure is observed in a function, subsystem, or component. There are many modes a component or system may fail. Failure modes of concern depend on the specific component, system, environment, and history of failures in similar systems. All probable independent failure modes for each item should be identified.

6-2.3.1 Conditions to be Examined.

To assure that a complete analysis has been performed, each component failure mode and/or output function should be examined for the following conditions:

- Failure to operate at the proper time
- Intermittent operation
- Failure to stop operating at the proper time
- Loss of output
- Degraded output or reduced operational capability

6-2.3.2 Functional Approach of Analyzing System.

The example used in Table 6-6 is a functional approach of analyzing the upper system level's ability to perform its intended function. The systems were identified in the functional block diagram as: industrial cooling water supply; chilled water system; air handling system; and the AC power supply. All failure modes of specific components are not analyzed. Only the system's ability to perform a function is evaluated. As the analysis steps down a level, a specific component can be identified and then a failure mechanism(s) associated with the component can be analyzed as is shown in Table 6-7.

6-2.3.3 Failure Mode Cause or Failure Mechanism.

The cause or failure mechanism of a failure mode is the physical or chemical processes that cause an item to fail. It is important to note that more than one failure cause is possible for any given failure mode. All causes should be identified including human induced causes. These can occur more frequently when initiating a redundant system upon a failure of the primary system. When analyzing the cause of each failure mode one should be careful not to over analyze why a part failed. For example, failure mode-bearing seized:

(1) Why did it seize? – Contamination was in the bearing.

(2) Why was there contamination? – Seal was cracked.

(3) Why was the seal cracked? – Scheduled PM could not be completed.

(4) Why was seal not replaced? – Because there were none in stock.

6-2.3.4 Root Cause.

The root cause should be the "seal was cracked". By analyzing further, the cause can be chased "out of bounds". The analysts must use their judgment to decide how far to investigate root causes while considering economical constraints and probability of failure vs mission criticality and acceptable risks.

6-2.4 Failure Effects Analysis.

A failure effects analysis is performed on each item of the RBD. The consequence of each failure mode on item operation, and the next higher levels in the block diagram should be identified and recorded. The failure under consideration may affect several indenture levels in addition to the indenture level under analysis. Therefore, local, next higher and end effects are analyzed. Failure effects must also consider the mission objectives, maintenance requirements and system/personnel safety.

6-2.4.1 Failure Effect Levels.

Example failure effect levels are shown in Table 6-3 and are defined as follows:

(1) Local effects are those effects that result specifically from the failure mode of the item in the indenture level under consideration. Local effects are described to provide a basis for evaluating compensating provisions and recommending corrective actions. The local effect can be the failure mode itself.

(2) Next higher-level effects are those effects which concentrate on the effect of a particular failure mode has on the operation and function of items in the next higher indenture level.

(3) End effects are the effects of the assumed failure on the operation, function and/or status of the system.

6-2.4.2 Item Failures.

Example end or system level effects of item failures are also shown in Table 6-3 and generally fall within one of the following categories:

(1) System failure where the failed item has a catastrophic effect on the operation of the system.

(2) Degraded operation where the failed item has an effect on the operation of the system, but the system's mission can still be accomplished.

(3) No immediate effect where the failed item causes no immediate effects on the system operation.

6-2.4.3 Assigning the Effect.

Try to be specific when assigning the effect. The above items are just categories and are not intended to be the only input for "end effect". Detailed effects will provide the analyst the most useful information later in the analysis.

6-2.4.4 System Level Failures.

Failures (shown in Table 6-3) at the system level are those failures which hinder the performance or actual completion of the specified mission. Failures at each indenture level is defined below.

(1) A major system failure would be failure in the main mission of the facility. A failure at the major system level would be defined as the inability to command, control, & communicate.

(2) A system failure of a mechanical system. A failure at the system level would be defined as the inability of the mechanical system to cool the facility to within a minimally acceptable temperature range allowed for the computers.

(3) A subsystem failure would be failure of the industrial cooling water. A failure at the subsystem level would be defined as the inability to provide cooling water to the facility.

(4) A component failure would be failure of a chiller. A failure at the system component level could be defined as the inability of the chiller to provide chilled water.

(5) A sub-component failure would be the failure of a condenser. A failure at the sub-component level would be defined as the inability of the condenser to remove heat from the water supply.

6-2.4.5 Typical Entries into the Failure Effects Categories.

Table 6-3 provides an example of typical entries into the failure effects categories. Remember to be as specific as necessary so that anyone who reads this will be able to decipher what the effects are without asking questions. Note the progression of one column at a time.

Table 6-3 Example of DA Form 7610 (AUG 2006), FMEA Progression

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System | DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply | SHEET: 1 of 1

REFERENCE DRAWINGS: | COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room | APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM	FAILURE EFFECTS			DETECTION METHOD	COMPEN-SATING PROVSION	SEVERITY CLASS	REMARKS
				LOCAL EFFECTS	NEXT HIGHER LEVEL	END EFFECTS				
100.0	Ind cool water /supply water to condenser at 75° F & 1000GPM	Provide water greater than 75° F	Cooling tower malfunction, pump degraded, fan will not start	The required amount of heat is not removed from water	Condenser not efficient, Chiller will use more energy $$	Air temp may rise but not significant				
100.1		Provide water less than 75° F	Fan will not turn off	Too much cooling will take place	Chiller will be less efficient and use more energy	No effect to air temp				
100.2		Provide water less than 1000GPM	Degraded pump	Pump will not be able to provide enough flow or pressure	Condenser not efficient, Chiller will use more energy	Air temp may rise but not significant				
100.3		Provide no water	Broken pipe	Excess water consumption, isolation actions will be required	Condenser in chiller will not function, Chiller will overheat	Air temp will rise above maximum allowed mission				
100.4			Blockage in pipe or pump failure	No water will be provided through the system	Condenser in chiller will not function, Chiller will overheat	Air temp will rise above maximum allowed mission				

6-2.5 Failure Detection Methods.

The FMEA identifies the methods by which occurrence of failure is detected by the system operator. Visual or audible warnings devices and automatic sensing devices, such as a SCADA system, are examples of failure detection means. Any other evidence to the system operator that a system has failed should also be identified in the FMEA. If no indication exists, it is important to determine if the failure will jeopardize the system mission or safety. If the undetected failure does not jeopardize the mission objective or safety of personnel and allows the system to remain operational a second failure situation should be explored to determine whether an indication will be evident to the operator or maintenance technician.

6-2.5.1 Failure Detection Methods – Indications.

These indications can be described as follows:

(1) A normal indication is an indication to the operator that the system is operating normally.

(2) An abnormal indication is an indication to the operator that the system has malfunctioned or failed. (alarm-chiller overheated)

(3) An incorrect indication is an erroneous indication to the operator that a malfunction has occurred when there is no fault. Conversely, an indication that the system is operating normally when, in fact, there is a failure.

6-2.5.2 Periodic Testing.

Periodic testing of stand-by equipment would be one method used to detect a hidden failure of the equipment. This testing helps to assure that the stand-by equipment will be operational at the inopportune time the primary equipment fails. The ability to detect a failure to reduce the overall effect will influence the severity of the failure. If the detection method does not reduce the overall effect, then the severity will not be influenced. The analysts should explore an alternative method for detection if this is the case.

6-2.5.3 Failure Mode Detection Prior to Occurring.

Typically, if the failure mode can be detected prior to occurring, the operator can prevent further damage to the system or take some other form of action to minimize the effect. An "over-temperature" alarm for a compressor would be an example. If the compressor had a loss of lubrication and was overheating, the alarm/SCADA would shut that chiller down prior to seizure. If the compressor were allowed to run to seizure, costly damage would occur, and the system would not be able to function.

6-2.6 Compensating Provisions.

Compensating provisions are actions that an operator can take to negate or minimize the effect of a failure on the system. Any compensating provision built into the system that can nullify or minimize the effects of a malfunction or failure must be identified.

6-2.6.1 Examples of Design Compensating Provisions.

Examples of design compensating provisions are:

(1) Redundant item that allows continued and safe operation.

(2) Safety devices such as monitors or alarm systems that permit effective operation or limit damage.

(3) Automatic self-compensating devices that can increase performance as unit degrades such as variable speed drives for a pump.

(4) Operator action such as a manual over-ride.

6-2.6.2 Multiple Compensating Provisions.

When multiple compensating provisions exist, the compensating provision which best satisfies the fault indication observed by the operator must be highlighted. The consequences of the operator taking the wrong action in response to an abnormal indication should also be considered and the effects of this action should be recorded in the remarks column of the worksheet.

6-2.6.3 Ability to Detect a Failure and React.

To be able to detect a failure and react correctly can be extremely critical to the availability of the system. For example, if a failure is detected in the primary pump (no flow) then the operator/technician must know what buttons and/or valves to actuate to bring in the backup pump. If by chance the operator/technician inadvertently actuates the wrong valve, there may be undesirable consequences because of their actions. This is a basic example but should be considered in the analysis on all failure modes.

6-2.7 Severity Rankings.

After all failure modes and their effects on the system have been documented in the FMEA the team now needs to provide a ranking of the effect on the mission for each failure mode. Make sure that prior to assigning these rankings that all prior columns of the FMEA are filled in. This will help the analyst in assigning each severity ranking relative to each other. This ranking will be used later in the CA to establish relative "severity" rankings of all potential failure modes.

6-2.7.1 Evaluating Item Failure Mode.

Each item failure mode is evaluated in terms of the worst potential consequences upon the system level which may result from item failure. A severity classification must be assigned to each system level effect. A lower ranking indicates a less severe failure effect. A higher ranking indicates a more severe failure effect. Severity classifications provide a qualitative measure of the worst potential consequences resulting from an item failure.

6-2.7.2 Assigning Severity Classification.

A severity classification is assigned to each identified failure mode and each item analyzed in accordance with the categories in Table 6-4.

Table 6-4 Severity Ranking Table

Ranking	Effect	Comment
1	None	No reason to expect failure to have any effect on Safety, Health, Environment or Mission.
2	Very Low	Minor disruption to facility function. Repair to failure can be accomplished during trouble call.
3	Low	Minor disruption to facility function. Repair to failure may be **longer** than trouble call but does not delay mission.
4	Low to Moderate	Moderate disruption to facility function. Some portion of Mission may need to be reworked or process delayed.
5	Moderate	Moderate disruption to facility function **100%** of Mission may need to be reworked or process **delayed**.
6	Moderate to High	Moderate disruption to facility function. Some portion of Mission is lost. **Moderate** delay in restoring function.
7	High	High disruption to facility function. Some portion of Mission is lost. **Significant** delay in restoring function.
8	Very High	High disruption to facility function. **All** of Mission is lost. Significant delay in restoring function
9	Hazard	Potential Safety, Health, or Environmental issue. Failure will occur with warning
10	Extreme Hazard	Potential Safety, Health, or Environmental issue. Failure will occur without warning

6-2.7.3 Items with High Severity.

Although this chart can be used for a qualitative (without data) analysis or a quantitative (with data) analysis, some facilities may choose the following categories to assign another familiar format of severity classifications for the quantitative CA, Table 6-5. These categories are used to "flag" the analysts to items with high severity.

6-2.7.4 Items with High Severity.

Although this chart can be used for a qualitative (without data) analysis or a quantitative (with data) analysis, some facilities may choose the following categories to assign another familiar format of severity classifications for the quantitative CA, Table 6-5. These categories are used to "flag" the analysts to items with high severity.

Table 6-5 Severity Classification for Qualitative CA

Category	Effect	Comment
I	Minor	A failure not serious enough to cause injury, property damage or system damage, but which will result in unscheduled maintenance or repair.
II	Marginal	A failure which may cause minor injury, minor property damage, or minor system damage which will result in delay or loss of availability or mission degradation.
III	Critical	A failure which may cause severe injury or major system damage which will result in mission loss. A significant delay in restoring function to the system will occur.
IV	Catastrophic	A failure which may cause death or lack of ability to carry out mission without warning (power failure, over-heating).

6-2.7.5 Exception when using Qualitative Analysis.

Do not use this method to categorize severity in a qualitative analysis. The qualitative analysis requires an equal scale (such as 1 through 10, or 1 through 5) for both severity and occurrence. If they are not equal, one category will hold more "weight" than the other in the CA.

6-2.7.6 System Level vs Component Level Severity.

A FMEA at the component level will have high severity rankings because there is no redundancy at that level. At the system level, however, the severity may decrease because when there is loss of one component in the system, there is a backup in place. The mission of the system at this indenture level is not compromised assuming the backup component or system is functional.

6-2.7.7 Special Remarks or Components.

If there are any special remarks or comments that need to be recorded should be included in the "REMARKS" category at the end of the FMEA. This should include specific hazards or explanations of the failure mode effects or other categories associated with it.

6-2.7.8 Example of a Completed FMEA.

An example of a completed functional FMEA of only the Industrial Cooling Water Supply is provided in Table 6-6. Hardware FMEA’s on all the systems are shown in Table 6-7. Notice that the functional FMEA did not include any redundancy as a consideration when assigning the effects.

6-2.8 Results of FMEA.

The team should now review the information on the FMEA to determine if any changes should be made. It is not uncommon for people to think of more failure modes or detection methods on items during the process. Make these changes or additions prior to proceeding on to the CA.

6-2.8.1 Critical Analysis Foundation.

Once all the information has been entered into the FMEA, the foundation for the CA has been established. The FMEA sheet will be referenced while creating the CA. Due to the amount of information on the FMEA, it is not feasible to include all of it on the CA.

6-2.8.2 FMEA on Subsystems Example.

In this example, a FMEA should also be conducted on the remaining systems of the HVAC System: the chilled water supply; the air handling system; and the AC power supply system.

6-2.8.3 Applying Critical Analysis to Example.

Once they are completed the steps discussed in the next paragraph for the CA should be applied to complete the FMECA process.

Table 6-6 Example of DA Form 7610 (AUG 2006), Completed FMEA (functional) for Industrial Water Supply

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM	FAILURE EFFECTS			DETECTION METHOD	COMPEN-SATING PROVSION	SEVERITY CLASS	REMARKS
				LOCAL EFFECTS	NEXT HIGHER LEVEL	END EFFECTS				
100.0	Ind cool water /supply water to condenser at 75° F & 1000GPM	Provide water greater than 75° F	Cooling tower malfunction, pump degraded, fan will not start	The required amount of heat is not removed from water	Condenser not efficient, Chiller will use more energy $$	Air temp may rise but not significant	Temp sensor/water analysis	SCADA indicator	6	If drainpipe breaks the secondary containment will be filled
100.1		Provide water less than 75° F	Fan will not turn off	Too much cooling will take place	Chiller will be less efficient and use more energy	No effect to air temp	Alarm temp sensor	SCADA indicator	2	
100.2		Provide water less than 1000GPM	Degraded pump	Pump will not be able to provide enough flow or pressure	Condenser not efficient, Chiller will use more energy	Air temp may rise but not significant	Flow/pressure sensor	SCADA indicator	10	
100.3		Provide no water	Broken pipe	Excess water consumption, isolation actions will be required	Condenser in chiller will not function, Chiller will overheat	Air temp will rise above maximum allowed mission	Inspection	SCADA indicator	4	Safety hazard when pipe ruptures injury could occur
100.4			Blockage in pipe or pump failure	No water will be provided through the system	Condenser in chiller will not function, Chiller will overheat	Air temp will rise above maximum allowed mission	Water analysis or flow/pressure sensor	SCADA indicator	5	In case of blockage, a secondary path may be available

Table 6-7 Example of DA Form 7610 (AUG 2006), Completed FMEA (hardware) for HVAC System

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System — SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM	FAILURE EFFECTS: LOCAL EFFECTS	FAILURE EFFECTS: NEXT HIGHER LEVEL	FAILURE EFFECTS: END EFFECTS	DETECTION METHOD	COMPEN-SATING PROVSION	SEVERITY CLASS	REMARKS
110.0	Reservoir/ contains 6000 gallons of water	Leak;	Crack in wall, Drainpipe broke	Water will not be contained	Lower condenser efficiency. Chiller uses more energy	No immediate effect	Inspection	SCADA Redundant reservoir	4	
120.0	Pump #1/ Transport Industrial water supply at 1000GPM	Transport water at a rate below 1000GPM	Impeller degraded, gasket leak, motor degraded	Pump can-not produce required rate of water	Lower condenser efficiency. Chiller uses more energy	No immediate effect	Flow sensor	SCADA Redundant system	4	
120.1		Produce no water flow	Broken coupling, leak on suction line, motor inoperable	Pump will not be able to pump	No condenser function. Chiller will lose ability to remove heat	Room temp above max allowed temp Mission failure	Flow sensor	SCADA Redundant system	5	
130.0	Cooling Tower #1/ maintain a water temp of 75°F	Scaling (deposits) on media	Untreated water	Fan will operate longer period of time. Poor cooling	Lower condenser efficiency. Chiller uses more energy	Room temperature will rise slightly	Inspection/ water analysis	SCADA Redundant system	6	
130.1		Clogged sprayers	Untreated/ unfiltered water	Water will not be cooled	Condenser will not be efficient	Room temperature will rise slightly	Inspection/ water analysis	SCADA Redundant system	5	

Table 6-7 Example of DA Form 7610 (AUG 2006), Completed FMEA (hardware) for HVAC System (cont'd)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System — SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM	FAILURE EFFECTS			DETECTION METHOD	COMPEN-SATING PROVSION	SEVERITY CLASS	REMARKS
				LOCAL EFFECTS	NEXT HIGHER LEVEL	END EFFECTS				
130.2		Fan failure	Motor winding open, No supply voltage to motor	Low evaporative cooling will take place	Lower condenser efficiency. Chiller uses more energy	Slight rise in air temp. No severe effect. Mission compromised	Flow sensor	Redundant system	4	
210.0	Pump #5/ Transport Industrial water supply at 960GPM	Degraded operation – produce water at rate less than 960GPM	Impeller degraded, gasket leak, motor degraded	Pump can-not produce required rate of water	Chiller needs to decrease water temp to satisfy air handler	No effect	Flow sensor	Redundant system	4	
210.1		Produce no water flow	Broken coupling, leak on suction line, motor inoperable	Damage to motor or pump shafts	Chiller will not be able to remove heat from water	No air-cooling Room temp above max. Mission failure.	Flow sensor	Redundant system	5	
220.0	Chiller/ Remove heat(10°F) from chilled water supply	Degraded operation – remove less than 10°F	Refrigerant leak degraded compressor, tube leak, dirty coil	Compressor will cycle on frequently/ chiller will be less efficient	Air handling unit will run continuously trying to meet demand	Air temp will rise but not above maximum allowed.	Temp sensor	Redundant chiller	5	
200.1		Remove no heat	Compressor seizure, motor failure	Chiller will be unable to function	Air handling unit will run continuously trying to meet demand	Minimal air cooling-temp rise above max. Mission failure	Temp sensor	Redundant chiller	7	This failure is costly and time consuming to repair.

6-3 CRITICALITY ANALYSIS (CA) METHODOLOGY.

6-3.1 Methodology – Moving into Criticality Analysis.

The FMECA is composed of two separate analyses, the FMEA and the CA. The FMEA must be completed prior to performing the CA. It will provide the added benefit of showing the analysts a quantitative ranking of system and/or subsystem failure modes. The CA allows the analysts to identify reliability and severity related concerns with particular components or systems. Even though this analysis can be accomplished with or without failure data, there are differences on each approach which are discussed in the following paragraphs. Figure 6-8 shows the process for conducting a FMECA using quantitative and qualitative means.

6-3.2 Criticality Analysis.

The CA provides relative measures of significance of the effects of a failure mode, as well as the significance of an entire piece of equipment or system, on safe, successful operation and mission requirements. In essence, it is a tool that ranks the significance of each potential failure for each component in the system's design based on a failure rate and a severity ranking. This tool will be used to prioritize and minimize the effects of critical failures early in the design.

6-3.2.1 Quantitative or Qualitative Approach.

The CA can be performed using either a quantitative or a qualitative approach. Tables 6-8 and 6-9 identify the categories for entry into their respective CA using DA Forms 7611 and 7612, respectively. Availability of part configuration and failure rate data will determine the analysis approach. As a general rule, use Table 6-8 when actual component data is available and use Table 6-9 when no actual component data or only generic component data is available.

6-3.2.2 Levels of Data.

Figure 6-9 is a representation of the different levels of data that a facility may have. Depending on the level of data available, the analysts must determine which approach they will use for the CA. The areas where there are overlaps between quantitative and qualitative, the analyst will have to assess what the expectations are for conducting the analysis to determine which approach will be used.

Figure 6-8 FMECA Flow

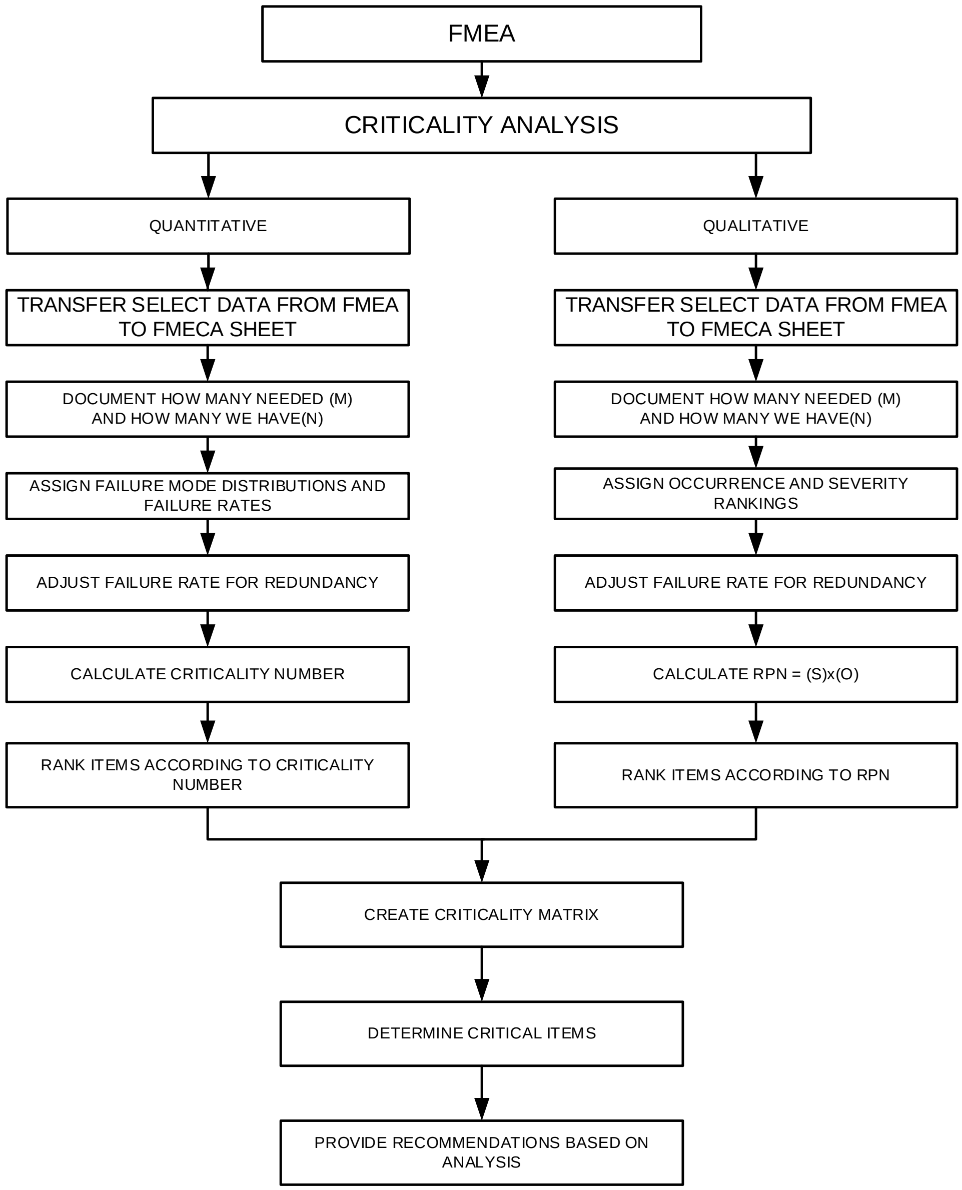


Table 6-8 Example of DA Form 7611 (AUG 2006), FMECA Worksheet – Quantitative

QUANTITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System | DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply | SHEET: 1 of 1

REFERENCE DRAWINGS: | COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room | APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	REDUNDANCY		FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBAB-ILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	FAILURE MODE CRITICALITY NUMBER (C_μ)	ITEM CRITICALITY NUMBER (εC_μ)	REMARKS
					HAVE (N)	NEED (M)							

Table 6-9 Example of DA Form 7611 (AUG 2006), FMECA Worksheet – Qualitative

QUALITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

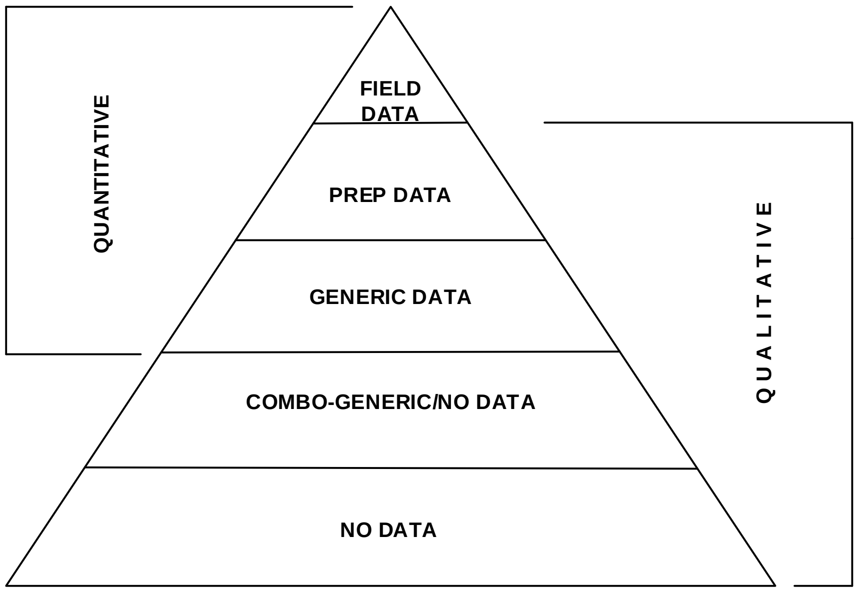
PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	FAILURE EFFECTS	SINGLE COMPONENT			REDUNDANT SYSTEM					REMARKS AND/OR RECOMMENDED ACTIONS
					OCCUR	SEVER-ITY	RPN (O)X(S)	HAVE (N)	NEED (M)	OCCUR	SEVER-ITY	RPN (O)X(S)	

Figure 6-9 Data Triangle



(1) Quantitative method is used when failure rates, failure modes, failure mode ratios, and failure effects probabilities are known. These variables are used to calculate a "criticality number" to be used to prioritize items of concern. This is used typically after the design has been completed when confident data on the system can be collected. However, in certain instances data may be available from other sources. This type of analysis will provide concrete figures which can be used for other types of analyses including FTA and RCM program.

(2) Qualitative method is used when no known failure rates and failure modes are available. The criticality or risk associated with each failure is subjectively classified by the team members. The use of a subjective ranking system is applied to the severity, and occurrence of the failures. This method will provide a relative ranking of item failure mode's effects for identifying areas of concern and for initiating other analyses such as RCM, fault tree, and logistics. As the system matures it is recommended that data be collected to enhance the analysis through a quantitative method.

6-3.3 Transfer Select Data from FMEA.

The information from the FMEA sheet that will be used in the FMECA worksheet will aid in developing the CA. Given the fact that not all the information will be shown on the FMECA sheet, does not mean that the excluded information will be ignored. The FMEA sheet will still be referenced frequently for data.

(1) All of the information on the FMEA can sometimes be difficult to read. This can be a major contributing factor to not include all information. This is just a suggestion that may or may not be desirable at every facility. In fact, some facilities may choose to add more

categories. Keep in mind, this UFC is just a guide and is meant to be flexible to achieve the objective of the analysis.

(2) Once it is determined which type of analysis will be conducted, qualitative or quantitative, the appropriate FMECA worksheet can be chosen. Examples of FMECA sheets for the two different types of analyses are provided in Tables 6-8 and 6-9.

(3) The following categories will be transferred from the FMEA sheet:

- Item Number
- Item/Functional ID
- Failure Modes
- Failure Mechanisms
- Failure Effects (qualitative only due to space limitations)
- Severity Classification/Ranking

(4) All other categories from the FMEA will be referenced during the CA.

6-3.4 Quantitative Criticality Analysis.

Once it is determined that sufficient failure rate data and failure mode distributions are available, a criticality worksheet for conducting a quantitative analysis that looks like Table 6-8 will be used. Note that some of the categories are derived from the FMEA sheet. The additional categories will be used to calculate the criticality number. Traditional methods will be used to derive this number except where redundant components are used, which is typical with a C5ISR facility. The required number of components necessary (M) to perform the function and the amount of components that are redundant (N) should be recorded. The effect of redundancy will be discussed in paragraph 6-3.5. A description of each category and variable used in the CA is listed below.

6-3.4.1 Beta.

Beta (β) is defined as the failure effect probability and is used to quantify the described failure effect for each failure mode indicated in the FMECA. The beta (β) values represent the conditional probability or likelihood that the described failure effect will result in the identified criticality classification, given that the failure mode occurs. The β values represent the analyst's best judgment as to the likelihood that the loss or end effect will occur. For most items the failure effect probability (β) will be one. An example would be if the generator engine shuts down (failure mode), it can be confidently stated that 100% of the time the effect will be loss of power.

(1) However, if the failure mode was that the generator produces low voltage (brown out condition), the end effect could vary. Effects such as degraded motor function or motor

burns up condition on various pieces of equipment could occur. Therefore, there are two possible effects for the generator's failure mode low voltage: degraded motor function and motor burns up.

(2) Now the analyst must make a judgment call of what percentage of time or probability each effect may occur. If the analyst determined that 80% of the time the motor is degraded, then beta (β) for that effect would be (.80). This would leave 20% of the time the effect would be motor burns up and would be assigned a beta (β) of (.20).

6-3.4.2 Alpha.

Alpha (α) is the probability, expressed as a decimal fraction, that the given part or item will fail in the identified mode. If all the potential failure modes for a device are considered, the sum of the alphas will equal one. Determining alpha is done as a two-part process for each component being analyzed. First, the failure modes are determined and secondly, modal probabilities are assigned.

(1) Modal failures represent the different ways a given part is known, or has been "observed", to fail. It is important to make the distinction that a failure mode is an "observed" or "external" effect so as not to confuse failure mode with failure mechanism. A failure mechanism is a physical or chemical process flaw caused by design defects, quality defects, part misapplication, wear out, or other processes. It describes the basic reason for failure or the physical process by which deterioration proceeds to failure.

(2) For example, when there is no air flow from an air handling unit caused by a broken belt. In this example, the failure mode would be the "no air flow from air handling unit" while the failure mechanism would be the "broken belt". Another failure mode could be low air flow and the mechanism would be belt slippage (loose belt).

(3) Once common part failure modes have been identified, modal probabilities (α) are assigned to each failure mode. This number represents the percentage of time, in decimal format, that the device is expected to fail in that given mode. This number is given as a percentage of the total observed failures. Using the air handler example, the probabilities of occurrence for each failure mode are shown in Table 6-10.

Table 6-10 Failure Mode Ratio (α)

Part Failure Modes	Failure Mode Ratio (α)
Blows to little air	0.55 or 55%
Blows too much air	0.05 or 5%
Blows no air	0.40 or 40%
The sum of modal probabilities is	1.00 or 100%

Note: These are hypothetical failure mode ratios.

(4) Alpha and beta are commonly confused. It is best to memorize that alpha is the failure mode ratio, the percentage of time how or in what manner an item is going to fail. However, beta is the conditional probability of a failure effect occurring given a specific failure mode; when a failure mode occurs, what percentage of time is this going to be the end effect. Beta typically is assigned 1 to only consider the worst possible end effect as a result of a failure mode.

6-3.4.3 Failure Rate.

The failure rate (λp) of an item is the ratio between the numbers of failures per unit of time and is typically expressed in failures per million hours or failures/10^6 hours. Although failure data compiled from actual field test are recommended, other sources for failure information are available for use until actual field data can be obtained.

(1) When analyzing system failure rates where redundant like components are used to accomplish a mission, the failure rate must be adjusted to reflect the “system failure rate”. This is explained in paragraph 6-3.5. When entering in the failure rate on the FMECA sheet, in parentheses it should identified that the failure rate is the single item component failure rate or the failure rate of the redundant system. The example in this chapter provides an example of how to show this. It indicates the single failure rate and the redundant failure rate.

(2) The source of the failure rate should also be noted in this category as well so that anyone who looks at the analysis will know if the data was derived by field data or some other source for reference purposes. This will be important if someone does question the validity of the data.

6-3.4.4 Modal Failure Rate.

The modal failure rate is the fraction of the item’s total failure rate based on the probability of occurrence of that failure mode. The sum of the modal failure rates for an item will equal the total item failure rate providing all part failure modes are accounted for. If there are three different failure modes, then all three failure rates (modal failure rates) will equal the item failure rate. The modal failure rate is given by the equation:

Equation 6-1. Modal Failure Rate

$$\lambda m = \alpha \, \lambda p$$

Where:
λm = the modal failure rate
α = the probability of occurrence of the failure mode (failure mode ratio)
λp = the item failure rate

6-3.4.5 Failure Mode (Modal) Criticality Number.

The failure mode criticality number is a relative measure of the frequency of a failure mode. In essence it is a mathematical means to provide a number to rank importance based on its failure rate. The equation used to calculate this number is as follows:

Equation 6-2. Failure Mode Criticality Number

$$C_m = (\beta \alpha \lambda_p t)$$

Where:
Cm = Failure mode criticality number
β = Conditional probability of the current failure mode's failure effect
α = Failure mode ratio
λ_p *= Item failure rate*
t = Duration of applicable mission phase (expressed in hours or operating cycles)

(1) This number is derived from the modal failure rate which was explained in paragraph 6-3.4.4. It also takes into consideration of the operating time that the equipment or system is running in hours or operating cycles.

(2) Below is an example of a centrifugal pump used for condenser water circulation. The failure rates were derived from the Non-electric Parts Reliability Data-95 (NPRD-95) publication and the failure mode probability was derived from the Failure Mode/Mechanism Distribution-97 (FMD-97) publication. The failure effect probability (β) will equal 1.

Failure mode criticality:

Component type: Centrifugal pump condenser circulation

Part number: P1

Failure rate (λ_p): 12.058 failures per million hours
Source: NPRD-95

Failure Mode probability (α):
- No output (0.29)
- Degraded (0.71)

Source: FMD-97

Time (t): 1 hour

Failure effect probability (β): 1

Failure mode criticality (C_m):

$C_m = \beta\ \alpha\ \lambda_p$ t

C_m (No output) = (1 x .29 x 12.058 x 1)

C_m (No output) = 3.5 x 10^{-6}

C_m (Degraded) = (1 x .71 x 12.058 x 1)

C_m (Degraded) = 8.56 x 10^{-6}

6-3.4.6 Item Criticality Number.

Item criticality number. The item criticality number is a relative measure of the consequences and frequency of an item failure. This number is determined by totaling all the failure mode criticality numbers of an item with the same severity level. The severity level was determined in the FMEA. The equation used to calculate this number is as follows:

Equation 6-3. Item Criticality Number

$$C_r = \sum (C_m)$$

Where:
C_r = Item criticality number
C_m = Failure mode criticality number

(1) If an item has three different failure modes, two of which have a severity classification of 3 and one with a classification of 5, the sum of the two "failure mode criticality numbers" (C_m) with the severity classification of 3 would be one "item criticality number" (C_r). The failure mode with the severity classification of 5 would have an "item criticality number" equal to its "failure mode criticality number".

(2) The example below was used in the failure mode criticality example. Both failure modes for this example have the same severity classification of 3. If the severity classifications were different, then the item criticality numbers would be calculated as separate items. In this case, since there are only two failure modes, the item criticality number for each severity level would equal the failure mode criticality number.

Item criticality:
Component type: Centrifugal pump condenser circulation

Part Number: P1

Failure rate (λ_p): 12.058 failures per million hours
Source: NPRD-95

Failure mode probability (α):
No output (0.29)
Degraded (0.71)
Source: FMD-97

Time (*t*): 1 hour

Failure effect probability (*β*): 1

Item criticality (C_r):

$$C_r = \sum_{n=1}^{j} (\beta \alpha \lambda_p t)_n \quad n = 1,2,3 \ldots j \; or \; C_r = \sum_{n=1}^{j} (C_m)_n$$

$C_r = (1 \times .29 \times 12.058 \times 1) + (1 \times .71 \times 12.058 \times 1)$

$C_r = 12.058$

6-3.5 Effects of Redundancy – Quantitative.

When redundancy is employed to reduce system vulnerability and increase uptime, failure rates need to be adjusted prior to using the preceding formula. This can be accomplished by using formulas from various locations depending on the application. Below are a few examples from the Reliability Toolkit: Commercial Practices Edition, page 161, which is based on an exponential distribution of failure (constant time between failures).

6-3.5.1 Failure Rate with Repairs.

Example 1: For a redundant system where all units are active "on-line" with equal failure rates and (n-q) out of n required for success. This equation takes repair time into consideration.

Equation 6-4. Failure Rate with Repairs

$$\lambda_{(n-q)/n} = \frac{n!\,(\lambda)^{q+1}}{(n-q-1)!\,(\mu)^{q}}, with\ repairs$$

Where:
n = number of active online units; n! is n factorial.
λ = failure rate for on-line unit (failures/hour)
q = number of online units that can fail without system failure
μ = repair rate (μ=1/MTTR; where MTTR is the mean time to repair (hour).

6-3.5.2 Failure Rate with Repairs Example.

Therefore, if a system has five active units, each with a failure rate of 220 f/10^6 hours, and only three are required for successful operation. If one unit fails, it takes an average of three hours to repair it to an active state. What is the effective failure rate of this configuration?

6-3.5.3 Failure Rate with Repairs Example Inputs.

Substituting the following values into the equation:

$$n = 5,\ q = 2,\ \mu = 1/3$$

$$\lambda(5-2) / 5 = \lambda 3 / 5$$

$$\lambda_{3/5} = \frac{5!\,(220x10^{-6})^3}{(5-2-1)!\,(1/3)^2} = 5.75x10^{-9} failures/hour$$

$$\lambda_{3/5} = .00575 \text{ failures}/10^6 \text{ hours}$$

6-3.5.4 Determining Criticality Number of Example.

Then this new failure rate ($\lambda_{3/5}$) would be substituted for (λ_p) to determine criticality numbers of the system.

6-3.5.5 Failure Rate without Repairs Example.

Example 2: If by chance in the above sample, the unit was never repaired then the formula to use would be:

Equation 6-5. Failure Rate without Repairs

$$\lambda_{(n-q)/n} = \frac{\lambda}{\sum_{i=n-q}^{n} \frac{1}{i}}, without\ repairs$$

Where:
n = number of active online units; n! is n factorial
λ = failure rate for on-line unit (failures/hour)
q = number of online units that can fail without system failure

6-3.5.6 Failure Rate without Repairs Example Inputs.

Using the same problem from above and substituting into this formula

$$\lambda_{3/5} = \frac{200x10^{-6}}{\left(\frac{1}{3}\right) + \left(\frac{1}{4}\right) + \frac{1}{5}} = \frac{220x10^{-6}}{\frac{47}{60}}$$

$\lambda_{3/5} \approx 280x10^{-6}$ *failures/hour*

$\lambda_{3/5} \approx 280$ *failures/*10^6 *hours*

6-3.5.7 Failure Rate with Repairs vs without Repairs.

A noticeable increase in failure rate because the components are not repaired.

6-3.5.8 Other Failure Rate Formulas.

Other useful failure rate formulas used for redundant systems are as follows:

6-3.5.8.1 Active Units and Standby Units.

Example 3 & 4: One standby off-line unit with n active on-line units required for success. Off-line spare assumed to have a failure rate of zero. On-line units have equal failure rates.

Equation 6-6. Example 3

$$\lambda_{\frac{n}{n+1}} = \frac{n[n\lambda + (1-P)\mu]\lambda}{\mu + n(P+1)\lambda}, with\ repair$$

Equation 6-7. Example 4

$$\lambda_{\frac{n}{n+1}} = \frac{n\lambda}{P+1}, without\ repair$$

Where:
n = number of active online units; n! is n factorial.
λ = failure rate for on-line unit (failures/hour)
q = number of online units that can fail without system failure
μ = repair rate (μ=1/MTTR; where MTTR is the mean time to repair (hr).
P = probability that the switching mechanism will operate properly when needed (P=1 with perfect switching)

6-3.5.8.2 Active Units with Different Failure and Repair Rates.

Example 5 & 6: Two active on-line units with different failure and repair rates. One of two is required for success.

Equation 6-8. Example 5

$$\lambda_{1/2} = \frac{\lambda_A + \lambda_B[(\mu_A + \mu_B) + (\lambda_A + \lambda_B)]}{(\mu_A)(\mu_B) + (\mu_A + \mu_B)(\lambda_A + \lambda_B)}, with\ repair$$

Equation 6-9. Example 6

$$\lambda_{1/2} = \frac{{\lambda_A}^2\lambda_B + {\lambda_B}^2\lambda_A}{{\lambda_A}^2 + {\lambda_B}^2 + \lambda_A\lambda_B}, without\ repair$$

Where:
λ = failure rate for on-line unit (failures/hour)

6-3.5.9 Calculating Criticality Number for Examples 5 and 6.

These new failure rates (λ) should then be placed back in the equation,

$$C_{rc} = \sum_{n=1}^{j} (\beta\alpha\lambda_p t)_n$$

to calculate the new Criticality Number which accounts for redundancy.

6-3.5.10 Additional Redundancy Reference Material.

There is a technical publication that exclusively addresses various redundancy situations that may be of use, Rome Air Development Center, RADC-TR-77-287, A Redundancy Notebook, Rome Laboratory, 1977.

6-3.5.11 Additional Relative Ranking Approach.

If the facility does have failure rate data but does not have failure mode distribution data, a relative ranking can still be achieved, allowing for redundancy, by using the method described in the qualitative analysis, paragraph 6-3.6.

6-3.6 Qualitative Criticality Analysis.

Qualitative analysis will be used when specific part or item failure rates are not available. However, if failure rates are known on some components and not known on others, the failure rate data can be used to support the rankings below. This will provide a relative ranking between all the components. Failure mode ratio and failure mode probability are not used in this analysis. This analysis will allow the analysts the ability to subjectively rank each failure modes level of severity in relationship to its probability of failure. The items of most concern will be identified and evaluated to decrease the negative impact on the mission.

6-3.6.1 Criticality Worksheet.

Once it is determined that a qualitative approach will be used the Criticality worksheet that looks like Table 6-9 will be used. Note that some of the categories are derived from the FMEA sheet. The information from the FMEA should be transferred into the respective columns of the criticality worksheet. The additional categories will be used to support and calculate the Risk Priority Number (RPN), which will be explained in paragraph 6-3.6.7. Adjustments to occurrence rankings to compensate for redundant components within a typical C5ISR facility must be addressed as well and will be discussed in paragraph 6-3.7. Therefore, it is essential that the required amount of components necessary (M) to perform the function and the amount of components that are redundant (N) should be recorded in the respective categories of the criticality worksheet. Table 6-11 is an example of the quantitative FMECA worksheet with redundant components.

6-3.6.2 Occurrence Ranking.

The occurrence ranking is a method used to subjectively assign a failure rate to a piece of equipment or component. Each step in the ranking will correspond to an estimated failure rate based on the analyst's experience with similar equipment used in a similar environment. As mentioned previously, a known failure rate can be cross referenced to an occurrence ranking thereby allowing a complete analysis of a system that does not have failure rate and failure mode information on every item or component. When known failure rate data is used in this type of analysis, it not only adds merit to the ranking for the equipment with failure data, but also adds merit to the occurrence rankings of unknown equipment by providing benchmarks within the ranking scale. These values will establish the qualitative failure probability level for entry into a CA worksheet format. Rates can be hours, days, cycles …etc.

Table 6-11 Example of DA Form 7611 (AUG 2006), Quantitative FMECA with Redundant Components

QUANTITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	REDUNDANCY HAVE (N)	REDUNDANCY NEED (M)	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBAB-ILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	FAILURE MODE CRITICALITY NUMBER (C_μ)	ITEM CRITICALITY NUMBER (εC_μ)	REMARKS
110.0	Reservoir/ contains 6000 gallons of water	Leak	Crack in wall, Ruptured drainpipe	4	2	1	$1.500X10^{-6}$ (single) NPRD-95 $.0104X10^{-6}$ (redundant)	1	1	61,320	$6.38X10^{-4}$	$6.38X10^{-4}$	
120.0	Pump #1/ Transport Industrial water supply at 1000GPM	Transport water at a rate below 1000GPM	Impeller degraded, gasket leak, motor degraded	3	4	1	$12.508X10^{-6}$ (single) NPRD-95 $1.4X10^{-17}$ (redundant)	1	.35	61,320	$3.00X10^{-13}$	$8.58X10^{-13}$	
120.1		Produce no water flow	Broken coupling, suction line leak, motor inoperable	3				1	.65	61,320	$5.58X10^{-13}$		
130.0	Cooling Tower #1/ maintain a water temp of 75°F	Scaling (deposits) on media	Untreated water	4	4	1	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	.36	61,320	$2.87X10^{-12}$	$6.38X10^{-12}$	
130.1		Clogged sprayers	Untreated/ unfiltered water	4				1	.44	61,320	$3.51X10^{-12}$		

Table 6-11 Example of DA Form 7611 (AUG 2006), Quantitative FMECA with Redundant Components (cont'd)

QUANTITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	REDUNDANCY		FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBAB-ILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	FAILURE MODE CRITICALITY NUMBER (C_μ)	ITEM CRITICALITY NUMBER (εC_μ)	REMARKS
					HAVE (N)	NEED (M)							
130.0		Fan failure	Motor winding open, No supply voltage to motor	3				1	.2	61,320	$1.54X10^{-12}$	$1.54X10^{-12}$	
210.0	Pump #5/ Transport Industrial water supply at 960GPM	Degraded operation – produce water at rate less than 960GPM	Impeller degraded, gasket leak, motor degraded	3	2	1	$12.508X10^{-6}$ (single) NPRD-95 $8.72X10^{-10}$ (redundant)	1	.35	61,320	$3.00X10^{-13}$	$8.58X10^{-13}$	
210.1		Produce no water flow	Broken coupling, suction line leak, motor inoperable	3				1	.65	61,320	$5.58X10^{-13}$		
220.0	Chiller/ Remove heat(10°F) from chilled water supply	Degraded operation – remove less than 10°F	Refrigerant leak degraded compressor, tube leak, dirty coil	3	2	1	$9.279X10^{-6}$ (single) NPRD-95 $1.72X10^{-10}$ (redundant)	1	.92	61,320	$9.70X10^{-6}$	$9.70X10^{-6}$	
220.1		Remove no heat	Compressor seizure, motor failure	4				1	.08	61,320	$8.45X10^{-6}$	$8.45X10^{-6}$	Expensive and time-consuming repair

Table 6-11 Example of DA Form 7611 (AUG 2006), Quantitative FMECA with Redundant Components (cont'd)

QUANTITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	REDUNDANCY HAVE (N)	REDUNDANCY NEED (M)	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBAB-ILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	FAILURE MODE CRITICALITY NUMBER (C_μ)	ITEM CRITICALITY NUMBER (εC_μ)	REMARKS
310.0	Air handler/ Maintain room temp of 72°F 3200cfm	Maintain air temp higher than 72°F	Dirty coils	3	2	1	$1.7657X10^{-6}$ (single) NPRD-95 $6.24X10^{-12}$ (redundant)	1	.35	61,320	$1.34X10^{-7}$	$3.826X10^{-7}$	
310.1		Provide air flow at a rate less than 3200cfm	Reduced motor output, Dirty intake filter	3				1	.40	61,320	$1.53X10^{-7}$		
310.2		Produce no air flow	Broken belt, motor failure, fan bearing seizure, No AC power	3				1	.25	61,320	$9.56X10^{-8}$		

6-3.6.3 Qualitative Occurrence Rankings.

Possible qualitative occurrence rankings (O) are shown in Table 6-12.

Table 6-12 Occurrence Rankings

Ranking	Failure Rate	Comment
1	1/10,000	Remote probability of occurrence; unreasonable to expect failure to occur
2	1/5,000	Very low failure rate. Similar to past design that has had low failure rates for given volume/loads
3	1/2,000	Low Failure rate based on similar design for volume/loads
4	1/1,000	Occasional failure rate. Similar to past design that has similar failure rates for given volume/loads.
5	1/500	Moderate failure rate. Similar to past design having moderate failure rates for given volume/loads.
6	1/200	Moderate to high failure rate. Similar to past design having moderate failure rates for given volume/loads.
7	1/100	High failure rate. Similar to past design having frequent failures that caused problems
8	1/50	High failure rate. Similar to past design having frequent failures that caused problems
9	1/20	Very high failure rate. Almost certain to cause problems
10	1/10+	Very high failure rate. Almost certain to cause problems

6-3.6.4 Severity Ranking.

The severity ranking, as mentioned in paragraph 6-2.7, is also important in determining relative concerns amongst failure modes. The severity of the consequences of the failure effect is evaluated in terms of worst potential consequences upon the system level which may result from item failure. A severity classification must be assigned to each system level effect. A lower ranking indicates a less severe failure effect. A higher ranking indicates a more severe failure effect. Severity classifications provide a qualitative measure of the worst potential consequences resulting from an item failure.

6-3.6.5 Severity Rankings Table.

The severity rankings (S) from Table 6-4 are again shown here in Table 6-13.

Table 6-13 Severity Rankings

Ranking	Effect	Comment
1	None	No reason to expect failure to have any effect on Safety, Health, Environment or Mission
2	Very Low	Minor disruption to facility function. Repair to failure can be accomplished during trouble call
3	Low	Minor disruption to facility function. Repair to failure may be **longer** than trouble call but does not delay mission.

4	Low to Moderate	Moderate disruption to facility function. Some portion of Mission may need to be reworked or process delayed.
Ranking	**Effect**	**Comment**
5	Moderate	Moderate disruption to facility function **100%** of Mission may need to be reworked or process **delayed**.
6	Moderate to High	Moderate disruption to facility function. Some portion of Mission is lost. **Moderate** delay in restoring function.
7	High	High disruption to facility function. Some portion of Mission is lost. **Significant** delay in restoring function.
8	Very High	High disruption to facility function. **All** of Mission is lost. Significant delay in restoring function
9	Hazard	Potential Safety, Health, or Environmental issue. Failure will occur with warning
10	Extreme Hazard	Potential Safety, Health, or Environmental issue. Failure will occur without warning

6-3.6.6 Risk Priority Number.

The Risk Priority Number (RPN) is the product of the Severity (1-10) and the Occurrence (1-10) ranking.

Equation 6-10. Risk Priority Number

$$RPN = (S) \times (O)$$

Where:
RPN = Risk Priority Number
S = Severity Ranking
O = Occurrence Ranking

6-3.6.7 Risk Priority Number – Identify the Concerns or Risks.

The Risk Priority Number is used to rank and identify the concerns or risks associated with the operation due to the design. This number will provide a means to prioritize which components should be evaluated by the team to reduce their calculated risk through some type of corrective action or maintenance efforts. However, when severity is at a high level, immediate corrective action may be given regardless of the resultant RPN.

6-3.6.8 Automotive Industry Action Group Risk Priority Number.

This method was developed by the Automotive Industry Action Group (AIAG) and can be found in the reference manual titled Potential Failure Mode and Effects Analysis – FMEA. However, this \1\ UFC /1/ also considers detection to determine the Risk Priority Number.

Equation 6-11. Risk Priority Number

$$RPN = (S) \times (O) \times (D)$$

Where:
RPN = Risk Priority Number
S = Severity Ranking
O = Occurrence Ranking
D = Detection Ranking

6-3.6.9 Detection Rankings.

Where detection is ranked (1-10), shown in Table 6-14, in a similar fashion as severity and occurrence.

Table 6-14 Detection Rankings

Ranking	Detection	Comment
1	Almost Certain	Current control(s) almost certain to detect failure mode. Reliable controls are known with similar processes.
2	Very High	Very high likelihood current control(s) will detect failure mode.
3	High	High likelihood current control(s) will detect failure mode.
4	Moderately High	Moderately high likelihood current control(s) will detect failure mode.
5	Moderate	Moderate likelihood current control(s) will detect failure mode.
6	Low	Low likelihood current control(s) will detect failure mode.
7	Very Low	Very low likelihood current control(s) will detect failure mode.
8	Remote	Remote likelihood current control(s) will detect failure mode.
9	Very Remote	Ver remote likelihood current control(s) will detect failure mode.
10	Almost Impossible	No known control(s) available to detect failure mode.

6-3.6.10 Excluding Detection.

Detection was not included in the examples because in mission critical facilities, the team considers detection of a failure mode when assigning a severity ranking. They also consider a compensating provision such as redundancy. The end effect is altered due to these two contributing factors, therefore changing the severity of the consequences of this failure by design of the facility.

6-3.6.11 Severity Ranking vs Occurrence Ranking based on System.

Given the scenario that a compressor overheats due to the lack of lubrication, the effects would be "compressor seizes, room temperature rises, and computers malfunction". This would produce a severity ranking of "7" or "8". But due to the ability of the system to detect a problem, shut down the one component, and activate a redundant component in its place, a severity of "2" or "3" may be assigned for the failure mode. Note that it is also possible that the occurrence ranking will also be altered as well due to the redundant system. Even if there was no redundant component the end effect is altered because the ability to detect and shut down the compressor will prevent it from seizing thus saving repair or replacement costs and shortening the duration of down time by minimizing the damage.

6-3.6.12 C5ISR vs Auto Industry Goals.

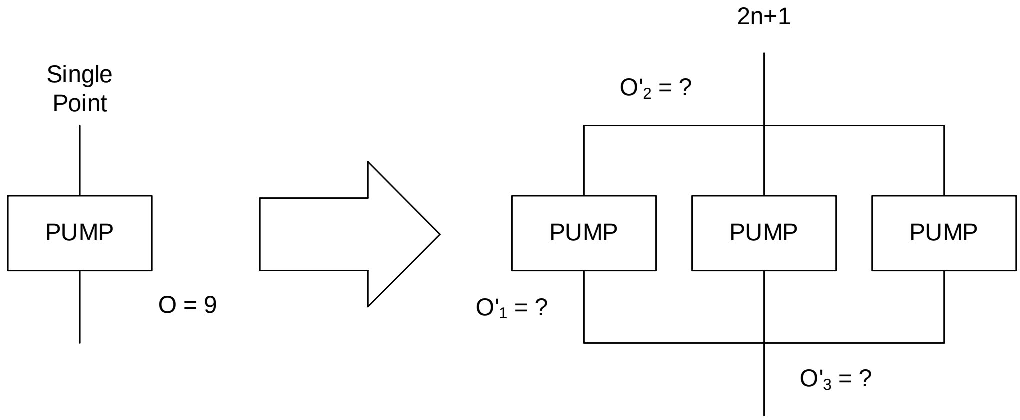
In addition, a C5ISR facility has a different "product" than the auto industry. The auto industry is producing parts and designers of the C5ISR facilities are primarily concerned with producing consistent temperature control and high-quality electricity. The auto industry does not want, under any circumstance, to allow a defective part out of their facility. If it does, the consequences would cost them immensely on recalls or warranty work. Therefore, it makes sense that they would consider detection of a faulty part prior to leaving their facility as important as severity in their analysis. This is not the case with a C5ISR facility. The designer’s goal in producing a C5ISR facility is to be available without interruption. Just because a failure has been detected does not necessarily mean that the end level effect is prevented. However, it may minimize the downtime, thus increasing availability. When severity is assigned, this would be taken into consideration. For that reason, even though detection is considered in classifying severity, it does not hold the same relative importance.

6-3.7 Effects of Redundancy – Qualitative.

Traditional methods for dealing with redundancy's effect on failure rate are rather lengthy and difficult to apply to a qualitative analysis. Therefore, further explanation is required for how to deal with criticality rankings for like components within a single redundant system.

For example, consider an occurrence ranking of 9 for a chilled water supply pump (see Figure 6-10). In essence, the analysis is ranking the failure rate associated with the loss of function of that component relative to the equipment operation, or mission as a whole, and not the component itself. So, the question becomes "how to subjectively, but meaningfully, rank like redundant components with the same system function?"

Figure 6-10 Single Point System vs Redundant System



6-3.7.1 Redundant Systems.

By design, a redundant system is more reliable and less vulnerable than a single component, with respect to system function and mission requirements. So, it makes sense that qualitative ranking of redundant components should take such concepts as degree of redundancy and presumed individual component reliability into consideration.

As a result of decreased system vulnerability, each individual component is less critical to the system function and mission requirement. Therefore, it is evident that O'_1, O'_2, and O'_3 should not all have the same ranking number as the single component system (9). Furthermore, the relationship between degree of redundancy and occurrence is not linear. So, it is also evident that the value for O'_1, O'_2, and O'_3 cannot be a strict division by n of the ranking number assigned to the redundant system's function (3, 3, and 3). This is supported with the redundancy formula in the quantitative criticality analysis in paragraph 6-3.5.1, Equation 6-4.

6-3.7.2 Occurrence Rankings.

The occurrence ranking number for a single component function must be weighted to reflect the operation, presumed reliability, and severity of loss of function of the redundant component system as accurately as possible. Furthermore, it should be observed that for mission critical facilities, the presence of one more component than needed is not sufficient to confidently assure mission availability. Therefore, a conservative factor should also be observed when determining individual occurrence rankings of redundant components, relative to the single point function.

6-3.7.3 Adjusted Occurrence Level.

The following mathematical equations can be used to emulate a non-linear redundancy/occurrence relationship while introducing a conservative mission critical factor:

Equation 6-12. Adjusted Occurrence Level

$$O' = Ox\frac{M}{N-1}$$

Where:
O = Occurrence level for loss of subsystem / system function, reliability data
O' = The adjusted occurrence level for the current redundant component being analyzed
M = The minimum number of components necessary
N = The number of components available

6-3.7.4 N+1 Occurrence Ranking.

Using this formula with only one redundant component will result in an occurrence ranking equal to the original. This formula reinforces the importance of having at least one extra component than necessary in a mission critical facility. The only way to decrease the occurrence ranking is to have 2 or more additional components than required.

$$O' = Ox\frac{M}{N-1}$$

Using:

M=2
N=3

$$O' = Ox\frac{2}{3-1}$$

$$O' = Ox\frac{2}{2}$$

$$O' = Ox1$$

Where:
O = Occurrence level for loss of subsystem / system function
M = The minimum number of components necessary
N = The number of components available
O' = The adjusted occurrence level for the current redundant component

6-3.7.5 Risk Priority Number.

If only two items are needed and four are available and the occurrence is nine:

M=2
N=4

$$O' = Ox\frac{2}{4-1}$$

$$O' = 9x\frac{2}{3}$$

$$O' = 6$$

Insert O' into the equation RPN = O'×S using the new severity ranking since the consequences of a failure of one component is not as severe to the end failure effect.

Original: $RPN = O \times S = 9 \times 8 = 72$

New: $RPN = O' \times S = 6 \times 5 = 30$

When sufficient failure rate data is available it is always recommended that quantitative CA be conducted through calculation or modeling. However, when a complete and detailed quantitative analysis is not necessary, realistically feasible, or desirable, the use of Equation 6-12 can be incorporated to quickly emulate the redundancy/occurrence relationship as part of a qualitative analysis.

6-3.7.6 Combined Method.

This “combined” method allows for an analysis to be conducted using the qualitative (subjective) approach and using supportive data to rank occurrence. Ranking occurrence with supportive data not only provides more merit to the results but offers flexibility by allowing the analyst to use data for components when available in the same analysis as other components that may not have any supportive data.

This is accomplished by allowing the failure rate (λ), failure mode probability (α), and the failure effect probability (β) to be multiplied to determine a failure rate for a particular failure mode. This rate can then be cross referenced in the occurrence ranking chart and assigned a new ranking (O'). Substituting in the formula:

$$RPN = (O') \times (S)$$

6-3.7.7 Adjusted Risk Priority Number.

This adjusted RPN will then be used in the final ranking process. Table 6-15 is an example of a FMECA using the qualitative method utilizing the redundancy formula to adjust the occurrence ranking. After the redundancy formula was applied, the number was rounded to the nearest whole number for this example. The components that only had one additional backup component did not have their occurrence rankings altered by this equation. Note: Rounding is not mandatory. This was done in the example for simplicity.

Table 6-15 Example of DA Form 7612 (AUG 2006), FMECA Worksheet Using Qualitative Rankings

QUALITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System | DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply | SHEET: 1 of 1

REFERENCE DRAWINGS: | COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room | APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	FAILURE EFFECTS	SINGLE COMPONENT			REDUNDANT SYSTEM					REMARKS AND/OR RECOMMENDED ACTIONS
					OCCUR	SEVER-ITY	RPN (O)X(S)	HAVE (N)	NEED (M)	OCCUR	SEVER-ITY	RPN (O)X(S)	
110.0	Reservoir/ contains 6000 gallons of water	Leak	Crack in wall, Drainpipe breaks	No immediate effect. The surrounding area will be saturated.	2	6	12	2	1	2	4	8	If drainpipe breaks secondary containment will be filled
120.0	Pump #1/ Transport Industrial water supply at 1000GPM	Transport water at a rate below 1000GPM	Impeller degraded, gasket leak, motor degraded	No immediate effect. Chiller inefficiency will cost $$.	3	4	12	4	1	1	3	3	
120.1		Produce no water flow	Broken coupling, leak on suction line, motor inoperable	Room temp will rise above max allowed temp. Mission failure.	6	5	30	4	1	2	3	6	
130.0	Cooling Tower #1/ maintain a water temp of 75°F	Scaling (deposits) on media	Untreated water	Room temperature will rise slightly	3	6	18	4	1	1	4	4	
130.1		Clogged sprayers	Untreated/ unfiltered water	Room temp will rise, Chiller efficiency decreases	3	5	15	4	1	1	4	4	

Table 6-15 Example of DA Form 7612 (AUG 2006), FMECA Worksheet Using Qualitative Rankings (cont'd)

QUALITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	FAILURE EFFECTS	SINGLE COMPONENT			REDUNDANT SYSTEM					REMARKS AND/OR RECOMMENDED ACTIONS
					OCCUR	SEVER-ITY	RPN (O)X(S)	HAVE (N)	NEED (M)	OCCUR	SEVER-ITY	RPN (O)X(S)	
130.2		Fan failure	Motor winding open, No power to motor	Air temp rise. No severe effect. Chiller efficiency decreases	3	4	12	4	1	1	3	3	
210.0	Pump #5/ Transport Industrial water supply at 960GPM	Degraded operation – produce water at rate less than 960GPM	Impeller degraded, gasket leak, motor degraded	No immediate effect. Chiller efficiency decreases $$$	1	4	4	2	1	1	3	3	
210.1		Produce no water flow	Broken coupling, leak on suction line, motor inoperable	No air cooling. Room temp rise above allowed. Mission failure	2	8	16	2	1	2	3	6	
220.0	Chiller/ Remove heat(10°F) from chilled water supply	Degraded operation – remove less than 10°F	Refrigerant loss, degraded compressor, leaky tube, dirty coil	Air temperature will rise but not above max allowed	7	6	42	2	1	7	3	21	
220.1		Remove no heat	Compressor seizure, motor failure	Min. air cooling. Temp above max. Mission failure	2	8	16	2	1	2	4	8	

Table 6-15 Example of DA Form 7612 (AUG 2006), FMECA Worksheet Using Qualitative Rankings (cont'd)

QUALITATIVE FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: Industrial Water Supply — SHEET: 1 of 1

REFERENCE DRAWINGS: — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	FAILURE EFFECTS	SINGLE COMPONENT			REDUNDANT SYSTEM					REMARKS AND/OR RECOMMENDED ACTIONS
					OCCUR	SEVER-ITY	RPN (O)X(S)	HAVE (N)	NEED (M)	OCCUR	SEVER-ITY	RPN (O)X(S)	
310.0	Air Handler/ Provide air to room at 72°F, 3200cfm	Provide air at a temp higher than 72°F	Dirty coils	Minimal change in temperature	3	4	12	2	1	3	3	9	
310.1		Provide airflow at a rate less than 3200cfm	Reduced motor output, dirty intake filter	Temperature variations in room dependent on location	2	3	6	2	1	2	3	6	
310.2		Provide no air flow	Broken belt, motor failure bearing seizure in fan, Loss of power	Temp rise above max allowed. Mission failure	2	7	14	2	1	2	3	6	

6-4 RANKINGS.

6-4.1 Criticality Rankings.

A criticality ranking is a list used to rank the failure modes of most concern first, down to the least concern, at the bottom. This procedure is essentially conducted in the same fashion whether it is a quantitative analysis or the more widely used qualitative (subjective) analysis.

6-4.1.1 Analyzing Failure Modes in Terms of RPN.

When failure modes are analyzed in terms of RPN, the highest RPN must be listed first (qualitative analysis). When failure rate data is used to calculate criticality numbers (quantitative analysis) the highest criticality number should be listed first. See Table 6-16 for an example failure mode criticality ranking using DA Form 7613. Table 6-17 using DA Form 7614 is another type of ranking that only ranks the item criticality number (Equation 6-3) that was discussed in paragraph 6-3.4.6. This is called an item criticality ranking. Both rankings have advantages, but the failure mode criticality ranking provides the most detail regarding failure rates and failure modes and is therefore the preferred type when conducting a quantitative analysis.

Table 6-16 Example of DA Form 7613 (AUG 2006), Failure Mode Criticality Rankings

FAILURE MODE CRITICALITY RANKING (QUANTITATIVE)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System — SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBABILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	MODAL CRITICALITY NUMBER (C_μ)
220.0	Chiller/ Remove heat (10°F) from chilled water supply	Degraded operation – remove less than 10°F	Refrig. loss, degraded comp., tube leak, dirty coil	3	$9.2791X10^{-6}$ (single) NPRD-95 $1.72X10^{-10}$ (redundant)	1	.92	61,320	$9.70X10^{-6}$
310.2	Air Handler/ Provide 3200cfm of air, keep room at 72°F	Provide no air flow	Broken belt, motor failure fan bearing seizure, Loss of power	3	$1.7657X10^{-6}$ (single) NPRD-95 $6.24X10^{-12}$ (redundant)	1	.25	61,320	$9.56X10^{-8}$
220.1	Chiller/ Remove heat (10°F) from chilled water supply	Remove no heat	Compressor seizure, motor failure	4	$9.2791X10^{-6}$ (single) NPRD-95 $1.72X10^{-10}$ (redundant)	1	.08	61,320	$8.45X10^{-6}$
110.0	Reservoir/ contain 6000 gallons of water	Leak	Crack in wall	4	$1.500X10^{-6}$ (single) $.0104X10^{-6}$ (redundant)	1	1	61,320	$6.38X10^{-4}$
120.1	Pump #1/ Transport Industrial water supply at 1000gpm	Produce no water flow	Broken coupling, suction line leak, motor inoperable	3	$12.058X10^{-6}$ (single) NPRD-95 $1.4X10^{-17}$ (redundant)	1	.65	61,320	$5.58X10^{-13}$

Table 6-16 Example of DA Form 7613 (AUG 2006), Failure Mode Criticality Rankings (cont'd)

FAILURE MODE CRITICALITY RANKING (QUANTITATIVE)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System — SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBABILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	MODAL CRITICALITY NUMBER (C_μ)
210.1	Pump #5/ Transport chilled water supply at 960gpm	Produce no water flow	Broken coupling, suction line leak, motor inoperable	3	$12.058X10^{-6}$ (single) NPRD-95 $8.724X10^{-10}$ (redundant)	1	.65	61,320	$5.58X10^{-13}$
130.1	Cooling Tower #1/ Maintain a water temp of 75°F	Clogged sprayers	Untreated/ unfiltered water	4	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	.44	61,320	$3.51X10^{-12}$
120.0	Pump #1/ Transport Industrial water supply at 1000gpm	Transport water a rate below 1000gpm	Impeller degraded, gasket leak, motor degraded	3	$12.058X10^{-6}$ (single) NPRD-95 $1.4X10^{-17}$ (redundant)	1	.35	61,320	$3.00X10^{-13}$
210.0	Pump #5/ Transport chilled water supply at 960gpm	Degraded operation – produce water at a rate less than 960gpm	Impeller degradation, gasket leak, motor degraded	3	$12.058X10^{-6}$ (single) NPRD-95 $8.724X10^{-10}$ (redundant)	1	.35	61,320	$3.00X10^{-13}$
130.0	Cooling Tower #1/ Maintain a water temp of 75°F	Sealing (deposits) on media	Untreated water	4	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	.36	61,320	$2.87X10^{-12}$

Table 6-16 Example of DA Form 7613 (AUG 2006), Failure Mode Criticality Rankings (cont'd)

FAILURE MODE CRITICALITY RANKING (QUANTITATIVE)

For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System — DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System — SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B — COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room — APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVER-ITY	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBABILITY (β)	FAILURE MODE RATIO (α)	OPERATING TIME (t)	MODAL CRITICALITY NUMBER (C_μ)
130.2	Cooling Tower #1/ Maintain a water temp of 75°F	Fan failure	Motor winding open, Loss of power to motor	3	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	.20	61,320	$1.54X10^{-12}$
310.1	Air Handler/ Provide 3200cfm of air to room, maintain	Provide airflow at a rate less than 3200cfm	Reduced motor output, dirty intake filter	3	$1.7657X10^{-6}$ (single) NPRD-95 $6.24X10^{-12}$ (redundant)	1	.40	61,320	$1.53X10^{-7}$
310.0	Air Handler/ Provide 3200cfm of air to room, maintain	Maintain air at a temp higher than 72°F	Dirty coils	3	$1.7657X10^{-6}$ (single) NPRD-95 $6.24X10^{-12}$ (redundant)	1	.35	61,320	$1.34X10^{-7}$
130.0	Cooling Tower #1/ Maintain a water temp of 75°F	Sealing (deposits) on media	Untreated water	4	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	.36	61,320	$2.87X10^{-12}$

Table 6-17 Example of DA Form 7614 (AUG 2006), Item Criticality Rankings

ITEM CRITICALITY RANKING (QUANTITATIVE)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNCTION	SEVERITY	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBABILITY (β)	OPERATING TIME (t)	ITEM CRITICALITY NUMBER (εC_μ)
220.0	Chiller/ Remove heat (10°F) from chilled water supply	3	$9.2791X10^{-6}$ (single) NPRD-95 $1.72X10^{-10}$ (redundant)	1	61,320	$9.70X10^{-6}$
120.0	Pump #1/ Transport water through Industrial water supply at 1000gpm	3	$12.058X10^{-6}$ (single) NPRD-95 $1.4X10^{-17}$ (redundant)	1	61,320	$8.58X10^{-13}$
210.0	Pump #5/ Transport water through chilled water supply at 960gpm	3	$12.058X10^{-6}$ (single) NPRD-95 $8.724X10^{-10}$ (redundant)	1	61,320	$8.58X10^{-13}$
220.1	Chiller/ Remove heat (10°F) from chilled water supply	4	$9.2791X10^{-6}$ (single) NPRD-95 $1.72X10^{-10}$ (redundant)	1	61,320	$8.45X10^{-6}$
110.0	Reservoir/ contain 6000 gallons of water	4	$1.500X10^{-6}$ (single) $.0104X10^{-6}$ (redundant)	1	61,320	$6.38X10^{-4}$

Table 6-17 Example of DA Form 7416 (AUG 2006), Item Criticality Rankings (cont'd)

ITEM CRITICALITY RANKING (QUANTITATIVE)
For use of this form, see TM 5-698-4; the proponent agency is USACE.

SYSTEM: Mechanical System DATE (YYYYMMDD): 20050819

PART NUMBER: HVAC System SHEET: 1 of 3

REFERENCE DRAWINGS: C-20005-B COMPLIED BY: AAA

MISSION: Provided Temperature Control to Room APPROVED BY: BBB

ITEM NUMBER	ITEM/FUNCTION	SEVERITY	FAILURE RATE λ_p (SOURCE)	FAILURE EFFECT PROBABILITY (β)	OPERATING TIME (t)	ITEM CRITICALITY NUMBER (εC_μ)
130.0	Cooling Tower #1/ Maintain a water temp of 75°F	4	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	61,320	$6.38X10^{-12}$
310.0	Air Handler/ Provide 3200cfm of air to room, maintain room at 72°F	3	$1.7657X10^{-6}$ (single) NPRD-95 $6.24X10^{-12}$ (redundant)	1	61,320	$3.826X10^{-7}$
130.2	Cooling Tower #1/ Maintain a water temp of 75°F	3	$10.0518X10^{-6}$ (single) NPRD-95 $1.3X10^{-16}$ (redundant)	1	61,320	$1.54X10^{-12}$

6-4.1.2 Failure Mode Criticality, Item Criticality and RPN Ranking.

The failure mode criticality ranking, item criticality ranking, and RPN ranking lists can be useful tools but should not be solely used to determine which items are of most concern. Where these rankings fall short are their inability to allow the analyst to be judgmental to determine higher risk or higher consequences of failures. It is quite possible that two or more failure modes have similar RPN's or criticality numbers, but one has a much higher severity or consequence of the failure. These items typically need to be addressed first. Therefore, it is highly suggested that this ranking should be complimented by developing a criticality matrix. The matrix is explained in paragraph 6-4.2.

6-4.1.3 Not Constructing a Criticality Matrix Approach.

If the analysts do not wish to construct a criticality matrix, the next best approach would be to organize the Criticality Ranking by not only the Criticality Number or RPN, but also list the items by severity. This can be accomplished quite easily in an Excel program sorting first by severity and then by Criticality Number or RPN. The analysts can then review all the higher severity items first and make sound judgments regarding what type of actions, if any, should be taken to decrease the severity. This critical ranking list is to be used in a flexible manner according to the best judgment of the analysts. If done correctly it will aid in safety, maintainability, and FTA, thereby enabling improvements in the design.

6-4.2 Criticality Matrix.

The Criticality Matrix is a graphical or visual means of identifying and comparing failure modes for all components within a given system or subsystem and their probability of occurring with respect to severity. It is used for quantitative and qualitative analyses. The matrix can be used along with the Critical Item List or by itself to prioritize components.

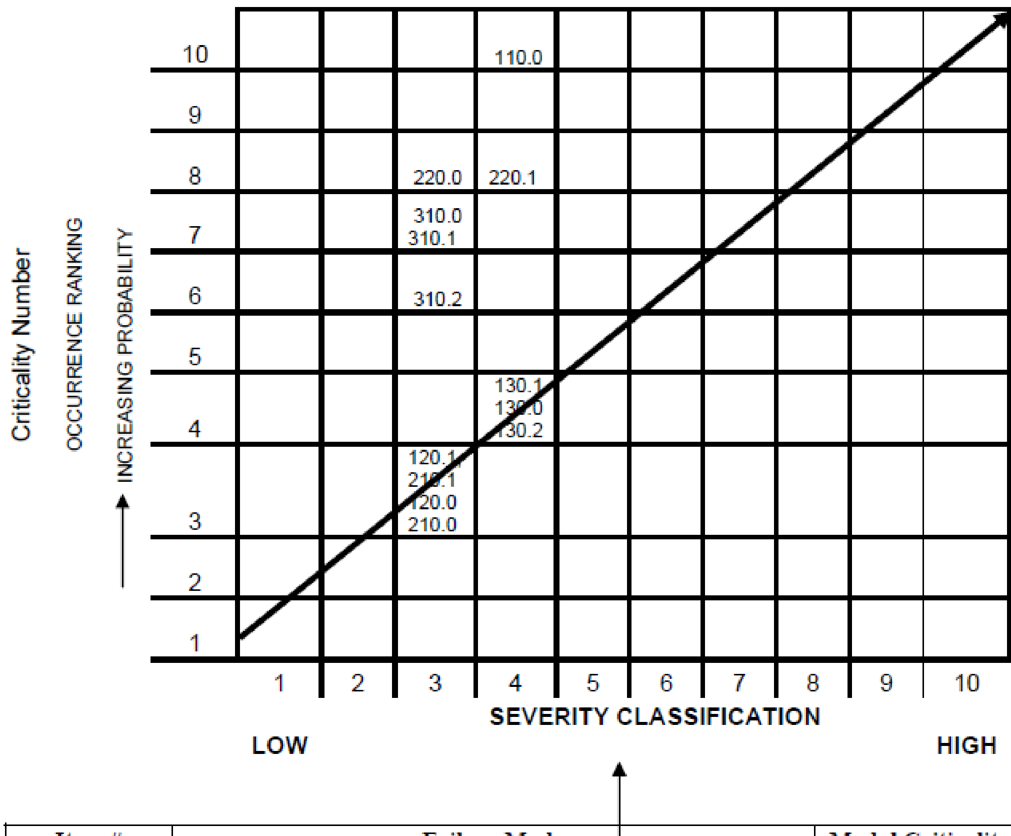
6-4.2.1 Differentiate Criticality of Components.

The matrix has the distinctive ability to differentiate criticality of components with the same or similar RPN and criticality number. For example: two components could have the same RPN, one with the severity of three and an occurrence ranking of ten, the other with a severity of ten and an occurrence ranking of three, thus producing a RPN of 30. Consequently, listing them only by RPN would produce an equal ranking. By placing them in the matrix it becomes very evident that an item that is in the severity category of "ten" should take priority for some type of corrective action.

6-4.2.2 Criticality Matrix Construction.

The matrix is constructed by inserting the assigned Item number, or other indicator, for each failure mode into matrix locations which represent the severity classification and probability of occurrence ranking. The criticality matrix example shown in Figure 6-11 is representative of the HVAC system FMECA example in Table 6-11. If there is not sufficient space available in the matrix to paste the Item number, then an alternative method to represent each failure mode should be used. The resulting matrix shows the relative ranking of criticality for each item's failures.

Figure 6-11 Criticality Matrix



Item #	Failure Mode	Modal Criticality Number
110.0	leak	$6.38x10^{-4}$
120.0	Transport water at a rate below 1000 gpm	$3.00x10^{-13}$
120.1	produce no water flow	$5.58x10^{-13}$
130.0	Scaling(deposits) on media	$2.87x10^{-12}$
130.1	Clogged sprayers	$3.51x10^{-12}$
130.2	Fan failure	$1.54x10^{-12}$
210.0	Degraded operation-produce water at a rate less than 960gpm	$3.00x10^{-13}$
210.1	produce no water flow	$5.58x10^{-13}$
220.0	Degraded operation-remove less than 10°F	$9.70x10^{-6}$
220.1	remove no heat	$8.45x10^{-6}$
310.0	Maintain air at a temp higher than 72°F	$1.34x10^{-7}$
310.1	Provide airflow at a rate less than 3200cfm	$1.53x10^{-7}$
310.2	Provide no air flow	$9.56x10^{-8}$

6-4.2.3 Criticality Matrix Item Numbers.

Item number's displayed in the upper most right-hand corner of the matrix require the most immediate attention. These failures have a high probability of occurrence and a catastrophic effect on system operation or personnel safety. Therefore, they should be evaluated first to determine if a redesign (such as, design in redundancy) is an alternative approach. Moving diagonally towards the lower left-hand corner of the matrix, the criticality and severity of potential failures decreases. In cases where failures display the same relative severity and criticality, it must be determined whether safety/mission success or cost is the driving factor of the analysis. If safety/mission success is of more concern, items shown on the right of the diagonal line require the most re-design attention, because the effects of their failures are more severe even though their criticality ranking may be less. If cost is a major concern, items to the left of the diagonal line require attention, because the high criticality numbers (occurrence rankings) reflect higher failure probability.

6-4.2.4 Criticality Matrix with Redundant System.

By employing redundancy, a duplicate system is constructed such that it serves as a backup for a critical single point failure. Though the initial failure of the component or system cannot be avoided, the effect of the failure will no longer be catastrophic since a compensating provision (the redundant system) will serve to operate in its place. If redundancy cannot be employed, then a more robust component with a lower failure rate may be an option. Every means possible should be evaluated to lower the failure rate on any high severity classification failure mode. If this cannot be accomplished, then a reaction plan must be developed to minimize the downtime of the system.

6-5 RESULTS.

6-5.1 Overview.

At the conclusion of the FMECA, critical items/failure modes are identified, and corrective action recommendations made based on the criticality list and/or the Criticality Matrix generated by the CA.

6-5.1.1 Utilizing the Criticality List.

Utilizing the criticality list, the items with the highest criticality number or RPN receive attention first. Utilizing the Criticality Matrix (recommended), items in the upper most right-hand quadrant will receive attention first. Typical recommendations call for design modifications such as the use of higher quality components, higher rated components, design in redundancy or other compensating provisions.

6-5.1.2 Recommendations.

Recommendations cited must be fed back into the design process as early as possible to minimize iterations of the design. The FMECA is most effective when exercised in a proactive manner to drive design decisions, rather than to respond after the fact.

6-5.2 Recommendations – from the Criticality Matrix Example.

Once the items are assigned their respective "squares" in the criticality matrix, the team now has the ability to rank which components need further review. From the above example the items can be quickly judged. If there are items that have similar RPNs and fall in the roughly the same vicinity in the matrix, then the team will have to determine which item should be addressed first. Remember, as the design matures and information is collected, this tool will be able to identify more clearly which items should take priority.

6-5.2.1 Item Number 110.0.

Item number 110.0 is the reservoir and has a high failure rate. Possibly another choice for a reservoir with a lower failure rate and an annual inspection/evaluation of condition of reservoir should be considered.

6-5.2.2 Item Number 220.1.

Item number 220.1 is the inability of the chiller to remove any heat from the chilled water supply. This has a relatively high failure rate and severity. The chiller should have inspections at specified intervals including eddy current testing annually to monitor breakdown of tubes. Motor should be tested annually as well for breakdown of windings. Because there is a redundant component this can be done at a predetermined time. Continuous monitoring of temperature with existing sensors and alarms should prevent catastrophic failure of the chiller. These procedures should address item 220.0 as well.

6-5.2.3 Item Numbers 310.0, 310.1, and 310.2.

Item numbers 310.0, 310.1, & 310.2 are all associated with the air handler system. Number 310.0 and number 310.1 have a higher failure rate and are therefore more likely to occur and possibly predict due to their nature of failure mechanisms which are a “wear out” type mechanism. Therefore, typical preventative maintenance actions at manufacture’s recommendations should be employed initially. This interval can be adjusted according to inspection reports from the maintenance actions. The fan should not be driven by one belt. Use a sheave with three grooves for three belts to decrease the chance that one broken belt will make the item fail. A spare motor should be on hand to quickly replace the existing motors in the event one fails. Bearings should be greased quarterly (do not over grease) and air filter(s) changed semiannually.

6-5.2.4 Item Numbers 130.0, 130.1, and 130.2.

Item numbers 130.0, 130.1, and 130.2 have relatively high severities and average failure rates. These items are all related to the cooling towers. Most of the failures associated with this item are related to contamination of the water, therefore monitoring the condition of the water through water analysis and changing the filters at a regular interval (again, adjust this as needed) should also be implemented. An annual inspection should be done as well. Replacement sprayers and fan motors should be readily available to quickly respond to a spontaneous failure in these locations.

6-5.2.5 Remaining Failure Modes.

The final four failure modes are associated with the pumps in both the chilled water supply and the industrial cooling water supply. The chilled water supply ranks higher because in the event of no chilled water there will be no heat removed from the room and therefore would lead to computer failure. This is an immediate effect versus the industrial cooling water system which will affect the efficiency of the chiller and possibly lead to a failure over time. Therefore, if a priority were to be in place,
the chilled water pump should take precedence. In either case, the recommendations for both pumps are the same. Along with the manufacture’s recommended PM in place for rebuilding the pump and periodic inspections, then a vibration analysis and an electrical test on the motor could be conducted at a semiannual basis. In the event of a spontaneous failure the redundant pump can be transferred over while the failed pump is repaired. It should be noted however, that if the power supply is disrupted to the first pump then there is a possibility that the second pump will also be unable to start. This means there better be a separate power feed line to the secondary pumps.

6-5.3 Incentives.

The FMECA is a valuable tool that can be utilized from early design to functional use of a system. It is most beneficial when initiated early in the design process by providing engineers a prioritized list of areas in the design that need attention. This early assessment will minimize costs associated with constructing a facility and maintaining it. To develop strategies after the facility is built not only costs more but will typically be compromised due to physical restraints.

6-5.3.1 Identifying Critical Items.

Due to the continuous challenge to provide clean reliable power and precise temperature control to a mission critical facility, it is somewhat intimidating to attempt to assess which items should be more critical to mission success. The effects of redundancy, failure rates and severity on this assessment of each component/subsystem can be complex and time consuming when using a pure statistical approach. However, the alternative method explained in this \1\ UFC /1/ should provide a simpler means to make this assessment or ranking possible, with or without failure data.

6-5.3.2 Method Modifications.

The method used in this \1\ UFC /1/ should be used as a guide and tailored to a facility's specific need. It is important that the user makes modifications to the forms to meet those needs. This \1\ UFC /1/is meant to be used as a tool and must be flexible to accomplish a meaningful analysis at different facilities.

6-5.4 Results.

6-5.4.1 Comparison of Single Component Failures.

The results from this type of analysis are for comparison of single component failures only. The information derived from this analysis will provide a baseline to conduct other analyses. For simultaneous multiple failure event analysis, other techniques, such as FTA, should be used. The FTA is very extensive and is usually applied to areas of concern that are identified through the FMECA process or from prior experience.

6-5.4.2 Strength and Weaknesses of FMECA.

It is very important to know the strengths and weaknesses of this analysis. The FMECA is a living document and should be updated on a continual basis as more and more information is collected on the system. It should provide a valuable resource to support reliability, corrective maintenance actions, and safety.

6-5.4.3 Effects of Redundancy.

The effects of redundancy should be taken into consideration when calculating criticality numbers or assigning occurrence rankings because redundancy reduces the failure rate, thus increasing the availability. After all, availability is the prime objective of the C5ISR facility.

CHAPTER 7 RELIABILITY CENTERED MAINTENANCE (RCM)

7-1 RCM.

7-1.1 The RCM Concept.

Prior to the development of the RCM methodology, it was widely believed that everything had a "right" time for some form of preventive maintenance (PM), usually replacement or overhaul. A widespread belief among many maintenance personnel was that by replacing parts of a product or overhauling the product (or reparable portions thereof), that the frequency of failures during operation could be reduced. Despite this previous commonly held view, the results seemed to tell a different story. In far too many instances, PM seemed to have no beneficial effects. Indeed, in many cases, PM made things worse by providing more opportunity for maintenance-induced failures.

7-1.1.1 Airline Study.

When the airline companies in the United States observed that PM did not always reduce the probability of failure and that some items did not seem to benefit in any way from PM, they formed a task force with the Federal Aviation Administration (FAA) to study the subject of preventive maintenance. The results of the study confirmed that PM was effective only for items having a certain pattern of failures. The study also concluded that PM should be required only when required to assure safe operation. Otherwise, the decision to do or not do PM should be based on economics.

7-1.1.2 RCM Approach.

The RCM approach provides a logical way of determining if PM makes sense for a given item and, if so, selecting the appropriate type of PM. The approach is based on the following precepts.

(1) The objective of maintenance is to preserve an item's function(s). RCM seeks to preserve system or equipment function, not just operability for operability's sake. Redundancy improves functional reliability but increases life cycle cost in terms of procurement and life cycle cost.

2) RCM focuses on the end system. RCM is more concerned on maintaining system function than individual component function.

(3) Reliability is the basis for decisions. The failure characteristics of the item in question must be understood to determine the efficacy of preventive maintenance. RCM is not overly concerned with simple failure rate; it seeks to know the conditional probability of failure at specific ages (the probability that failure will occur in each given operating age bracket).

(4) RCM is driven first by safety and then economics. Safety must always be preserved. When safety is not an issue, preventive maintenance must be justified on economic grounds.

(5) RCM acknowledges design limitations. Maintenance cannot improve the inherent reliability – it is dictated by design. Maintenance, at best, can sustain the design level of reliability over the life of an item.

(6) RCM is a continuing process. The difference between the perceived and actual design life and failure characteristics is addressed through age (or life) exploration.

7-1.1.3 RCM Concept.

The RCM concept has completely changed the way in which PM is viewed. It is now a widely accepted fact that not all items benefit from PM. Moreover, even when PM would be effective, it is often less expensive (in all senses of that word) to allow an item to "run to failure" rather than to do PM. In the succeeding discussions, the RCM concept will be examined in more detail. The meaning of terms that are central to the RCM approach will be explored. These terms include failure characteristics, efficiency, run to failure, cost, and function.

7-1.2 Benefits of RCM.

7-1.2.1 Reduced Costs.

A significant reason for creating the joint airline/FAA task force was the new Boeing 747 (B747) jumbo jet. Boeing and United Airlines, the initial buyer of the aircraft, were already considering the development of the PM program for the B747. This new airliner was vastly larger and more complex than any ever built. Given the cost of maintenance on smaller aircraft already in service, the maintenance costs for the B747, using the traditional approach to PM, would have threatened the profitability, and hence the viability, of operating the new aircraft. Examples of the ultimate savings achieved in using RCM to develop the PM program for the B747 and other aircraft are shown in Table 7-1. Similar savings have been achieved by other industries for other equipment when going from a traditional to an RCM-based PM program. It is important to note that these costs savings are achieved with no reduction in safety, an obvious requirement in the airline industry.

Table 7-1 Cost Benefits of using RCM for Developing PM Program

Type of PM	Required Using Traditional Approach	Required Using RCM
Structural Inspections	4,000,000 hours for DC-8	66,000 hours for B747
Overhaul	339 items for DC-8	7 items for DC-10
Overhaul of turbine engine	Scheduled	On-condition (cut shop maintenance costs by 50% compared with DC-8)

7-1.2.2 Increased Availability.

For many systems, including C5ISR facilities, availability is of primary importance. Availability was defined in paragraph 2-1.5. As indicated in the definition, the level of availability achieved in actual use of a product is a function of how often it fails and how quickly it can be restored to operation. The latter, in turn, is a function of how well the product was designed to be maintainable, the amount of PM required, and the logistics resources and infrastructure that have been put in place to support the product. RCM directly contributes to availability by reducing PM to that which is essential and economic.

7-1.3 Origins of RCM.

7-1.3.1 Airlines.

As stated earlier, RCM had its origins with the airline industry. Nowhere had the then prevailing philosophy of maintenance been challenged more. By the late 1950's, maintenance costs in the industry had increased to a point where they had become intolerable. Meanwhile, the Federal Aviation Agency (FAA) had learned through experience that the failure rate of certain types of engines could not be controlled by changing either the frequency or the content of scheduled fixed-interval overhauls. As a result of these two factors, a task force consisting of representatives of the airlines and aircraft manufacturers was formed in 1960 to study the effectiveness of PM as being implemented within the airline industry.

(1) The task force. The task force developed a rudimentary technique for developing a PM program. Subsequently, a maintenance steering group (MSG) was formed to manage the development of the PM program for the new Boeing 747 (B747) jumbo jet. This new airliner was vastly larger and more complex than any ever built. Given the cost of maintenance on smaller aircraft already in service, the maintenance costs for the B747, using the traditional approach to PM, would have threatened the profitability, and hence the viability, of operating the new aircraft.

(2) MSG-1. The PM program developed by the steering group, documented in a report known as MSG-1, was very successful. That is, it resulted in an affordable PM program that ensured the safe and profitable operation of the aircraft.

(3) MSG-2. The FAA was so impressed with MSG-1 that they requested that the logic of the new approach be generalized, so that it could be applied to other aircraft. So, in 1970, MSG-2, Airline Manufacturer Maintenance Program Planning Document, was issued. MSG-2 defined and standardized the logic for developing an effective and economical maintenance program. MSG-2 was first used on the L1011, DC10, and MD80 aircraft. In 1972, the European aviation industries issued EMSG (European Maintenance System Guide), which improved on MSG-2 in the structures and zonal analysis. EMSG was used on the Concorde and A300 Airbus.

7-1.3.2 Adoption by Military.

The problems that the airlines and FAA had experienced with the traditional approach to maintenance were also affecting the military. Although profit was not an objective common to both the airlines and military, controlling costs and maximizing the availability of their aircraft were. Consequently, in 1978, the DOD contracted with United Airlines to conduct a study into efficient maintenance programs. The study supplemented MSG-2 by emphasizing the detection of hidden failures and moved from a process-oriented concept to a task-oriented concept. The product of the study was MSG-3, a decision logic that was called RCM.

7-1.3.3 Use for Facilities and Other Industries.

Although created by the aviation industry, RCM quickly found applications in many other industries. RCM is used to develop PM programs for public utility plants, especially nuclear power plants, railroads, processing plants, and manufacturing plants. It is no overstatement to say that RCM is now the pre-eminent method for evaluating and developing a comprehensive maintenance program for an item. Today, a variety of documents are available on RCM.

7-1.4 Relationship of RCM to Other Disciplines.

7-1.4.1 Reliability.

It is obvious why the first word in the title of the MSG-3 approach is reliability. Much of the analysis needed for reliability provides inputs necessary for performing an RCM analysis, as will be seen in succeeding paragraphs. The fundamental requirement of the RCM approach is to understand the failure characteristics of an item. As used herein, failure characteristics include the underlying failure rate, the consequences of failure, and whether the failure manifests itself and, if it does, how. Reliability is measured in different ways, depending on one's perspective: inherent reliability, operational reliability, mission (or functional) reliability, and basic (or logistics) reliability. RCM is related to operational reliability.

(1) Inherent versus operational reliability. From a designer's perspective, reliability is measured by "counting" only those failures that are design related. When measured in this way, reliability is referred to as "inherent reliability." From a user's or operator's perspective, all events that cause the system to stop performing its intended function is a failure event. These events certainly include all design-related failures that affect the systems' function. Also included are maintenance-induced failures, no-defect found events, and other anomalies that may have been outside the designer's contractual responsibility or technical control. This type of reliability is called "operational reliability."

(2) Mission or functional reliability versus basic or logistics reliability. Any failure that causes the product to fail to perform its function or mission is counted in "mission reliability." Redundancy improves mission reliability. Consider a case where one part of

a product has two elements in parallel where only one is needed (redundant). If a failure of one element of the redundant part of the product fails, the other continues to function allowing the product to do its job. Only if both elements fail will a mission failure occur. In "basic" reliability, all failures are counted, whether a mission or functional failure has occurred. This measure of reliability reflects the total demand that will eventually be placed on maintenance and logistics.

7-1.4.2 Safety.

Earlier, it was stated that one of the precepts on which the RCM approach is that safety must always be preserved. Given that the RCM concept came out of the airline industry, this emphasis on ensuring safety should come as no surprise. In later paragraphs, the way the RCM logic ensures that safety is ensured will be discussed. For now, it is sufficient to note that the RCM specifically addresses safety and is intended to ensure that safety is never compromised. In the past several years, environmental concerns and issues involving regulatory bodies have been accorded an importance in the RCM approach for some items that is equal (or nearly so) to safety. Failures of an item that can cause damage to the environment or which result in some Federal or state law being violated can pose serious consequences for the operator of the item. So, the RCM logic is often modified, as it is in this UFC, to specifically address environmental, mission, or other concerns.

7-1.4.3 Maintainability.

RCM is a method for prescribing PM that is effective and economical. Whether or not a given PM task is effective depends on the reliability characteristics of the item in question. Whether or not a task is economical depends on many factors, including how easily the PM tasks can be performed. Ease of maintenance, corrective or preventive, is a function of how well the system has been designed to be maintainable. This aspect of design is called maintainability. Providing ease of access, placing items requiring PM where they can be easily removed, providing means of inspection, designing to reduce the possibility of maintenance-induced failures, and other design criteria determine the maintainability of a system.

7-2 MAINTENANCE.

Maintenance is defined as those activities and actions that directly retain the proper operation of an item or restore that operation when it is interrupted by failure or some other anomaly. Within the context of RCM, proper operation of an item means that the item can perform its intended function. These activities and actions include fault detection, fault isolation, removal and replacement of failed items, repair of failed items, lubrication, servicing (includes replenishment of consumables such as fuel), and calibrations. Other activities and resources are needed to support maintenance. These include spares, procedures, labor, training, transportation, facilities, and test equipment. These activities and resources are usually referred to as logistics. Although some organizations may define maintenance to include logistics, it will be used in this document in the more limited sense and will not include logistics.

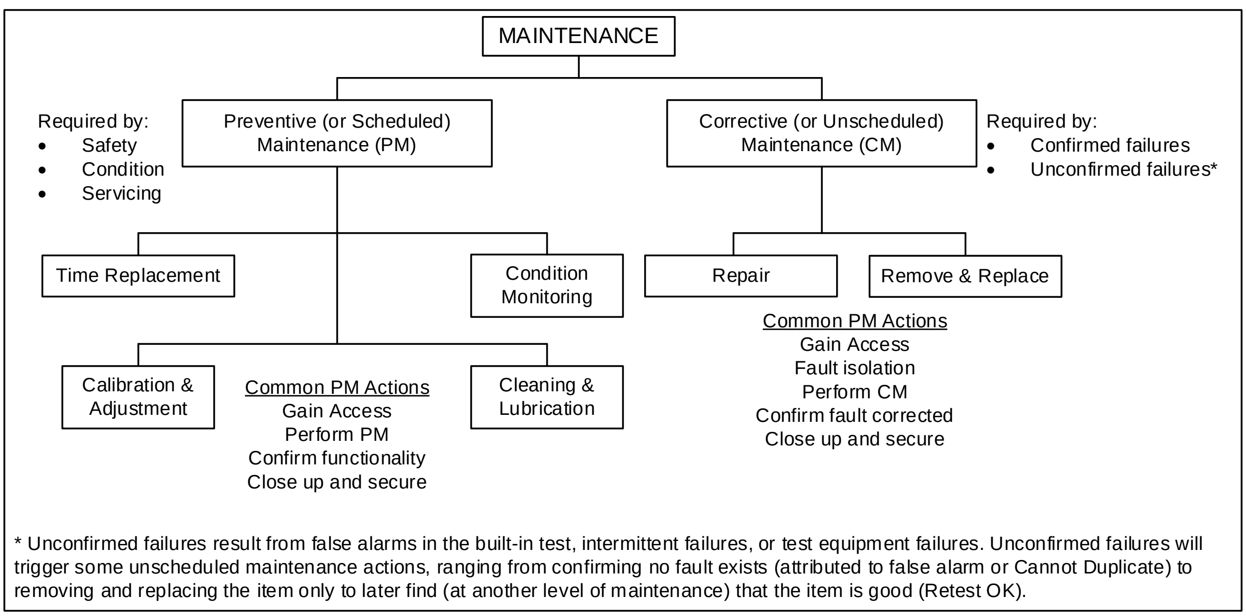
7-2.1 Categories of Maintenance.

Maintenance is usually categorized by either when the work is performed or where the work is performed.

7-2.1.1 Categorizing by when Maintenance is Performed.

In this case, maintenance is divided into two major categories: preventive and corrective. Figure 7-1 illustrates how these two categories are further broken down into specific tasks. These categories of maintenance, corrective and preventive, are further subdivided in some references into reactive, preventive, predictive, and proactive maintenance.

Figure 7-1 Major Categories of Maintenance by when Performed.



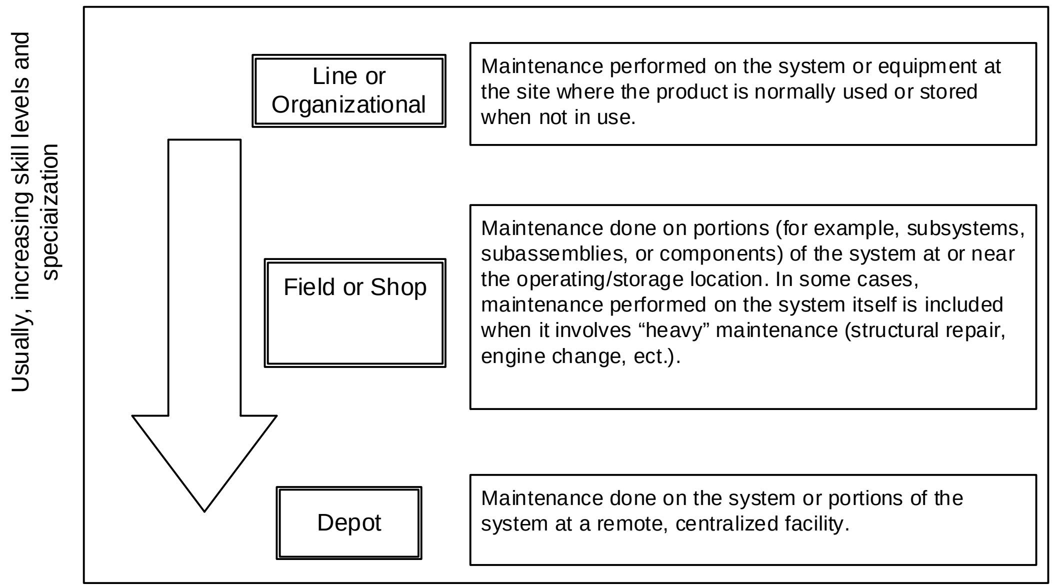
(1) Reactive maintenance. This term is equivalent to corrective maintenance, and both are also referred to as breakdown, repair, fix-when-fail, or run-to-failure maintenance.

(2) Proactive maintenance. Includes actions intended to extend useful life, such as root-cause failure analysis, continual improvement, and age exploration. Proactive and predictive are treated herein as categories of preventive maintenance, with proactive included under Scheduled, predictive under Condition-based, and age exploration as a separate step in the RCM process.

7-2.1.2 Categorizing by where Maintenance is Performed.

Maintenance can also be categorized by where the work is performed. These categories are referred to as levels of maintenance. The categories most often used are shown in Figure 7-2.

Figure 7-2 Typical Approach to Categorizing Maintenance by where it is Performed.



7-2.2 Categorization by when Maintenance is Performed.

7-2.2.1 Preventative Maintenance.

Preventive maintenance (PM) is usually self-imposed downtime (although it can be done while corrective maintenance is being performed and it may even be possible to perform some PM while the product is operating). PM consists of actions intended to prolong the operational life of the equipment and keep the product safe to operate. This UFC defines two types of PM: Scheduled and Condition-based. In both cases, the objectives of PM are to ensure safety, reduce the likelihood of operational failures, and obtain as much useful life as possible from an item. Table 7-2 has examples of each type of PM.

(1) Scheduled maintenance. When a specified interval between maintenance is required, the maintenance is referred to as scheduled preventive maintenance. The interval may be in terms of hours, cycles, rounds fired, or other measure meaningful to the way the item is operated. Note that with scheduled PM, no attempt is made to ascertain the condition of the item. Scheduled maintenance may also consist of recalibrations or adjustments made at regular intervals. Some texts categorize inspections as scheduled PM. Certainly, inspections are based on some periodic interval or event (for example, inspection of an aircraft prior to and after each flight).

However, since the purpose of an inspection is to ascertain the condition of the item, it has been included under the next category of PM, Condition-based.

Table 7-2 Examples of Tasks under Two Categories of Preventive Maintenance

Category	Tasks	Examples	Notes
Scheduled [1]	Remove and replace (R&R)	R&R batteries in smoke alarm twice annually	Maintenance is performed without regard to actual condition of item. Interval based on useful life and other factors. Includes all lubrication and servicing.
		R&R gun barrel after 5,000 rounds have been fired	
		Change oil every 3,000 miles	
		Lubricate bearings every 25,000 shaft revolutions	
	Overhaul or recondition	Overhaul transmission every 100,000 miles	Item is overhauled or reconditioned without regard to actual condition. Interval based on useful life and other factors.
		Refinish blades every 2,000 operating hours	
	Recalibrate	Recalibrate depth setting on drill press daily	Compensate for changes in calibration due to vibration and other conditions of use.
		Recalibrate gage against standard at beginning of each shift	
Condition[2]	Inspect item or area	Visually inspect belts and pulleys for excessive wear prior to starting machine	Inspections can be performed using human senses (e.g., visually check belts for wear), using non-destructive inspection (NDI) techniques (e.g., inspect for corrosion using dye penetrant), or special measuring equipment (check tread depth using gage). Can also include functional check to determine proper operation.
		Inspect for corrosion every 2 weeks	
		Inspect for delamination or disbond weekly	
		Inspect tires for cuts and proper tread depth before and after each flight	
		Inspect for hidden failure of redundant item	
	Monitor condition	Continuously monitor vibration profile and R&R bearing when limits reached	Objective is to act before useful life has been reached or a functional failure has occurred. Parameter limits and profiles based on analysis, test, and field experience. Monitoring can but does not need to be continuous.
		Check sample of oil every 50 operating hours for presence of wear metals and overhaul engine when limits reached	

1. Based on time.
2. Based on observed or measured condition.

(2) Condition-based maintenance. Preventive maintenance performed to ascertain the condition of an item, detect, or forecast an impending failure, or performed because of such actions is referred to as Condition-based PM.

(a) A hidden failure of an item is one that has already occurred, has not affected performance of the end system, but will if another item fails. Ideally, through some form of warnings or monitoring device, no failure will be "hidden." It is impractical and not always feasible to detect every failure of every item in a system and alert the operator or maintainer that the failure has occurred. Inspections are therefore needed to detect such failures. See paragraph 7-4.3.1.3 for a more complete discussion of hidden failures. Maintenance that is required to correct a hidden failure condition is, of course, corrective maintenance.

(b) Some texts use terms such as predictive maintenance and on-condition. The definition of condition-based PM used herein includes these concepts. In summary, the objectives of condition-based PM are to first evaluate the condition of an item, then, based on the condition, either determine if a hidden failure has occurred or a failure is imminent, and then take appropriate action.

7-2.2.2 Corrective Maintenance and Run-to-Failure.

As already alluded to, corrective maintenance (CM) is required to restore a failed item to proper operation.

(1) Restoration. Restoration is accomplished by removing the failed item and replacing it with a new item, or by fixing the item by removing and replacing internal components or by some other repair action.

(2) When CM is required. CM can result from system failures or from condition based PM.

(a) When system operation is impaired by the failure of one or more items, the operator is usually and immediately alerted to the problem. This alert may come from obvious visual or sensory signals (such as, the operator can see, hear, or feel that a problem has occurred) or from monitoring equipment (indicators, built-in diagnostics, annunciator lights, etc.). When the alert comes from the latter, it is possible that a system failure has in fact not occurred. That is, the detecting equipment itself has failed or a transient condition has occurred resulting in an indication of system failure that is false or cannot be duplicated. Whether or not an actual system failure has occurred, any indication that one has will necessitate CM. The CM may result in a Cannot Duplicate (CND) or Retest OK (RTOK), in-place repair, or replacement. CNDs and RTOKs are serious problems in very complex systems for two reasons. First, they consume maintenance time and can cause unnecessary loss of system availability. Second, without in-depth test and analysis, one cannot be certain whether the detecting equipment failed, the system did fail, or transients caused the failure (and is not evident except under those transient conditions).

(b) When inspection or condition monitoring detects a hidden or failure, then some form of corrective maintenance is required.

(c) If the only concern were to obtain the greatest possible amount of life from an item, it would be allowed to run-to-failure. Under a run-to-failure approach, only CM would be required. No PM would be performed. However, the consequences on economics, safety, and mission requirements of some failures make a run-to-failure approach untenable. Consequently, most practical maintenance programs consist of a combination of PM and CM. Determining what combination is "right" for an item is one of the objectives of the RCM process.

7-2.3 Maintenance Concepts.

7-2.3.1 Level of Maintenance.

In considering how maintenance can be categorized, the idea of levels of maintenance was introduced. The term "levels of maintenance" has traditionally been used by the military services, although its use is not unknown in commercial industry. Within the services, the norm was once three levels of maintenance (line or organizational, field or shop, and depot). Under a 3-level concept, items are either repaired while installed on the end product or are removed and replaced. Various terms are used to refer to an item that is removed and replaced and include Line Replaceable Unit (LRU) and Weapon Replaceable Assembly (WRA). For convenience, LRU will be used in this document to refer to items that are normally removed from and replaced on the end product.

(1) The benefits of a 2-level maintenance concept. To reduce costs and increase availability, the services have been working for several years to implement a 2-level maintenance concept. Under this concept, repairs made on the system are kept to a minimum and, whenever possible, consist of remove and replace (R&R) actions. The idea is that by making R&R the preferred maintenance on the product, the downtime of the system can be kept to a minimum. Failed items are then sent back to the second level of maintenance, usually a depot or original equipment manufacturer (OEM).

(2) Making a 2-level concept work. A 2-level maintenance concept will only be affordable and practical if three criteria are met. First, each LRU's reliability must be "sufficiently high" given the item's cost. If not, availability will suffer, due to an excessive number of high-cost spares failing, and the supply "pipeline" will be expensive. Second, the integrated diagnostic capability (Built-in Test, Automatic Test Equipment, manual methods, etc.) must be very accurate and reliable. Otherwise, the supply pipeline to the second level of maintenance will be filled with good LRUs mistakenly being sent for repair – CNDs and RTOKs are a serious problem under any maintenance concept but spell disaster for a 2-level maintenance concept. Finally, a responsive and cost-effective means of transporting LRUs between the field and the depot must be available.

7-2.3.2 Centralized Versus De-Centralized.

When maintenance at a given level is performed at several locations located relatively close to the end user, a decentralized maintenance concept is being implemented. For example, suppose a 3-level maintenance concept is being used. When an LRU fails at an operating location, it is removed and replaced with a good LRU. The operating location sends the failed LRU to a co-located field repair activity (FRA) where it is repaired. Such repair can consist of either in-place repair or R&R of constituent components often called Shop Replaceable Units. Under a centralized concept, each operating location would not have a co-located FRA. Instead, one or more centralized FRAs would be strategically located throughout the geographic operating area (such as, country, continent, hemisphere, etc.). Each operating location would ship its failed LRUs to the nearest centralized FRA. Such a concept is most effective when the LRUs are highly reliable. If the reliability is high, then few failures will occur at any given operating location making it difficult to keep the technicians proficient in repairing the LRUs. Also, with few failures, the technicians and any support equipment (for example, automatic test equipment) will be under utilized. Under such conditions, it is difficult to justify a co-located FRA.

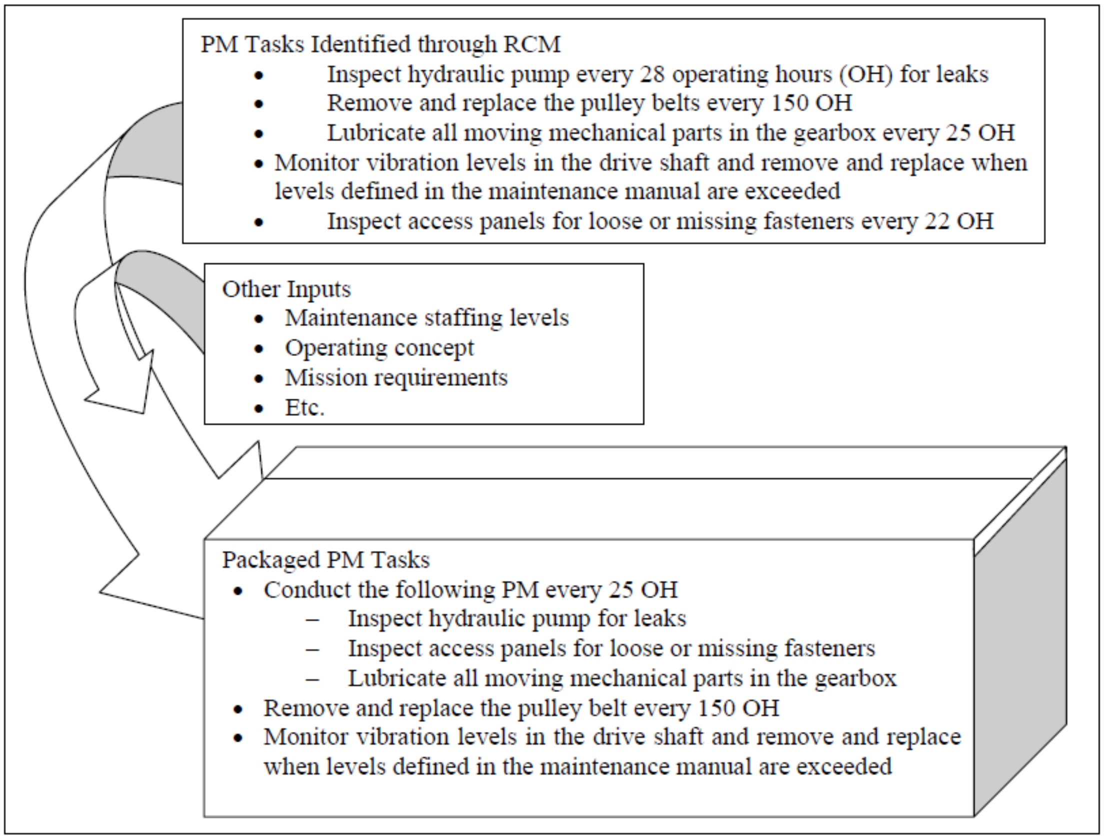
7-2.4 Packaging a Maintenance Program.

The total maintenance requirements for a product will dictate a set of preventive maintenance (PM) tasks and a set of corrective maintenance (CM) tasks. The latter tasks are essentially "maintenance on demand" and cannot be predicted. PM, as discussed previously, will consist of on-condition and scheduled maintenance. Once all PM tasks have been identified, they must be grouped, or packaged. By packaging PM tasks, maintenance resources can be used more effectively and minimize the number of times that the system will be out of service for PM.

7-2.4.1 Packaging Example.

An example is shown in Figure 7-3. The pump inspection could be conducted at 28 hours, the panel inspection at 22 hours, and lubricated the gearbox at 25 hours. But it is much more efficient to "package" the tasks as shown in the example.

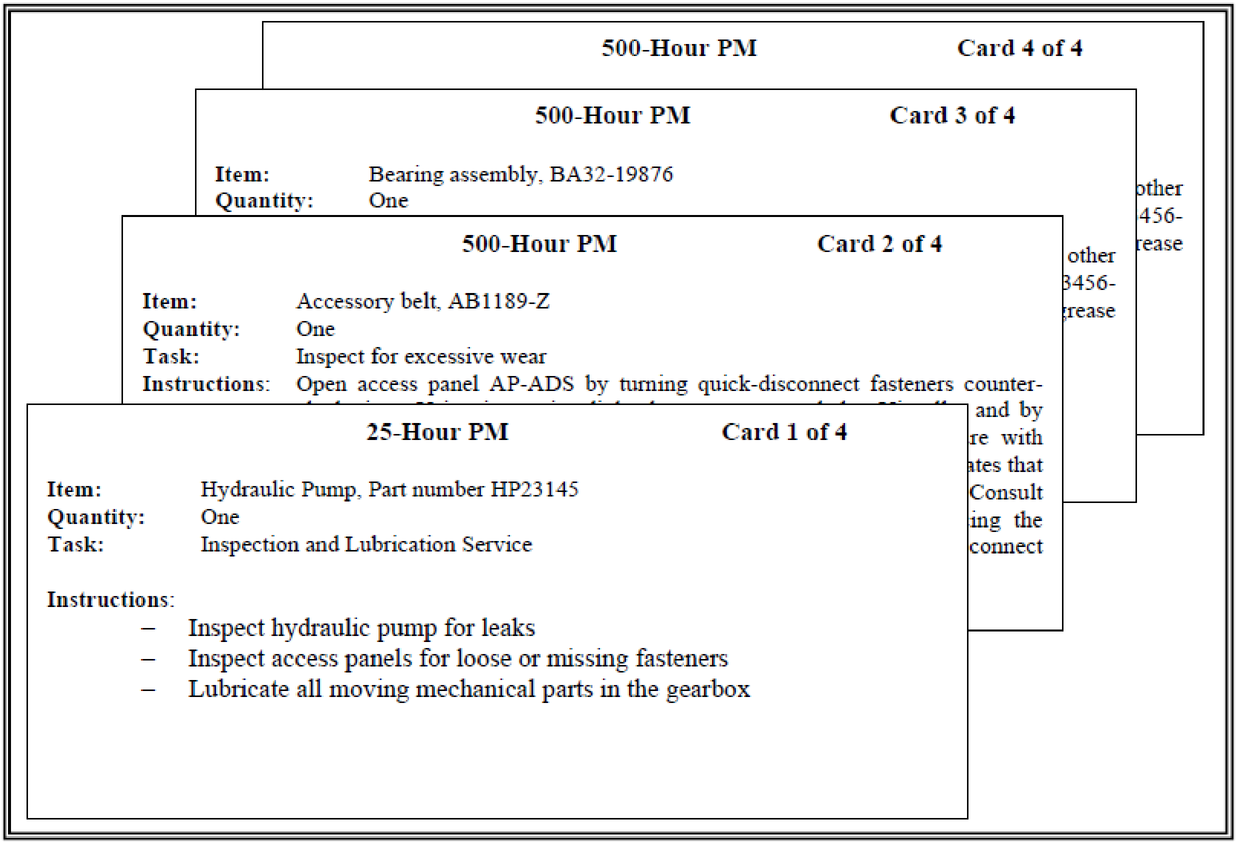
Figure 7-3 An Example of Packaging PM Tasks



7-2.4.2 Document the Packaging for Maintenance Personnel.

One method of documenting the packaging of PM tasks is to create inspection cards. For a given point in time (calendar time, number of operating hours, etc.), a set of cards defines the PM tasks to be performed. Figure 7-4 illustrates this approach.

Figure 7-4 Example of how PM Cards can be used to Document Required PM Tasks

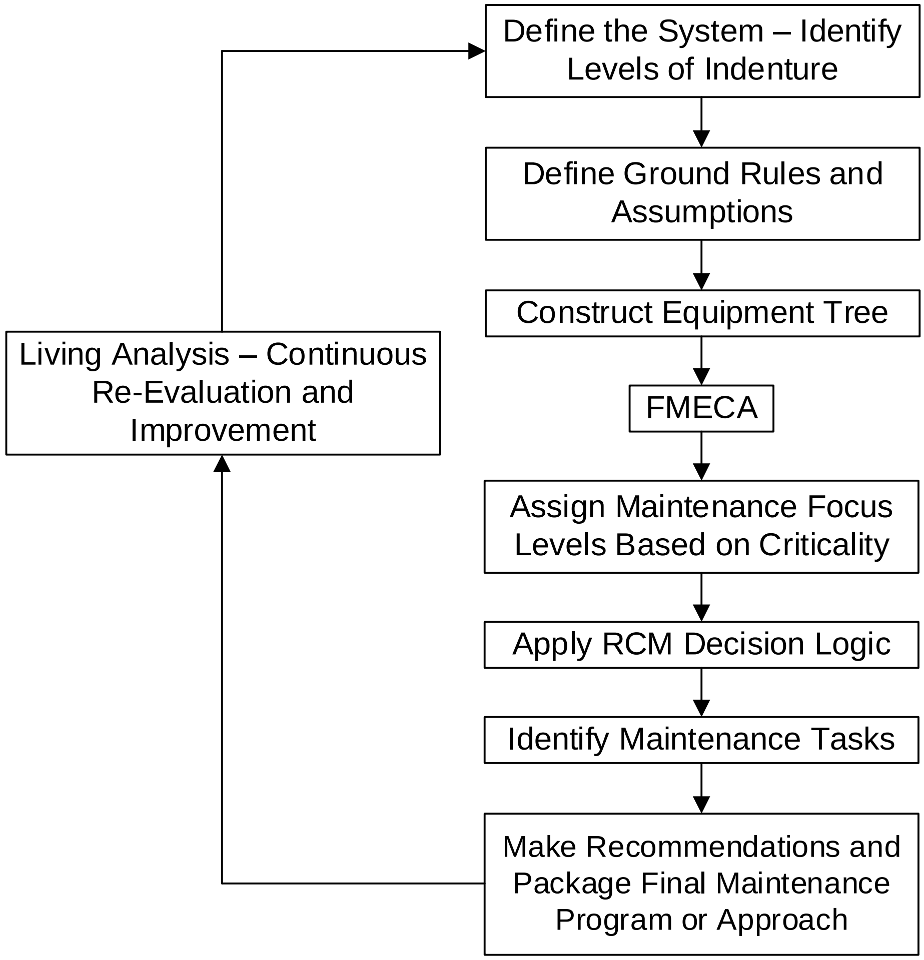


7-3 ELEMENTS OF RCM PROGRAM.

7-3.1 RCM Implementation Plan.

An overview of steps of the RCM process is shown in Figure 7-5.

Figure 7-5 The RCM Process Starts in the Design Phase and Continues for the Life of the System



7-3.1.1 Major Tasks.

As shown in Figure 7-5, several major tasks are required to implement the RCM concept.

- Define the System – Identify and document the boundaries of the analysis
  - Identify and document equipment included in the analysis
  - Identify and document the indenture level the analysis is intended to extend to
- Define Ground Rules and Assumptions – Identify and document ground rules and assumptions used to conduct the analysis

- Construct Equipment Tree – Construct equipment block diagrams to indicate equipment configuration, down to the lowest indenture level intended to be covered by the analysis
- Conduct FMECA – Analyze failure modes, effects and criticality
- Assign Maintenance Focus Levels – Classify maintenance focus levels based on criticality rankings
- Apply RCM Decision Logic – Apply RCM logic trees for items, especially those identified as being critical
- Identify Maintenance Tasks – Identify maintenance tasks to be performed on the given item
- Package Maintenance Program – Develop a maintenance tasking schedule for the analyzed equipment

Note: RCM Analysis is intended to be a living analysis. Effort should be made to continue to collect more complete information and add it to the analysis, to continue to provide a foundation for effective continuous improvement. Results and recommendations should be periodically reviewed and reevaluated, taking into consideration additional information of any kind.

(1) Conduct supporting analyses. RCM is a relatively information-intensive process. To provide the information needed to conduct the RCM analysis, several supporting analyses are either required, often as prerequisites to beginning the RCM analysis, or desirable. These supporting analyses include the FMEA, FTA, functional analysis, and others.

(2) Conduct the RCM analysis. The RCM analysis consists of using a logic tree to identify effective, economical, and, when safety is concerned, required PM. (As will be seen, PM is required when safety is involved; if no PM is effective, then redesign is mandatory).

7-3.1.2 The Implementation Plan.

Planning to implement an RCM approach to defining the PM for a system or product must address each of the tasks noted in the preceding paragraph. The plan must address the supporting design phase analyses needed to conduct an RCM analysis. Based on the analysis, an initial maintenance plan, consisting of the identified PM with all other maintenance being corrective, by default, is developed. This initial plan should be updated through Life Exploration during which initial analytical results concerning frequency of failure occurrence, effects of failure, costs of repair, etc. are modified based on actual operating and maintenance experience. Thus, the RCM process is iterative, with field experience being used to improve upon analytical projections.

7-3.2 Data Collection Requirements.

7-3.2.1 Required Data.

Since conducting an RCM analysis requires an extensive amount of information, and much of this information is not available early in the design phase, RCM analysis for a new product cannot be completed until just prior to production. The data falls into four categories: failure characteristics, failure effects, costs, and maintenance capabilities and procedures.

7-3.2.1.1 Failure Characteristics.

Studies conducted by the MSGs and confirmed by later studies showed that PM was effective only for certain underlying probability distributions. Components and items, for example, for which a constant failure rate applies (for example, the underlying probability distribution is the exponential) do not benefit from PM. Only when there is an increasing probability of failure should PM be considered.

7-3.2.1.2 Failure Effects.

The effects of failure of some items are minor or even insignificant. The decision whether to use PM for such items is based purely on costs. If it is less expensive to allow the item to fail, and to perform CM, than it is to perform PM, then the item is allowed to fail. As stated earlier, allowing an item to fail is called run to failure.

7-3.2.1.3 Costs.

The costs that must be considered are the costs of performing a PM task(s) for a given item, the cost of performing CM for that item, and the economic penalties, if any, when an operational failure occurs.

7-3.2.1.4 Maintenance Capabilities and Procedures.

Before selecting certain maintenance tasks, the analyst needs to understand what the capabilities are, or are planned, for the system. In other words, what is or will be the available skill levels, what maintenance tools are available or are planned, and what are the diagnostics being designed into or for the system.

7-3.2.2 Sources of Data.

Table 7-3 lists some of the sources of data for the RCM analysis. The data elements from the FMEA that are applicable to RCM analysis are highlighted in paragraph 7-5.4.2. Note that when RCM is being applied to a product already in use, or when a maintenance program is updated during Life Exploration, historical maintenance and failure data will be inputs for the analysis. An effective Failure Reporting and Corrective Action System (FRACAS) is an invaluable source of data. FRACAS is a closed-loop system for collecting, analyzing, and documenting failures and recording any corrective action taken to eliminate or reduce the probability of future such failures. FRACAS is used when iterative tests or demonstrations are conducted on breadboard, or prototype products to identify mechanisms and trends for corrective action. FRACAS is used for existing systems to monitor performance.

Table 7-3 Data Sources for the RAM Analysis

Data Source	Comment
Lubrication requirements	Determined by designer. For off-the-shelf items being integrated into the product, lubrication requirements and instructions may be available.
Repair manuals	For off-the-shelf items being integrated into the product.
Engineering drawings	For new and off-the-shelf items being integrated into the product.
Repair parts list	
Quality deficiency reports	For off-the-shelf items being integrated into the product.
Other technical documentation	For new and off-the-shelf items being integrated into the product.
PREP Database	For new and off-the-shelf items being integrated into the product.
Recorded observations	From test of new items and field use of off-the-shelf items being integrated into the product.
Hardware block diagrams	For new and off-the-shelf items being integrated into the product.
Bill of Materials	For new and off-the-shelf items being integrated into the product.
Functional block diagrams	For new and off-the-shelf items being integrated into the product.
Existing maintenance plans	For off-the-shelf items being integrated into the product. Also, may be useful if the new product is a small evolutionary improvement of a previous product.
Maintenance technical orders/manuals	For off-the-shelf items being integrated into the product
Discussions with maintenance Personnel and field operators	For off-the-shelf items being integrated into the product. Also, may be useful if the new product is a small evolutionary improvement of a previous product.
Results of FMEA, FTA, and other reliability analyses	For new and off-the-shelf items being integrated into the product. Results may not be readily available for the latter.
Results of Maintenance task analysis	For new and off-the-shelf items being integrated into the product. Results may not be readily available for the latter.

7-3.3 Commitment to Life Cycle Support of the Program.

7-3.3.1 The Process Perspective.

As will be shown in this paragraph, RCM must be viewed as a continuing process, rather than an event that occurs once. Although a maintenance program based on RCM should be developed during design, it should be refined throughout the operational life of the system. In addition, RCM can be used to develop a maintenance program for an existing system for which the initial maintenance program was not based on RCM.

7-3.3.2 Learning from Experience.

Much of the information used to develop an RCM program, either during design for a new system or after fielding for an existing system will be based on estimates, may change over time, or be subject to some combination of these two factors. Consequently, it is essential to use experiential data to update the maintenance program.

7-3.3.3 Continuous PM Improvement.

RCM fundamentals established at design should be revisited on at least an annual interval. This process will maintain the efficiency intended for the facility at design. This takes into consideration changes in cost, Reliability degradation, changes in mission, changes in maintenance approach to name a few occurrences.

7-3.4 RCM as a Part of Design.

It is ideal to implement an RCM approach during the design and development of a new system to develop a maintenance program. The reasons will be briefly discussed here but will become clearer as the reader proceeds through the remaining paragraphs of this UFC.

7-3.4.1 Effective Use of Analyses.

During design and development, numerous analyses are performed. Many of these analyses directly support an RCM analysis. In turn, the results of going through the RCM process of developing a maintenance program can affect and contribute to these analyses. Obviously, implementing RCM during design and development makes very effective use of analyses that are usually performed.

7-3.4.2 Impact on Design.

As will be seen when the RCM logic diagrams are discussed, redesign is either mandatory or desirable in many cases. The cost and level of effort of design changes made during the design and development phase of a system are much less than if they were made after the system was fielded. Additionally, the effectiveness of design changes is higher when made during the design and development phase. Of course, RCM can and is used to develop maintenance programs for fielded systems, for which RCM was not applied during design and development. However, it is always best to implement RCM during design and development.

7-3.5 Focus on the Four Ws.

Discussion of the four Ws: what can fail, why does it fail, when will it fail, and what are the consequences of failures.

7-3.5.1 What can Fail?

In determining required maintenance, the first and most fundamental question that must be answered is what can fail. A variety of methods can be used to answer this question.

(1) Analytical methods. FMEA, FTA, and relayed analyses address, among other issues, what can fail that will prevent a system, subsystem, or component from performing its function(s).

(2) Test. Analytical methods are not infallible, and a particular failure may be overlooked or cannot be anticipated by analysis. Testing often reveals these failures. Testing can, of course, also be used to confirm or validate the results of analytical methods.

3) Field experience. Often, the same type of component, assembly, or even subsystem that is already used in one system may be used in a new system. If data is collected on field performance of these components, assemblies, and subsystems, it can be used to help answer the question, what can fail. Obviously, field experience is equally applicable to RCM when applied to an already fielded system.

7-3.5.2 Why Does an Item Fail?

To determine which, if any preventive maintenance tasks are appropriate, the reason for failure must be known. Insights into the modes and mechanisms of failure can be gained through analysis, test, and experience. Some of the analytical methods are the same as those used to determine What Can Fail. The methods include the FMEA and FTA. Others include root cause analysis, destructive physical analysis, and non-destructive inspection techniques. Table 7-4 lists some nondestructive inspection (NDI) techniques and Table 7-5 lists some of the modes and mechanisms of failure.

Table 7-4 Non-Destructive Inspection (NDI) Techniques, Briefly

Acoustic emission	Magnetic particle examination
Dye penetrant	Radiography
Eddy current	Spectrometric oil analysis
Emission spectroscopy	Stroboscopy
Ferrography	Thermography
Leak testing	Ultrasonics

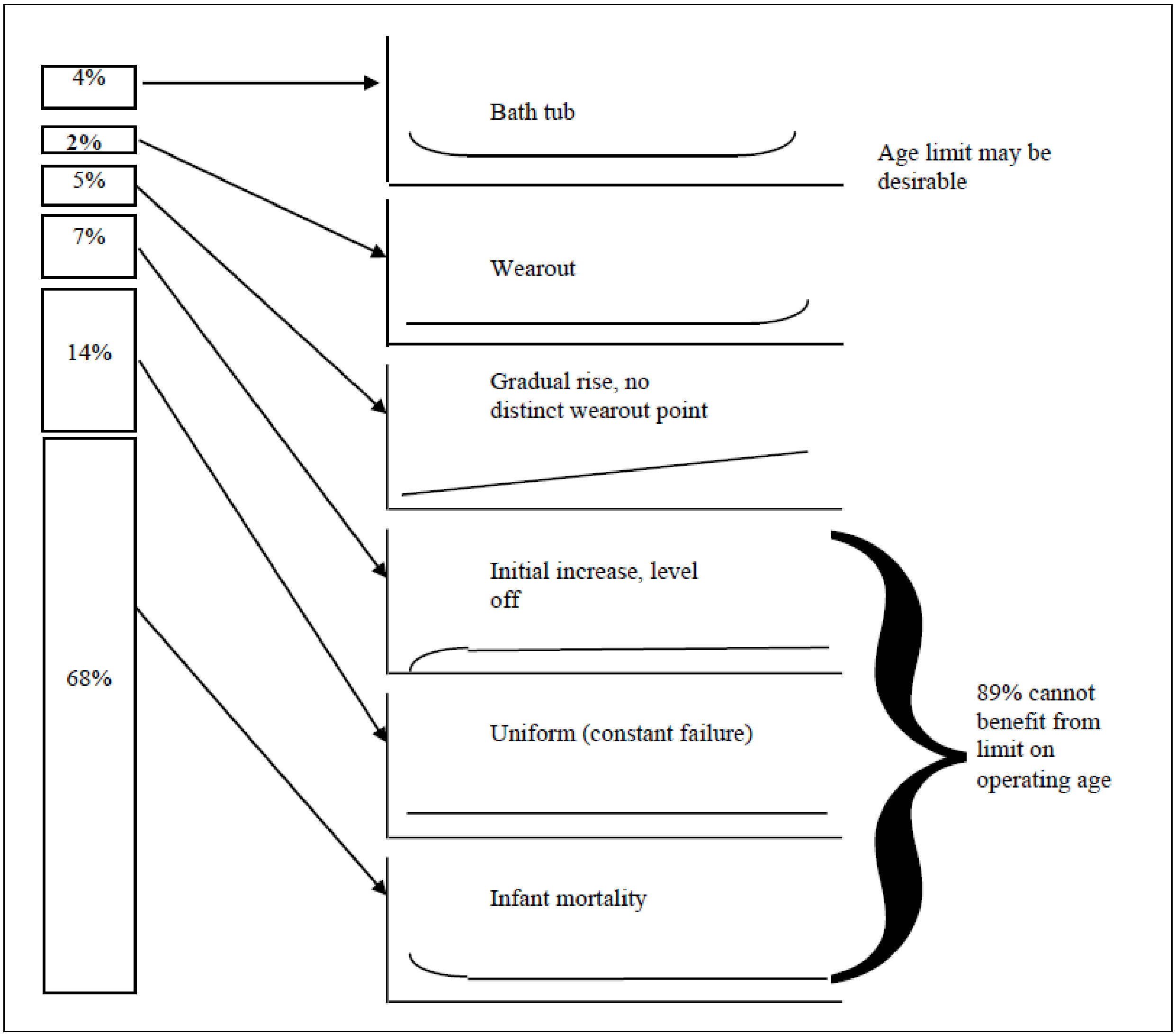
Table 7-5 Examples of Failure Mechanisms and Modes

Modes		
Stuck open (valve) Shorted (connector) Low torque (motor)	Fractured (shaft) Leakage (seal) Excessive friction (shaft journal)	Wear (bearing) Slippage (belt drive) Short (resistor)
Mechanisms		
Brinelling (bearing ring) Fretting (pump shaft) Ionization (microcircuit) Plastic deformation (springs)	Spalling (concrete) Condensation (circuit board) Glazing (clutch plate) Wear (clutch plate)	Elongation/yielding (structure) Freezing (battery) Fatigue (springs) Galvanic corrosion (structure)

7-3.5.3 When Will an Item Fail? (Occurrence).

If the underlying time to failure distribution is known for a part or assembly, then the probability of failure at any point in time can be predicted. For some items, the underlying distribution is exponential and the item exhibits a constant failure rate. In such cases, a new item used to replace an old item has the same probability of failing in the next instant of time as did the old item. Consequently, changing such an item at some prescribed interval has no effect on the probability of failure. It makes more sense to run the item to failure. If that is not possible, if safety is involved for example, then redesign is necessary. As shown in Figure 7-6, only a small percentage of items can benefit from PM. Knowing the underlying distribution of times to failure is essential in determining if PM is applicable.

Figure 7-6 Applicability of Age Limit Depending on Failure Pattern



7-3.5.4 What are the Consequences of the Item Failing? (Severity).

Not all failures are equal in their effect on the system. Obviously, any failures that can cause death or injury to system operators or maintainers, or others who may be served by the system (for example, airline passengers) or are nearby the most serious. Very close in seriousness are failures that can result in compromised mission requirements, pollution to the environment, or a violation of government statutes. At the bottom of the list are failures such as cosmetic damage and other problems that have no effect on system operation. Knowing the effect of a failure helps prioritize decisions. Serious failures usually demand some form of PM or redesign is necessary. Minor failures usually do not lead to redesign and PM is performed only if it is less expensive than running the item to failure. Table 7-6, on the following page, lists some examples of failure effect categorization used in FMEAs and in the RCM process. The way failure effects are categorized for C5ISR facilities should be based on the functions of the facility. Obviously, any failure that could kill or injure personnel or cause loss of the C5ISR mission would have to be categorized as the most serious. The criteria shown in Table 7-6, or some combination could be the basis for a C5ISR facility-specific categorization approach. Note that in using the RCM approach to developing a PM program, all failure must be put into one of three categories (Preventative Maintenance, Predictive Maintenance, Corrective Maintenance). These categories are used in the logic trees.

Table 7-6 Examples of Failure Effect Categorization

AIAG Standard (Automobile Industry Standard)		
Effect	**Severity of Effect**	**Ranking**
Hazardous without warning	Very high severity ranking when a potential failure mode affects safe system operation and/or involves noncompliance with federal safety regulation without warning	10
Hazardous with warning	Very high severity ranking when a potential failure mode affects safe system operation and/or involves noncompliance with federal safety regulation warning	9
Very High	System/item inoperable with loss of primary function	8
High	System/item operable, but at reduced performance level. User dissatisfied	7
Moderate	System/item operable, but comfort/convenience item inoperable	6
Low	System/item operable, but comfort/convenience item operate at reduced level	5
Very Low	Defect noticed by most customers	4
Minor	Defect noticed by average customers	3
Very Minor	Defect noticed by discriminating customers	2
None	No effect	1
Example of a Simplified Categorization		
Critical	Death, loss of system, violation of governmental statute	
High	Injury, loss of some system functions, very high economic loss	
Moderate	Damage to system requiring maintenance at first opportunity, economic loss	
Low	Minor damage to system, low economic loss	
Negligible	Cosmetic damage, no economic loss	
RCM Analysis		
Safety	Directly and adversely effects on operating safety	
Operational	Prevents the end system from completing a mission	
Economic	Does not adversely affect safety and does not adversely affect operations - the only effect is the cost to repair the failure	

7-4 FUNDAMENTALS OF RCM.

7-4.1 Objectives of RCM.

This chapter provides a discussion of the two primary objectives of RCM: Ensure safety through preventive maintenance actions, and, when safety is not a concern, preserve functionality in the most economical manner. For C5ISR facilities, mission should be considered at the same level as safety.

7-4.2 Applicability of Preventive Maintenance.

7-4.2.1 Effectiveness.

PM can be effective only when there is a quantitative indication of an impending functional failure or indication of a hidden failure. That is, if reduced resistance to failure can be detected (potential failure) and there is a consistent or predictable interval between potential failure and functional failure, then PM is applicable. Condition monitoring has long been used to monitor operating parameters that have been shown to be dependable predictors of an impending failure. Age limit information can also be utilized to determine effectiveness of preventative maintenance efforts (see Figure 7-6). Preventive maintenance (PM) is effective if a potential failure condition is definable or there is a quantitative indication of an impending failure. PM is generally effective only for items that wear out. It has no benefit for items that have a purely random pattern of failure (such as, failures are exponentially distributed, and the failure rate is constant – see Appendix B for a discussion of statistical distributions). Consequently, performing a PM action for electronics is rare, if ever, since electronics exhibit a random pattern of failures. Mechanical items, on the other hand, usually have a limited useful period of life and then begin to wear out.

7-4.2.2 Economic Viability.

The costs incurred with any PM being considered for an item must be less than for running the item to failure. The failure may have operational or non-operational consequences. The costs to be included in such a comparison for these two failure consequences are Operational and Nonoperational.

7-4.2.2.1 Operational.

The operational cost is defined as the indirect economic loss because of failure plus the direct cost of repair. An example of an operational cost is the revenue lost by an airline when a flight must be canceled and passengers booked another airline. For military organizations where profit is not an objective, an operational cost might be the cost of a second flight or mission. Sometimes, it may be difficult for a military organization to quantify an operational cost in terms of dollars and a subjective evaluation may be needed.

7-4.2.2.2 Non-Operational.

The non-operational cost is defined as the direct cost of repair. The direct cost of repair is the cost of labor, spare parts, and any other direct costs incurred because of repairing the failure (by removing and replacing the failed item or performing in-place repair of the item).

7-4.2.3 Preservation of Function.

The purpose of RCM is not to prevent failures but to preserve functions. Many maintenance people who are unfamiliar with RCM initially find this idea difficult to accept. For many years prior to and following World War II, the "modern" view within the maintenance community was that every effort should be made to prevent all failures. Preventing failure was the focus of every maintenance technician. But products became increasingly complex and maintenance costs increased both in absolute terms and as a percentage of a product's total life cycle costs. It was soon clear that preventing all failures was technically and economically impractical. Instead, attention was turned to preserving all the essential functions of a product. This shift from preventing failures to preserving function was fundamental to the development of the RCM approach to defining a maintenance program.

7-4.2.4 Opportunity Cost.

From time to time manufactures of equipment improve existing equipment maintenance capabilities by providing an improved part of a more effective maintenance process. Both can contribute to a cost-effective improvement of the overall RCM plan. Manufactures in general desire to improve their equipment and track performance and maintenance issues for continuous improvement and to keep ahead of competition.

7-4.3 Failure.

For RCM purposes, three types of failures are defined: functional, evident, and hidden.

7-4.3.1 Types of Failures.

7-4.3.1.1 Functional Failure.

A functional failure is one in which a function of the item is lost. A functional failure directly affects the mission of the system. To be able to determine that a functional failure has occurred, the required function(s) must be fully understood. As part of a FMEA, all functions have been defined. This definition can be very complex for products that have varying levels of performance (for example, full, degraded, and loss of function).

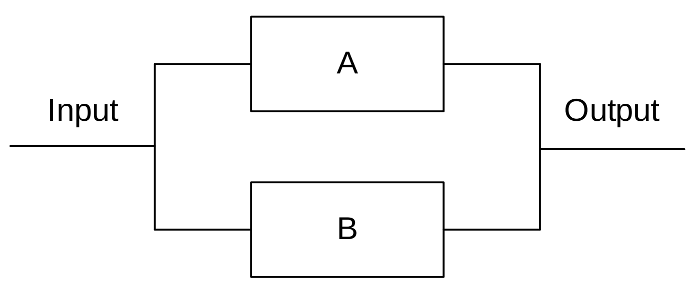
7-4.3.1.2 Evident Failures.

When the loss of a function can be observed or is made evident to the operator, the failure is said to be evident. In the latter case, dials or displays, audible or visual alarms, or other forms of instrumentation alert the operator to the failure.

7-4.3.1.3 Hidden Failures.

A hidden failure is a functional failure of an item that has occurred, has not affected performance of the end system, and is not evident to the operator, but will cause a functional failure of the end system if another item fails. In other words, because of redundancy or the nature of the item's function in the system, no single-point failure of the end system has occurred. If, on the other hand, multiple failures occur, then the system will fail to perform its function. A simple example is the system shown in Figure 7-7. Either of the two redundant items, A and B, can perform a critical function. Redundancy was used because the function is critical and a single point failure was unacceptable. If either item A or B can fail without the knowledge of the operator, it is considered a hidden failure. The system would now be subject to a single point failure (such as, the function can be lost by one more failure – the failure of the other redundant component). Hidden failures must be found by maintenance personnel.

Figure 7-7 Block Diagram of A simple Redundant System



7-4.3.2 Consequences of Failure.

A basic objective of the RCM analysis is to make decisions regarding the selection of a maintenance action for a specific functional failure of a specific item based on the consequence of the failure. Three categories of failure consequences are generally used. They are safety, operational (mission), and economic.

7-4.3.2.1 Safety.

If a functional failure directly has an adverse effect on operating safety, the failure effect is categorized as Safety. The functional failure must cause the effect by itself and not in combination with other failures. That is, the failure must be a single-point failure. (Note that a hidden failure for which no preventive maintenance is effective and which, in combination with another failure, would adversely affect safety must be treated as a safety-related failure. The methodology is designed to address this situation).

7-4.3.2.2 Operational.

When the failure does not adversely affect safety but prevents the end system from completing a mission, the failure is categorized as an Operational failure. For many end systems, operational failure results in loss of revenue. In other cases, a critical objective cannot be met. See Table 7-7 for examples.

(a) An adverse effect on safety means that the result of the failure is extremely serious or catastrophic. Results can include property damage, injury to operators or other personnel, death, or some combination of these.

(b) In some industries, this category is expanded to include failures that result in a federal statute being violated. An industry such as the petroleum or power industry often includes failures that would result in violations of the Environmental Protection Act. Other industries may include failures with other effects in this category.

Table 7-7 Examples of Effects of Operational Failures

End System	Effect of Operational Failure
Airliner	Airline must cancel flight and either send passengers to another airline or add a flight. In either case, revenue is adversely affected.
Manufacturing equipment	Production must be halted until repairs are made adversely affecting sales. Some orders may be canceled because delivery dates cannot be met (unless no other sources can provide the product to the customers – in that case, loss of customer confidence may result affecting future sales).
Military aircraft	Prolonged or lost conflict, inability to respond to a political crisis in a timely manner, or exposure to a period of vulnerability
Financial information system	Loss of revenue due to an inability to make investments, penalties due to late payments, etc.
C5ISR Facility	Facility cannot provide necessary electrical power to support an assigned mission.

7-4.3.2.3 Economic.

When a functional failure does not adversely affect safety and does not adversely affect operations, then the failure is said to have an Economic effect. The only penalty of such a failure is the cost to repair the failure.

7-5 RCM PROCESS.

7-5.1 C5ISR Candidates for RCM Analysis.

It is important to note from the onset that an RCM analysis is not beneficial for all products. The criteria listed in Table 7-8 will help the analyst determine if an RCM analysis is potentially of value. There are three major systems comprising C5ISR facilities that are candidates for RCM analysis, mechanical systems, electrical systems, and control systems. All three combine to support the facilities mission and provide the necessary environmental conditions to maintain operation of critical equipment and personnel. All the components shown in paragraph 7-5.1 are candidates for RCM optimization and require a maintenance program geared toward the mission requirement of the facility.

Table 7-8 Criteria for Applying RCM to Products

Criteria	Comment
Product has or is projected to have a large number of PM tasks.	Existing product already in service or new system for which the PM tasks were identified using an approach other than RCM.
Product maintenance costs are or are projected to be very high.	Existing product already in service. PM tasks identified using an approach other than RCM or RCM requires updating. New system for which maintenance tasks were identified using approach other than RCM
Product requires or is projected to require frequent corrective maintenance.	Existing product already in service. PM tasks either identified using an approach other than RCM or RCM requires updating. New System for which maintenance tasks were identified using an approach other than RCM.
Hazardous conditions could result from failure	New product, or existing product for which the PM tasks were identified using an approach other than RCM.

7-5.1.1 Mechanical Systems.

The types of mechanical systems typical for a C5ISR facility include those listed below.

- Chillers
- Boilers
- Cooling Towers
- HVAC distribution equipment including Fan Coil Units
- Valves
- Piping

7-5.1.1.2 Other Systems.

Mechanical systems also include generators, fuel oil delivery systems and storage and pumping components. These are critical to the mission of the facility but are frequently neglected.

7-5.1.1.3 Temperatures.

Mechanical systems not only maintain a comfortable environment for the occupants but are also designed to maintain optimal equipment operating temperatures.

7-5.1.2 Electrical Systems.

Electrical systems begin at the transformer feeding the building or the 13.8kV feeder and continue through the entire distribution system generally to the panels containing the 220 or 208/120-volt distribution. Some facility mission requirements require solutions all the way to the operating equipment at the wall outlet. Typical components comprising the electrical system include those listed below.

- Transformer, liquid filled and air cooled
- Connections
- Cables
- Switch Gear
- Circuit Breakers
- Motor Control Centers
- Motors
- Cable Connections
- UPS systems including Gel and Wet Cell Lead Acid Batteries

7-5.1.3 System Controls.

Control systems are the third major component making a C5ISR facility as reliable as possible. Control systems are the brains behind the operational characteristics during normal and abnormal conditions. Control systems are commonly identified as SCADA systems and are designed to monitor conditions and react in a manner to maintain a set point. Typical SCADA systems are comprised of a series of sensors sending signals to a central command center where the signals are interpreted. Signals are sent from the command center to actuators to throttle input conditions and provide the necessary environmental condition required for the mission operations. Typical components for a SCADA system are listed below.

- Computer access panel
- Digital drivers
- Power Supplies
- PLC
- Interface devices such as control panels or circuit breakers

7-5.2 RCM Data Sources.

Conducting an RCM analysis requires an extensive amount of information. Since much of this information is not available early in the design phase, RCM analysis for a new product cannot be completed until just prior to production. Table 7-9 lists some general sources of data for the RCM analysis. The data elements from the FMEA that are applicable to RCM analysis are highlighted in paragraph 7-5.4.2. Note that when RCM is being applied to a product already in use, or when a maintenance program is updated during Life Exploration, historical maintenance and failure data will be inputs for the analysis.

Table 7-9 General Data Sources for the RCM Analysis

Data Source	Comment
Lubrication requirements	Determined by designer. For off-the-shelf items being integrated into the product, lubrication requirements and instructions may be available.
Repair manuals	For off-the-shelf items being integrated into the product.
Engineering drawings	For new and off-the-shelf items being integrated into the product.
Repair parts list	
Quality deficiency reports	For off-the-shelf items being integrated into the product.
Other technical documentation	For new and off-the-shelf items being integrated into the product.
PREP Database	For new and off-the-shelf items being integrated into the product.
Recorded observations	From test of new items and field use of off-the-shelf items being integrated into the product.
Hardware block diagrams	For new and off-the-shelf items being integrated into the product.
Bill of Materials	For new and off-the-shelf items being integrated into the product.
Functional block diagrams	For new and off-the-shelf items being integrated into the product.
Existing maintenance plans	For off-the-shelf items being integrated into the product. Also, may be useful if the new product is a small evolutionary improvement of a previous product.
Maintenance technical orders/manuals	For off-the-shelf items being integrated into the product
Discussions with maintenance Personnel and field operators	For off-the-shelf items being integrated into the product. Also, may be useful if the new product is a small evolutionary improvement of a previous product.
Results of FMEA, FTA, and other reliability analyses	For new and off-the-shelf items being integrated into the product. Results may not be readily available for the latter.
Results of Maintenance task analysis	For new and off-the-shelf items being integrated into the product. Results may not be readily available for the latter.

7-5.2.1 C5ISR Data Sources.

RCM related data may be obtained from several different types of sources. Some potential sources of maintainability data include those listed below.

- Historical data from similar products used in similar conditions (PREP Database, IEEE Gold Book)
- Product design or manufacturing data
- Test data recoded during demonstration testing
- Field data

7-5.2.1.2 Expressing Data.

The data maybe expressed in a variety of terms. These include observed values or modified values (true, predicted, estimated, extrapolated, etc.) of the various maintainability measures. Some precautions are therefore necessary regarding the understanding and use of such data as listed below.

- Historical – Used primarily during the concept definition phase to generate specifications requirements. In later phases historical data may be compared with actual data obtained for the product. They can also serve as additional sources of information for maintainability verification.
- Product Design and Manufacturing – Data obtained using design analysis or prediction, or from data generated during the design phase or the manufacturing phase. Design data may be used as the basis for product qualification and acceptance, review and assessment of historical data relevancy and the validity of previous assessments. Before this type of data is used in an analysis the analyst must understand the data collection and analysis methodology, why the specific method was chosen, and any possible limitations.
- Product Demonstration and Field – These data are essential for sustaining engineering activities during the in-service phase of the system life cycle. They include maintainability related data obtained from formal or informal demonstration test on mock-ups, prototypes, or production equipment in either a true or simulated environment or data generated during actual item use.

7-5.2.1.3 Other Data Categories.

Other categories of data that would be beneficial to collect include information on the maintenance support conditions. Operational maintainability may not be determined solely by inherent maintainability, but by logistical factors. Therefore, information to be collected should include shortages in spares (due to inadequate initial provisioning, long pipeline times, etc.), test resources, and human resources. Such data are important to determine why a system's maintainability as measured in the field, may not be meeting the values expected based on the design data.

7-5.2.1.4 SCADA Systems.

SCADA systems are excellent data collection mechanisms, providing the system is initially designed to capture critical information. It can also be utilized to monitor trends of component operational conditions to provide information on proactive logistics supplies.

7-5.3 PM Tasks Under RCM.

7-5.3.1 Lubrication and Servicing Task.

Many mechanical items in which movement occurs require lubrication. Examples include internal combustion engines that require oil and periodic replacement of that oil (and associated filters). Lubrication and servicing tasks are sometimes overlooked due their relative simplicity and because they are "obvious." Prior to the latest version of the airline's RCM approach, lubrication and servicing tasks were often omitted from the decision logic tree, with the understanding that such tasks cannot be ignored. In the current MSG-3, these tasks are explicitly included in the decision logic, as they are in this document.

7-5.3.2 Inspection or Functional Check Task.

Inspections normally refer to examinations of items to ensure that no damage, failure, or other anomalies exist. Inspections can be made of an entire area (for example, the body or "under the hood"), a subsystem (for example, the engine, controls, or feed mechanism), and a specific item, installation, or assembly (for example, the battery, shaft, or flywheel).

7-5.3.2.1 Visual Inspections or Checks.

These are checks conducted to determine that an item is performing its intended function. The check may be performed by physically operating the item and observing parameters on displays or gauges, or by visually looking to see if the function is being performed properly. In neither case are quantitative tolerances required. A functional check consists of operating an item and comparing its operation with some pre-established standard. Functional checks often involve checking the output of an item (for example, pressure, torque, voltage, or power) and checking to determine if the output is acceptable (such as, within a pre-established range, greater than a pre-established minimum value, or less than a pre-established maximum value). These checks are conducted as failure finding tasks.

7-5.3.2.2 Use of NDI.

Inspections may consist of purely visual examinations or be made using special techniques or equipment. Many inspections require the special capability of non-destructive inspection (NDI) techniques. Table 7-10 lists some of the NDI methods available to maintenance personnel.

Table 7-10 NDI Techniques

Legend: C = Cracks; W = Wear; F = Fractures; CR = Corrosion; E = Erosion; L = Leaks; MA = Material Analysis; MC = Material Conditions; S = Stress; D = Deformation; MT = Material Thickness; DT = Deposit Thickness; PR = Physical Restrictions

NDE Method \ Main Application		C	W	F	CR	E	L	MA	MC	S	D	MT	DT	PR	OTHER	Remarks
1	Acoustic cross correlation						X									Locating buried pipes
2	Acoustic emission	X		X			X		X		X				X	Internal structural noise
3	Coating thickness												X		X	Magnetic methods and eddy currents. Ferrite content of ferritic-austenitic steels
4	Dye penetrant	X		X			X									Including the chalk, water, alcohol methods
5	Eddy current testing	X	X	X	X	X	X				X	X			X	Heat exchanger tubes, wire rope, surface checks, sorting
6	Emission spectroscopy (Metascope)							X								Low and high alloy steels. Including X-ray fluorescence
7	Endoscopy	X	X	X	X	X	X						X	X		Inspection of internal surface
8	ER-probe				X											Average corrosion rates
9	Ferrography		X													Lubricated mechanical systems
10	Hardness testing								X							Brinell, Vickers, Rockwell B, C&N, Rockwell superficial, Knoop, Shore, Scleroscope, Equotip, UCI
11	Hydrogen cell				X											Average corrosion rates
12	Isotope techniques		X				X		X			X	X	X	X	Tracer tech., ball test, radiometry, collim. Photon
13	Laser distance measurements (optocator)		X									X			X	Topography, symmetry
14	Leak testing resistance						X								X	Liquid penetrant, ultrasonics, pressure change, foam, tracers, sulphur diffusion, ozalide paper, halogen
15	LPR-probe, polarization				X											Instantaneous corrosion rate
16	Magnetic plugs		X													Lubricated mechanical systems
17	Magnetic particle examination	X													X	Weld defects, laminations – only ferromagnetic materials
18	Mechanical calibration		X		X	X						X	X		X	Physical dimensions
19	NDE method combination	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Check of entire component condition. Predictive programs
20	NDE meth. under. dev.	(X)							(X)	(X)	(X)				(X)	
	20.1 SPAT									X						Stress pattern analysis by thermal emission
	20.2 Pulsed video thermography (PVT)								X						X	Composite materials. Glued metals, delamination, and coatings.
	20.3 Moire contour										X				X	Topography

Table 7-10 NDI Techniques (cont'd)

Main Application / NDE Method	C	W	F	CR	E	L	MA	MC	S	D	MT	DT	PR	OTHER	Legend: C = Cracks; W = Wear; F = Fractures; CR = Corrosion; E = Erosion; L = Leaks; MA = Material Analysis; MC = Material Conditions; S = Stress; D = Deformation; MT = Material Thickness; DT = Deposit Thickness; PR = Physical Restrictions **Remarks**
20.4 Holographic interferometry (HI)									X					X	Lack of adhesion, material defects, thin samples
20.5 Computerized tomography (CT)	X													X	Annual rings, knots, moisture, concrete column cross sections
20.6 Positron annihilation								X						X	Voids in metals. Fatigue in titanium
21 Noise measurements														X	Noise level, bearing checks
22 Pattern recognition	X	X	X	X	X					X	X	X	X		
23 P-scan	X	X	X	X	X						X			X	Weld inspection, stress corrosion, corrosion topography, creep defects. Full documentation
24 Pinhole														X	Coatings, high/low voltage
25 Pressure testing	X		X			X				X					Including vacuum testing. See also leak
26 Radiography	X	X	X	X	X	X					X	X	X	X	Check of joints, geometry, laminations, reinforced concrete, and corrosion/erosion
27 Replica technique	X	X	X					X		X				X	Surface microstructure, crack type, wear grooves, topography
28 Spectrometric oil analysis programs		X													Lubricated mechanical systems
29 Strain gauge technique									X	X					Weight, pressure, oscillation
30 Stroboscopy	X	X	X											X	Visual condition monitoring, rotation direction and rate
31 Test coupons				X	X										Average corrosion rate
32 Thermography	X			X		X						X		X	Surface temp., bearing pressure, moisture, energy loss
33 Ultrasonic leak, detection						X								X	Electrical discharge, flow
34 Ultrasonics	X	X	X	X	X	X		X	X	X	X				Including sound attenuation
35 Vibration monitoring	X	X	X											X	Machinery includes bearings, gears, turbines, centrifuges, etc.
36 Visual inspection	X	X	X	X	X	X	X			X		X	X		Spark pattern & chemical analysis
37 X-ray crawlers														X	Checking welds inside pipes
38 X-ray diffraction									X						Measurement residual stresses

7-5.3.3 Restoration Task.

Many items, primarily mechanical, wear out as they are used. At some point, it may be necessary, and possible, to restore the item to "like new" condition. Examples include internal combustion engines, electric motors, and pumps.

7-5.3.4 Discard Task.

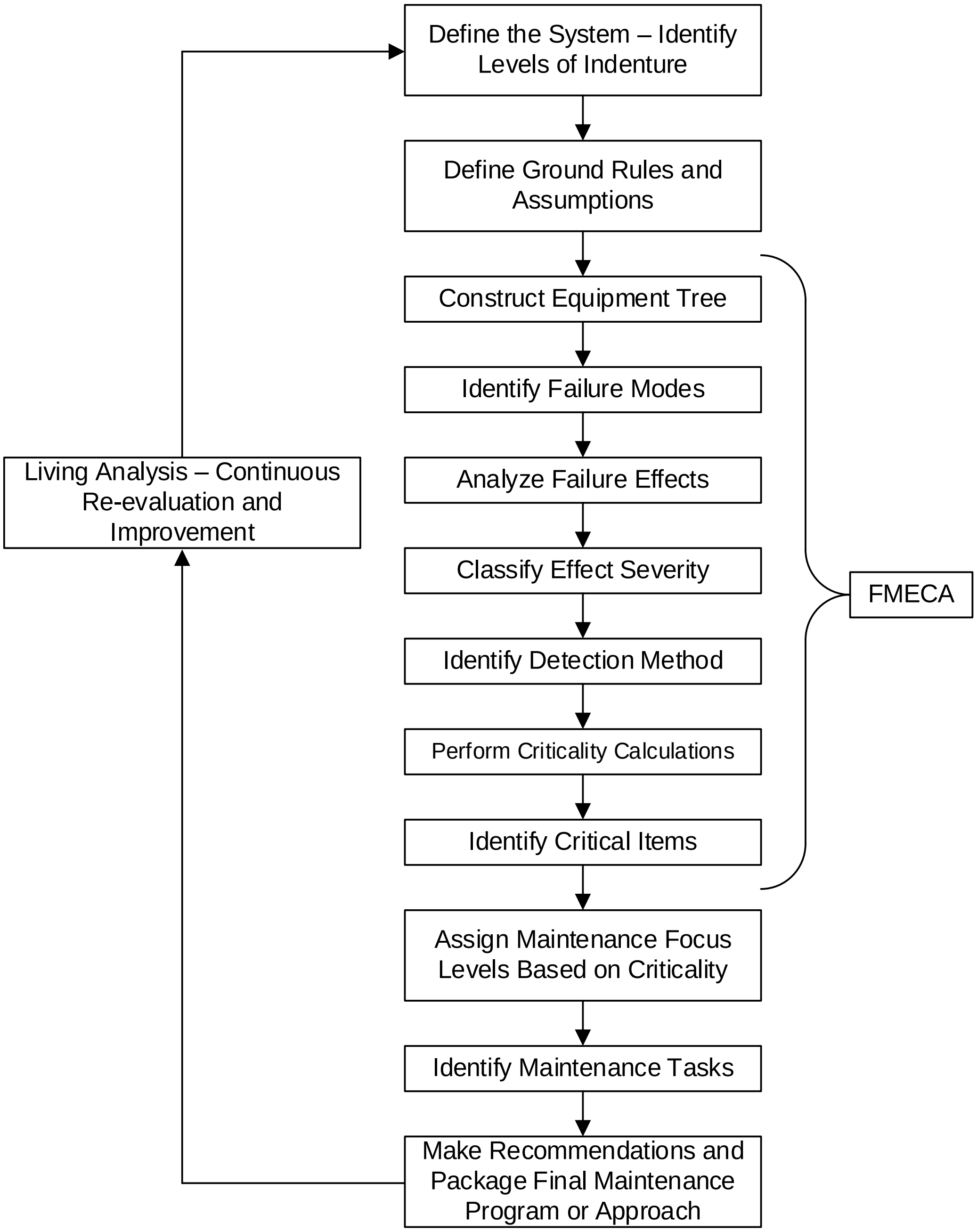
Some items upon failure or after their useful life has been reached (such as, they are worn out), cannot be repaired or restored. These items must be discarded and replaced with a new item identical in function. Examples include seals, fan belts, gaskets, screws (stripped threads), and oil filters.

7-5.4 The RCM Process.

The objective of conducting an RCM analysis is to rank all included equipment and systems by their relative importance, and risk, to the overall facility mission, and to prescribe PM tasks based on subsystem and system ranking. The RCM process is outlined below, by an expanded Figure 7-8, and following text.

- Define the System – Identify and document the boundaries of the analysis
    - Identify and document equipment included in the analysis
    - Identify and document the indenture level the analysis is intended to extend to
- Define Ground Rules and Assumptions – Identify and document ground rules and assumptions used to conduct the analysis
- Construct Equipment Tree – Construct equipment block diagrams to indicate equipment configuration, down to the lowest indenture level intended to be covered by the analysis
- Identify Failure Modes – Identify the potential failure modes for the analyzed equipment at the indenture levels covered by the analysis
- Analyze Failure Effects – Analyze the effects of the identified failure modes on the lowest levels of indenture and above
- Classify Effect Severity – Classify the effects of the identified failure modes on the lowest levels of indenture and above
- Identify Detection Method – Identify and classify the methods, in place, by which potential failures may be detected or avoided
- Perform Criticality Calculations – Perform Criticality Analysis

Figure 7-8 The RCM Process



- Identify Critical Items – Identify items within the analysis that ranked highly critical
- Assign Maintenance Focus Levels – Classify maintenance focus levels based on criticality rankings
- Apply RCM Decision Logic – Apply RCM logic trees for items, especially those identified as being critical

- Identify Maintenance Tasks – Identify maintenance tasks to be performed on the given item
- Package Maintenance Program – Develop a maintenance tasking schedule for the analyzed equipment

7-5.4.1 Identify the System Configuration.

Since the RCM analysis usually begins before the final design has been completed, the system configuration is changing. Even when the design is complete, model changes can be made. The configuration, of course, determines how functions are performed, the relationship of items within a product, and so forth. Consequently, it is important that the precise configuration of the product or system for which the RCM analysis is being conducted be documented as part of the analysis. It is also important that the analysis be updated to account for any changes in the configuration (some of which may be required as a direct result of the RCM analysis itself).

7-5.4.2 Perform a FMEA and Other Analyses.

To perform the RCM analysis, many pieces of information are needed. These include the information listed below.

- The types of failures that can occur in the product
- The failure characteristics of the items that make up the product being analyzed
- The nature of the failures (hidden, evident, safety, operational, ect.)
- The capabilities of the maintenance organization
- The maintenance concepts
- A thorough understanding of operation

Obviously, such information will probably not be known or be very shaky early in design. For that reason, the RCM analysis should not be started until sufficient and reasonably stable information is available. Of course, the objective is to develop and complete the initial maintenance program prior to the product being transferred to the customer.

RCM Analysis can be conducted using a traditional quantitative, qualitative, or flexible approach.

- Traditional quantitative approach can be used when there is sufficient failure rate data available to calculate criticality numbers. A quantitative approach is the preferred analysis method. However, to be effective, high levels of failure specific data must be available. When specific failure rates for specific failure modes and failure mechanisms are unavailable, analysis must be conducted qualitatively.

- Qualitative analysis must be used when specific part or item failure rates are not available. Therefore, failure mode ratio and failure mode probability are not used in this analysis. Instead, the equipment is ranked in terms of discrete occurrence levels. Under traditional qualitative analysis severity, occurrence, and detection method levels are determined subjectively and utilized to produce a component risk assessment.
- The flexible technique is born of traditional qualitative analysis. Under this approach, RPN calculations will be generated by the same formulas as given by traditional qualitative approach. However, the arguments of the component level RPN calculation (*O, S, D*) will be defined differently. See Equation 6-11.

7-5.4.2.2 Other Inputs.

When FTAs are needed to understand the effects of, for example, multiple failures, the information derived from these analyses can also be valuable inputs to the RCM analysis.

7-5.4.2.3 Other Information.

Other important sources of information for the RCM analysis include RBDs, Functional Block Diagrams, system requirements documents, descriptions of system applications, technical manuals/drawings/layouts, and indenture level identification system.

7-5.4.2.4 Sources.

To provide the needed information, various sources must be exploited. One of the most obvious sources is the body of analyses conducted as part of the design process. These include the Failure Mode and Effects Analysis (FMEA) or Failure Modes, Effects, and Criticality Analysis (FMECA), FTA, maintainability analysis, and so forth.

7-5.4.2.5 FMEA.

The FMEA can be a primary source of much of the information needed for the RCM analysis. Table 7-11 shows excerpts of the form prescribed in the Automotive Industry Group standard on FMEA/FMECA. Table 7-12 indicates the data in many of the columns can be directly used for the RCM analysis. The columns having data most applicable for the RCM analysis are shaded. In addition to those shown, columns can be added for functions, functional failure, compensating provisions, and three columns for failure effects: local effects, next higher level, and end effects. Other chart examples for recording FMECA data can be used as shown in Table 7-12. Further information is available in TM 5-698-4, Failure Modes, Effects and Criticality Analysis (FMECA) for C4ISR Facilities.

Table 7-11 Data Elements from FMEA that are Applicable to RCM Analysis

(Form from the Automotive Industry Group Standard on FMEA)

Item/ Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	SEV	CLASS	Potential Cause(s)/ Mechanisms of Failure	OCC	Current Design Controls	DET	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
												Action Taken	New Sev	New Occ	New Det	New RPN

Legend: SEV – Severity of failure effect
OCC – Probability of occurrence
DET – Method of detection
RPN – Risk Priority Number

A completed chart may be similar to the following example:

Table 7-12 Example of Failure Modes and Effects Analysis Worksheet; DA Form 7610

ITEM NUMBER	ITEM/FUNC-TIONAL ID	POTENTIAL FAILURE MODES	FAILURE MECHANISM (CAUSE)	SEVERITY	FAILURE RATE λ_P (SOURCE)	DETECTION METHOD	CRITICALITY NUMBER (C_M)
130.2	Cooling Tower #1/ maintain a water temp of 75°F.	Fan failure	Motor winding open, Loss of power to motor	3	10.0518×10^{-6}	3	99.05×10^{-5}
310.1	Air Handler/ Provide 3200cfm of air to room, maintain room at 72°F,	Provide airflow at a rate less than 3200cfm	Reduced motor output –winding degradation, belt slippage- belt too loose, loose sheave, Dirty intake filter	3	1.7657×10^{-6}	2	1.06×10^{-5}
310.0	Air Handler/ Provide 3200cfm of air to room, maintain room at 72°F,	Maintain air at a temp higher than 72°F	Dirty coils	3	1.7657×10^{-6}	7	3.7×10^{-5}

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Where:

- Failure modes are the generic way an item failed
- Failure mechanisms are the specific circumstances that allowed the given failure mode to occur
- Severity is the assessment of the consequence of a given failure
- Occurrence is the probability of the failure occurring (failure rate)

7-5.4.3 Applying RCM Decision Logic.

The overall decision logic for applying the RCM methodology is depicted in Figure 7-9. The decision logic represented in this figure is adapted from that used in the Reliability Analysis Center's Master Steering Group –3 (MSG-3). The most significant difference is in the portions of the tree labeled ②, ④, ⑦, and ⑧. MSG-1 through MSG-3 used the term "safety" for these portions of the tree.

7-5.4.3.1 Safety.

Safety is of paramount importance to the airline industry, as it is in other industries, such as the nuclear power industry.

7-5.4.3.2 Other Critical Considerations.

Many industries have concerns that are as important, or nearly so, as safety considerations. The petroleum and chemical industries, for example, are subject to severe economic and even criminal penalties under Federal statutes for events in which the environment is polluted. For other industries, failures that result in the violation of other Federal, state, or local statutes, or in other unacceptable consequences may be treated as seriously as safety-related failures are in the airline industry. For that reason, in the portions of the tree labeled ②, ④, ⑦, and ⑧, the term "hazardous effects" is used rather than "safety effects". (The circled numbers in this and following discussions refer to a corresponding numbered portion of the referenced figures.) When applying RCM decision logic, it is important to consider the criticality of the current item. Highly critical items have the direct potential to compromise mission goals, and risk should be heavily mitigated. It is important to recognize single point failures, as well as their functional contribution to critical and non-critical systems, and to prescribe maintenance approaches accordingly. Conversely, some items recognized as being very non-critical may be allowed to run to failure, especially non-critical items that are inherently very reliable. This viewpoint should also be incorporated into the use of RCM decision logic to build an intelligent, and cost effective, maintenance strategy.

7-5.4.4 Use of Logic Tree.

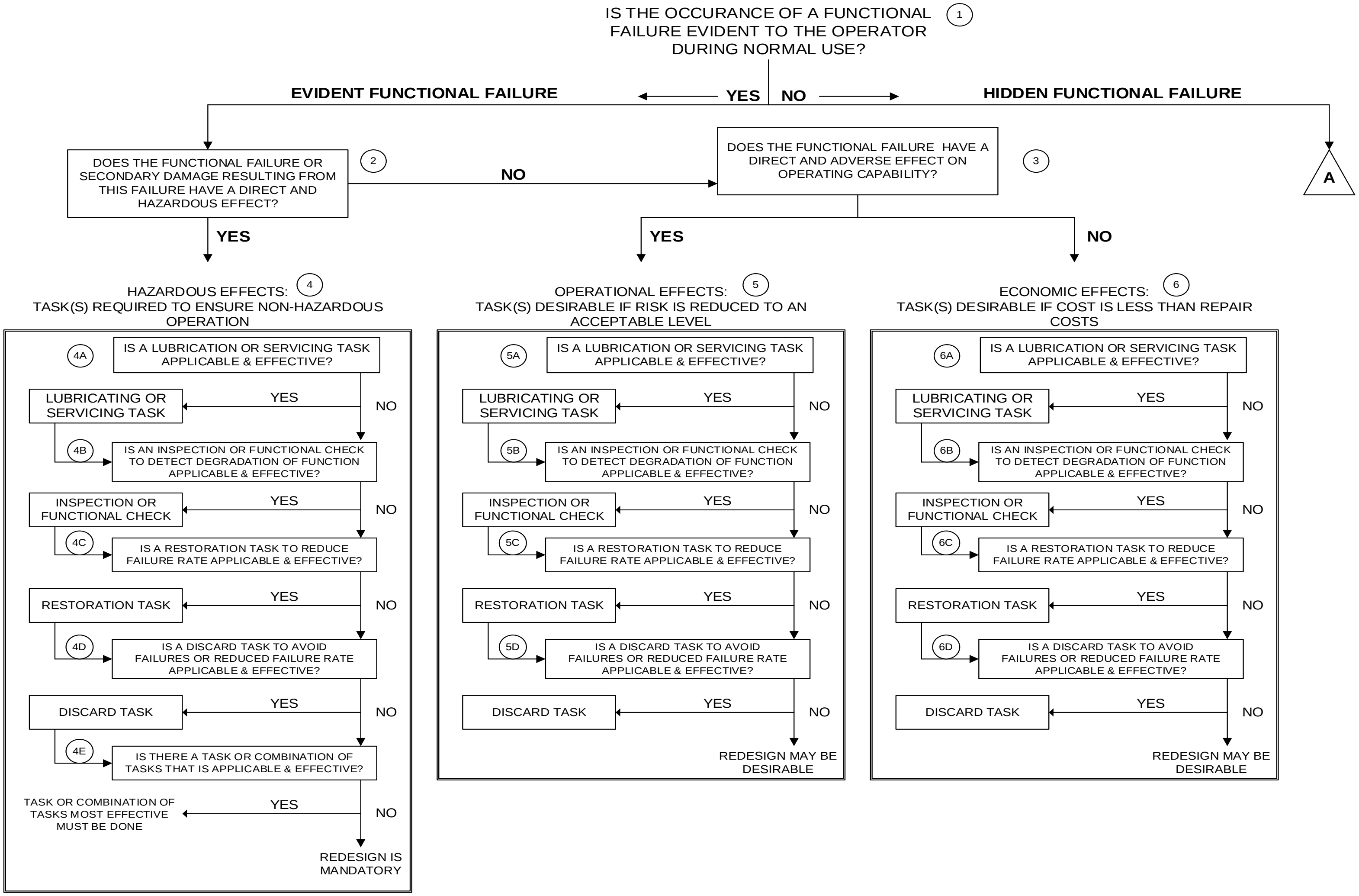
As can be seen from Figure 7-9, the decision logic tree consists of a series of Yes-No questions. The answers to these questions lead to a specific path through the tree. The questions are structured to meet the objectives of the RCM analysis: ensure the safe (non-hazardous) and economical operation and support of a product while maximizing the availability of that product. This objective is met by selecting preventive maintenance (PM) tasks when appropriate, redesign, some combination of PM and redesign, and by corrective maintenance (CM) when PM is either applicable or effective.

(1) The first question asked is "Is the occurrence of a functional failure evident to the operator or (or user) during normal use?" A "No" answer means that the failure is hidden, and the analyst is directed to ⑦ in the tree. The portion of the tree below ⑦ is discussed under paragraphs 7-5.4.8 and 7-5.4.9. A "Yes" answer means that the failure can be observed or is made known to the operator/user, in which case, the analyst is directed to ②.

(2) At ②, the question is "Does the (evident) functional failure or secondary damage resulting from the functional failure have a direct and hazardous effect?" A "Yes" answer directs the analyst to ④. The portion of the tree below ④ is discussed under paragraph

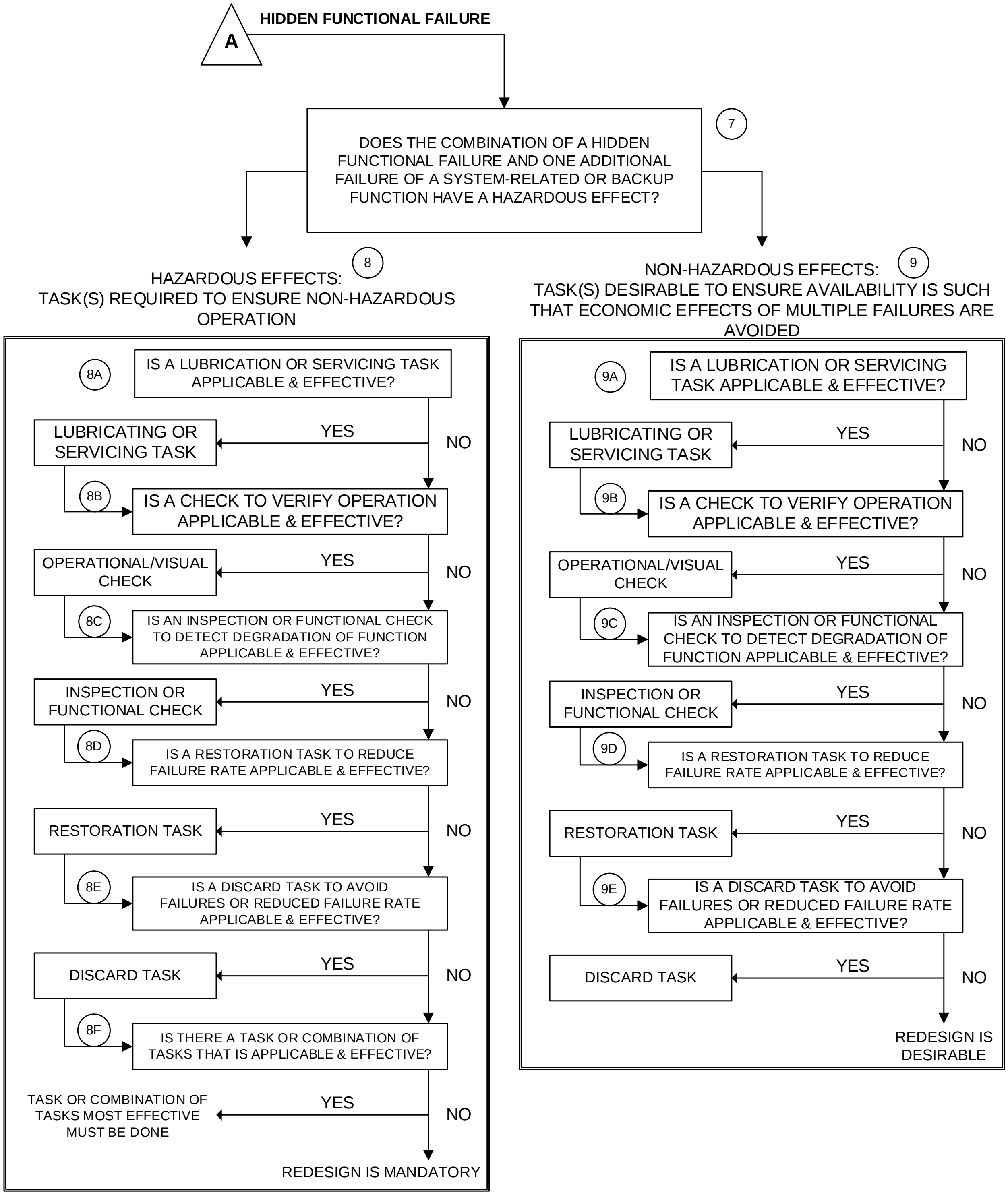
7-5.4.5. A "No" answer directs the analyst to ③. The portion of the tree below ③ is discussed under paragraphs 7-5.4.6 and 7-5.4.7.

Figure 7-9 RCM Decision Logic Tree (Adapted from MSG-3)



* Hazardous effects include property damage, injury or death to operators or other people, violation of Federal environmental or health statutes, and other effects determined by the company or industry to be serious or catastrophic.

Figure 7-9 RCM Decision Logic Tree (Adapted from MSG-3) (cont'd)



* Hazardous effects include property damage, injury or death to operators or other people, violation of Federal environmental or health statutes, and other effects determined by the company or industry to be serious or catastrophic.

7-5.4.5 Evident Failure – Hazardous Effects.

The portion of the decision logic tree that deals with situations where an evident functional failure has hazardous effects is shown in Figure 7-10.

(1) This portion of the tree steps the analyst through a series of questions intended to identify all PM tasks that will reduce to an acceptable level the probability of occurrence of the functional failure that results in the effects, reduce the effects to purely operational or economic effects, or result in a combination of these two improvements.

(2) If none of the PM tasks listed is either applicable or effective, then redesign is mandatory. The reason for making redesign mandatory is obvious. The effects categorized as "hazardous" are unacceptable. Consequently, when PM cannot fulfill any of the objectives listed, a redesign the product must be performed to eliminate the mode of failure that causes the hazardous effects, reduce to an acceptable level the probability of occurrence of the functional failure that results in the effects, or result in a combination
of these two improvements.

7-5.4.6 Evident Failure – Operational Effects.

The portion of the decision logic tree that deals with situations where an evident functional failure has a direct and adverse effect on operating capability is shown in Figure 7-11. This portion of the tree steps the analyst through a series of questions intended to identify all PM tasks that will reduce the risk of failure to an acceptable level. If none of the PM tasks listed is either applicable or effective, then redesign may be desirable. The cost of a functional failure that results in operational effects includes both the cost of the PM and the economic cost incurred because of the end system not completing a mission or being able to perform its function(s).

(1) If the costs exceed the cost to redesign the product, redesign is economically justified. The purpose of the redesign would be to eliminate the mode of failure that causes the operational effects, reduce to an acceptable level the probability of occurrence of the functional failure that results in the effects, or some combination of these.

(2) Even if redesign is economically justified, other considerations, such as schedule, may outweigh the advantages gained.

Figure 7-10 Evident Failure – Hazardous Effects

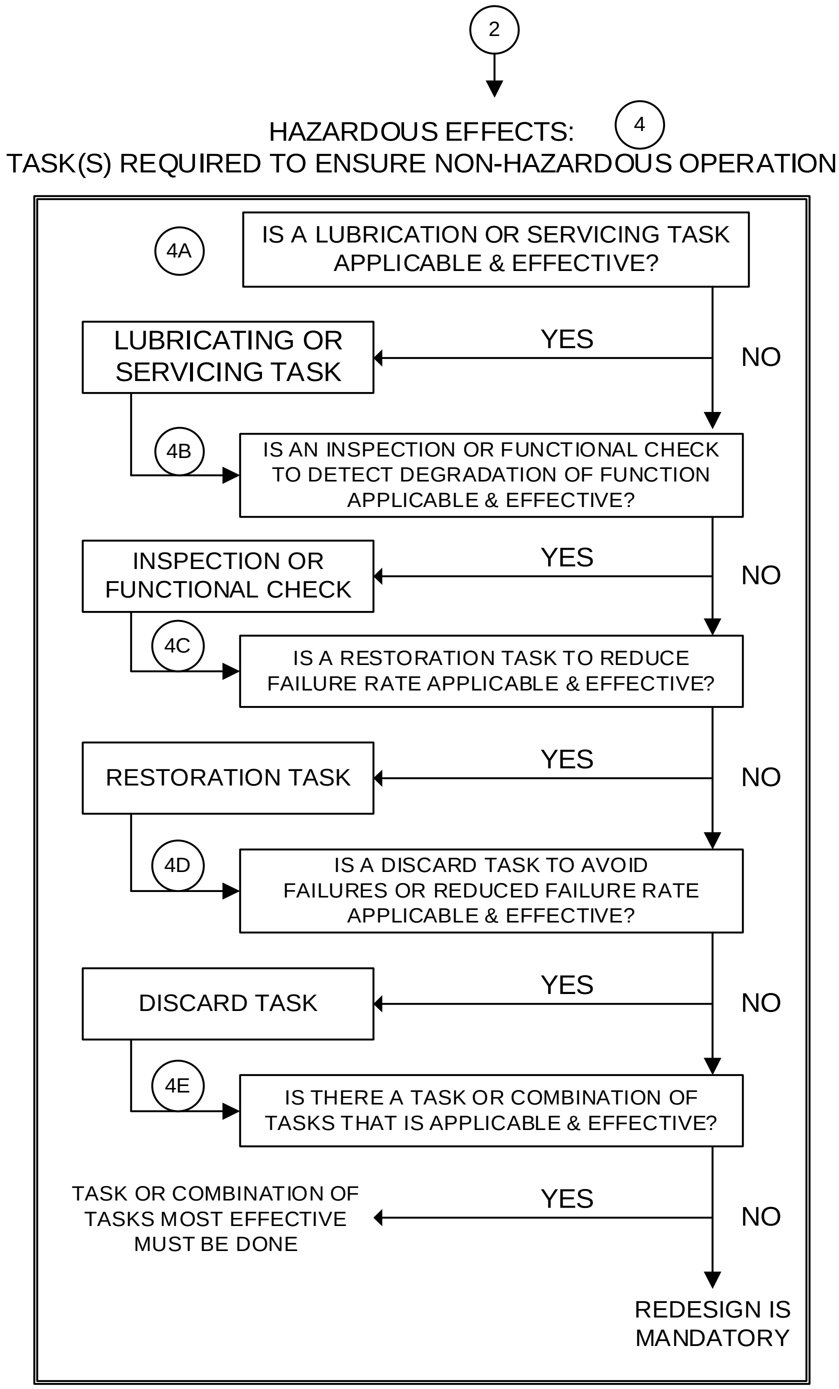
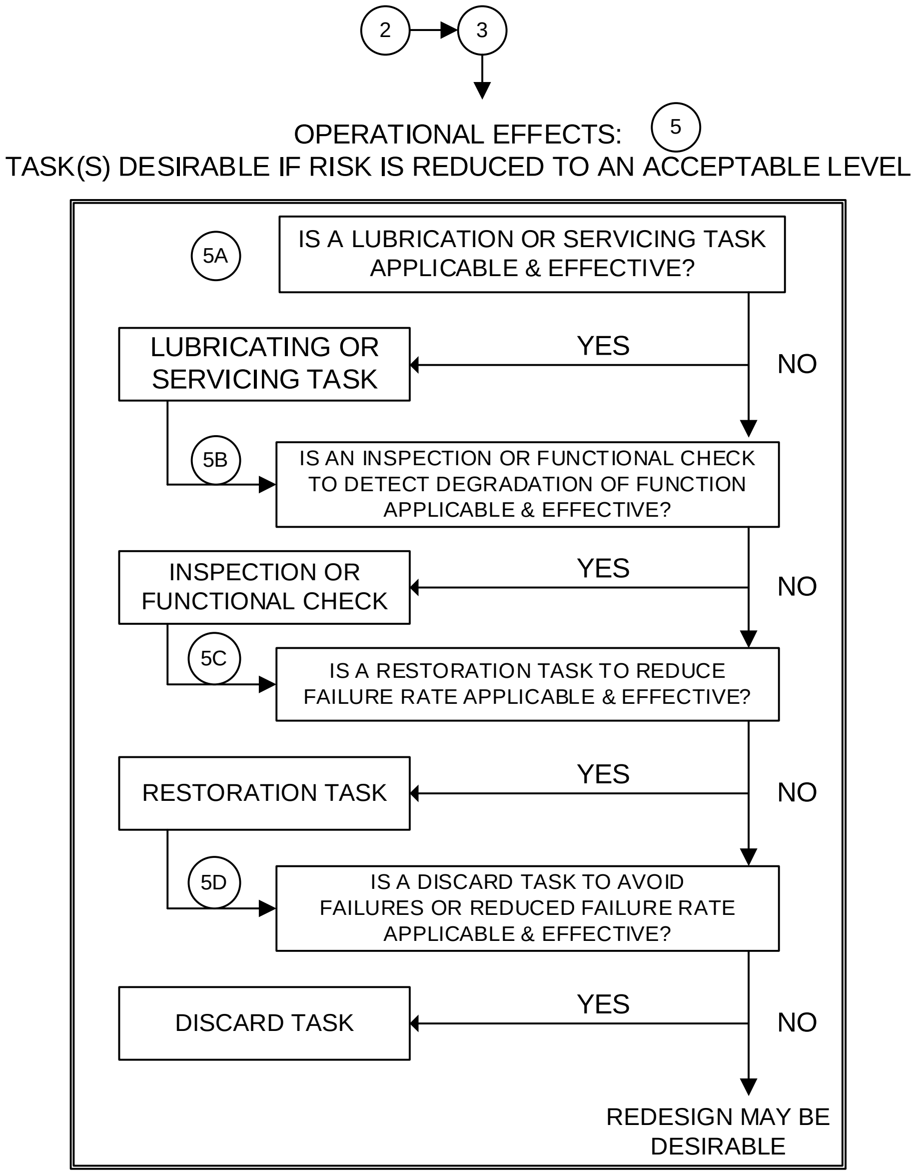


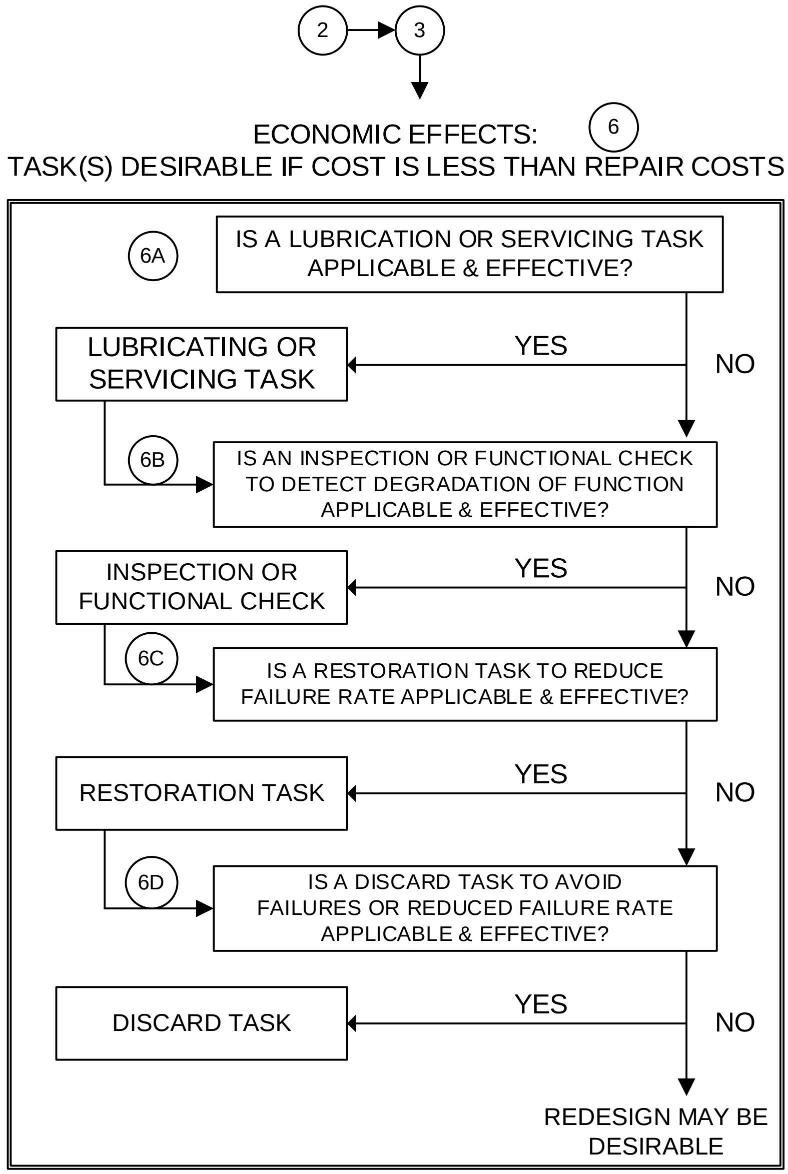
Figure 7-11 Evident Failure – Operational Effects



7-5.4.7 Evident Failure – Economic Effects.

The portion of the decision logic tree that deals with situations where an evident functional failure has only an economic effect is shown in Figure 7-12. This portion of the tree steps the analyst through a series of questions intended to identify all PM tasks that are desirable if their costs are less than the cost of repair. If none of the PM tasks listed is either applicable or effective, then redesign may be desirable. Again, the decision to redesign or not redesign is one of economics. If redesign is less than the economic effects of the failure, then it may be desirable. Otherwise, redesign is not justified.

Figure 7-12 Evident Failure – Economic Effects



7-5.4.8 Hidden Failure – Hazardous Effects.

The portion of the decision logic tree that deals with situations where a hidden functional failure has a hazardous effect in combination with another failure is shown in Figure 7-13. This portion of the tree steps the analyst through a series of questions intended to identify all PM tasks that are required to ensure non-hazardous operation. The tasks are effective if they reduce to an acceptable level the probability of occurrence of the functional failure that results in the effects, reduce the effects to purely operational or economic effects, or result in a combination of these.

(1) If none of the PM tasks listed is either applicable or effective, then redesign is mandatory. The reason for making redesign mandatory is obvious. The effects categorized as "hazardous" are unacceptable. Consequently, when PM cannot fulfill any of the objectives listed, a redesign must be performed the product to eliminate the mode of failure that causes the hazardous effects, reduce to an acceptable level the probability of occurrence of the functional failure that results in the effects, or result in a combination of these.

(2) Note that by redesigning to make the failure evident, the effects might be reduced to purely economic or operational.

7-5.4.9 Hidden Failure – Non-Hazardous Effects.

The portion of the decision logic tree that deals with situations where a hidden functional failure has a non-hazardous effect is shown in Figure 7-14. This portion of the tree steps the analyst through a series of questions intended to identify all PM tasks that are desirable to ensure availability is sufficiently high to avoid the economic effects of multiple failures. If none of the PM tasks listed is either applicable or effective, then redesign is desirable.

Figure 7-13 Hidden Failure – Hazardous Effects

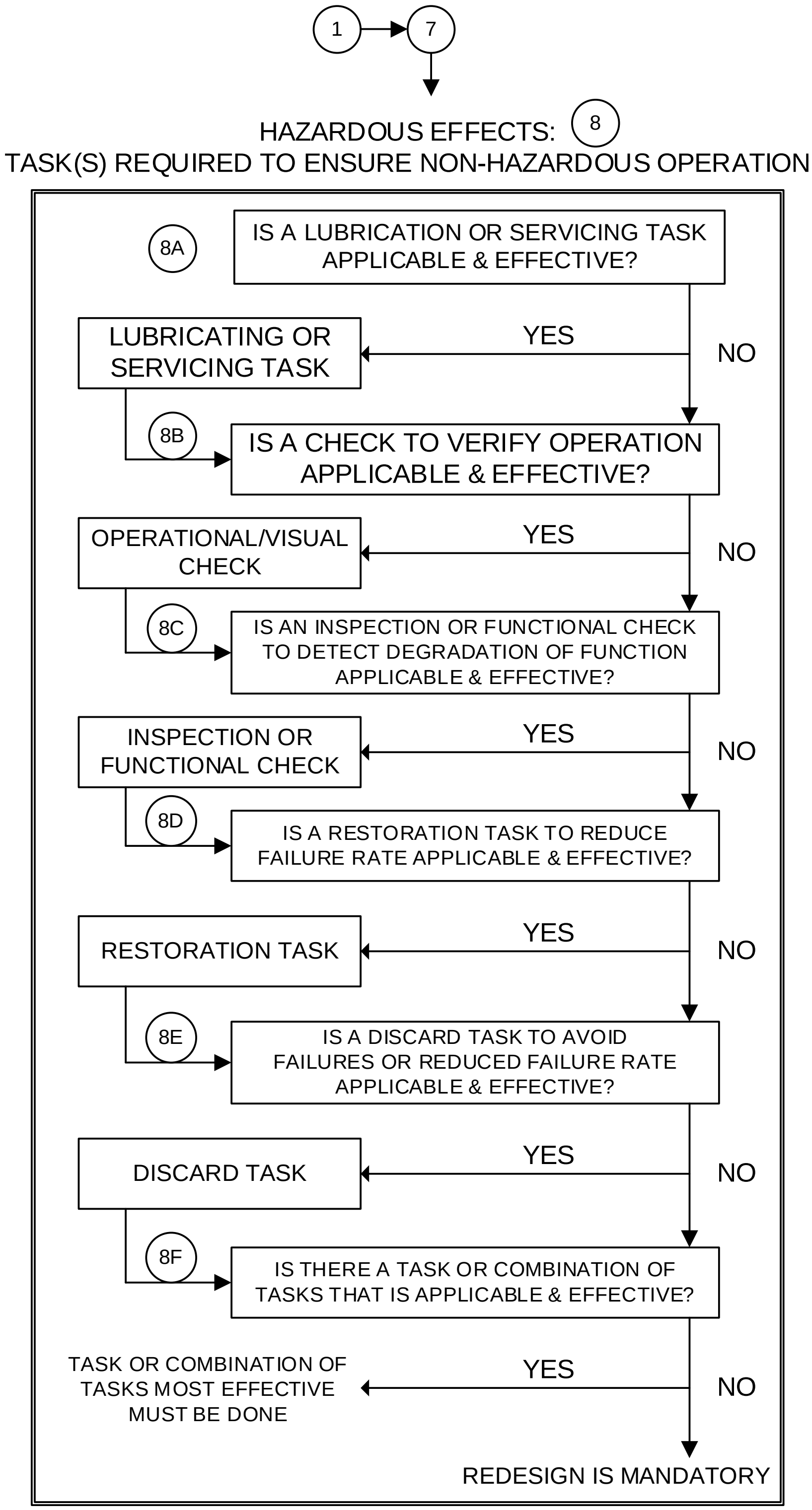
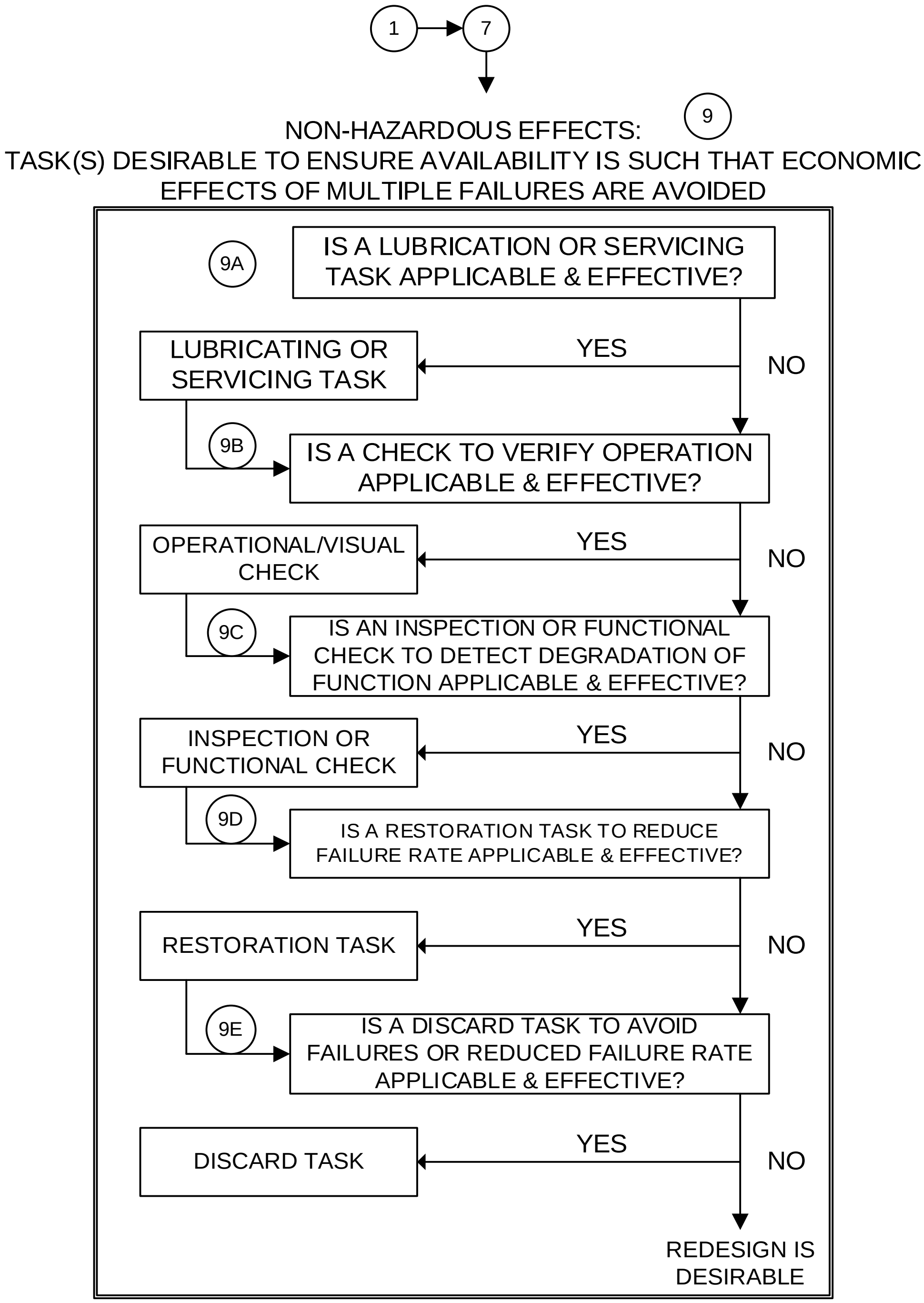


Figure 7-14 Hidden Failure – Non-Hazardous Effects



7-5.4.10 Package Final Maintenance Program.

The result of the RCM analysis will be a set of preventive maintenance (PM) tasks and, by default, a set of corrective maintenance (CM) tasks. PM will consist of on-condition and scheduled maintenance.

(1) Frequency of tasks. The frequency with which each of the scheduled PM tasks must be performed will no doubt vary from item to item. It is also probable that many of these tasks may be grouped and performed together at some calendar or operating time interval. The process of grouping the scheduled tasks into sets of tasks to be performed at some prescribed time is called "packaging" the maintenance program.

(2) Example of packaging. For example, it may be that for a given product that the scheduled tasks listed below were identified.

- Three visual inspections: A to be conducted every 45 hours of operation, B to be conducted every 52 hours of operation, and C to be conducted every 105 hours of operation.
- A lubrication performed every 55 hours of operation
- A non-destructive inspection every 100 hours of operation
- An overall task performed when a stated operating characteristic is out of limits
- A hard-time replacement task every 60 hours of operation

One way to package these tasks is listed below.

- Conduct the following PM every 50 operating hours (such as, at 50, 100, 150, 200, ect.)
    - Visual Inspections A and B
    - Lubrication
    - Hard-time replacement
- Conduct the following PM every 100 operating hours (such as, at 100, 200, 300, ect.)
    - Visual inspection C
- Perform overhaul task whenever the operating characteristic goes out of limits

Note that at the 100, 200, 300, etc. hour points, all the tasks except the overhaul task are performed. This example is purposely over-simplified, and many other factors may (and probably will) have to be considered when packaging the tasks. The point is that by packaging PM tasks, maintenance resources are used as effectively as possible and minimize the downtime of the product for PM.

7-5.4.11 Continuously Improve the Maintenance Program.

Given the possibility for errors in the initial maintenance program, it is prudent to implement the RCM process as an on-going effort, one requiring perpetual evaluation and adjustment, as depicted in Figure 7-8. The process for continuously improving the RCM-based maintenance program consists of Maintenance Audit, Trend Analysis, and Life Exploration. The purpose of this process is to continuously improve the initial maintenance program developed using the RCM concept.

7-5.4.11.1 The Initial Maintenance Program.

The maintenance program that is developed based on the RCM analysis done prior to the first product being delivered to the customer is the initial maintenance program. This initial program will have been based on the best information that was available at the time the analysis was performed. One of the critical pieces of information is the underlying failure distribution for each item. The information used in the initial RCM analysis was based on a mix of analysis and test results. When off-the-shelf items are used in the product, the information can include actual field experience. It must be recognized, however, that some of the information will not be 100% accurate.

7-5.4.11.2 Maintenance Audit.

Auditing the maintenance performed in actual service provides the data needed to refine and improve the maintenance program. In analyzing the data, the maintenance analysts and planners attempt to address the technical content of the program, intervals for performing tasks, packaging of tasks, training, the maintenance concept, and the support infrastructure.

(a) In addressing technical content, analysts and planners must determine if the current maintenance tasks cover all identified failure modes and result in the desired/required level of reliability. Failure modes may have been missed or the current maintenance tasks may not be effectively addressing identified failure modes. The latter may result from incorrectly identifying the underlying failure probability distribution function. Much of this information can be confirmed or updated through a reliability assessment. Listed below are the type of questions that can be answered by such an assessment.

- Were assessments of useful life too conservative?
- Have replacement intervals been made too short?
- Is wearout occurring later or earlier than anticipated?
- Have the operating conditions or concept changed?
- Has the reliability performance been as expected?
- Have any new failure modes been uncovered?

- Are failure modes identified in development occurring with the expected frequency and pattern (such as, underlying pdf of failures)?
- Have any modifications to the product been made or are any planned that would add or delete failure modes, change the effects of a given failure mode, or require additional or different PM tasks?
- Were the consequences of failures forecast during development adequately identified?

(b) In addressing performance interval, analysts and planners must determine if the intervals for PM tasks result in decreased resistance to failure. Most often, the objective is to extend the interval as much as possible, without compromising safety, when doing so will reduce costs. Initial intervals are frequently set at conservative levels.

(c) In addressing task packaging, analysts and planners must determine if like tasks with similar periodicity are or can be grouped together to minimize downtime and maximize effectiveness. Lessons learned during actual operation and maintenance may make it necessary to revise the initial packaging.

(d) The analysts and planners should evaluate if available personnel, as currently being trained and using available tools and data, are effectively performing the identified PM tasks. If not, changes to training, procedures, tools, and so forth should be considered.

(e) The analysts and planners should determine if the maintenance concept for the product is effective or should be revised.

(f) The analysts and planners should address the adequacy and responsiveness of the support infrastructure. If the performance of the infrastructure is not as anticipated, recommendations regarding policy, spares levels, and other factors should be considered.

7-5.4.11.3 Trend Analysis.

By collecting data on failures, time to failure, effectiveness of maintenance tasks, and costs of maintenance, trends can be identified. The objective of trend analysis is to anticipate problems and adjust the maintenance program to prevent their occurrence. For the RCM effort, two factors typically addressed by trend analysis are the rate of occurrence of failures and maintenance costs.

(a) For trending purposes, at least three data points are needed. The first two establish the trend (positive or negative) and the third serves as confirmation. In control charting used for quality control, a trend is said to exist when 7 consecutive points continue to rise or fall. However, when measurements are based upon sample surveys over time, data at different points in time may vary because the underlying phenomenon has changed (such as, a trend exists) or due to sampling error (such as, the underlying phenomenon has not changed at all). It is not an easy task to seek out the one from the other.

(b) Statistical methods can be used to determine if a trend exists. For example, if a system failure rate is changing (such as, it is not constant), the Laplace Statistic will show that a trend exists at a certain level of confidence. The Laplace transform is an integral transform perhaps second only to the Fourier transform in its utility in solving physical problems. The Laplace transform is particularly useful in solving linear ordinary differential equations such as those arising in the analysis of electronic circuits (Wolfram MathWorld).

(c) In addition to trend analysis, impending failures can be detected using pattern recognition, data comparison, tests against limits and ranges, correlation, and statistical process analysis.

7-5.4.11.4 Life Exploration.

The process of collecting and analyzing in-service or operational reliability data to update the maintenance program is called Life (or Age) Exploration. The data that should be collected during Life Exploration includes historical field service data. Historical field service data typically describes three kinds of maintenance activities: corrective maintenance actions, preventive maintenance action, and service maintenance action.

(a) Historical corrective maintenance data. Corrective maintenance actions occur in response to an operational failure of the system. Corrective maintenance actions are always unscheduled, unwanted, inconvenient, and random.

(b) Historical preventive maintenance data. Preventive maintenance actions occur in accordance with a schedule and are intended to minimize the need for corrective maintenance actions.

(c) Historical service maintenance data. Service maintenance actions are those tasks performed to replenish expended parts and supplies required to operate a system. Many assets require adjustment, replenishment of supplies, lubrication, and cleaning.

7-5.5 Specific Considerations for Implementing RCM for C5ISR Facilities.

7-5.5.1 Current Versus New Facilities.

Many C5ISR facilities were built, and the mechanical and electrical equipment developed and installed without an RCM analysis having been conducted. Implementing RCM for an existing C5ISR facility, when the current PM program was not based on RCM, is different from implementing it on a facility, new or old, for which the PM program was based on RCM.

7-5.5.1.1 Current PM Program in Place.

Of course, a program of preventive maintenance will already be in place for an existing facility. Without an RCM analysis, the PM program was probably based on past programs. Indications that the PM program is inefficient or ineffective are an excessive number of corrective maintenance actions (with an associated low facility availability), or an extremely large number of required PM actions that are imposing a very heavy economical penalty. Attempts to change the existing PM program may meet with some resistance (see paragraph 7-5.5.3.3).

7-5.5.1.2 Need for Supporting Analyses.

If an RCM analysis was not originally performed for the facility, its systems and equipment, much of the supporting analysis may also have been omitted. If such analyses, such as an FMEA, were not conducted, they must be conducted before an RCM-based PM program can be developed. For many of the installed systems and equipment, performing an FMEA or other analysis may be quite difficult because much of the data may not be available. Either the data was not acquired with the systems and equipment (such as, data rights were not procured), or the data is missing. In such cases, engineers will have to use engineering judgment and require more time to adequately analyze the systems and equipment.

7-5.5.1.3 Feasibility of Redesign.

If following the RCM logic, it is possible that the path may lead to a "Redesign is mandatory" or "redesign may be desirable" outcome. Redesign during initial development is a sometimes-difficult task. Once a system or piece of equipment is in operation, redesign is even more difficult. However, an advantage of a facility is that adding redundancy is less constrained, in terms of space and weight, than for other systems.

7-5.5.2 Training.

The RCM process is very disciplined and logical. It involves the integration of many different analytical tools, data, experience, and a decision logic tree. Without proper training, those assigned the responsibility of implementing RCM will find it difficult to succeed. Training in the RCM methodology and the related disciplines must be an essential element of an organization's plan for implementing RCM. For C5ISR facilities, especially when maintenance is outsourced, funding must be provided for training to ensure that an RCM analysis is properly performed. Of course, training to ensure maintenance is properly performed is also essential.

7-5.5.3 Pitfalls.

In implementing an RCM program in organizations where the concept is new, pitfalls can make implementation ineffective.

7-5.5.3.1 Run to Failure Shock.

For many maintenance managers and technicians, allowing an item to run to failure runs counter to conventional wisdom. It is important that they understand the concepts of reliability and turn their focus from preventing failures to preserving function.

7-5.5.3.2 Failure to Accept the "Preserve Function" Principle.

Most maintenance personnel traditionally have viewed their role as one of preventing failures. To effectively implement an RCM program, it is essential that maintenance personnel focus on preserving the function or functions of an item, not preventing failures.

7-5.5.3.3 Challenging the Past.

Tradition and conventional wisdom remain the principal guidance for many maintenance organizations. Challenging past practices almost always invokes strong resistance, especially if the new practices are not fully understood. Education is the best way to deal with cultural resistance.

7-5.5.3.4 Organization Structure.

The RCM process requires close coordination and cooperation among several groups of people, including but not limited to designers, maintainers, and logistic planners. Organizational structures can impede or even prevent the level of cooperation and coordination needed to make RCM a success. The concept of integrated process/product teams is one that facilitates and encourages cross-discipline cooperation.

7-5.5.3.5 Threat of Reduction in Staff.

When RCM was first implemented within the airline industry, drastic reductions in scheduled maintenance tasks were made possible. Consequently, the number labor hours and people required to, for example, conduct structural inspections of an aircraft were significantly reduced. When a segment of an organization perceives that a new policy or procedure will eliminate their jobs, the natural reaction is to fight against the new policy or procedure. However, with vision and planning, management can find ways to effectively use the resources freed up by implementing RCM and minimize the impact on jobs by using normal attrition, cross training, etc.

7-5.5.3.6 Inadequate Buy-in.

All too often, management implements a new policy or procedure without fully supporting that policy or procedure. If either resources or management interest is insufficient, the new policy or procedure will probably fall short of expectations. This is especially true for RCM, an approach that is often met with skepticism and resistance by the very same people who must help implement it.

7-5.5.3.7 Informal Procedures.

RCM is a very structured, disciplined method of developing a comprehensive and effective maintenance program. It cannot be effectively implemented on an informal or ad hoc basis. The procedures for implementing an RCM approach within an organization must be formal, documented, and managed.

7-5.5.3.8 Inadequate Data Collection.

If the underlying pattern of failures for a given item is unknown, one cannot objectively determine if PM should be considered. Without adequate information regarding the frequency of failure or the parameters of the failure PDF, one cannot objectively determine when a PM task should be performed. Data that is adequate in both quantity and type (for example, time to failure) is essential to the RCM process.

7-5.6 Evaluation of Alternatives.

As a result of performing an RCM analysis, alternatives will present themselves. These alternatives fall into two categories: Maintenance Tasks and Designs. Both categories are a natural result of the RCM analysis. Examining the logic trees in paragraph 7.5-4 indicates more than one type of maintenance task may be applicable and effective for a given failure. In some cases, for example where the effects of a failure are hazardous or a hidden failure can occur, redesign is mandatory or desirable. How is it determined which tasks to perform? How are the "best" design changes (for example, in the case of failures with hazardous effects) selected? How is it determined if a design change is cost-effective (for example, in the case of a hidden failure). These questions are addressed using Trade-off Studies, Operational Analysis, and Cost-Benefit Analysis.

7-5.6.1 Trade-off Studies.

Designing a new system or a change to an existing one, even a moderately complex one, requires a series of compromises. These compromises are inevitable, given the fact that requirements often conflict. Design decisions necessary to meet one requirement may result in another requirement not being met. For example, strength and fatigue life requirements drive the selection of materials and the size (bulk) of structures in one direction. The maximum weight requirement drives these same factors in the opposite direction. Systems engineering is the process of selecting design solutions that balance the requirements and provide an optimized system. Usually, this balance means that some requirements may not be fully met. The process of selecting one design solution over another is often referred to as design trade-offs. Trade-off studies consist of the steps listed below.

- Compare two or more design solutions
- Determine which provides the best results given cost and schedule constraints

- Determine if the system requirements can be met with the selected design solution
- If the system requirements cannot be met, determine the budget and schedule required to support a design solution that does allow the system requirements to be met, or re-evaluate the requirements

7-5.6.1.2 RCM and Desired Design Changes.

An RCM analysis may indicate that a change to the design is required or desirable. In such cases, trade-off studies will probably be needed to determine if a solution can be found that is effective (affordability is addressed in a cost-benefit analysis – see paragraph 7.5.6.2).

7-5.6.1.3 RCM and Mandatory Design Changes.

When the RCM analysis shows that two or more PM tasks are applicable, trade-off studies will be needed to determine which task(s) is (are) most effective. Of course, when a specific failure has hazardous effects, redesign is mandatory if no PM tasks are effective and applicable.

7-5.6.1.4 Operational Analysis.

To determine if a specific failure has operational effects (but no hazardous effects), an analysis of the operational concept is necessary. This analysis addresses the impact of a given failure on measures of operational performance. The measures are a function of the type of product and how that product is used. For the airline industry, for example, the cost of an operational failure includes lost revenue, potential penalties (in the form of compensation to passengers), loss of customer confidence and loyalty, and the cost of fixing the failure. For a military organization that operates aircraft, the costs might include a decrease in readiness, the inability to fulfill a mission, the cost of reassigning another aircraft to replace the original aircraft, and the cost to fix the failure. For a commercial company, the cost of an operational failure of a product could include the loss of customer confidence and loyalty, the cost of repair under warranty, and possible claims by the customer for lost revenue or other non-hazardous effects of the failure.

7-5.6.2 Cost-benefit Analysis.

Another type of analysis frequently used whenever one of two or more alternatives (design A vs. design B, task 1 vs. task 2, process I vs. process II, etc.) must be selected is a cost-benefit analysis (CBA).

7-5.6.2.1 Potential Benefits.

In a CBA, the potential life-cycle benefits of and life-cycle costs to implement a given alternative are compared with those of the other alternatives. One of the most difficult steps in a CBA is finding a common basis for comparison. That basis is almost always dollars, since the costs of implementing a choice can almost always be directly measured in terms of dollars. Some of the benefits of an alternative may be intangible. However, it may be possible to attach a dollar value to even these benefits. Benefits to which a dollar value cannot be assigned should be evaluated and assigned relative numeric values for comparison purposes. For example, a maximum benefit could be assigned a value of 5, an average benefit a value of 3, and a minimum benefit a value of 1. Evaluating and comparing benefits that have both dollar values and relative numeric values requires extra effort, but it allows all benefits to be considered in the analysis.

7-5.6.2.2 Costs.

In a simple CBA, the annual costs of implementing each alternative design change, for example, are estimated. For this purpose, the analyst would sum up the estimates of the costs listed below. The analyst would estimate the annual benefits of the first alternative and then repeat this process for each of the other alternative design.

- The cost of the labor hours needed to develop the design
- The cost of any additional testing required
- Any differences in material costs
- Changes in manufacturing costs
- Additional costs due to changes in schedule
- Other costs

7-5.6.2.3 Conversion.

The analyst must convert the annual estimates to a common unit of measurement to properly compare competing alternatives. This conversion is done by discounting future dollar values, which transforms future benefits and costs to their "present value." The present value (also referred to as the discounted value) of a future amount is calculated using Equation 7-1.

Equation 7-1. Present Value

$$PV = \frac{FV}{(1 + i)n}$$

Where:
PV = Present Value
FV = Future Value
i = Interest rate per period
n = Number of compounding periods

7-5.6.2.4 Comparison.

When the costs and benefits for each competing alternative have been discounted, the analyst compares and ranks the discounted net value (discounted benefit minus discounted cost) of the competing alternatives. In the ideal case one alternative will have the lowest discounted cost and provide the highest discounted benefits – it clearly would be the best alternative. More often, however, the choice is not so clear-cut, and other techniques must be used to determine which alternative is best.

7-5.6.2.5 Dollar Values.

Earlier, it was mentioned that some benefits may not be quantifiable in terms of dollars and may have relative numeric values assigned for comparison purposes. In those cases, these numeric values can be used as tie breakers if the cost figures do not show a clear winner among the competing alternatives, and if the non-quantifiable benefits are not key factors. If they are key factors, the quantified benefits can be converted to scaled numeric values consistent with the non-quantifiable benefits. The evaluation then consists of comparing the discounted costs and the relative values of the benefits for each alternative. When the alternative with the lowest discounted cost provides the highest relative benefits, it is clearly the best alternative (the same basic rule used when there are discounted benefits). If that is not the case, the evaluation is more complex.

7-5.6.2.6 Numerical Values.

Finally, if no benefits have dollar values, numerical values can be assigned (using some relative scale) to each benefit for each competing alternative. The evaluation and ranking are then completed in the manner described in the previous paragraph.

7-5.6.2.7 Sensitivity Analysis.

Sensitivity analysis can be used to test the sensitivity and reliability of the results obtained from a CBA. For more information on conducting a CBA and related analysis, see the references in TM 5-698-2 Appendix A.

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APPENDIX A FACTORS INFLUENCING FIELD MEASURES OF RELIABILITY

A-1 INHERENT RELIABILITY VERSUS OPERATIONAL RELIABILITY.

The reliability achieved by diligent attention to failure modes and mechanisms during design and manufacture is defined as inherent reliability. The reliability observed during operation of the system in its intended environment is defined as operational reliability.

A-1.1 Inherent Reliability.

Inherent reliability is the level of reliability inherent in the system as designed and manufactured. All failures are due to inherent weaknesses in the design, flaws in the materials, or defects from the manufacturing processes. The level of inherent reliability achieved is determined through analysis and test. Although in applying analytical methods and in testing the system (the "actual" system or prototypes), the design and development team attempts to simulate the actual operating environment, it is difficult if not impossible to account for some aspects of operation.

A-1.2 Operational Reliability.

Operational reliability is the measure a customer or user of a system uses. Whenever a system fails to perform its function(s) or requires maintenance, the customer will count such events as failures, regardless of the cause. Inherent weaknesses in the design, flaws in the materials, and defects from the manufacturing processes will cause such failures, but so will maintenance errors, improper operation, and changes in operating concept. In addition, if the operating environment is substantively different from that defined during design, more failures or failure modes may occur than were addressed during design and manufacturing. Consequently, operational reliability can never be higher than inherent reliability and is usually lower.

A-2 ACCOUNTING FOR THE DIFFERENCES.

The differences between design and operational reliability can be accounted for. This can be done in two ways: the way procedures are designed and developed, and the way in which design requirements are developed.

A-2.1 Design of Procedure.

Recognizing that humans make mistakes, design techniques that minimize the chance of human error can be applied. For example, parts can be designed to mate in only one way, preventing maintenance personnel from making an incorrect connection. Displays can be designed so they are easy to read and use conventional symbols. Controls can be designed using standard orientation (for example, turn right to shut off a valve). In a similar manner, procedures can be written in a clear, concise, and logical manner. Such attention to the human element during design can minimize the opportunity for human error.

A-2.2 Design Requirements.

If the customer needs an operational reliability of 1000 hours Mean Time Between Failures (MTBF) for a system, 1000 hours cannot be used as the design requirement. If it was used and missed one failure mode due to the inexact understanding of the operating environment, the operational reliability requirement would not be met. The system must be designed to a higher level. An arbitrarily high inherent reliability requirement should not be set. To do so would drive up costs unnecessarily. A commonly used approach for setting the inherent reliability requirement is to use past experience. If experience with previous systems indicates that the operational reliability runs 10%-15% lower than what was measured during design and manufacture, then, as a rule of thumb, the inherent reliability requirement for new systems should be 12% higher than the operational reliability requirement. For example, if the inherent reliability for past systems was 1,000 hours MTBF and the observed operational reliability was only 850 hours (15% less), and the operational reliability requirement for a new system is 1,000 hours, the inherent reliability requirement must be about 11.8% higher or 1,180 hours. If this level of inherent reliability is achieved, then it is expected the operational reliability to be 1180 - (15% x 1180) = 1,003 hours.

APPENDIX B STATISTICAL DISTRIBUTION USED IN RELIABILITY AND MAINTAINABILITY

B-1 INTRODUCTION TO STATISTICAL DISTRIBUTION.

Many statistical distributions are used to model various reliability and maintainability parameters. The distribution used depends on the nature of the data being analyzed.

B-1.1 Exponential and Weibull.

These two distributions are commonly used for reliability modeling – the exponential is used because of its simplicity and because it has been shown in many cases to fit electronic equipment failure data, and the Weibull because it consists of a family of different distributions that can be used to fit a wide variety of data and it models wear out (such as, an increasing hazard function).

B-1.2 Normal and Lognormal.

Although also used to model reliability, the normal and lognormal distributions are more often used to model repair times. In this application, the normal is most applicable to simple maintenance tasks that consistently require a fixed amount of time to complete with little variation. The lognormal is applicable to maintenance tasks where the task time and frequency vary, which is often the case for complex systems and products.

B-2 THE EXPONENTIAL DISTRIBUTION.

The exponential distribution is widely used to model electronic reliability failures in the operating domain that tend to exhibit a constant failure rate. To fail exponentially means that the distribution of failure times fits the exponential distribution as shown in Table B-1. The characteristics of the exponential distribution are listed below.

- It has a single parameter, λ, which is the mean. For reliability applications, λ called the failure rate.
- λ, the failure rate, is a constant. If an item has survived for t hours, the chance of it failing during the next hour is the same as if it had just been placed into service.
- The mean-time-between-failure (MTBF) = $1/\lambda$.
- The mean of the distribution occurs at about the 63rd percentile. Thus, if an item with a 1000-hour MTBF had to operate continuously for 1000 hours, the probability of success (survival) would be only 37%.

Figure B-1 shows the exponential Probability Density Function for varying values of λ.

Table B-1 Summary of the Exponential Distribution

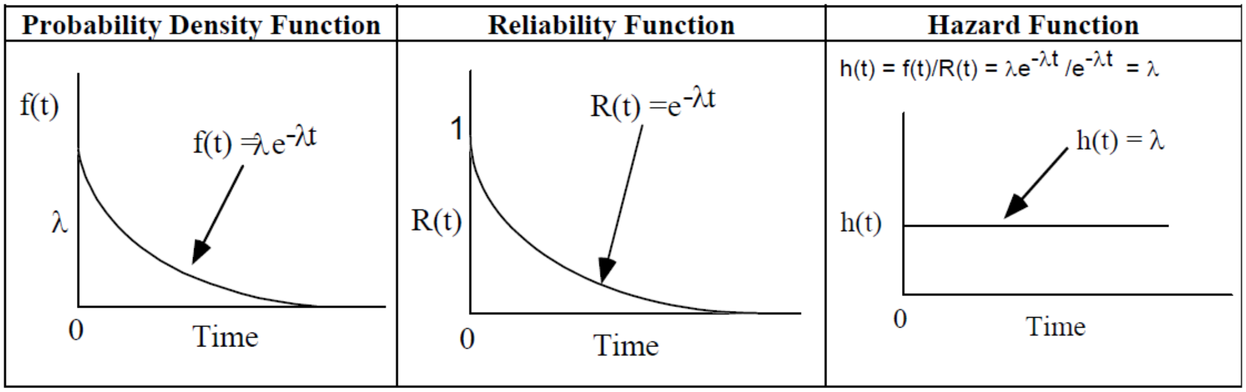
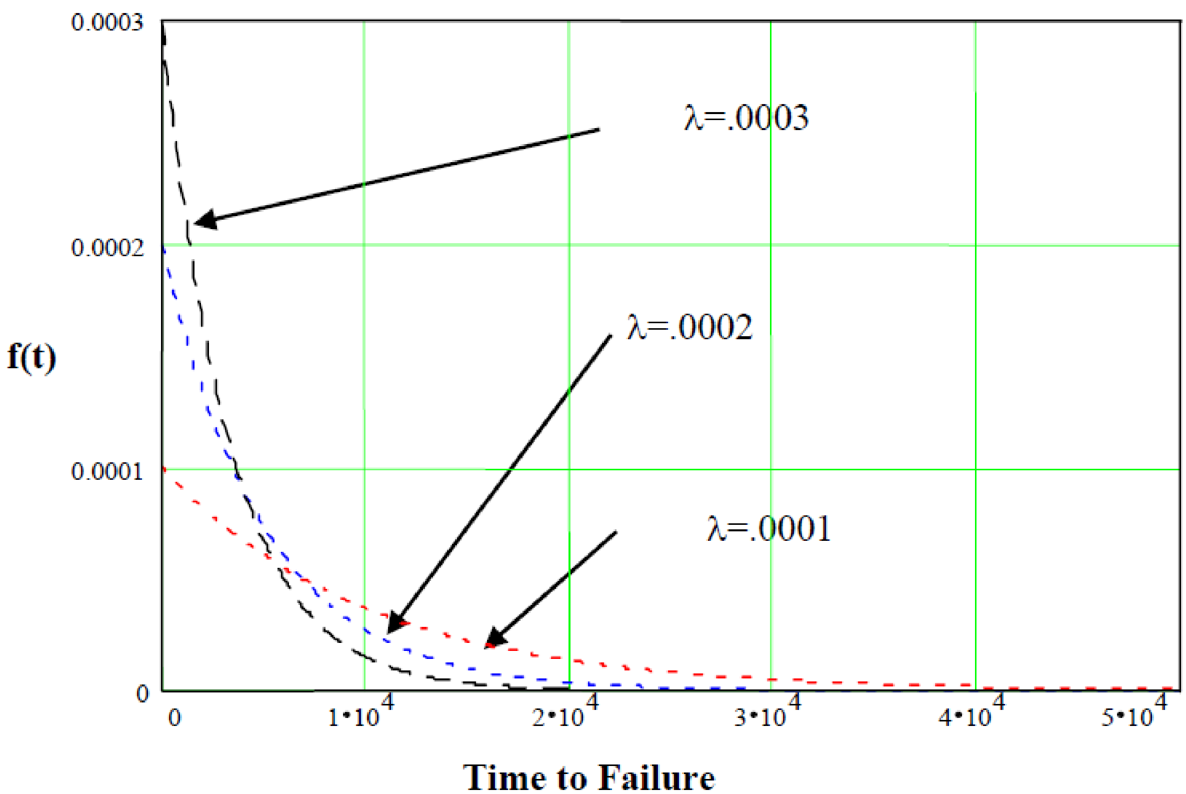


Figure B-1 The Exponential PDF for Varying Values of λ



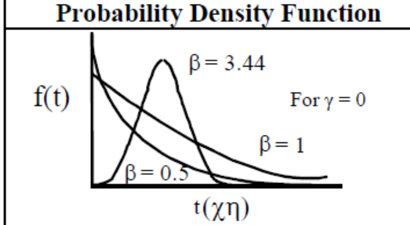
B-3 THE WEIBULL DISTRIBUTION.

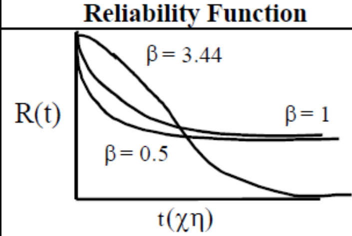
The Weibull distribution is an important distribution because it can be used to represent many different pdfs; therefore, it has many applications. The characteristics of the Weibull are listed below.

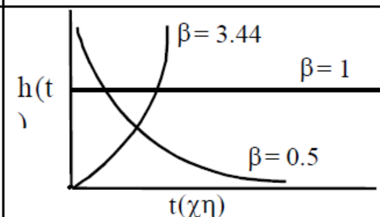
- It has 2 (β, η, and γ) parameters.
  - The shape parameter, β, describes the shape of the Probability Density Function.
  - The scale parameter, η, is the 63rd percentile value of the distribution and is called the characteristic life. In some texts, Θ, is used as the symbol for the characteristic life.
  - The location parameter, γ, is the value that represents a failure-free or prior use period for the item. If there is no prior use or period where the probability of failure is zero, then γ = 0 and the Weibull distribution becomes 2-parameter distribution.
- β, η, and γ can be estimated using Weibull probability paper or software programs.
- When β = 1 and γ = 0, the Weibull probability is exactly equivalent to the exponential distribution.
- When β, = 3.44, the Weibull closely approximates the normal distribution.

The distribution is described in Table B-2. Figure B-2 shows the 2-parameter Weibull pdf for different values of β, and a given value of η.

Table B-2 Summary of the Weibull Distribution

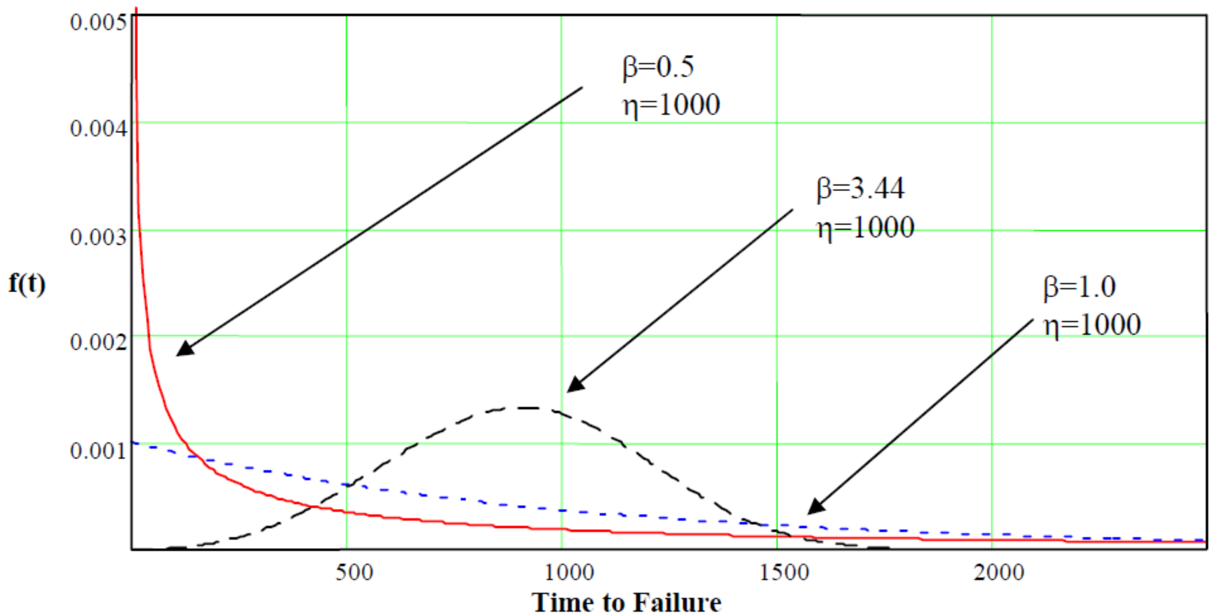
<table>
<tr><th>Probability Density Function</th><th>Reliability Function</th><th>Hazard Function</th></tr>
<tr>
<td>

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}\exp\left[-\frac{(t-\gamma)}{\eta}^{\beta}\right]$$</td>
<td>

$$R(t) = \exp\left[-\frac{(t-\gamma)^{\beta}}{\eta}\right]$$</td>
<td>

$$h(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}$$</td>
</tr>
</table>

Figure B-2 The Two-Parameter Weibull PDF for Different Values of *β* and a Given Value of *η*



B-4 THE NORMAL DISTRIBUTION.

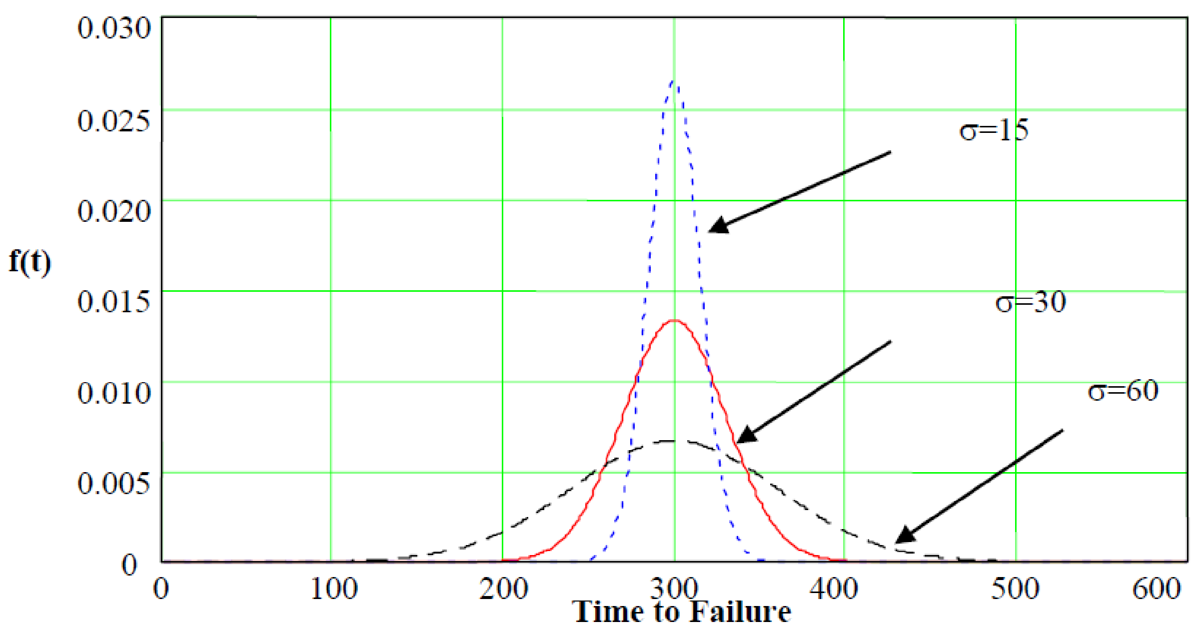
The pdf of the Normal distribution is often called the bell curve because of its distinctive shape. The Normal distribution is described in Table B-3. The characteristics of the Normal distribution are listed below.

- It has two parameters:
    - The mean, μ, is the 50th percentile of the distribution. The distribution is symmetrical around the mean.
    - The standard deviation, σ, is a measure of the amount of spread in the distribution.
- If *t* has the pdf defined in Figure B-3 and $\mu = 0$ and $\sigma = 1$, then t is said to have a standardized normal distribution.
- The integral of a distribution's pdf is its cumulative distribution function, used to derive the reliability function. The integral of the normal pdf cannot be evaluated using the Fundamental Theorem od Calculus because a function for which the derivative equals exp(-x/2) cannot be found. However, numerical integration methods have been used to evaluate the integral and tabulate values for the standard normal distribution.

Table B-3 Summary of the Normal Distribution

Probability Density Function	Reliability Function	Hazard Function
$f(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(t-\mu)^2}{2\sigma^2}}$	$R(t) = \int_t^{\infty} f(t)dt$	$h(t) = \frac{f(t)}{R(t)}$

Figure B-3 The Normal PDF for Varying Values of *σ* and Fixed *μ*.



B-5 THE LOGNORMAL DISTRIBUTION.

The lognormal distribution is summarized in Table B-4. The characteristics of the lognormal distribution are listed below.

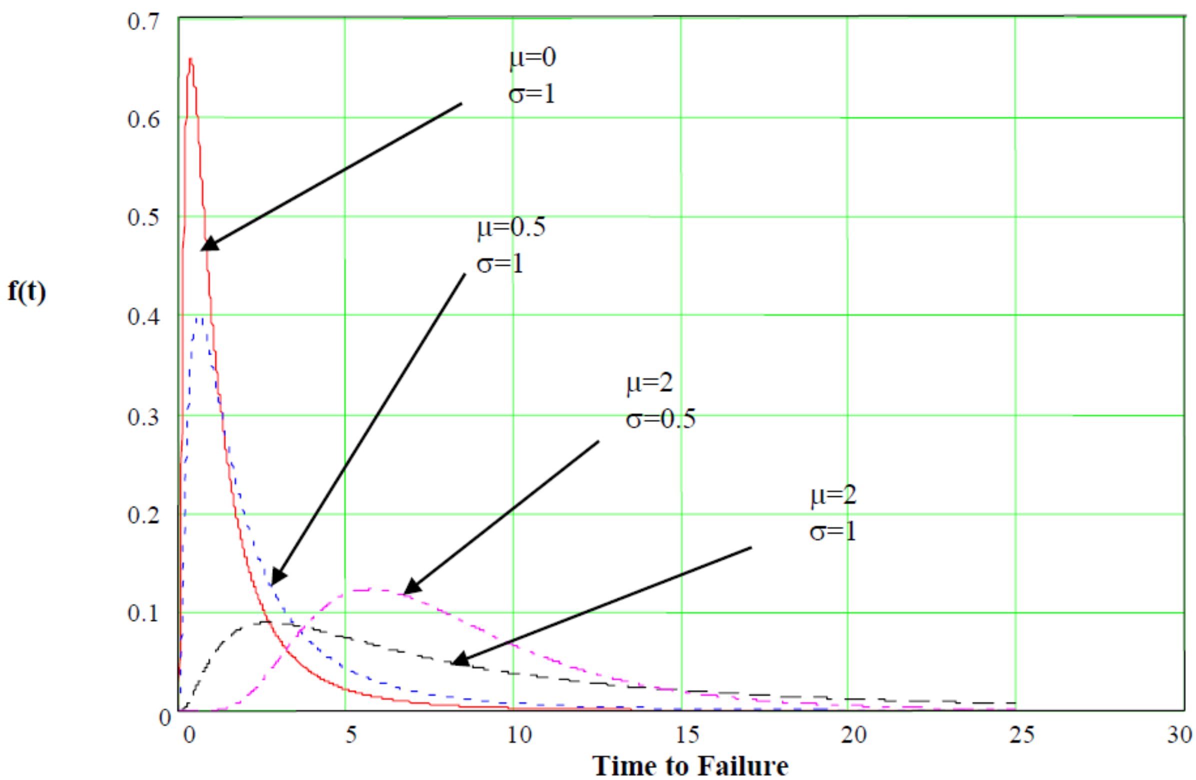
- It has two parameters:
  - The mean, μ. Unlike the mean of the Normal distribution, the mean of the lognormal is not the 50th percentile of the distribution and the distribution is not symmetrical around the mean.
  - The standard deviation, σ.
- The logarithms of the measurements of the parameter of interest (for example, time to failure, time to repair) are normally distributed.

Figure B-4 shows the distribution for different values of μ and σ.

Table B-4 Summary of the Lognormal Distribution

Probability Density Function	Reliability Function	Hazard Function
$f(t) = \frac{1}{\sigma t\sqrt{2\pi}} e^{\frac{-(\ln(t)-\mu)^2}{2\sigma^2}}$	$R(t) = \int_t^{\infty} f(t)dt$	$h(t) = \frac{f(t)}{R(t)}$

Figure B-4 The Lognormal PDF for Different Values of μ and a Fixed σ



APPENDIX C AVAILABILITY AND OPERATIONAL READINESS

C-1 AVAILABILITY.

In general, availability is the ability of a product or service to be ready for use when a customer wants to use it. That is, it is available if it is in the customer's possession and works when it's turned on or used. A product that's "in the shop" or is in the customer's possession but doesn't work is not available. Measures of availability are shown in Table C-1.

Table C-1 Quantitative Measures of Availability

Measure	Equation	Description
Inherent Availability: A_i	$\frac{MTBF}{MTBF + MTTR}$	• Where MTBF is the mean time between failure and MTTR is the mean time to repair • A probabilistic measure • Reflects the instantaneous probability that a component will be up. A_i considers only downtime for repair due to failures. No logistics delay time, preventative maintenance, etc. is included.
Operational Availability: A_O	$\frac{MTBM}{MTBM + MDT}$	• Where MTBM is the mean time between maintenance (preventative and corrective) and MDT is the mean downtime, which includes MTTR, and all other time involved with downtime such as logistic delays • A probabilistic measure • Similar to inherent availability but includes ALL downtime. Included is downtime for corrective maintenance and preventative maintenance, including any logistics delay time.

MTBF = Mean Time Between Failure MTBM = Mean Time Between Maintenance
MDT = Mean Downtime MTTR = Mean Time to Repair (corrective only)

C-1.1 Nature of the Equations.

Note that the equations are time independent and probabilistic in nature. The value of availability yielded by each equation is the same whether the period of performance being considered is 1 hour or a year.

C-1.2 Derivation of Steady State Equation for Availability.

The equations in Table C-1 are steady state equations. The equation for inherent availability (Equation C-1) is the steady state equation derived from Equation C-2, as time approaches infinity:

Equation C-1. Inherent Availability

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

Equation C-2. Inherent Availability

$$A_i = \frac{MTBF}{MTBF + MTTR} + \frac{MTTR}{MTBF + MTTR} e^{-\left(\frac{1}{MTBF} + \frac{1}{MTTR}\right)t}$$

1. Equation C-1 represents a limit for inherent availability. It represents the long-term proportion of time that a system will be operational.

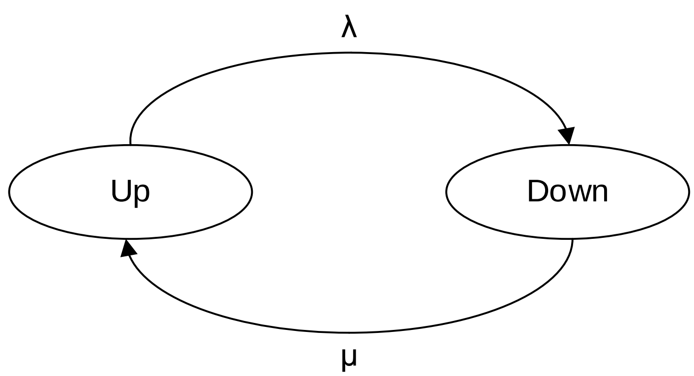
2. Assuming that the times to failure and time to repair are both exponentially distributed, with rates *λ* and *μ*, respectively, Equation C-1 can be expressed as:

Equation C-3. Inherent Availability

$$A_i = \frac{\frac{1}{\lambda}}{\frac{1}{\lambda} + \frac{1}{\mu}} = \frac{\mu}{\mu + \lambda}$$

3. The derivation of Equation C-1 now follows. A simple Markov model is used to evaluate availability. The probabilities of being in either the up state or the down state are determined using the Laplace transform. The model and equations are:

Figure C-1 Simple Markov Model



Equation C-4.

$$\frac{dP_{Up}(t)}{dt} = -\lambda \square_{Up}(t) + \mu P_{Down}(t)$$

Equation C-5.

$$sL_{Up}(s) - P_{Up}(0) = sL_{Up}(s) - 1 = -\lambda L_{Up}(s) + \mu L_{Down}(s)$$

Equation C-6.

$$1 - sL_{Up}(s) = sL_{Down}(s) = \lambda L_{Up}(s) - \mu L_{Down}(s)$$

Equation C-7.

From Equation C-4, $L_{Up}(s) = \frac{1+\mu L_{Down}(s)}{s+\lambda}$

Equation C-8.

From Equation C-5, $L_{Down}(s) = \frac{\lambda L_{Up}(s)}{s+\mu}$

4. Substituting the expression for $L_{Down}(s)$ into Equation C- 7,

Equation C-9.

$$L_{Up}(s) = \frac{1}{s+\mu+\lambda} + \frac{\mu}{s(s+\mu+\lambda)}$$

5. Then, availability equals the inverse of the Laplace transform for $L_{Up}(s)$. To obtain the inverse,

Equation C-10.

$$\frac{1}{s+\mu+\lambda} + \frac{\mu}{s(s+\mu+\lambda)} = \frac{1}{\lambda+\mu}\left(\frac{\mu(s+\mu+\lambda)+\lambda_s}{s(s+\mu+\lambda)}\right)$$

$$= \frac{1}{\lambda+\mu}\left(\frac{\mu}{s} + \frac{\lambda}{s+\mu+\lambda}\right)$$

$$= \frac{\mu}{\lambda+\mu} * \frac{1}{s} + \frac{\lambda}{\mu+\lambda} * \frac{1}{s+\mu+\lambda}$$

$$= \frac{1}{\lambda+\mu}\left(\frac{\mu}{s} + \frac{\lambda}{s+\mu+\lambda}\right)$$

$$= \frac{\mu}{\lambda+\mu} * \frac{1}{s} + \frac{\lambda}{\mu+\lambda} * \frac{1}{s+\mu+\lambda}$$

$$= \frac{\mu}{\lambda+\mu}\int_0^\infty e^{-st}dt + \frac{\lambda}{\lambda+\mu}\int_0^\infty e^{-(s+\mu+\lambda)t}dt$$

$$= \int_0^\infty \frac{\mu}{\lambda+\mu} e^{-st}dt + \frac{\lambda}{\lambda+\mu} e^{-(s+\mu+\lambda)t}dt$$

$$= \int_0^\infty \frac{\mu}{\lambda+\mu} e^{-st}dt + \frac{\lambda}{\lambda+\mu} e^{-(s+\mu+\lambda)t}dt$$

$$= L\left[\frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} e^{-(\mu+\lambda)t}\right]$$

$$A = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} e^{-(\mu+\lambda)t}$$

6. Taking the limit of Equation C-10 as t approaches infinity,

Equation C-11.

$$A_i = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} * 0 = \frac{\mu}{\lambda + \mu}$$

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

Q.E.D

C-2 OPERATIONAL READINESS.

Closely related to the concept of operational availability but broader in scope is operational readiness. Operational readiness is defined as the ability of a military unit to respond to its operational plans upon receipt of an operations order. It is, therefore, a function not only of the product availability, but also of assigned numbers of operating and maintenance personnel, the supply, the adequacy of training, and so forth.

C-2.1 Readiness in the Commercial World.

Although operational readiness has traditionally been a military term, it is equally applicable in the commercial world. For example, a manufacturer may have designed and can make very reliable, maintainable products. What if he has a poor distribution and transportation system or does not provide the service or stock the parts needed by customers to effectively use the product? Then, the readiness of this manufacturer to go to market with the product is low.

C-2.2 Relationship of Availability and Operational Readiness.

The concepts of availability and operational readiness are obviously related. Important to note, however, is that while the inherent design characteristics of a product totally determine inherent availability, other factors influence operational availability and operational readiness. The reliability and maintainability engineers directly influence the design of the product. Together, they can affect other factors by providing logistics planners with the information needed to identify required personnel, spares, and other resources. This information includes the identification of maintenance tasks, repair procedures, and needed support equipment.

APPENDIX D PREP DATABASE IEEE DOT STANDARD 3006.8

The header below represents the header in the database. Each column heading is explained in the text boxes. The formulas, representing the column heading, are contained in the Table E-1 below.

Category	Class	Unit-Years	Failures	Failure Rate (Failures/Year)	MTBF	MTTR	MTTM	MDT
Name of the Category (Example: Boiler) of the item.	Name of the Class (Example: Boiler, Hot Water) of the item.	The number of calendar hours collected for each item divided by 8760.	The number of failures recorded for each item during the data collection.	Failure Rate based on a year.	Average time between failures in hours.	Mean time to replace or repair a failed component. Logistics delay time associated with the repair, such as parts acquisitions, crew mobilization, are not included	Average downtime for preventative maintenance. This includes any logistics delay time.	Average downtime caused by preventative and corrective maintenance, including any logistics delay time.

Table D-1 Reliability and Maintainability Calculations

Calculated Data	Formula for Calculation
A_i, Inherent Availability	A_i = MTBF/(MTBF+MTTR)
A_o, Operational Availability	A_o = MTBM/(MTBM+MDT)
λ, Failure Rate (failures/hour(h))	λ = Tf/Tp
λ_y, Failure Rate (failures/year(y))	λ_y = Tf/(Tp / 8760)
MDT, Mean Down Time (h)	MDT = (Rdt + Rlt + Mdt) / Tde
MTBF, Mean Time Between Failures (h)	MTBF = Tp / Tf
MTBM, Mean Time Between Maintenance (h)	MTBM = Tp / Tde
MTTM, Mean Time To Maintain (h)	MTTM = Mdt / Tma
MTTR, Mean Time To Repair (h)	MTTR = Rdt / Tf
R(t), Reliability (for time interval t)	$R(t) = e^{-\lambda t}$
Hrdt/Year, Hours Downtime per Year	Hrdt/Year = (1 - A_o) × 8760

Table D-2 USACE-PREP Equipment Reliability Database

Category			Class	Unit-years	Failures	Failure rate (failures/year)	MTBF (hours)	MTTR (hours)	MTTM (hours)	MDT (hours)
Accumulator				**1463.2**	**10**	**0.006 834 233**	**1 281 782**	**7.80**	**0.94**	**0.98**
	Pressurized	H01-100	Accumulator, pressurized	1072.8	7	0.006 525 131	1 342 502	10.29	0.96	1.01
	Unpressurized	H01-200	Accumulator, unpressurized	390.4	3	0.007 683 510	1 140 104	2.00	0.33	0.42
Air compressor				5124.5	1592	0.310 662 877	28 198	12.20	1.55	4.24
	Electric	H02-100	Air compressor, electric	4534.6	1492	0.329 029 093	26 624	11.80	1.48	4.16
	Fuel	H02-200	Air compressor, fuel	590.0	100	0.169 499 396	51 682	17.45	2.72	5.71
Air conditioner	All types	H03-000	Air conditioner	4947.4	781	0.157 860 257	55 492	5.95	1.59	2.63
Air dryer	All types	H04-000	Air dryer, all types	2307.2	170	0.073 681 948	118 889	9.11	1.44	5.36
Air handling unit				12 173.7	2650	0.217 681 964	40 242	5.06	1.99	3.27
	Humid			379.1	68	0.179 375 438	48 836	2.55	2.53	3.21
		H05-110[a]	Air handling unit, humid, pan humid, w/o drive	25.0	0	0.027 695 536	429 882	0.00	0.00	0.00
		H05-130	Air handling unit, humid, pan humid, with drive	212.8	30	0.140 975 629	62 138	3.02	2.73	2.94
		H05-120[a]	Air handling unit, humid, spray humid, w/o drive	38.1	0	0.018205276	653 976	0.00	0.00	0.00
		H05-140	Air handling unit, humid, spray humid, with drive	103.2	38	0.368 256 160	23 788	2.27	1.59	4.31
	Multizone system	H05-310	Air handling unit, multizone system, packaged	1103.7	448	0.405 891 785	21 582	6.18	4.34	9.97
	Non-humid			10 690.9	2134	0.199 609 243	43 886	4.75	1.67	2.38
		H05-210	Air handling unit, non-humid, without drive	7821.1	1734	0.221 709 225	39 511	4.95	1.88	2.40
		H05-220	Air handling unit, non-humid, with drive	2869.8	400	0.139 380 939	62 849	4.18	1.51	2.36
Air separator	All types	H06-000	Air separator, all types	84.7	9	0.106 272 848	82 429	6.31	0.88	3.35
Surge arrester	Surge and lightning	E01-000	Surge arrester, surge and lightning	1863.4	12	0.006 439 803	1 360 290	9.50	12.28	11.66
Battery	Rechargeable			13 228.7	121	0.009 146 782	957 714	13.40	0.16	0.45
		E02-110	Battery, gel cell-sealed	3106.8	53	0.017 059 514	513 496	2.00	0.13	0.15
		E02-120	Battery, lead acid	5022.6	65	0.012 941 467	676 894	24.08	0.25	4.31
		E02-130	Battery, nickel-cadmium	5099.3	3	0.000 588 315	14 889 985	10.33	0.16	0.16

Blower				4307.0	239	0.055 490 708	157 864	9.44	0.17	0.63
	Without drive	H07-100	Blower, without drive	3947.4	189	0.047 880 115	182 957	10.75	0.17	0.32
	With drive	H07-200	Blower with drive	359.7	50	0.139 016 903	63 014	3.79	1.04	24.95
Boiler				5125.6	2190	0.427 265 681	20 502	17.69	6.61	8.72
	Hot water	H08-100	Boiler, hot water	2566.6	688	0.268 055 191	32 680	3.94	6.35	6.89
	Steam			2559.0	1502	0.586 952 425	14 925	24.40	6.70	9.37
		H08-210	Boiler, steam, high pressure, > 103.4 kPa (15 psig)	942.7	781	0.828 434 093	10 574	39.77	5.52	6.84
		H08-220	Boiler, steam, low pressure, ≤ 103.4 kPa (15 psig)	1616.2	721	0.446 097 568	19 637	13.25	48.03	40.86
Bus duct or busway	All types	E03-000	Bus duct or busway, all types, per 30.5 m (100 ft)	2462.3	143	0.058 075 621	150 838	1.65	1.08	1.26
Cabinet heaters	Forced air flow			14 053.8	64	0.004 553 920	1 923 618	3.10	1.23	1.56
		E04-100	Cabinet heaters, forced air flow, steam or hot water	13 931.1	64	0.004 594 025	1 906 825	3.10	1.23	1.56
		E04-200[a]	Cabinet heaters, forced air flow, electric	122.7	0	0.005 649 689	2 107 341	0.00	0.67	0.67
Cable				736 799.6	1366	0.001 853 964	4 725 011	5.59	4.34	4.43
	AC			698 824.2	924	0.001 322 221	6 625 216	7.29	4.35	4.50
		E06-111	Cable, ac, 0 V to 600 V, above ground, in conduit, per 305 m (1000 ft)	29 442.9	2	0.000 067 928	28 959 932	8.00	13.06	13.01
		E06-112[a]	Cable, ac, 0 V to 600 V, above ground, in trays, per 305 m (1000 ft)	15.9	0	0.043 545 391	273 412			
		E06-113	Cable, ac, 0 V to 600 V, above ground, no conduit, per 305 m (1000 ft)	33 286.3	4	0.000 120 170	72 896 904	2.50	0.05	0.08
		E06-121	Cable, ac, 0 V to 600 V, below ground, in duct, per 305 m (1000 ft)	40 000.4	5	0.000 124 999	70 080 730	16.40	0.73	2.79
		E06-122	Cable, ac, 0 V to 600 V, below ground, in conduit, per 305 m (1000 ft)	24 426.8	49	0.002 005 991	4 366 919	11.22	87.71	28.22
		E06-123	Cable, ac, 0 V to 600 V, below ground, insulated, per 305 m (1000 ft)	3095.3	80	0.025 845 534	338 937	7.60		7.60

		E06-211	Cable, ac, 601 kV to 15 kV, above ground, in conduit, per 305 m (1000 ft)	523 356.6	281	0.000 536 919	16 315 315	8.56	40.51	16.11
		E06-212[a]	Cable, ac, 601 kV to 15 kV, Above ground, in trays, per 305 m (1000 ft)	180.1	0	0.003 849 060	3 093 176			
		E06-214	Cable, ac, 601 kV to 15 kV, above ground, in trays, in conduit, per 305 m (1000 ft)	2646.0	2	0.000 755 852	11 589 564	4.00		4.00
		E06-221	Cable, ac, 601 kV to 15 kV, below ground, in conduit, per 305 m (1000 ft)	19 525.5	46	0.002 355 896	3 718 331	15.70	211.43	41.55
		E06-222	Cable, ac, 601 kV to 15 kV, below ground, in duct, per 305 m (1000 ft)	78.1	1	0.012 799 383	684 408			
		E06-223	Cable, ac, 601 kV to 15 kV, below ground, insulated, per 305 m (1000 ft)	22 770.3	454	0.019 938 292	439 356	5.13	3.97	4.01
	Aerial			37 500.3	439	0.011 706 565	748 298	2.03	0.35	1.91
		E07-200	Cable, aerial, > 15 kV, per 1.6 km (1 mile)	30 884.9	127	0.004 112 048	2 130 325	2.54	0.35	2.08
		E07-100	Cable, aerial, 0 kV to 15 kV, per 1.6 km (1 mile)	6615.5	312	0.047 162 173	185 742	1.82		1.82
	DC	E08-100	Cable, dc, insulated, per 305 m (1000 ft)	475.1	3	0.006 313 969	1 387 400	2.00		2.00
Cable connection	Underground	E05-100	Cable connection, underground, duct, ≤ 600 V	21 574.5	8	0.000 370 808	23 624 073	0.75		0.75
Capacitor bank	All types	E10-000	Capacitor/capacitor bank, all types	2041.1	104	0.050 951 857	171 927	2.37	4.27	3.13
Charger	Battery	E11-000	Charger, battery	666.0	26	0.039 040 966	224 380	7.46	0.72	2.29
Chiller				3607.7	1283	0.355 626 726	24 633	8.57	1.86	3.33
	Absorption	H10-100	Chiller, absorption	587.7	93	0.158 231 093	55 362	11.40	0.68	0.72
	Centrifugal			1054.5	529	0.501 674 408	17 462	7.73	11.29	24.68
		H10-210	Chiller, centrifugal, ≤ 600 tons (2110 kW)	152.1	298	1.959 149 120	4471	5.75	29.58	140.30
		H10-230	Chiller, centrifugal, > 1000 tons (3517 kW)	242.9	152	0.625 733 105	14 000	9.23	35.17	35.44

		H10-220	Chiller, centrifugal, 600 tons to 1000 tons (2110 kW to 3517 kW)	659.4	79	0.119 797 371	73 123	11.81	5.28	5.51
	Reciprocating			1193.5	192	0.160 868 248	54 455	10.77	1.65	2.21
		H10-321	Chiller, reciprocating, closed, with drive, 50 tons to 200 tons (176 kW to 703 kW)	881.8	139	0.157 633 096	55 572	11.11	1.53	2.06
		H10-331	Chiller, reciprocating, open, w/o drive, 50 tons to 200 tons (176 kW to 703 kW)	285.7	53	0.185 495 934	47 225	10.02	2.98	3.80
		H10-311[a]	Chiller, reciprocating, with drive, < 50 tons (176 kW)	26.0	0	0.026 651 082	446 729		1.00	1.00
	Rotary			122.5	15	0.122 477 741	71 523	7.33	8.47	9.47
		H10-420	Chiller, rotary, < 600 tons (2110 kW)	32.0	1	0.031 244 650	280 368	1.00	1.63	1.60
		H10-410	Chiller, rotary, 600 tons to 1000 tons (2110 kW to 3517 kW)	90.5	14	0.154 754 694	56 606	8.60	8.74	9.79
	Screw			649.5	454	0.698 994 807	12 532	7.83	8.12	10.69
		H10-510	Chiller, screw, ≤ 300 tons (1055 kW)	499.0	380	0.761 497 960	11 504	5.37	27.44	15.71
		H10-520	Chiller, screw, > 300 tons (1055 kW)	150.5	74	0.491 734 634	17 814	23.24	6.37	7.97
Circuit breaker				180 935.2	1437	0.007 942 070	1 102 987	15.11	7.99	11.33
	Air			9012.4	93	0.010 319 132	848 909	11.65	73.27	60.16
		E12-111	Circuit breaker, air, 3-phase, > 600 V, > 600 A, normally closed (NC)	8885.8	90	0.010 128 467	864 889	11.65	73.27	60.16
		E12-112	Circuit breaker, air, 3-phase, > 600 V, > 600 A, normally open (NO)	126.5	3	0.023 707 970	369 496			
	Fixed (includes molded case)			150 305.9	10	0.000 066 531	31 667 972	25.36	8.29	9.74
		E12-211	Circuit breaker, fixed (includes molded case), 3-phase, ≤ 600 V, ≤ 600 A, normally closed (NC)	34 569.2	4	0.000 115 710	75 706 529	23.25	3.09	9.64

		E12-212	Circuit breaker, fixed (includes molded case), 3-phase, ≤ 600 V, ≤ 600 A, normally open (NO)	26 607.0	3	0.000 112 752	77 692 576	18.67	8.61	8.73
		E12-221	Circuit breaker, fixed (includes molded case), 3-phase, ≤ 600 V, > 600 A, normally closed (NC)	88 546.5	1	0.000 011 294	75 667 016		13.62	13.62
		E12-222	Circuit breaker, fixed (includes molded case), 3-phase, ≤ 600 V, > 600 A, normally open (NO)	583.2	2	0.003 429 339	2 554 428	37.50	2.69	3.03
	Fixed (molded case)	E12-311	Circuit breaker, fixed (molded case), 600 V, single phase, normally closed (NC)	7027.5	1	0.000 142 299	61 560 528	1.00		1.00
	Metal clad (drawout)			9529.8	179	0.018 783 250	466 373	9.58	2.12	4.33
		E12-411	Circuit breaker, metal clad (drawout), ≤ 600 V, ≤ 600 A, normally closed (NC)	5705.6	18	0.003 154 788	2 776 732	6.50	2.02	2.02
		E12-412	Circuit breaker, metal clad (drawout), ≤ 600 V, ≤ 600 A, normally open (NO)	911.2	4	0.004 389 750	1 995 558	6.00	2.93	2.94
		E12-421	Circuit breaker, metal clad (drawout), ≤ 600 V, > 600 A, normally closed (NC)	2290.1	153	0.066 809 897	131 118	9.90	2.56	26.74
		E12-422	Circuit breaker, metal clad (drawout), ≤ 600 V, > 600 A, normally open (NO)	622.9	4	0.006 421 989	1 364 063	2.00	2.38	2.37
	Oil filled			1573.9	640	0.406 641 344	21 542	19.01	28.83	30.54
		E12-512	Circuit breaker, oil filled, > 5 kV, normally closed (NC)	1392.3	631	0.453 204 694	19 329	18.98	28.84	30.56
		E12-511	Circuit breaker, oil filled, > 5 kV, Normally open (NO)	181.6	9	0.049 569 941	176 720	23.75	8.00	20.60
	SF6 filled	E12-610	Circuit breaker, SF6 filled, normally closed (NC)	315.2	418	1.326 315 057	6605	12.81	51.03	42.52
	Vacuum			3170.7	96	0.030 277 684	289 322	10.71	0.61	2.91
		E12-711	Circuit breaker, vacuum, < 15 kV, < 600 A, normally closed (NC)	514.4	3	0.005 832 348	1 501 968	5.33	0.05	0.06

		E12-712[a]	Circuit breaker, vacuum, < 15 kV, < 600 A, normally closed (NC)	458.2	0	0.001 512 626	7 870 965		1.84	1.84
		E12-721	Circuit breaker, vacuum, < 15 kV, > 600 A, normally closed (NC)	1476.2	65	0.044 031 239	198 950	11.58	2.60	14.89
		E12-722	Circuit breaker, vacuum, < 15 kV, > 600 A, normally closed (NC)	716.8	28	0.039 061 903	224 259	9.39	0.35	0.49
		E12-730[a]	Circuit breaker, vacuum, > 15 kV	5.0	0	0.138 553 516	85 929			
Compressor	Refrigerant			1344.2	19	0.014 134 513	619 760	8.69	0.93	1.02
		H11-010	Compressor, refrigerant, ≤ 1 ton (3.52 kW)	74.7	2	0.026 780 146	327 108	9.00	1.31	1.53
		H11-020	Compressor, refrigerant, > 1 ton (3.52 kW)	1052.0	5	0.004 752 765	1 843 138	3.50	0.91	0.93
		H11-100	Compressor, refrigerant, screw	217.5	12	0.055 165 812	158 794	10.83	0.94	1.15
Computer				406.3	100	0.246 142 641	35 589	4.30	4.82	23.48
	Control system server	C02-200	Computer, control system server	156.9	94	0.598 997 888	14 624	4.52	4.65	27.62
	Personal computer (PC) workstation	C02-100	Computer, PC workstation	249.3	6	0.024 063 554	364 036	1.90	5.09	4.09
Condenser				3972.6	305	0.076 775 438	114 099	8.10	2.83	4.91
	Double tube	H12-100	Condensers, double tube	298.7	8	0.026 781 865	327 087	2.50	2.63	2.63
	Propeller type fans/coils	H12-200	Condensers, propeller type fans with coils, direct expansion (DX)	2097.2	267	0.127 309 780	68 809	8.18	1.98	4.91
	Shell and tube	H12-300	Condenser, shell and tube	1576.7	30	0.019 027 462	460 387	9.50	6.86	7.06
Control center	Motor/load center	C03-100	Control center, motor/load center	1109.4	12	0.010 816 417	809 880	5.03	6.40	6.38
Control panel				6247.8	73	0.011 684 020	749 742	2.86	4.29	4.36
	Generator	C04-100	Control panel, generator, w/o switchgear	1808.4	30	0.016 589 350	528 050	4.38	0.62	1.45
	Heating, ventilation, and air conditioning (HVAC)/chillers/air-handling unit (AHU)	C04-200	Control panel, HVAC/chillers/AHU, w/o switchgear	3841.9	32	0.008 329 286	1 051 711	2.07	1.41	1.45
	Switchgear controls	C04-300	Control panel, switchgear controls	597.6	11	0.018 407 130	475 903	1.27	7.01	6.96

Control system				605.1	385	0.636 294 482	13 767	5.35	0.92	1.68
	≤ 1000 acquisition points	C12-100	Control system, ≤ 1000 acquisition points	384.7	99	0.257 318 645	34 043	1.73	1.26	1.43
	> 1000 acquisition points	C12-200	Control system, > 1000 acquisition points	220.3	286	1.298 060 184	6749	6.75	0.88	1.72
Convector	Fin tube baseboard			6387.9	8	0.001 252 62	6 994 782	2.44	0.13	0.15
		H13-110	Convector, fin tube baseboard, electric	1519.8	8	0.005 263 936	1 664 154	2.44	0.33	0.43
		H13-120[a]	Convector, fin tube baseboard, steam or hot water	4868.2	0	0.000 142 384	83617694		0.08	0.08
Cooling tower				2063.7	556	0.269 418 665	32514	13.56	1.50	2.24
	Atmospheric type (w/o fans)	H14-100	Cooling tower, atmospheric type (w/o fans, motors, and internal lift pump)	323.7	24	0.074 137 736	118158	88.92	0.99	1.14
	Atmospheric type (with fans)	H14-300	Cooling tower, atmospheric type (with fans, motors, and internal lift pump)	1037.4	502	0.483 905 897	18103	8.77	4.34	8.28
	Evaporative type (w/o fans)	H14-200	Cooling tower, evaporative type (w/o fans, motors, and internal lift pump)	515.3	3	0.005 821 372	1 504 800	16.67	1.44	1.46
	Evaporative type (with fans)	H14-400	Cooling tower, evaporative type (with fans, motors, and internal lift pump)	187.2	27	0.144 194 894	60 751	6.25	3.83	4.78
Damper assembly				18 711.9	74	0.003 954 699	2 215 086	23.10	0.07	0.65
	Motor operated	H15-100	Damper assembly, motor operated	15 793.2	48	0.003 039 287	2 882 255	28.73	0.07	0.54
	Pneumatically operated	H15-200	Damper assembly pneumatically operated	2918.7	26	0.008 907 946	983 392	11.83	4.00	59.87
Dehumidifier	> 10 lb/h (4.54 kg/h)	H16-100	Dehumidifier, > 4.54 kg/h (10 lb/h)	98.3	68	0.691 808 122	12 662	16.26	17.27	32.31
Direct fired furnace				1301.1	404	0.310 517 283	28 211	3.64	13.86	23.35
	≤ 500 MB/h	H17-100	Direct fired furnace, ≤ 500 MBH (147 kW)	161.4	6	0.037 173 459	235 652	0.83	3.33	3.82
	> 500 MB/h	H17-200	Direct fired furnace, >500 MBH (147 kW)	1139.6	398	0.349 230 237	25 084	3.67	15.69	24.90
Distribution panel				7939.1	31	0.003 904 724	2 243 436	20.86	3.4	11.70

	≤ 225 A	E13-100	Distribution panel, ≤ 225 A, circuit breakers, not included (wall mount unit)	6552.6	25	0.003 815 271	2 296 036	22.69	1.41	10.90
	> 225 A	E13-200	Distribution panel, > 225 A, circuit breakers, not included (wall mount unit)	1386.5	6	0.004 327 482	2 024 272	16.00	10.06	14.34
Drive				4534.9	169	0.037 266 634	235 063	13.08	2.15	14.04
	Adjustable speed	E14-100	Drive, adjustable speed	3158.4	96	0.030 395 480	288 201	15.51	3.45	22.10
	Variable frequency	E14-200	Drive, variable frequency	1376.5	73	0.053 032 158	165 183	9.07	1.28	7.59
Engine				1245.6	2007	1.611 246 868	5437	1.36	2.87	2.71
	Diesel	E15-100	Engine, diesel	207.2	134	0.646 760 906	13 544	9.64	3.27	4.11
	Gas	E15-200	Engine, gas	1038.4	1873	1.803 679 412	4857	1.00	0.75	0.94
Evaporator	Coil			8150.2	40	0.004 907 850	1 784 896	13.03	0.27	0.29
		H18-100	Evaporator, direct expansion, coil	7114.1	31	0.004 357 533	2 010 312	14.55	0.27	0.29
		H18-120	Evaporator, direct expansion, shell tube	1036.1	9	0.008 686 501	1 008 461	5.17	0.28	0.30
Fan				19 708.4	1549	0.078 595 830	111 456	10.70	2.09	3.71
	Centrifugal	H19-100	Fan, centrifugal	11 895.7	577	0.048 504 894	180 600	10.51	1.71	3.57
	Propeller/disc	H19-200	Fan, propeller/disc	3857.7	649	0.168 236 811	52 069	10.88	2.09	4.37
	Tubeaxial	H19-300	Fan, tubeaxial	2244.8	69	0.030 737 667	284 992	5.51	4.04	4.09
	Vaneaxial	H19-400	Fan, vaneaxial	1710.3	254	0.148 515 645	58 984	14.24	1.10	1.61
Filter				5796.7	33	0.005 692 936	1 538 749	11.66	0.30	0.36
	Electrical	E16-200[a]	Filter, electrical, tempest	342.1	0	0.002 026 405	5 875 341			
	Mechanical			5454.6	33	0.006 049 940	1 447 948	11.66	0.30	0.36
		H20-100	Filter, mechanical, air regulator set	3314.5	22	0.006 637 450	1 319 784	15.33	0.05	0.08
		H20-200[a]	Filter, mechanical, fuel oil	743.2	0	0.000 932 659	12 765 459		0.49	0.49
		H20-300	Filter, mechanical, lube oil	1396.9	11	0.007 874 695	1 112 424	3.95	1.47	1.72
Fuse				10 226.0	483	0.047 232 405	185 466	4.00		4.00
	> 15 kV	E17-300	Fuse, > 15 kV	4756.7	483	0.101 541 423	86 270	4.00		4.00
	> 5 kV ≤ 15 kV	E17-200[a]	Fuse, > 5 kV ≤ 15 kV	3590.5	0	0.000 193 050	61 672 329			
	0 kV to 5 kV	E17-100[a]	Fuse, 0 kV to 5 kV	1878.8	0	0.000 368 923	32 271 812			
Gauge	Fluid level	C05-100	Gauge, fluid level	830.2	4	0.004 817 989	1 818 186	3.31	7.13	6.04
Generator				4538.6	2283	0.503 018 519	17 415	23.24	2.93	3.93

	Diesel engine			3045.1	1305	0.428 550 581	20 441	19.29	2.02	3.08
		E18-111	Generator, diesel engine, packaged, < 250 kW, continuous	15.0	16	1.063 558 550	8 237			
		E18-112	Generator, diesel engine, packaged, < 250 kW, standby	857.8	281	0.327 590 557	26 741	12.24	1.69	4.88
		E18-121	Generator, diesel engine, packaged, 250 kW to 1.5 MW, continuous	266.0	155	0.582 686 262	15 034	25.74	0.52	1.15
		E18-122	Generator, diesel engine, packaged, 250 kW to 1.5 MW, standby	1439.8	358	0.248 652 553	35 230	12.95	1.72	2.63
		E18-211	Generator, diesel engine, unpackaged, 750 kW to 7 MW, continuous	180.6	328	1.815 727 611	4825	25.08	3.86	5.00
		E18-212	Generator, diesel engine, unpackaged, 750 kW to 7 MW, standby	285.9	167	0.584 093 735	14 998	23.91	2.57	3.11
	Gas turbine			983.7	485	0.493 016 528	17 768	25.05	2.39	2.72
		E19-111	Generator, gas turbine, packaged, 750 kW to 7 MW, continuous	185.5	295	1.590 684 138	5507	27.31	0.83	1.23
		E19-112	Generator, gas turbine, packaged, 750 kW to 7 MW, standby	612.4	113	0.184 526 491	47 473	6.05	4.40	4.42
		E19-211	Generator, gas turbine, unpackaged, 750 kW to 7 MW, continuous	185.9	77	0.414 185 923	21 150	50.33	13.26	15.87
	Hydro turbine	E20-000	Generator, hydro turbine	90.4	27	0.298 790 286	29 318	78.36	238.44	310.21
	Natural gas			281.4	250	0.888 285 342	9862	5.87	139.75	64.13
		E21-110	Generator, natural gas, < 250 kW, continuous	7.4	5	0.674 926 036	12 979	1.50		1.50
		E21-120	Generator, natural gas, < 250 kW, standby	222.4	31	0.139 419 404	62 832	6.33	32.87	34.60
		e21-210	generator, natural gas, ≥ 250 kW, continuous	51.7	214	4.140 691 264	2116		191.73	71.13
	Steam	E23-000	Generator, steam, heat recovery	20.5	86	4.185 891 452	2093	162.40		45.84
	Steam turbine	E22-000	Generator, steam turbine	117.4	130	1.107 687 280	7908	100.59	288.24	263.61
Heat exchanger				4858.5	272	0.055 984 436	156 472	10.81	1.11	1.74

	Boiler system	H21-100	Heat exchanger, boiler system, steam	964.0	164	0.170 129 316	51 490	7.22	18.15	19.15
	Lube oil	H21-200	Heat exchanger, lube oil	546.2	15	0.027 462 330	318 982	12.21	6.52	14.46
	Radiator	H21-310	Heat exchanger, radiator, small tube	1801.7	65	0.036 076 572	242 817	12.55	0.23	0.60
	Water to water	H21-400	Heat exchanger, water to water	1546.6	28	0.018 104 293	483 863	10.10	0.38	0.86
Heat pump	All types	H22-000	Heat pump	1330.4	82	0.061 635 471	142 126	3.26	0.76	6.37
Heater	Lube/fuel oil or jacket water	E24-110	Heater, lube/fuel oil or jacket water, electric	768.1	62	0.080 713 618	108 532	3.13	1.21	1.28
Humidifier	All types	H23-000	Humidifier	1569.1	38	0.024 217 472	361 722	4.11	1.86	2.00
Humistat assembly	All types	H24-000	Humistat assembly	643.3	10	0.015 544 284	563 551	1.00		1.00
Inverter	All types	E25-000	Inverter, all types	612.1	38	0.062 079 275	141 110	17.45	3.93	7.59
Line conditioner	All types	E26-000[a]	Line conditioner, all types	10.7	0	0.064 971 423	183 247			
Meter				18 288.1	26	0.001 421 689	6 161 684	38.78	0.38	1.80
	Electric	C06-100	Meter, electric	15 067.2	7	0.000 464 587	18 855 470	1.29	3.29	3.10
	Fuel	C06-200	Meter, fuel	238.2	13	0.054 567 200	160 536	72.00		72.00
	Water	C06-300	Meter, water	2982.7	6	0.002 011 594	4 354 756	4.75	0.01	0.04
Motor	Electric			33 939.9	567	0.016 705 988	524 363	29.11	1.09	3.59
		E29-100	Motor, electric, dc	1513.9	119	0.078 605 141	111 443	67.60	0.42	0.97
		E29-210	Motor, electric, induction, ≤ 600 V	3195.9	340	0.106 385 715	82 342	21.50	14.55	53.01
		E29-220	Motor, electric, induction, > 600 V	429.9	11	0.025 584 819	342 391	4.44	3.29	3.31
		E29-310[a]	Motor, electric, single phase, ≤ 5 A	25 377.5	0	0.000 027 314	435 895 106		0.49	0.49
		E29-320	Motor, electric, single phase, >5 A	1455.1	1	0.000 687 237	12 746 688	3.00	0.71	0.72
		E29-410	Motor, electric, synchronous, ≤ 600 V	1726.6	94	0.054 441 911	160 905	7.34	1.77	6.37
		E29-420	Motor, electric, synchronous, > 600 V	241.0	2	0.008 298 661	1 055 592	36.00	3.00	4.65
Motor generator set	3 phase			509.9	23	0.045 104 339	194 216	6.71	0.84	0.84
		E27-120	Motor generator set, 3 phase, 400 Hz	202.6	1	0.004 937 036	1 774 344	8.00	2.87	2.89

		E27-110	Motor generator set, 3 phase, 60 Hz	307.4	22	0.071 573 093	122 392	6.62	0.82	0.83
Motor starter				4056.8	33	0.008 134 545	1 076 889	4.33	0.62	1.34
	≤ 600 V	E28-100	Motor starter, ≤ 600 V	3505.6	28	0.007 987 258	1 096 747	3.37	0.72	1.66
	> 600 V	E28-200	Motor starter, > 600 V	551.2	5	0.009 071 298	965 683	9.15	0.48	0.87
Network hub				234.0	2	0.008 545 408	1 025 112	2.75		2.75
	Ethernet	C07-100	Network hub, Ethernet	229.0	2	0.008 732 057	1 003 200	2.75		2.75
	Fiber-optic	C07-200[a]	Network hub, fiber-optic	5.0	0	0.138 553 516	85 929			
Network printer				13 311.4	4682	0.351 727 580	24 906	1.69	1.55	3.29
	Inkjet	NWP-100	Network printer, inkjet	1260.0	670	0.531 744 876	16 474	1.74	1.78	5.57
	Laser	NWP-200	Network printer, laser	12 051.4	4012	0.332 906 396	26 314	1.68	1.50	2.87
Oil cooler	All types	E30-000	Oil cooler	92.9	3	0.032 302 791	271 184	13.25	0.50	2.20
Pipe				14 886.9	22	0.001 477 814	5 927 674	8.38	7.72	7.72
	Flex			1818.8	10	0.005 498 167	1 593 258	3.38	4.00	3.50
		H25-112	Pipe, flex, non-reinforced, > 100 mm (4 in)	206.3	3	0.014 544 485	602 290	3.33	4.00	3.60
		H25-111	Pipe, flex, reinforced, < 100 mm (4 in)	273.8	3	0.010 957 670	799 440	8.00		8.00
		H25-122	Pipe, flex, reinforced, > 100 mm (4 in)	1338.7	4	0.002 987 876	2 931 848	2.25		2.25
	Refrigerant			11 221.0	6	0.000 534 713	16 382 612	9.33	3.06	3.20
		H25-310	Pipe, refrigerant, < 25 mm per 30.5 m (1 in per 100 ft)	7913.6	3	0.000 379 094	23 107 704	10.67	2.00	2.11
		H25-320	Pipe, refrigerant, 25 mm to 80 mm per 30.5 m (1 in to 3 in per 100 ft)	3307.4	3	0.000 907 065	9 657 520	8.00	8.78	8.73
	Water			1847.1	6	0.003 248 338	2 696 764	14.08	8.00	8.01
		H25-410[a]	Pipe, water, ≤ 50 mm per 30.5 m (2 in per 100 ft)	462.5	0	0.001 498 852	7 943 294			
		H25-450[a]	Pipe, water, > 300 mm per 30.5 m (12 in per 100 ft)	8.2	0	0.084 984 454	140 094			
		H25-420	Pipe, water, 50 mm to 100 mm per 30.5 m (2 in to ≤ 4 in per 100 ft)	292.3	6	0.020 530 031	426 692	14.08		14.08
		H25-430[a]	Pipe, water, 100 mm to 200 mm per 30.5 m (4 in to 8 in per 100 ft)	268.7	0	0.002 579 961	4 614 729			

		H25-440[a]	Pipe, water, 200 mm to 300 mm per 30.5 m (8 in to 12 in per 100 ft)	815.6	0	0.000 849 893	14 008 612		8.00	8.00
Pressure control assembly	All types	C08-000	Pressure control assembly	896.3	82	0.091 485 687	95 753	8.10	3.53	4.08
Pressure regulator	Hot gas	C09-100	Pressure regulator, hot gas	2711.4	29	0.010695434	819 041	2.94	1.68	19.52
Programmable logic controller	All types	C10-000	Programmable logic controller (PLC)	203.9	6	0.029 422 829	297 728	23.50	2.00	73.27
Pump				25 386.6	3097	0.121 993 479	71 807	11.83	1.75	6.24
	Centrifugal			23 888.4	2917	0.122 109 700	71 739	11.91	1.92	6.47
		H26-110	Pump, centrifugal, with drive	21 835.4	2655	0.121 591 798	72 045	11.95	2.21	7.95
		H26-120	Pump, centrifugal, w/o drive	2052.9	262	0.127 621 356	68 641	11.28	1.04	1.52
	Positive displacement	H26-200	Pump, positive displacement	1498.2	180	0.120 140 438	72 915	7.91	0.70	4.74
Recloser (interrupter)				8368.5	85	0.010 157 168	862 445	5.00	6.02	5.97
	Electronic	E31-100	Recloser (interrupter), electronic	1949.4	13	0.006 668 840	1 313 572			
	Hydraulic	E31-200	Recloser (interrupter), hydraulic	2939.1	58	0.019 734 144	443 901		8.00	8.00
	Undefined type	E31-099[a]	Recloser (interrupter), undefined type	3480.0	14	0.004 022 941	2 177 511	5.00	5.00	5.00
Rectifiers	All types	E32-000	Rectifiers, all types	563.4	2	0.003 549 686	2 467 824	16.00	3.45	3.47
Relay	Electromechanical			5307.4	5	0.000 942 089	9 298 488	26.33	3.63	3.70
		E33-110	Relay, electromechanical, differential, differential voltage	828.1	2	0.002 415 059	3 627 240	35.50	4.28	4.51
		E33-120[a]	Relay, electromechanical, drawout	790.4	0	0.000 876 976	13 576 000			
		E33-130	Relay, electromechanical, overcurrent	3688.8	3	0.000 813 265	10 771 400	8.00	3.35	3.36
Router	Wired	RTR-100	Router, wired	2763.5	262	0.094 806 605	92 399	2.14	1.13	3.37
Sending unit				43 914.1	171	0.003 893 968	2 249 633	6.39	0.07	1.56
	Air velocity	C13-100	Sending unit, air velocity	7492.2	47	0.006 273 186	1 396 420	6.96	0.04	1.30
	Pressure	C13-200	Sending unit, pressure	7565.9	95	0.012 556 363	697 654	5.82	0.10	2.22
	Temperature	C13-300	Sending unit, temperature	28 856.0	29	0.001 004 991	8 716 496		0.25	0.39
Server				8145.9	540	0.066 290 672	132 145	3.02	1.00	2.41

	Blade	SVR-100	Server, blade	526.0	25	0.047 528 517	18 310	2.68	0.70	2.29
	Rack mount	SVR-200	Server, rack mount	6323.2	387	0.061 203 480	143 129	3.02	0.98	2.38
	Tower case	SVR-300	Server, tower case	1296.8	128	0.0987 065 589	88 748	3.08	1.09	2.49
Strainer				9788.4	88	0.008 990 193	974 395	16.96	0.35	0.62
	Air or gaseous	H27-110	Strainer, air or gaseous, air systems	304.2	1	0.003 287 222	266 4864			
	Liquid			9484.2	87	0.009 173 117	954 964	16.96	0.35	0.62
		H27-210[a]	Strainer, liquid, coolant	488.2	0	0.001 419 921	8 384 847		1.62	1.62
		H27-220[a]	Strainer, duplex fuel/lube oil	280.2	0	0.002 473 565	4 813 224		0.86	0.86
		H27-230[a]	Strainer, liquid, fuel oil	460.4	0	0.001 505 416	7 908 659		1.67	1.67
		H27-240	Strainer, liquid, lube oil	1161.2	25	0.021 528 741	406 898	14.29	1.85	4.12
		H27-251	Strainer, water, ≤ 100 mm (4 in)	6466.1	25	0.003 866 327	2 265 716	2.25	0.00	0.00
		H27-252	Strainer, water, > 100 mm (4 in)	628.1	37	0.058 908 203	148 706	25.58	4.03	8.99
Switch				36 667.8	385	0.010 499 665	834 312	8.63	2.01	7.08
	Automatic transfer			2883.7	101	0.035 024 398	250 111	7.89	2.40	2.96
		E34-110	Switch, automatic transfer, ≤ 600 V, > 600 A	1030.8	27	0.026 193 875	334 429	2.66	8.98	8.32
		E34-120	Switch, automatic transfer, ≤ 600 V, 0 A to 600 A	1852.9	74	0.039 936 775	219 347	9.90	1.82	2.42
	Disconnect			19 349.5	23	0.001 188 660	7 369 646	17.83	1.75	1.90
		E34-211	Switch, disconnect, enclosed, ≤ 600 V	8372.7	6	0.000 716 616	12 224 124		2.09	2.09
		E34-212	Switch, disconnect, enclosed, > 600 V to ≤ 5 kV	2238.8	2	0.000 893 351	9 805 776	46.00	3.03	3.38
		E34-213	Switch, disconnect, enclosed, > 5 kV	2091.2	15	0.007 172 820	1 221 277	15.82	2.08	2.86
		E34-222[a]	Switch, disconnect, fused, dc, > 600 A; ≤ 600 V	861.5	0	0.000 804 591	14 797 365			
		E34-221[a]	Switch, disconnect, fused, dc, ≤ 600 A; ≤ 600 V	5785.4	0	0.000 119 811	99 372 047		0.54	0.54
	Electric	E34-310	Switch, electric, on/off breaker type, non-knife, ≤ 600 V	3115.2	2	0.000 642 008	13 644 684	1.00	0.01	0.01
	Float	E34-400	Switch, float, electric	2513.6	87	0.034 611 071	253 098	9.84	0.91	22.86
	Manual transfer			640.4	0	0.001 082 408	10 999 388			

		E34-510[a]	Switch, manual transfer, ≤ 600 V, ≤ 600 A	266.6	0	0.002 599 818	4 579 482			
		E34-520[a]	Switch, manual transfer, ≤ 600 V, > 600 A	373.8	0	0.001 854 517	6 419 906			
	Oil filled	E34-610[a]	Switch, oil filled, ≥ 5 kV	300.2	0	0.002 308 614	5 157 129		1.38	1.38
	Pressure	E34-700	Switch, pressure	6661.0	169	0.025 371 639	345 267	7.04	3.08	16.89
	Static			921.5	2	0.002 170 468	4 035 996	13.00	2.04	2.11
		E34-810[a]	Switch, static, ≤ 600 V, 0 A to 600 A	498.4	0	0.001 390 875	8 559 953		0.03	0.03
		E34-820	Switch, static, ≤ 600 V, > 600 A ≤ 1000 A	130.0	1	0.007 692 794	1 138 728	2.00	0.05	0.08
		E34-830	Switch, static, ≤ 600 V, > 1000 A	271.7	1	0.003 680 066	2 380 392	24.00	3.47	3.58
		E34-850[a]	Switch, static, with insulated-gate bipolar transistor (IGBT) technology	15.3	0	0.045 210 636	26 3341			
		E34-860[a]	Switch, static, w/o IGBT technology	6.0	0	0.114 582 754	103 906			
	Vibration	E34-900	Switch, vibration	282.7	1	0.003 537 644	2 476 224		0.50	0.50
Switchgear				6747.6	47	0.006 965 393	1 257 646	24.32	3.35	3.56
	Bare bus			4229.7	42	0.009 929 718	882 200	24.31	3.64	3.94
		E36-110	Switchgear, bare bus, ≤ 600 V (circuit breaker not included)	2493.6	23	0.009 223 683	949 729	7.91	4.28	4.35
		E36-130	Switchgear, bare bus, > 5 kV (circuit breaker not included)	895.7	15	0.016 746 168	523 105	2.27	1.28	1.30
		E36-120	Switchgear, bare bus, > 600 V to ≤ 5 kV (circuit breaker not included)	840.4	4	0.004 759 530	1 840 518	195.75	6.59	9.67
	Insulated bus			1713.6	5	0.002 917 820	3 002 242	24.40	2.90	2.97
		E36-210[a]	Switchgear, insulated bus, ≤ 600 V (circuit breaker not included)	505.2	0	0.001 372 077	8 677 224		3.18	3.18
		E36-220	Switchgear, insulated bus, > 600 V to ≤ 5 kV (circuit breaker not included)	405.8	2	0.004 928 902	1 777 272	5.00	0.77	0.78
		E36-230	Switchgear, insulated bus, > 5 kV (circuit breaker not included)	802.7	3	0.003 737 584	2 343 760	37.33	14.01	14.43

	Load center (free standing unit)	E36-300[a]	Switchgear, load center (free standing unit)	804.3	0	0.000 861 792	13 815 200		0.59	0.59
Tank				4876.1	137	0.028 096 327	311 785	18.02	1.11	3.10
	Air	E37-110	Tank, air, receiver	1519.1	22	0.014 482 011	604 888	11.53	1.25	1.63
	Liquid			3357.0	115	0.034 257 224	255 712	18.99	0.88	5.31
		E37-210	Tank, liquid, day, fuel	484.8	2	0.004 125 040	2 123 616	5.00	0.31	0.35
		E37-220	Tank, liquid, fuel	614.7	21	0.034 162 930	256 418	13.80	1.28	2.52
		E37-230	Tank, liquid, water	2257.4	92	0.040 754 653	214 945	20.57	0.91	7.23
Thermocouple	All types	C14-000	Thermocouple	5761.5	101	0.017 530 270	499 707	13.48	14.00	479.86
Thermostat	Radiator	C15-100	Thermostat, radiator	8735.0	153	0.017 515 835	500 119	3.16	1.13	2.00
Transducer				26 305.4	81	0.003 079 211	2 844 885	3.74	0.06	0.09
	Flow	C16-100	Transducer, flow	1188.0	5	0.004 208 706	2 081 400	2.00	1.17	1.18
	Pressure	C16-200	Transducer, pressure	2139.0	28	0.013 090 212	669 202	7.50	2.28	3.07
	Temperature	C16-300	Transducer, temperature	22 978.4	48	0.002 088 916	4 193 563	1.89	0.02	0.03
Transformer				164 239.4	456	0.002 776 435	3 155 125	14.92	10.83	11.43
	Dry			96 735.4	248	0.002 563 695	3 416 944	3.63	2.77	3.40
		E38-111	Transformer, dry, air cooled, ≤ 500 kVA	86095.4	226	0.002 624 996	3 337 148	2.13	2.36	2.33
		E38-112	Transformer, dry, air cooled, > 500 kVA ≤ 1500 kVA	1700.3	3	0.001 764 436	4 964 760	2.00	5.41	36.50
		E38-113[a]	Transformer, dry, air cooled, > 1500 kVA ≤ 3000 kVA	999.7	0	0.000 693 337	17 171 772		4.39	4.39
		E38-114[a]	Transformer, dry, air cooled, > 3000 kVA ≤ 5000 kVA	1142.2	0	0.000 606 854	19 618 918		5.50	5.50
		E38-121	Transformer, dry, isolation, delta wye, < 600 V	6797.8	19	0.002 795 011	3 134 156	21.26	0.93	2.52
	Liquid			67 504.0	208	0.00 3081 299	2 842 957	36.89	13.29	14.16
		E38-211	Transformer, liquid, forced air, ≤ 5000 kVA	5849.5	52	0.008 889 630	985 418	8.69	0.98	2.08
		E38-212	Transformer, liquid, forced air, > 5000 kVA ≤ 10 000	600.6	23	0.038 292 418	228 766	251.00	22.96	23.60
		E38-213	Transformer, liquid, forced air, >10 000 kVA ≤ 50 000 kVA	482.1	34	0.070 518 976	124 222	965.33	21.69	24.34
		E38-214	Transformer, liquid, forced air, > 50 000	18.6	24	1.289 752 650	6792	11.95	2.43	5.30
		E38-221	Transformer, liquid, non-forced air, ≤ 3000 kVA	59 708.0	63	0.001 055 134	8 302 262	2.33	2.00	2.02

		E38-222	Transformer, liquid, non-forced air, > 3000 kVA ≤ 10 000 kVA	190.7	1	0.005 242 671	1 670 904	1.00	2.67	2.50
		E38-223	Transformer, liquid, non-forced air, > 10 000 kVA ≤ 50 000 kVA	654.3	11	0.016 811 614	521 068	6.09	0.58	0.65
UPS				1232.8	65	0.052 726 440	166 141	5.24	2.08	6.48
	Rotary	E39-100	Uninterruptible power supply (UPS), rotary	134.7	2	0.014 848 263	589 968	8.75	6.11	7.81
	Small computer room floor	E39-200	Uninterruptible power supply (UPS), small computer room floor	724.7	41	0.056 575 669	154 837	6.25	2.12	3.74
	Solid state			373.4	22	0.058 919 780	148 677	2.93	1.14	11.44
		E39-310	Uninterruptible power supply (UPS), solid state, 60 Hz/module	357.3	22	0.061 578 810	142 257	2.93	1.09	13.83
		E39-320[a]	Uninterruptible power supply (UPS), solid state, with IGBT technology	16.1	0	0.042 990 437	276 941		1.30	1.30
Valve				157 135.7	1345	0.008 559 481	1 023 427	11.94	2.62	8.08
	3-way			16 490.6	7	0.000 424 484	20 636 822	5.86	0.52	0.81
		H28-110	Valve, 3-way, diverting/sequencing	736.9	4	0.005 428 034	1 613 844	9.13	0.02	0.59
		H28-120	Valve, 3-way, mixing control	15 753.7	3	0.000 190 432	46 000 792	1.50	1.02	1.03
	Backflow preventer	H28-200	Valve, backflow preventer	742.6	30	0.040 401 283	216 825	13.27	1.11	15.63
	Ball			2703.6	5	0.001 849 362	4 736 770	1.20	0.19	0.24
		H28-310[a]	Valve, ball, normally closed (NC)	1092.7	0	0.000 634 368	18 768 000		0.19	0.19
		H28-320	Valve, ball, normally open (NO)	1611.0	5	0.003 103 705	2 822 434	1.20		1.20
	Butterfly			18 225.8	26	0.001 426 553	6 140 677	3.88	0.55	0.67
		H28-410	Valve, butterfly, normally closed (NC)	2809.7	26	0.009 253 770	946 641	3.88	1.01	1.67
		H28-420[a]	Valve, butterfly, normally open (NO)	15 416.1	0	0.000 044 963	64 793 976		0.48	0.48
	Check	H28-500	Valve, check	4699.2	44	0.009 363 323	935 565	26.69	1.11	8.60
	Control			22 796.4	647	0.028 381 678	308 650	17.32	0.50	15.34
		H28-610	Valve, control, normally closed (NC)	17 563.1	388	0.022 091 808	396 527	17.76	0.23	8.54

		H28-620	Valve, control, normally open (NO)	5233.3	259	0.049 490 515	177 004	16.93	1.56	38.85
	Expansion	H28-700[a]	Valve, expansion	1984.1	0	0.000 349 348	34 080 094			
	Gate			19 302.5	97	0.005 025 268	1 743 191	10.45	0.81	33.26
		H28-830	Valve, gate, double flap	173.2	76	0.438 785 195	19 964	10.67		10.67
		H28-810	Valve, gate, normally closed (NC)	1830.5	8	0.004 370 485	2 004 354	7.50	0.59	0.99
		H28-820	Valve, gate, normally open (NO)	17 298.8	13	0.000 751 498	11 656 721	9.31	1.30	150.13
	Globe			41 402.3	66	0.001 594 112	5 495 221	16.65	1.00	1.74
		H28-910[a]	Valve, globe, normally closed (NC)	22 125.4	0	0.000 031 328	80 035 718		1.00	1.00
		H28-920	Valve, globe, normally open (NO)	19 277.0	66	0.003 423 773	2 558 581	16.65	0.40	129.72
	Plug			15 233.3	148	0.009 715 539	901 648	1.81	0.05	1.59
		H28-A10	Valve, plug, normally closed (NC)	8845.9	123	0.013 904 727	630 002	1.37	0.05	1.17
		H28-A20	Valve, plug, normally open (NO)	6387.4	25	0.003 913 946	2 238 151	4.00		4.00
	Reducing	H28-B10	Valve, reducing, makeup water	701.9	100	0.142 473 496	61 485	5.56	0.59	17.99
	Relief	H28-C00	Valve, relief	10 598.4	165	0.015 568 452	562 676	7.55	102.91	137.61
	Suction	H28-D00	Valve, suction	2255.1	10	0.004 434 439	1 975 447	7.25	0.61	0.77
Valve operator				10 025.1	80	0.007 980 004	1 097 744	10.02	1.06	1.47
	Electric	C17-100	Valve operator, electric	3684.0	43	0.011 672 052	750 511	16.42	0.98	1.40
	Hydraulic	C17-200	Valve operator, hydraulic	68.2	6	0.087 937 681	99 616	3.00	2.16	2.20
	Pneumatic	C17-300	Valve operator, pneumatic	6272.8	31	0.004 941 961	1 772 576	2.92	0.98	1.76
Voltage regulator	Static	E40-100	Voltage regulator, static	3381.5	77	0.022 771 080	384 698	15.73	0.53	2.23
Water cooling coil	Fan coil unit	H29-100	Water cooling coil, fan coil unit	16 076.0	96	0.005 971 646	1 466 932	3.72	2.04	2.09
Water heater	Domestic hot water			1399.8	44	0.031 431 955	278 697	6.37	1.28	12.85
		H30-110	Water heater, domestic hot water, electric	957.5	19	0.019 843 370	441 457	9.64	0.82	29.64
		H30-130	Water heater, domestic hot water, gas	442.4	25	0.056 516 246	155 000	3.53	1.35	9.11
Workstation	All types	WST-000	Workstation	169 635.1	7948	0.046 853 516	186 966	0.73	0.62	1.11

[a] Failure rate calculated using 50% single-sided confidence interval.Part 2: Equipment reliability surveys conducted between 1976 and 1994.

APPENDIX E GLOSSARY

E-1 ACRONYMS.

AC	Alternating Current
AIAG	Automotive Industry Action Group
BIT	Build-in-Test
\1\ C5ISR	Command, Control, Communications, Computer, Cyber, Intelligence, Surveillance and Reconnaissance /1/
CA	Criticality Analysis
CAIP	Critical Asset Identification Process
CBA	Cost-Benefit Analysis
CND	Cannot Duplicate
CM	Corrective Maintenance
DOD	Department of Defense
DOE	Design of Experiments
EMSG	European Maintenance System Guide
EPRI	Electric Power Research Institute
FAA	Federal Aviation Administration
FEA	Finite Element Analysis
FIT	Framework for Integrated Test
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FRACAS	Failure Reporting Analysis and Corrective Actions
FTA	Fault Tree Analysis
HFE	Human Factors Engineering
HVAC	Heating, Ventilating and Air Conditioning
IEEE	Institute of Electrical and Electronic Engineers

LRU	Line Replaceable Unit
MDT	Mean Downtime
MSG	Maintenance Steering Group
MTBF	Mean Time Between Failures
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NERC	North American Electric Reliability Corporation
NDI	Nondestructive Inspection
NPRD	Nonelectronic Parts Reliability Data
O&M	Operations and Maintenance
O&S	Operating & Support
OEM	Original Equipment Manufacturer
OH	Operating Hours
OSHA	Occupational Safety and Health Administration
PC	Personal Computer
PDF	Probability Density Function
PLC	Programmable Logic Controller
PM	Preventative Maintenance
PREP	Power Reliability Enhancement Program
PREPIS	Power Reliability Enhancement Program Information System
QFD	Quality Function Deployment
R/A	Reliability/Availability
R&M	Reliability and Maintainability
R&R	Remove and Replace

RAM	Reliability, availability, and maintainability
RBD	Reliability Block Diagram
RCM	Reliability-Centered Maintenance
RGT	Reliability Growth Test
RPN	Risk Priority Number
RTOK	Retest OK
SCA	Sneak Circuit Analysis
SCADA	Supervisory Control and Data Acquisition
SE	Systems Engineering
TA	Thermal Analysis
TAAF	Test Analyze and Fix
TM	Technical Manual
UFC	Unified Facilities Criteria
UPS	Uninterruptable Power Supply
US	United States
USACE	United States Army Corps of Engineers
WCCA	Worst Case Circuit Analysis
WRA	Weapon Replaceable Assembly

E-2 DEFINITION OF TERMS.

Active Redundancy: Two or more components in a parallel combination where all are powered and active simultaneously. Not all components are required to function for the system (or next higher assembly) to function.

Active Time: That time during which an item is in an operational inventory.

Affordability: Affordability is a measure of how well customers can afford to purchase, operate, and maintain a product over its planned service life. Affordability is a function of product value and product costs. It is the result of a balanced design in which long-term support costs are considered equally with near-term development and manufacturing costs.

Alignment: Performing the adjustments that are necessary to return an item to specified operation.

Alpha (α): The probability, expressed as a decimal that a given part will fail in the identified mode. The sum of all alphas for a component will equal one (1).

Assessment: Current evaluation of a component's or system's reliability. A prediction.

Availability: The instantaneous probability that a component will be up.

Availability, Inherent (A_i): The instantaneous probability that a component will be up. Ai considers only downtime for repair due to failures. No logistics delay time, preventative maintenance, etc. is included.

Availability, Operational (A_o): A_o is the instantaneous probability that a component will be up but differs from inherent availability in that it includes ALL downtime. Included is downtime for both corrective maintenance and preventative maintenance, including any logistics delay time.

Beta (β): The conditional probability that the effect of a failure mode will occur, expressed as a decimal. If a failure is to occur, what is the probability that the outcome will occur.

Block Diagrams: Availability block diagrams and reliability block diagrams are visual representations of the interactions between contributors to reliability, availability, and maintainability. Each block tends to represent a physical component in the system and its associated reliability/availability.

Boolean Algebra: Boolean algebra is a method of calculating system availability based on logical interactions between components. AND and OR operators define mathematical operations.

Brownout: Occurs during a power failure when some power supply is retained, but the voltage level is below the minimum level specified for the system. A very dim household light is a symptom of a brownout.

Calibration: A comparison of a measuring device with a known standard and a subsequent adjustment to eliminate any differences. Not to be confused with alignment.

Cannot Duplicate (CND): A situation when a failure has been noted by the operator but cannot be duplicated by maintenance personnel attempting to correct the problem. Also see Retest OK.

Checkout: Tests or observations of an item to determine its condition or status.

Compensating Provision: Actions available or that can be taken to negate or reduce the effect of a failure on a system.

Component: A piece of electrical or mechanical equipment viewed as an entity for the purpose of reliability evaluation.

Condition-Based PM: Maintenance performed to assess an item's condition and performed as a result of that assessment. Some texts use terms such as predictive maintenance and on-condition. The definition of condition-based PM used herein includes these concepts. In summary, the objectives of condition-based PM are to first evaluate the condition of an item, then, based on the condition, either determine if a hidden failure has occurred or determine if a failure is imminent, and then take appropriate action. Maintenance that is required to correct a hidden failure is, of course, corrective maintenance.

Confidence Level/Interval: A statistical measure of the uncertainty associated with an estimate. For example, an estimate of MTBF is 103 hours. Using statistical techniques (such as the chi-square method) a 95% confidence interval of 100.1 to 105.9 is obtained. That is, 95% of the time, the actual MTBF will be between 100.1 and 105.9 hours. The confidence interval depends on sample size and variance.

Corrective Action: A documented design, process, procedure, or materials change implemented and validated to correct the cause of failure or design deficiency.

Corrective Maintenance (CM): All actions performed as a result of failure, to restore an item to a specified condition. Corrective maintenance can include any or all the following steps: Localization, Isolation, Disassembly, Interchange, Reassembly, Alignment and Checkout.

Cost: The expenditure of resources (usually expressed in monetary units) necessary to develop, acquire, or use a product over some defined period of time.

Critical Equipment/Systems: Critical equipment/systems include those items of equipment or systems that directly supply power to equipment and systems used to perform the primary mission(s) of the C5ISR site.

Criticality: A relative measure of the consequences of a failure mode and the frequency of its occurrence.

Criticality Analysis (CA): A procedure by which each potential failure mode is ranked according to the combined influence of severity and probability of occurrence.

Critical Load: That portion of the technical load used to successfully accomplish the site missions and having a requirement for 100 percent continuity in power service, such as from the Uninterruptible Power Supply (UPS) system. These loads also include any equipment which, upon loss of power, will create an unacceptable impact on the mission or mission equipment.

Dependability: A measure of the degree to which an item is operable and capable of performing its required function at any (random) time during a specified mission profile, given item availability at the start of the mission. (Item state during a mission includes the combined effects of the mission-related system R&M parameters but excludes non-mission time; see availability).

Design Agency: The agency responsible for the overall design of the facility.

Detection Method: The method by which a failure can be discovered by the system operator under normal system operation or by a maintenance crew carrying out a specific diagnostic action.

Diagnostics: The hardware, software, or other documented means used to determine that a malfunction has occurred and to isolate the cause of the malfunction. Also refers to "the action of detecting and isolating failures or faults."

Downtime: That element of time during which an item is in an operational inventory but is not in condition to perform its required function.

Effectiveness: The degree to which PM can provide a quantitative indication of an impending functional failure, reduce the frequency with which a functional failure occurs, or prevent a functional failure.

End Effect: The consequence a failure mode has upon the operation, function, or status at the highest indenture level.

Equipment: A general term designating an item or group of items capable of performing a complete function.

Failure (f): The termination of the ability of a component or system to perform a required function.

\1\ **Facility Energy:** The energy delivered to, generated by and/or consumed by an operational facility. /1/

Failure, Catastrophic: A failure that causes loss of the item, human life, or serious collateral damage to property.

Failure, Hidden: A failure that is not evident to the operator; that is, it is not a functional failure. A hidden failure may occur in two different ways. In the first, the item that has failed is one of two or more redundant items performing a given function. The loss of one or more of these items does not result in a loss of the function. The second way in which a hidden failure can occur is when the function performed by the item is normally inactive. Only when the function is eventually required will the failure become evident to the operator. Hidden failures must be detected by maintenance personnel.

Failure, Intermittent: Failure for a limited period of time, followed by the item's recovery of its ability to perform within specified limits without any remedial action.

Failure, Random: A failure, the occurrence of which cannot be predicted except in a probabilistic or statistical sense.

Failure Analysis: Subsequent to a failure, the logical systematic examination of an item, its construction, application, and documentation to identify the failure mode and determine the failure mechanism and its basic course.

Failure Cause: The physical or chemical processes, design defects, quality defects, part misapplication or other processes which are the basic reason for failure, or which can initiate the physical process by which deterioration proceeds to failure.

Failure Effect: The consequence(s) a failure mode has on the operation, function, or status of an item. Failure effects are typically classified as local, next higher level, and end.

Failure Mechanism: The physical, chemical, electrical, thermal, or other process which results in failure.

Failure Mode: The way in which a failure is observed, describes the way the failure occurs, such as, short, open, fracture and excessive wear.

Failure Mode and Effects Analysis (FMEA): A procedure by which each potential failure mode in a product (system) is analyzed to determine the results or effects thereof on the product and to classify each potential failure mode according to its severity or risk probability number.

Failure Modes, Effects, and Criticality Analysis (FMECA): The term is used to emphasize the classifying of failure modes as to their severity (criticality).

Failure Rate (λ): The mean (arithmetic average, also known as the forced outage rate) number of failures of a component and/or system per unit exposure time. The most common unit in reliability analyses is hours (h). However, some industries use failures per year (f/y) which is denoted by the symbol (λ_y).

Failure Reporting and Corrective Action System (FRACAS): A closed-loop system for collecting, analyzing, and documenting failures and recording any corrective action taken to eliminate or reduce the probability of future such failures.

False Alarm: A fault indicated by BIT or other monitoring circuitry where no fault can be found or confirmed.

Fault: Immediate cause of failure (for example, maladjustment, misalignment, defect, etc.).

Fault Detection (FD): A process that discovers the existence of faults.

Fault Isolation (FI): The process of determining the location of a fault to the indenture level necessary to affect repair.

Fault Tree Analysis: An analysis approach in which each potential system failure is traced back to all faults that could cause the failure. It is a top-down approach, whereas the FMEA is a bottom-up approach.

Hidden Failure: See Failure, Hidden.

Hours Downtime Per Year (Hrdt/Year): Average hours the item is expected to be not functional in a one-year period, caused by both preventative maintenance and failures. This includes any logistics delay time.

Indenture Levels: The levels which identify or describe the relative complexity of an assembly or function.

Isolation: Determining the location of a failure to the extent possible, using accessory equipment.

Item: Used interchangeably in this document with product or equipment. Usually refers to the individual article rather than the inclusive class or kind of product.

Item Criticality Number (C_r): A relative measure of consequence of an item failure and its frequency of occurrence. This factor is not applicable to a qualitative analysis.

Laplace Statistic: A statistic used to determine if a data set indicates a positive or negative trend, at a given level of confidence.

Levels of Maintenance: The division of maintenance, based on different and requisite technical skill, which jobs are allocated to organizations in accordance with the availability of personnel, tools, supplies, and the time within the organization. Typical maintenance levels are organizational, intermediate, and depot.

Life Cycle Cost (LCC): The sum of acquisition, logistics support, operating, and retirement and phase-out expenses.

Line Replaceable Unit (LRU): A unit designed to be removed upon failure from a larger entity (product or item) in the operational environment, normally at the organizational level.

Local Effect: The consequence a failure mode has on the operation, function or status of the specific item being analyzed.

Localization: Determining the location of a failure to the extent possible, without using accessory test equipment.

Logistic Delay Time: That element of downtime during which no maintenance is being accomplished on the item because of either supply or administrative delay.

Logistics Support: The materials and services required to enable the operating forces to operate, maintain, and repair the end item within the maintenance concept defined for that end item.

Maintainability: The relative ease and economy of time and resources with which an item can be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. Also, the probability that an item can be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

Maintenance: All actions necessary for retaining an item in or restoring it to a specified condition.

Maintenance Action: An element of a maintenance event. One or more tasks (such as, fault localization, fault isolation, servicing, and inspection) necessary to retain an item's condition or restore it to a specified condition.

Maintenance Concept: A description of the planned general scheme for maintenance and support of an item in the operational environment. It provides a practical basis for design, layout, and packaging of the system and its test equipment. It establishes the scope of maintenance responsibility for each level of maintenance and the personnel resources required to maintain the system.

Maintenance Event: One or more maintenance actions required to effect corrective and preventive maintenance due to any type of failure or malfunction, false alarm, or scheduled maintenance plan.

Maintenance Task: The maintenance effort necessary for retaining an item in or changing/restoring it to a specified condition.

Maintenance Time: An element of downtime that excludes modification and delay time.

Mean: Also called the expected value of a random variable, the mean is defined as follows: Let X be a continuous random variable with a probability density function = *f*. The expected value of X is:

$$E(X) = \int_{x} x f(x) dx$$

The mean, or expected value, is analogous to the concept of center of mass in mechanics.

Mean Downtime (MDT): The average downtime caused by preventative and corrective maintenance, including any logistics delay time. This is synonymous with mean time to restore system (MTTRS) as found in some publications.

Mean Time Between Failures (MTBF): The mean exposure time between consecutive failures of a component. MTBF is a require measurement used for calculating inherent availability. It can be estimated by dividing the exposure time by the number of failures in that period.

Mean Time Between Maintenance (MTBM): The average time between all maintenance events that cause downtime, both preventative and corrective maintenance, and includes any associated logistics delay time.

Mean Time To Failure (MTTF): The mean exposure time between consecutive repairs (or installations) of a component and the next failure of that component. MTTF is commonly found for nonrepairable items such as fuses or bulbs, etc.

Mean Time To Maintain (MTTM): The average downtime for preventative maintenance. This includes any logistics delay time.

Mean Time To Repair (MTTR): The mean time to replace or repair a failed component. Logistics delay time associated with the repair, such as parts acquisitions, crew mobilization, are not included. It can be estimated by dividing the summation of repair times by the number of repairs and, therefore, is practically the average repair time. The most common unit in reliability analyses is hours (h/f).

Mission Phase Operational Mode: The statement of the mission phase and mode of operation of the system or equipment in which the failure occurs.

Mission Reliability: The probability that a system will complete its intended mission. Hardware failures that do not hinder the success of the mission (for example, due to redundancy) are not counted against mission reliability.

Next Higher Level Effect: The consequence a failure mode has on the operation, functions, or status of the items in the next higher indenture level above the specific item being analyzed.

Non-Destructive Inspection (NDI): Any method used for inspecting an item without physically, chemically, or otherwise destroying or changing the design characteristics of the item. However, it may be necessary to remove paint or other external coatings to use the NDI method. A wide range of technology and methods are usually described as nondestructive inspection, evaluation, or testing (collectively referred to as non-destructive evaluation or NDE). The core of NDE is commonly thought to contain ultrasonic, visual, radiographic, eddy current, liquid penetrant, and magnetic particle inspection methods. Other methodologies include acoustic emission, use of laser interference, microwaves, NMR and MRI, thermal imaging, and so forth.

On-Condition Maintenance: See Condition-based PM.

One-Line Diagram: A one-line diagram is a drawing of an electrical or mechanical system that shows how the parts interact. It shows paths of electrical flow, water flow, gas flow, etc. It will also list system component and component sizes.

Operating and Support (O&S) Costs: Those costs associated with operating and supporting (such as, using) a product after it is purchased or fielded.

Operational Readiness: The ability of a military unit to respond to its operation plan(s) upon receipt of an operations order. (A function of assigned strength, item availability, status, or supply, training, etc.).

Operational Reliability: The reliability of a system or equipment after it is put in operation.

Parallel Combination: The combining of two or more items in such a way that not all components are required for operation – thus, the parallel combination is characterized by alternate paths of operation.

Predicted: That which is expected at some future time, postulated on analysis of past experience and tests.

Predictive Maintenance: See Condition-based PM.

Preventative Maintenance (PM): All actions performed in an attempt to retain an item in a specified condition. These actions may or may not result in downtime for the component and may or may not be performed on a fixed interval.

Probability Distribution: A formula that describes the probabilities associated with the values of a discrete random variable.

Product: An equipment, item, or hardware contracted for by a customer. Usually used to describe the inclusive class or kind of item, equipment, etc., rather than each individual entity.

Qualitative Analysis: A means of conducting an analysis without data. Team member subjectively rank probabilities of occurrence, typically 1-10, in place of failure rates.

Quantitative Analysis: An analysis that is supported with data. Data is available for assigning failure rates and failure mode probabilities.

Reassembly: Assembling the items that were removed during disassembly and closing the reassembled items.

Redundancy: The existence of more than one means for accomplishing a given function. Each means of accomplishing the function need not necessarily be identical.

Reliability (R(t)): The probability that a component can perform its intended function for a specified time interval (t) under stated conditions. This calculation is based on the exponential distribution.

Reliability-Centered Maintenance (RCM): A disciplined logic or methodology used to identify preventive and corrective maintenance tasks to realize the inherent reliability of equipment at a minimum expenditure of resources, while ensuring safe operation and use.

Reliability Prediction: An estimate of reliability based on information that includes historical data, piece parts count, complexity, and piece part failure rates.

Retest Ok (RTOK): A situation where a failure was detected on the system, either through inspection or testing, but no fault can be found in the item that was eventually removed for repair at a field or depot location. Also see Cannot Duplicate.

Risk Priority Number (RPN): The Risk Priority Number (RPN) is the product of the Severity (1-10) and the Occurrence (1-10) ranking. The Risk Priority Number is used to rank and identify the concerns or risks associated with the operation due to the design. RPN = (S) x (O).

Severity: Considers the worst possible consequence of a failure classified by the degree of injury, property damage, system damage and mission loss that could occur.

Scheduled Maintenance: Periodic prescribed inspection and/or servicing of products or items accomplished on a calendar, mileage, or hours of operation basis. Included in Preventive Maintenance.

Servicing: The performance of any act needed to keep an item in operating condition, (such as lubricating, fueling, oiling, cleaning, etc.), but not including preventive maintenance of parts or corrective maintenance tasks.

Single-Point Failure: A failure of an item that causes the system to fail and for which no redundancy or alternative operational procedure exists.

Standby Redundancy: Two or more components in a parallel combination where not all components are required at any time. The other components are disconnected, and power is applied prior to or simultaneously with switching.

Subsystem: A combination of sets, groups, etc. that performs an operational function within a product (system) and is a major subdivision of the product. (Example: Data processing subsystem, guidance subsystem).

Success: Achievement of an objective or completion of a function or set of functions.

Switch: A device that selects one component in a parallel or redundant configuration as the functioning component. Used for standby redundancy. Incorporates such provisions as logic circuits and fault detection.

System: A group of components connected or associated in a fixed configuration to perform a specified function.

System Downtime: The time interval between the commencement of work on a system (product) malfunction and the time when the system has been repaired and/or checked by the maintenance person, and no further maintenance activity is executed.

Technical Load: That portion of the operational which consists of general lighting and heating, ventilating, and air conditioning (HVAC) systems necessary to maintain normal operations and loads directly associated with the C5ISR missions at the site.

Testability: A design characteristic that allows status (operable, inoperable, or degraded) of an item to be determined and the isolation of faults within the item to be performed in a timely manner.

Total Downtime Events (Tde): The total number of downtime events (including scheduled maintenance and failures) during the Tp.

Total Failures (Tf): The total number of failures during the Tp.

Total Maintenance Actions (Tma): The total number of preventative maintenance actions which take the component down during the Tp.

Total Period (Tp): The calendar time over which data for the item was collected.

Total System Downtime: The time interval between the reporting of a system (product) malfunction and the time when the system has been repaired and/or checked by the maintenance person, and no further maintenance activity is executed.

Unscheduled Maintenance: Corrective maintenance performed in response to a suspected failure.

Uptime: That element of ACTIVE TIME during which an item is in condition to perform its required functions. (Increases availability and dependability).

Useful Life: The number of life units from manufacture to when the item has an unrepairable failure or unacceptable failure rate. Also, the period of time before the failure rate increases due to wearout.

User: The using Government Agency.

Using Government Agency: The Government Agency that will be responsible for completing the site missions and will have operational authority for the facility.

Wearout: The process that results in an increase of the failure rate or probability of failure as the number of life units increases.

Year (y): The unit of time measurement approximately equal to 8765.81277 hours (h). Any rounding of this value will have adverse effects on analyses depending on the magnitude of that rounding. 8766 is used commonly as it is the result of rounding to 365.25×24 (which accounts for a leap year every 4th year). 8760, which is 365×24, is the most commonly used value in the power reliability field. By convention, 8760 will be used throughout this document.

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APPENDIX F REFERENCES

DEPARTMENT OF DEFENSE

DOD Instruction 3020.45, *Defense Critical Infrastructure Program (DCIP) Implementation*

MIL-M-24100, *Functionally Oriented Maintenance Manuals (FOMM) for Electronic, Electromechanical, and Ordnance Equipment, Systems, and Platforms*

\1\ MIL-STD-882, *Department of Defense Standard Practice: System Safety*

MIL-STD-1472, *Department of Defense Design Criteria Standard: Human Engineering*

MIL-STD-3071, *Tactical Microgrid Communications and Control* /1/

GOVERNMENT

NASA, *Reliability Centered Maintenance Guide for Facilities and Collateral Equipment*

TM 5-691, *Utility Systems Design Requirements for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*

TM 5-698-1, *Reliability/Availability of Electrical & Mechanical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) Facilities*

TM 5-698-2, *Reliability-Centered Maintenance (RCM) for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*

TM 5-698-3, *Reliability Primer for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*

TM 5-698-4, *Failure Modes, Effects and Criticality Analysis (FMECA) for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*

TM 5-698-5, *Survey of Reliability and Availability Information for Power Distribution, Power Generation, and Heating, Ventilating and Air Conditioning (HVAC) Components for Commercial, Industrial, and Utility Installations*

TM 5-698-6, *Reliability Data Collection Manual for Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) Facilities*

NON-GOVERNMENT

AIAG, *Potential Failure Mode and Effects Analysis – FMEA*

FMD-97, *Failure Mode/Mechanism Distribution-97*

\1\ IEEE 3005.4*, Recommended Practice for Improving the Reliability of Emergency and Standby Power Systems*

IEEE 3006.8, *Recommended Practice for Analyzing Reliability Data for Equipment Used in Industrial and Commercial Power Systems* /1/

IEEE 493-2007, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*

John Wiley and Sons, Inc., *Methods for Statistical Analysis of Reliability and Life Test Data*

North American Electric Reliability Corporation, *"Reliability Issues Steering Committee Report on Resilience," November 8, 2018.* https://www.nerc.com/comm/RISC/Related%20Files%20DL/RISC%20Resilience%20Report_Approved_RISC_Committee_November_8_2018_Board_Accepted.pdf

NPRD-95, *Non-electric Parts Reliability Data-95*

\1\ Reliability Analysis Center, *Reliability Toolkit: Commercial Practices Edition* /1/

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 1-200-01, *DoD Building Code*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UFC 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Application*

\1\ **Websites**

FEMA HAZUS, https://www.fema.gov/flood-maps/products-tools/hazus /1/

UFC 3-520-05
1 May, 2015
Change 2, 9 January, 2020

UNIFIED FACILITIES CRITERIA (UFC)

\2\STATIONARY AND MISSION BATTERIES/2/

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-520-05
1 May, 2015
Change 2, 9 January, 2020

UNIFIED FACILITIES CRITERIA (UFC)

\2\STATIONARY AND MISSION BATTERIES/2/

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **\1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	09/09/15	Clarified NFPA 1 applicability to stationary batteries. Updated ventilation requirements for valve-regulated lead acid batteries. Removed dates from industry standards for consistency with other UFCs; this administrative edit is not marked with a \1\ /1/.
2	01/09/20	Revised Title and updates to Paragraphs 3.3.2 and 3.3.3; this edit is marked with a \2\ /2/.

This UFC supersedes UFC 3-520-05, dated 14 April 2008.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, \2*DOD Building Code*/2/, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 3-520-05, \2*Stationary and Mission Batteries/2/*

Superseding: This is a complete revision and reissuance of UFC 3-520-05, *Stationary Battery Areas*, dated April 14, 2008.

Description: This UFC 3-520-05 provides criteria for the design of stationary \2\and mission/2/ battery installations.

Reasons for Document:

- Provide technical requirements for enclosed battery areas.
- Address multi-discipline requirements for battery area layout and design. This document addresses architectural, electrical, mechanical, civil, fire protection, and plumbing requirements.
- Incorporate new and revised industry standards.

Impact: There are negligible cost impacts associated with this UFC. However, the following benefits should be realized:

- Standardized criteria have been prepared to assist engineers with the unique installation requirements for battery systems.
- Over design of battery areas should be avoided by ensuring that industry standard documents are preferentially applied.
- Safety requirements associated with batteries are addressed.

Unification Issues:

None.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

Unified Facility Criteria (UFC) 3-520-05 provides design criteria for stationary secondary battery installations. These batteries are operated on a continuous float charge and may require ventilation to limit hydrogen gas concentrations. This UFC also addresses \2\mobile/2/ lithium-based batteries that are stored or charged inside facilities.

This UFC serves as a planning, engineering, and design reference for professional facility planners, designers, and constructors, including DoD personnel and Government contractors. Designers and planners will use this document for individual project planning, for preparing engineering documentation, and for preparing contract documents for construction and renovation projects.

1-1.1 UFC Hierarchy.

UFC 3-501-01 provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-520-01 for interior electrical system requirements. This UFC cites and supplements existing Government and commercial standards and specifications governing the architectural, mechanical, plumbing, and electrical requirements for design of stationary secondary battery installations.

1-1.2 Upgrades and Modifications to Existing Systems.

Modernization of electrical systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required. Upgrades or modifications of existing facilities should consider the design criteria in this UFC, but it is not intended that an entire facility require modernization solely because of a minor modification to a part of the facility.

1-2 EXCLUSIONS.

Appendix B provides examples of battery installation types that are covered by this UFC.

1-2.1 Excluded Battery Applications.

Design of primary battery installations, mobile applications of secondary batteries, batteries used in consumer electronics, and battery maintenance facilities are not covered by this UFC.

1-2.2 Lithium Batteries.

Mobile applications of lithium batteries when the batteries are installed in the end-use application are not covered by this UFC.

Note: This UFC does provide guidance for lithium-based batteries when stored or charged inside a facility; refer to Chapter 3 for requirements. Refer to Appendix B for additional information regarding applicability of lithium-based batteries. Lithium-ion batteries are the most common technology used. In general, this UFC refers to batteries using lithium as "lithium batteries".

1-2.3 Electric Vehicle Charging.

Refer to NFPA 70 for charging requirements for electric vehicles.

1-3 APPLICATION.

1-3.1 Battery Types.

The following battery types are addressed:

- Vented (flooded) lead acid.
- Valve-regulated lead acid (VRLA).
- Vented (flooded) nickel cadmium.
- Lithium.

Note: NFPA 1 uses the term "flooded" to describe vented batteries with a free-flowing liquid electrolyte.

Note: The term "battery cabinet" refers to a cabinet or enclosure designed to contain one or more batteries or battery cells; this term is preferentially used to maintain consistency with industry codes and standards.

1-3.2 Facilities.

Criteria in this UFC apply to DoD-owned or -leased facilities located on or outside of DoD installations, whether acquired by appropriated or non-appropriated funds, or third-party financed and constructed. Facilities include all temporary or permanent structures independent of their size.

1-3.3 Conflicts.

If a conflict exists between this UFC and any other DoD document, referenced code, standard, or publication, this UFC takes precedence.

1-3.4 Compliance.

Comply with the design criteria of this UFC for new construction and major renovation projects. For Air Force projects, comply with the additional criteria of AFPAM 32-1186, *Valve-Regulated Lead Acid Batteries for Stationary Application*. Renovation of existing battery installations solely for the purpose of meeting the design criteria of this UFC is not required. Apply the criteria in this UFC for retrofits of existing installations.

1-4 SAFETY.

Comply with UFC 3-560-01, *Electrical Safety, O&M*, and NFPA 70E, *Standard for Electrical Safety in the Workplace*, Article 320, for battery-related electrical safety requirements. EM 385-1-1, *Safety and Health Requirements*, and OSHA 1926.441 also apply to this UFC.

1-5 REFERENCES.

Appendix A contains a complete list of references used in this manual. \1\ The publication date of the code or standard is not included in this document.

The design is intended to use the most current version of a publication, standard, or code in effect when the design contract is signed unless written direction is provided to the contrary. If dates are not indicated in the contract or in the absence or other direction, the issue/version of publication in effect at the time the design started is to be used. Designs that have been started and then delayed will need to evaluate which version is applicable, and may have to update to the newer version if considerable time has gone by. This may require some redesign. /1/

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CHAPTER 2 STATIONARY BATTERY DESIGN CRITERIA

2-1 GENERAL.

2-1.1 Battery Types.

Chapter 2 provides requirements for the following battery types:

- Vented (flooded) lead acid.
- Valve-regulated lead acid (VRLA).
- Vented (flooded) nickel cadmium.

Note: UFC 3-520-01 prohibits lithium batteries for stationary applications in occupied facilities. Refer to Chapter 3 for requirements for lithium batteries used in military mission systems that are stored or charged inside facilities./2/

2-1.2 Required Criteria.

Comply with NFPA 70, *National Electrical Code* (NEC), and NFPA 1, *Fire Code*, for battery room design requirements. \1\ Apply the NFPA 1 criteria to all stationary batteries with a nominal voltage of 48 VDC or higher, regardless of the battery electrolyte capacity. /1/ Comply with UFC 3-520-01, *Interior Electrical Systems*, for battery selection, sizing, and application.

\1\ *Note: Refer to Appendix B-1 for examples of stationary batteries.* /1/

Regulatory requirements and restrictions vary depending upon location. Battery installations may require permits and environmental control and reporting due to their component heavy metals and acidic or basic electrolyte. Consult Title 29 Code of Federal Regulations (CFR) Parts 1910 and 1926 *Occupational Safety and Health Standards*, Title 40 Code of Federal Regulations *Protection of Environment*, and other applicable regulations for additional information.

2-2 ARCHITECTURAL REQUIREMENTS.

2-2.1 Location.

Where required by NFPA 1, install stationary batteries in a noncombustible, locked cabinet or other enclosure to prevent access by unauthorized personnel unless located in a separate equipment room accessible only to authorized personnel.

Locate the battery near the loads to be served while still satisfying the mechanical design criteria. UPS systems containing batteries can be located in the same room as the equipment they support.

2-2.2 Battery Rooms.

Provide the occupancy separation requirements specified in NFPA 1. When more than one battery chemistry is employed, locate each type of battery in a separate room with each room individually meeting the occupancy separation requirements and with no direct access between the rooms. Services not associated with the battery room must not pass through the room. Do not design the battery room to have access to other spaces. Do not use battery rooms for material storage, such as storage of office supplies, cleaning supplies, or spill control equipment; design a separate space for these materials.

2-2.3 Battery Cabinets.

Provide battery cabinets, including battery cabinets for UPS systems, that are a commercial manufactured product, designed and UL listed or third-party verified and tested for battery containment. Provide a minimum 200 mm (8 in.) working clearance around the batteries within the cabinet or provide drawout racks that allow for the specified working clearance. For outside installations prevent entry of contaminants, water, insects, and wildlife.

2-2.4 Spill Control.

Provide spill control for battery installations as required by NFPA 1. An electrolyte spill is defined as an unintended release of liquid electrolyte that exceeds 1.0 liters. Do not use battery cabinets without integral spill containment for vented lead acid or nickel cadmium batteries. Permanently installed physical containment structures must be capable of resisting continuous exposure to a 70 percent concentration of the electrolyte’s acid or alkaline chemical. Do not allow the containment area to encroach upon space designated for room egress.

Note: VRLA batteries do not require spill containment.

When floor drains are provided in the battery area, design them in accordance with UFC 3-420-01, *Plumbing Systems*.

2-2.5 Electrolyte Neutralization.

Provide for spilled electrolyte neutralization in accordance with NFPA 1. Provide neutralizing and absorbing materials local to, but outside of, the battery area to address local incidents.

Select a slip-resistant floor finish in all battery rooms. Select an acid or alkali resistant floor finish and battery cabinet finish as appropriate for the battery chemistry employed. Wall and ceiling finishes in vented (flooded) cell installations must be acid or alkali resistant.

2-2.6 Battery Racks.

Obtain the battery rack from the same manufacturer that supplies the battery. Racks and trays must resist corrosion from continuous exposure to a 70 percent concentration of the electrolyte's acid or base chemical. Provide insulated battery lifting devices and provide tools with insulated handles.

Select the battery rack to fit within the defined footprint while also satisfying the need for maintenance access. Figures 2-1 and 2-2 show acceptable battery rack configurations for vented cells.

Figure 2-1. Two-Step Battery Rack Configurations (End View)

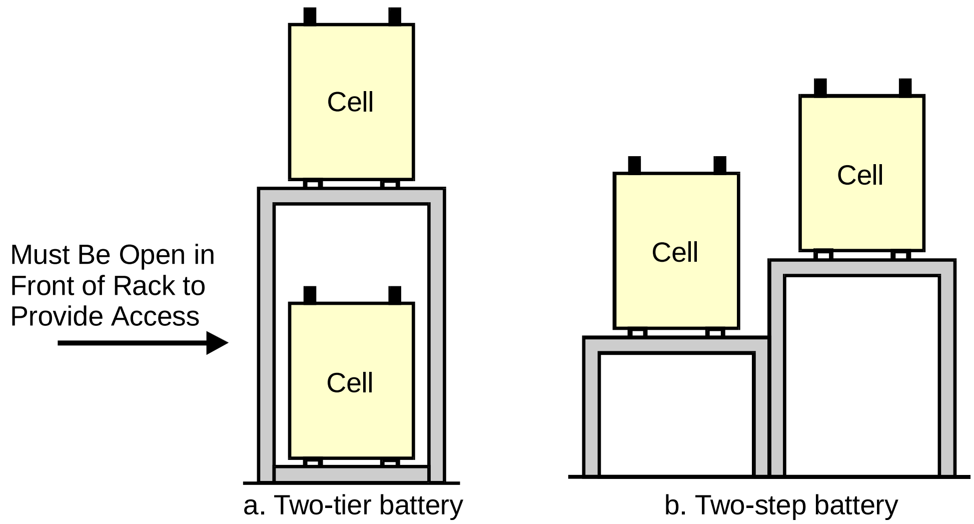
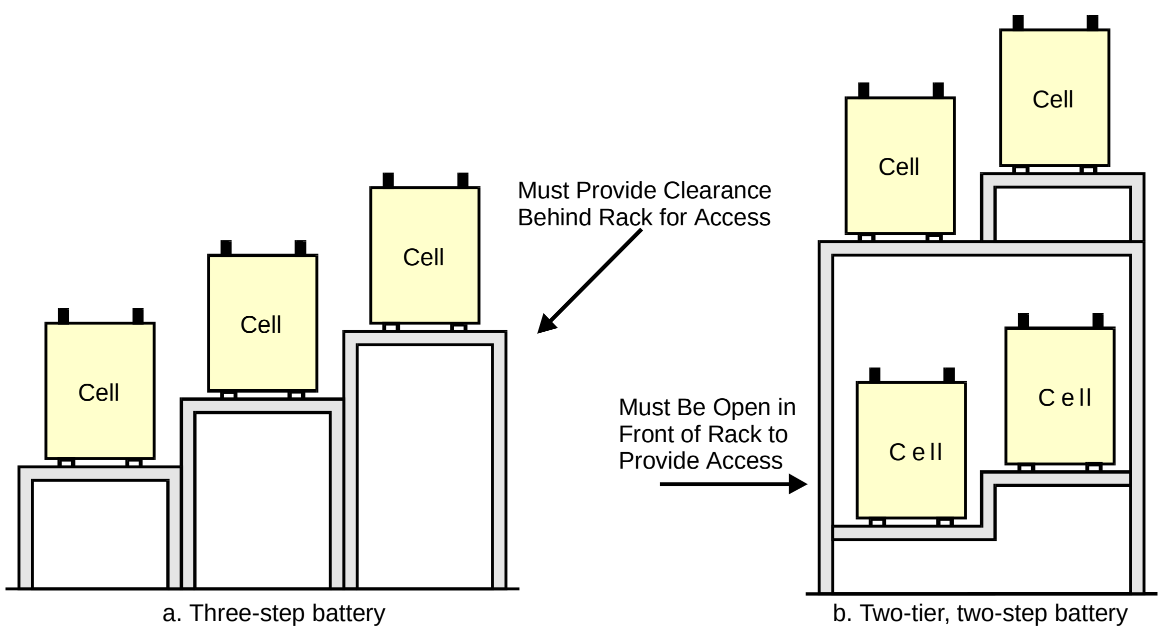


Figure 2-2. Larger Battery Rack Configurations (End View)



2-2.7 Seismic Design.

Provide restraints in all racks for vented cell installations to prevent the individual cells from overturning. In addition, comply with ASCE/SEI 7-10 for battery racks. Table 2-1 shows the rack requirements based on seismic design category.

Table 2-1. Battery Rack Requirements by Seismic Design Category

Seismic Design Category	Description
A—earthquakes are unlikely.	Racks do not require cell restraints.
B—distant earthquakes might cause minor motion.	Racks require side restraints.
C, D, E, F—local or nearby earthquake.	Racks require heavy-duty construction with side restraints and should have additional floor anchor points.

If the stationary battery supports a Mission-Critical Level 1 system as classified by UFC 3-310-04, *Seismic Design of Buildings*, seismically qualify the battery and battery rack in accordance with UFC 3-310-04 and IEEE 693, *IEEE Recommended Practice for Seismic Design of Substations*.

2-2.8 Additional Criteria.

Provide an overhead hoist or equivalent portable material handling equipment for the handling of batteries if the battery cells or modules each weigh over 50 lb (23 kg).

2-3 MECHANICAL REQUIREMENTS.

2-3.1 Installation.

Installation, operating, and maintenance requirements vary for each battery type. Comply with the following IEEE documents for installation criteria, as appropriate for the selected battery type:

IEEE Std 484, *IEEE Recommended Practice for Installation Design and Installation of Vented Lead acid Batteries for Stationary Applications*.

IEEE Std 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel cadmium Batteries for Stationary Applications*.

IEEE Std 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead acid Storage Batteries for Stationary Applications*.

IEEE 1635, *IEEE/ASHRAE Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*.

2-3.2 Ventilation and Hydrogen Control.

2-3.2.1 Hydrogen Generation.

Design ventilation systems to maintain concentrations of hydrogen gas in the battery room below 1 percent concentration.

Calculate the hydrogen generation rate based on the worst-case event of simultaneous boost (equalize) charging of all of the batteries in accordance with NFPA 1. \1\ Refer to IEEE 1635 for examples of fire code worst-case calculations. /1/ Obtain the hydrogen generation rate for the installed battery model and size from the battery manufacturer or apply IEEE 1635 if manufacturer data is not available. \1\ For VRLA stationary batteries, calculate the hydrogen generation rate based on a maximum hydrogen generation rate of 1.27×10^{-7} m^3/s (2.69×10^{-4} cfm) per charging ampere per cell at 25 °C and standard pressure. /1/

2-3.2.2 Ventilation System Design.

Provide ventilation and alarm in accordance with the *International Mechanical Code*, Section 502.4.

2-3.2.2.1 \2\Exhaust System./2/

\2\Provide an emergency exhaust system to contain and directly exhaust smoke and gases from storage and charging rooms. Ensure controls maintain exhaust fan operation under all conditions including ATFP, fire alarm, etc. unless exhaust fan operation would create an unsafe condition such as impeding egress./2/

2-3.2.2.2 \2\Battery Exhaust Duct Requirements./2/

\2\Battery room exhaust duct systems must extend directly to the exterior of the building and must follow the shortest route to the point of discharge. Do not install fire dampers in exhaust duct. Provide a continuous fire-rated duct wrap for the entire length of battery room exhaust duct.

Where battery room exhaust must pass through adjacent spaces, ensure the duct is maintained at a negative pressure. Provide exhaust duct with an upwardly directed discharge. Exhaust discharge opening must be at least 6 feet from exterior walls and roofs, 10 feet from operable openings into buildings, and 10 feet above grade. Exhaust fan must be ANSI/AMCA 99-16 type A with non-sparking wheel and motor location outside of the air stream./2/

2-3.2.2.3 System Design.

Design mechanical systems for continuous operation, free from excessive vibration. Provide green indicator light confirming fan operation located in battery area. Isolate mechanical equipment to eliminate structure-borne vibration that will have an adverse effect on battery usage and performance.

2-3.2.3 Ventilation for Batteries Inside Cabinets.

Provide ventilation for batteries inside cabinets, including UPS systems, in accordance with the *International Mechanical Code*, Section 502.5. The requirement to maintain concentrations of hydrogen gas below 1 percent concentration applies to the inside of the cabinet as well as the area in which the cabinet is installed.

2-3.3 Thermal Management.

The optimal operating temperature range for a lead acid or nickel cadmium battery is between 68° F (20° C) and 77° F (25° C). Operation in this range provides the best balance between capacity and service life. Maintaining the battery installation within the optimal temperature range reduces the possibility of thermal runaway in VRLA batteries.

Maintain the battery area temperature for lead acid batteries below 85° F (29° C) using transfer air when available.

2-4 ELECTRICAL REQUIREMENTS.

2-4.1 Electrical Equipment.

2-4.1.1 Overcurrent Protection and Isolation.

Provide overcurrent protection for each battery string. Provide separate overcurrent protection for each individual string in a paralleled battery string. If the DC conductors leave a separate battery room:

- Provide a disconnect device outside the room near the entrance, or
- Provide a shunt trip device near the entrance that opens a disconnect device inside the battery room.

2-4.1.2 Conductors and Terminations.

Do not use Type AC, NM, NMC, NMS, and UF cable in battery rooms. Do not use flexible metal conduit or flexible metallic tubing.

Install connections to battery terminal posts, including intercell connections, in a manner that minimizes strain on the battery posts.

2-4.1.3 Battery Charging.

Provide temperature compensated charging for VRLA batteries based on the battery temperature, not the ambient temperature.

Include temperature compensated charging for \1\ vented lead acid or nickel cadmium battery /1/ installations where the area is not environmentally controlled and large temperature variations can occur.

2-4.2 Bonding.

Bond conductive battery racks, cabinets, and cable racks to ground using #6 AWG minimum conductors.

2-4.3 Lighting.

Design illuminance levels in the battery room to comply with UFC 3-530-01 and IESNA Lighting Handbook Reference and Application recommendations with a minimum illumination level of 300 lux (30 fc). Consider the type of battery rack and the physical battery configuration to ensure that all points of connection, and maintenance and testing are adequately illuminated.

Install battery room lighting fixtures that are pendant or wall mounted, and do not provide a collection point for explosive gases. Provide fixtures that include lamp protection by shatterproof lenses or wire guards. Select fixtures in battery rooms for vented cells that are constructed to resist the corrosive effects of acid vapors. Luminaires and lamps must provide minimal heat output in general and provide minimal radiant heating of the batteries. Do not install lighting track in battery rooms. Fixture mounting must not interfere with operation of lifting devices used for battery maintenance. Receptacles and lighting switches should be located outside of the battery area.

2-4.4 Instrumentation and Control.

Provide instrumentation to measure battery voltage with high and low alarms, battery current, and ground detection for ungrounded systems. Provide the alarm system operation, level of reporting, and any additional instrumentation and alarm options appropriate for the specific conditions of each battery system.

2-5 EMERGENCY FACILITIES.

Provide portable or stationary water facilities for rinsing eyes and skin in case of electrolyte spillage. Locate within 20 feet of the battery. Design stationary facilities in accordance with UFC 3-420-01. Design portable facilities in accordance with ISEA Z358.1.

2-6 FIRE PROTECTION REQUIREMENTS.

Comply with UFC 3-600-01 and NFPA 1; however, smoke detection is not required.

2-6.1 Sprinkler System.

When the facility requires a wet-pipe automatic sprinkler system, provide an automatic sprinkler system in each battery room. Provide a supervised shut-off valve, check valve, flow switch, and test valve for the sprinkler line supplying a battery room. These items must be located outside of and adjacent to the associated battery room.

Actuation of the flow switch must remove power to the battery chargers that serve that battery room.

2-6.2 Portable Fire Extinguishers.

Portable fire extinguishers are not required to be installed.

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CHAPTER 3 LITHIUM BATTERY DESIGN CRITERIA.

3-1 GENERAL.

\2\Chapter 3 provides requirements for military mission, lithium batteries that will be stored or charged inside facilities. For the Navy and Marine Corps, follow all requirements of NAVSEA S9310-AQ-SAF-010 *Technical Manual for Navy Lithium Battery Safety Program Responsibilities and Procedures*. Where conflicts exist, the most stringent requirement applies. Refer to Appendix B for a discussion of the typical military mission battery applications. Obtain the safety data package (SDP), preliminary hazards list (PHL), and preliminary hazards analysis (PHA) from the responsible program office./2/

\2\This chapter does not apply to portable, commercial-off-the-shelf (COTS) cells and batteries that are: UL listed, 18 volts or less, and less than 100 Watt-hours as defined in chapter 3 of NAVSEA S9310-AQ-SAF-010./2/

3-2 REQUIRED CRITERIA.

\2\Consider lithium batteries as hazardous. Comply with NFPA 70, *National Electrical Code* (NEC), NFPA 1, *Fire Code*, NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, and NAVSEA S9310-AQ-SAF-010 for battery room design requirements. Comply with the additional requirements provided in the following sections and minimum safety requirements in Figure 3-1./2/

3-3 ARCHITECTURAL REQUIREMENTS.

3-3.1 Location.

\2\The preferred location for lithium battery storage is in an unoccupied, segregated shelter adjacent to the occupied building. If lithium batteries are located in an occupied building, locate the batteries in dedicated rooms, separated from other portions of the building by a fire barrier in accordance with NFPA 1. Isolate charging rooms from storage rooms and provide two means of egress with panic hardware.

Do not provide space for spent batteries. Spent batteries are batteries that are no longer serviceable. All spent batteries must be stored outdoors. Do not store or charge lithium batteries in the same room with either nickel cadmium or lead acid batteries.

NOTE: For unmanned underwater vehicles (UUV) batteries that are not removable for charging, the UUV hull acts as a pressure and fire barrier. In this case, separate storage and charging areas are not required. For UUV platforms with removable batteries, follow the requirements of this chapter./2/

3-3.2 \2\Storage Closets./2/

\2\Store military mission, lithium batteries in fire-rated closets of conventional construction designed specifically for the particular battery type. Provide a minimum of three (3) fire rated storage enclosures. Obtain concurrence from the supported command to determine the number of storage closets. The percentage of batteries that are subject to loss upon a catastrophic failure is determined by the number of closets. Coordinate with the supported command to determine the appropriate risk mitigation based on operational requirements and battery costs.

Closets must be provided with exhaust per paragraph 3-5.1. Provide sprinklers and makeup air for each battery storage closet. Provide each closet with grated storage shelving to allow airflow and sprinkler coverage./2/

3-3.3 \2\Charging Stations./2/

\2\Battery charging presents the greatest hazard for battery failure. Locate charging stations away from egress pathways and other battery room functions where personnel are likely to be.

Charge and discharge lithium batteries in designated stations designed specifically for the particular battery type. Size the charging station providing sufficient working clearance around the mission battery, FF&E battery charger, and FF&E charging table. Figure 3-1 indicates a typical dimension of 3 foot by 3 foot, but adjust this dimension to accommodate the mission battery and FF&E. Separate each station with a fire-rated, full-height wall. Ensure the open side of charging stations is not directed towards other charging cubbies or flammables. Provide each station with exhaust per Paragraph 3-5.1. Provide sprinklers directly overhead of charging stations./2/

3-3.4 Seismic Design.

Comply with Section 2-2.7.

3-3.5 \2\Signage./2/

\2\Provide signage for identification of hazardous material in battery rooms in accordance with UFC 3-600-01./2/

3-4 VENTILATION.

\2\Lithium batteries do not vent hydrogen under normal conditions, but will vent hazardous and explosive gases upon failure. Lithium batteries are designed to release overpressure due to thermal runaway through integral vent ports. Ventilate all spaces at a minimum of 6 air changes per hour (ACH) at all times.

Provide a combined emergency exhaust and ventilation system. Provide conditioned makeup air from adjacent spaces to ensure a negative pressure relationship between the battery rooms and adjacent spaces. Provide barometric dampers in transfer duct to create a negative pressure with respect to adjacent areas./2/

3-5 \2\BATTERY EXHAUST SYSTEM/2/

3-5.1 \2\Exhaust System./2/

\2\Provide an emergency exhaust system to contain and directly exhaust smoke and gases from storage and charging rooms. Provide a minimum emergency exhaust rate of 12 air changes per hour ACH. The design of the ventilation system is intended to limit the concentration of explosive gases to 25% of the lower explosive limit upon thermal runaway of a battery.

Provide a volatile organic compound (VOC) detector in the exhaust duct immediately before the exhaust fan inlet. Upon detection of VOCs, the exhaust fan shall increase speed to provide 12 ACH to all storage and charging areas. Provide a local control button and alarm in the battery charging room to energize emergency exhaust. Provide a local pilot light showing exhaust fan run status. Actuation of the emergency exhaust fan must remove power to the battery chargers. Ensure controls maintain exhaust fan operation under all conditions including ATFP, fire alarm, etc. unless exhaust fan operation would create an unsafe condition such as impeding egress./2/

3-5.2 \2\Battery Exhaust Duct Requirements./2/

\2\Extend battery room exhaust duct systems directly to the exterior of the building and follow the shortest route to the point of discharge. Do not install fire dampers in exhaust duct. Provide a continuous fire-rated duct wrap for the entire length of battery room exhaust duct.

Where battery room exhaust must pass through adjacent spaces, ensure the duct is maintained at a negative pressure. Provide exhaust duct with an upwardly directed discharge. Exhaust discharge opening must be at least 6 feet from exterior walls and roofs, 10 feet from operable openings into buildings, and 10 feet above grade. Exhaust fan must be ANSI/AMCA 99-16 type A with non-sparking wheel and motor location outside of the air stream. /2/

3-6 THERMAL MANAGEMENT.

\2\Provide a separate cooling system independent of the building HVAC system for each battery room designed to maintain an ambient temperature of 65 °F (18.3 °C)./2/

3-7 FIRE PROTECTION.

Comply with UFC 3-600-01 and NFPA 1; however, smoke detection is not required.

3-7.1 Sprinkler System.

Provide a wet-pipe automatic sprinkler system for each battery room. Provide a supervised shut-off valve, check valve, flow switch, and test valve for the sprinkler line supplying a battery room. These items must be located outside of and adjacent to the associated battery room. Actuation of the flow switch must remove power to the battery chargers. \2\Provide a fire alarm hand pull in the room./2/

Note: Sprinkler systems are not required for small remote facilities or mobile storage containers (Conex boxes) that have been designed specifically for storage and charging of lithium batteries, and are physically separated from other facilities by a minimum of 50 feet.

3-7.2 Fire Department.

Coordinate with and inform the base fire department of the type of operations performed at the facility and the maximum credible event mishap.

Note: The base Fire Map at the fire station(s) should include charging and storage areas for lithium batteries.

3-8 BATTERY CHARGING EQUIPMENT.

Install battery charging equipment designed for the specific lithium battery model. \2\Interlock battery charging circuits with emergency exhaust fan and sprinkler flow switch./2/

3-9 LIGHTING.

Design illuminance levels in the battery room to comply with UFC 3-530-01 and IESNA Lighting Handbook Reference and Application recommendations with a minimum illumination level of 300 lux (30 fc).

Install battery room lighting fixtures that are pendant or wall mounted. Provide fixtures that include lamp protection by shatterproof lenses or wire guards. Luminaires and lamps must provide minimal heat output in general and provide minimal radiant heating of the batteries. Do not install lighting track in battery rooms. Fixture mounting must not interfere with operation of lifting devices used for in the battery room. \2\Only dedicated receptacles for battery chargers may be located inside the battery rooms./2/

3-10 EMERGENCY FACILITIES.

Provide portable or stationary water facilities for rinsing eyes and skin in case of electrolyte spillage. Locate within 20 feet of the battery \2\enclosures./2/ Design stationary facilities in accordance with UFC 3-420-01. Design portable facilities in accordance with ANSI/ISEA Z358.1.

3-11 \2\ /2/

\2\

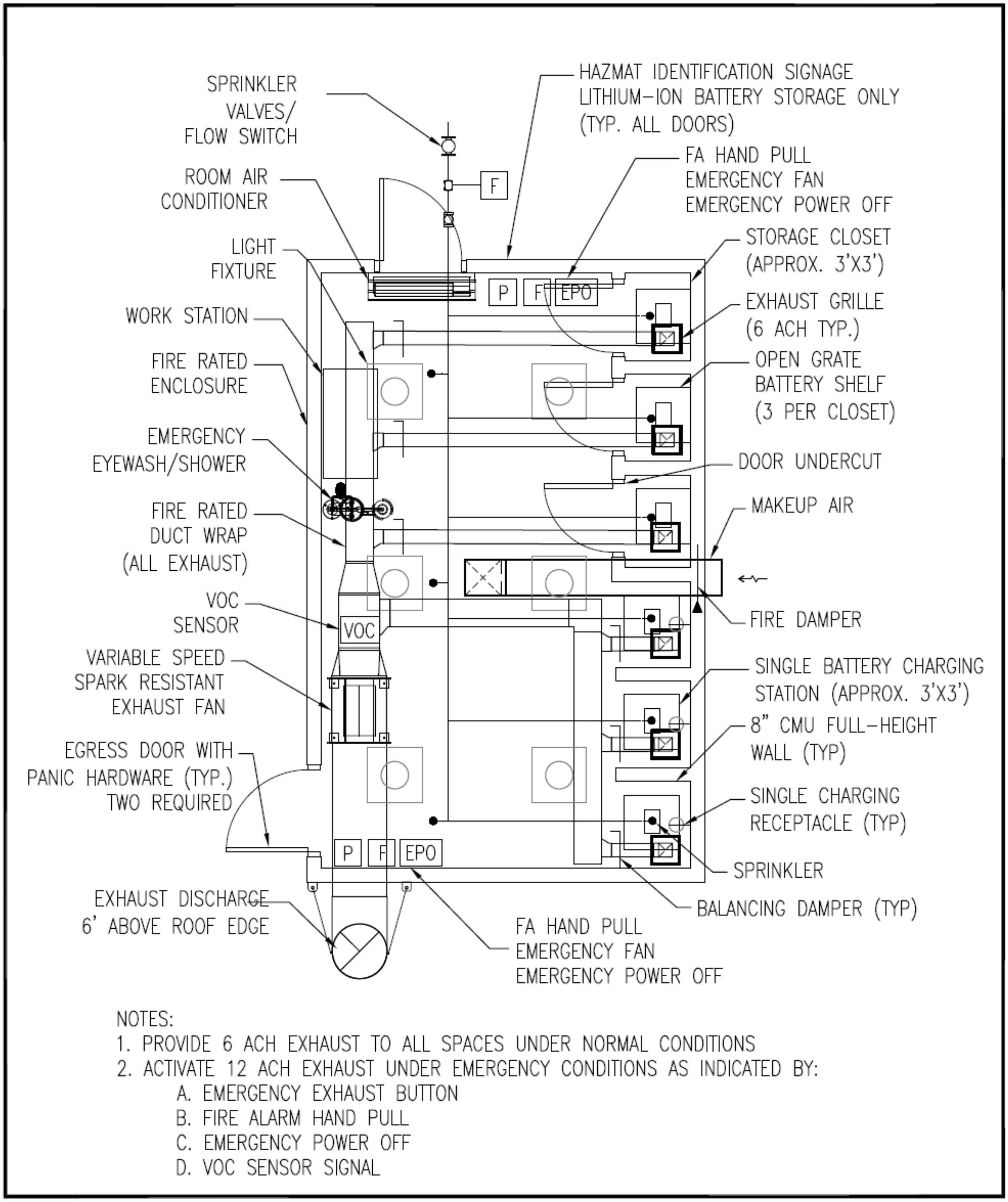

Figure 3-1 Concept Battery Storage and Charging Room Arrangement and Minimum Safety Features

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APPENDIX A REFERENCES

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

www.ansi.org

ANSI/ISEA Z358.1-2009, *Emergency Eyewash and Shower Equipment*

AMERICAN SOCIETY OF CIVIL ENGINEERS (AFCE)

www.asce.org

ASCE/SEI 7-2010, *Minimum Design Loads for Buildings and Other Structures*

AMERICAN SOCIETY OF HEATING, REFRIGERATION, AND AIR CONDITIONING ENGINEERS (ASHRAE)

www.ashrae.org

ANSI/ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Indoor Quality*

CODE OF FEDERAL REGULATIONS

http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR

Title 29 Code of Federal Regulations, *Labor – Occupational Safety and Health Administration (OSHA), Department of Labor – Parts 1910 and 1926*

Title 40 Code of Federal Regulations, *Protection of Environment*

DEPARTMENT OF THE AIR FORCE

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

AFPAM 32-1186, *Valve-Regulated Lead Acid Batteries for Stationary Applications*

DEPARTMENT OF THE ARMY

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

EM 385-1-1, *Safety and Health Requirements*

DEPARTMENT OF THE NAVY

http://www.public.navy.mil/comnavsafecen/Documents/afloat/Surface/CS/Lithium%20Batteries%20Info/LithBattSafe.pdf

NAVSEA S9310-AQ-SAF-010, *Technical Manual for Navy Lithium Battery Safety Program, Responsibilities and Procedures*

IEEE

www.ieee.org

IEEE Std 484, *IEEE Recommended Practice for Installation Design and Installation of Vented Lead acid Batteries for Stationary Applications*

IEEE Std 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel cadmium Batteries for Stationary Applications*

IEEE Std 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead acid Storage Batteries for Stationary Applications*

IEEE 1635*, IEEE/ASHRAE Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*

IEEE 693, *IEEE Recommended Practice for Seismic Design of Substations*

ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (ESNA)

www.ies.org

Lighting Handbook Reference and Application, Tenth Edition

INTERNATIONAL CODE COUNCIL (ICC)

http://www.icc-safe.org/

International Mechanical Code (IMC), 2012

NATIONAL FIRE PROTECTION ASSOCIATION

www.nfpa.org

NFPA 1, *Fire Code*

NFPA 10, *Standard for Portable Fire Extinguishers*

NFPA 70, *National Electrical Code*

NFPA 70E, *Electrical Safety in the Workplace*

NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*

Lithium-Ion Batteries Hazard and Use Assessment, Fire Protection Research Foundation, www.nfpa.org/assets/files/pdf/research/rflithiumionbatterieshazard.pdf

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 3-310-04, *Seismic Design of Buildings*

UFC 3-400-02*, Design: Engineering Weather Data*

UFC 3-410-04N, *Industrial Ventilation*

UFC 3-420-01, *Plumbing Systems*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-530-01, *Design: Interior, Exterior Lighting and Controls*

UFC 3-560-01, *Electrical Safety, O&M*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

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APPENDIX B STATIONARY BATTERY APPLICABILITY

Appendix B provides examples of the types of stationary batteries that are addressed by this UFC. Examples of batteries not addressed by this UFC are also provided. The examples are typically provided in terms of the end-use application.

B-1 APPLICABLE BATTERY TYPES/LOCATIONS.

- Power plant backup power applications.
- Substations and switching stations – switchgear power.
- UPS systems.
- Engine generator batteries, if installed inside enclosed areas.
- Centralized emergency lighting.
- Communication center batteries.
- Stationary batteries in storage on float charge.
- Stationary batteries maintained on float charge before shipboard installation.

B-2 EXCLUDED BATTERY TYPES/LOCATIONS.

- Small batteries used for portable equipment.
- Vehicle batteries.
- Batteries in storage and not on float charge.
- Small emergency lights with an internal battery.
- On board batteries, such as those on boats/amphibious craft or aircraft, are not addressed by this UFC except when those batteries are not installed in the craft but stored or maintained on float charge inside a facility prior to the intended use.
- Battery maintenance and repair facilities – these facilities typically handle large quantities of electrolyte, which leads to unique designs for ventilation control.

B-3 LITHIUM BATTERIES.

Lithium batteries are addressed by this UFC as follows:

- Lithium batteries for consumer electronics devices, such as cellular phones or notebook computers, are not addressed by this UFC.
- Lithium batteries for use in the traditional stationary applications listed above in Section B-1 are not addressed by this UFC and are not

authorized by UFC 3-520-01. Industry standards for the use of lithium batteries in stationary applications are still under development.

- Lithium batteries used in military mission systems are addressed by this UFC for their storage and charging inside a facility. These batteries are typically large format lithium-ion batteries and the end-use application is for shipboard, aircraft, and mobile applications.

Examples of military mission systems that use lithium-ion batteries include:

- Joint Strike Fighter aircraft – 28-volt and 270-volt systems.
- Ground Combat Vehicle program – rechargeable battery packs.
- Improved Target Acquisition System – rechargeable battery packs.
- Active Denial System – rechargeable battery packs.
- Global Hawk/Triton and similar unmanned aerial vehicle applications.
- \2\Knifefish Unmanned underwater Vehicle (UUV) – 30V rechargeable batteries./2/

APPENDIX C LITHIUM BATTERIES RISK ASSESSMENT

Appendix C provides an overview of lithium battery applications and failure modes.

C-1 DESCRIPTION.

Lithium batteries have been used in non-stationary applications for many years and lithium-ion batteries have become the dominant type of rechargeable battery for consumer electronics devices.

C-1.1 Design.

Lithium batteries use lithium metal or some other source of lithium ions in the negative electrode. During the battery discharge, the lithium ions travel to the positive electrode, which can be one of various materials, including a transition metal oxide, a transition metal phosphate, a sulfur compound, or even oxygen in the atmosphere or water. The electrolyte is typically a conductive salt in a solution, or a conductive polymer. Li-ion battery technology is most commonly used.

C-1.2 Packaging.

Lithium batteries are packaged as battery packs, which typically contain the individual cells, the battery management system (BMS), safety systems as necessary, thermal systems as necessary, and either a charger or the interface to an external charger. In order to ensure safety and performance, complete lithium-ion battery packs and systems should be provided as an integrated system and all manufacturer requirements must be followed.

C-2 FAILURE MODES.

Both energetic and non-energetic failures of lithium batteries can occur for a number of reasons including: poor cell design (electrochemical or mechanical), cell manufacturing flaws, external abuse of cells (thermal, mechanical, or electrical), poor battery pack design or manufacture, poor protection electronics design or manufacture, and poor charger or system design or manufacture. Reliability and safety is a function of the entire integrated system.

Refer to *Lithium-Ion Batteries Hazard and Use Assessment*, Fire Protection Research Foundation, for a detailed assessment of lithium battery failure modes and effects.

C-2.1 Non-Energetic Failures.

Lithium-ion batteries can fail in both non-energetic and energetic modes. Typical non-energetic failure modes (usually considered benign failures) include loss of capacity, internal impedance increase (loss of rate capability), activation of a permanent disabling mechanism, shutdown separator, fuse, or battery pack permanent disable, electrolyte leakage with subsequent cell dry-out, and cell swelling. The ideal lithium-ion battery failure mode is a slow capacity fade and internal impedance increase caused by normal aging of the cells within the battery. This is the most common failure mode.

C-2.2 Energetic Failures.

Energetic failures can cause overheating and fires. Energetic failures include thermal runaway, in which a cell rapidly releases its stored energy. These failures can initiate by thermal abuse, mechanical abuse, electrical abuse, poor design, or manufacturing. Although these types of failures are rare, the consequences of failure can be significant.

C-2.3 Charging.

Lithium batteries require that charging be matched to the battery for proper and safe operation. Proper matching of the battery and charger requires knowledge of the lithium cell chemistry, voltage, current requirements and all safety limitations. Improper matching can result in damage to the cells and possible cell failure.

C-3 STATIONARY APPLICATIONS.

Lithium batteries are still developing for stationary applications. They are considered suitable for various stationary battery applications with the proper design, and the proper safety and electronic control systems. Lithium batteries can be designed and optimized for high-power applications such as uninterruptible power supplies They can also be optimized for long-duration discharge applications such as telecommunications and renewable energy storage. Lithium batteries are smaller and lighter than most other battery alternatives, making them suitable as replacements and for applications that have limited space and increasing energy requirements. It is important to recognize that a lithium battery that is optimized for one stationary application may not be appropriate or safe to use in a different application.

Although lithium batteries have been used for several years in consumer electronics devices and are growing in their use for military mission applications, they are still not significantly used in traditional stationary applications. UFC 3-520-01 prohibits their use in stationary applications for the following reasons:

- The technology is new and is still developing for stationary applications.
- These batteries are still more expensive than equivalent lead acid or nickel cadmium batteries.
- \2\Deleted/2/
- The Tri-Service does not yet have criteria in place to assist with specifying this type of battery for stationary applications.

APPENDIX D GLOSSARY

ACRONYMS

A	Ampere
AC	Designation for NFPA 70 Armored Cable
Ah	Ampere-hour
AFPAM	Air Force Pamphlet
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
AWG	American wire gauge
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
DC	Direct Current
DoD	Department of Defense
Fc	Foot-candle
FRP	Fiberglass Reinforced Plastic
HR	Hydrogen Rate
IEEE	Institute of Electrical and Electronics Engineers
IESNA	Illuminating Engineering Society of North America
In	Inches
mm	Millimeters
NEC	National Electrical Code
NFPA	National Fire Protection Association
NM, NMC	Designations for NFPA 70 Nonmetallic Sheathed Cable
O&M	Operations & Maintenance
PVC	Polyvinyl Chloride

UF	Designation for NFPA 70 Underground Feeder and Branch-Circuit Cable
UFC	Unified Facility Criteria
VR	Ventilation Rate
VRLA	Valve-Regulated Lead acid

TERMS

Battery Cabinet: Refer to **Enclosure**.

Enclosure: A surrounding case or housing to protect the contained equipment against external conditions and to prevent personnel from accidentally contacting live parts. With respect to enclosures for stationary batteries, the enclosure might be a dedicated battery cabinet or it might contain additional equipment, such as an uninterruptible power supply.

Float Charge: The method of maintaining a battery in a charged condition by continuous, long-term charging at a level to balance self-discharge.

Full Float Operation: Operation of a dc system with the battery, battery charger, and load all connected in parallel, and with the battery charger supplying the normal dc load plus any self-discharge or charging current, or both, required by the battery. The battery will deliver current only when the load exceeds the charger output.

Primary Battery: A battery that produces electric current by electrochemical reactions without regard to the reversibility of those reactions. In the context of this UFC, a primary battery is not rechargeable, and is intended to be used once, then discarded.

Recombinant Cell: A battery cell characterized by the recombination of internally generated gases. For example, a VRLA cell is designed to recombine internally generated oxygen and suppression of hydrogen gas evolution to limit water consumption.

Room: A contained area within a facility, normally accessible through a door. With respect to stationary batteries, a room might be dedicated for the battery installation or it might contain additional equipment.

Secondary Battery: A battery that is capable of repeated use through chemical reactions that are reversible, i.e., the discharged energy can be restored by supplying electrical current to recharge the cell.

Stationary Battery: A storage battery designed for service in a permanent location.

Storage Battery: A battery consisting of one or more cells electrically connected for producing electric energy.

Valve-Regulated Lead acid (VRLA) Cell: A cell that is sealed with the exception of a valve that opens to the atmosphere when the internal gas pressure exceeds atmospheric pressure by a pre-selected amount. VRLA cells provide a means for recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption.

Vented Battery: A battery in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries are commonly referred to as “flooded.”

UFC 3-530-01
09 February 2023
Change 1, 15 December 2023

UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR AND EXTERIOR LIGHTING SYSTEMS

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UFC 3-530-01
09 February 2023
Change 1, 15 December 2023

UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR AND EXTERIOR LIGHTING SYSTEMS

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	15 DEC 2023	Updated ASHRAE 90.1 reference in paragraph 1-4.1 and Appendix G.

This UFC supersedes UFC 3-530-01 Change 4, dated 01 November 2019.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides requirements for the design of interior and exterior lighting systems and controls based on the Illuminating Engineering Society (IES) Lighting Library® and the Energy Policy Act of 2005. This UFC meets the current IES standard of practice and addresses general lighting requirements for DoD facilities.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-530-01, Design: Interior, Exterior Lighting and Controls, Change 4, 01 November 2019.

1-3 APPLICABILITY.

This document applies to the interior or exterior lighting systems for construction, repair, and maintenance projects. This UFC establishes the baseline requirement for:

- Energy efficiency
- Control strategy
- Lighting criteria
- Lighting best practices

For applications that are not listed in this UFC, refer to the IES Lighting Library for lighting criteria and lighting best practices.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4.1 ASHRAE Compliance.

ASHRAE 90.1 applies to all projects except low-rise residential, which must comply with IECC. Refer to UFC 1-200-02 for applicable year of ASHRAE. **\1\ /1/** When UFC 1-200-02 adopts a newer publication year of ASHRAE 90.1, it will have precedence over these UFC requirements.

1-5 ENVIRONMENTAL SEVERITY AND HUMID LOCATIONS.

In corrosive and humid environments, provide design details and use materials, systems, components, and coatings that are durable and minimize the need for preventative and corrective maintenance over the expected service life of the component or system. UFC 1-200-01, section titled “Corrosion Prone Locations” identifies corrosive environments and humid locations requiring special attention. UFC 1-200-01, section titled “Requirements for Corrosion Prone Locations” provides examples of necessary actions. To determine Environmental Severity Classifications (ESC) for specific project locations, refer to UFC 1-200-01 Appendix titled “Environmental Severity Classifications (ESC) for DoD Locations”.

1-6 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-7 GLOSSARY.

APPENDIX F contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

APPENDIX G contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 TECHNICAL REQUIREMENTS – INTERIOR LIGHTING

2-1 PRIORITIES FOR INTERIOR LIGHTING SYSTEMS.

Design interior lighting systems to reduce energy consumption, reduce maintenance costs, and improve lighting quality, at the lowest life cycle cost in DoD facilities.

2-1.1 Energy Reduction.

Provide Solid State Lighting/Light Emitting Diode (SSL/LED) systems for all interior lighting. SSL/LED systems are established technologies for interior lighting applications that have been proven to save energy over traditional light sources. There are few exceptions in specific medical applications where SSL systems are not allowed; refer to UFC 4-510-01 Design: Military Medical Facilities.

Reduce energy consumption by using energy efficient technologies, maintaining effective illuminance levels, and implementing control strategies. Maintain illumination level prescribed averages and uniformity ratios as closely as possible, in order to provide sufficient light levels without contributing to excessive energy usage.

2-1.2 Maintenance Reduction.

Reduce maintenance by technology selection, reducing equipment quantities, and implementing controls strategies. Select light sources, drivers, and controls that are rated and warranted for long useful lives to increase the amount of time between maintenance cycles. Minimize light source types on an individual project.

2-1.3 Luminaire Placement.

Locate luminaires in locations to ensure access for regular servicing such as driver replacement and cleaning.

Coordinate luminaire locations with ceiling obstructions, such as structure, HVAC, and fire suppression systems.

2-1.4 Lighting Quality.

Apply the following to ensure the priority of lighting quality is achieved.

2-1.4.1 Direct Glare.

In regularly occupied spaces, use luminaires with a luminance of less than 650 cd/ft^2 (7,000 cd/m^2) between 45 and 90 degrees from nadir. Exceptions include high and low bay luminaires in industrial applications, luminaires properly aimed at walls, and indirect luminaires that provide uplighting only, provided there is no view down into these uplights from a regularly occupied space above.

In non-regularly occupied spaces, shield light sources in luminaires with louvers, perforations, lenses, or other refracting technologies to avoid a direct view of the light sources and the resultant direct glare.

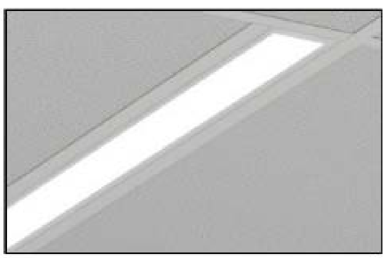
2-1.4.1.1 Luminance Comparison

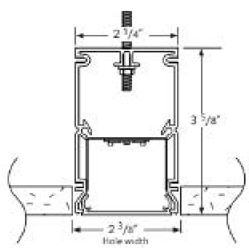
Figure 2-1 compares the luminance of two linear LED products. One has a nominal 2” (610 mm) wide lens and the other has a nominal 4” (1219 mm) wide lens. Both products have the same lumen output. The smaller lensed luminaire has values greater than 650 cd/ft^2 (7,000 cd/m^2) between 45 and 90 degrees from nadir. Therefore, this luminaire does not meet the luminance requirements and must be installed with a dimmer, see Alternate Path 1, because of its higher luminance values.

Figure 2-1 Luminance Comparison

CANDELA ARRAY

2 3/8" lens width, 500 lumens/foot output





LUMINANCE DATA (cd/sq.m)

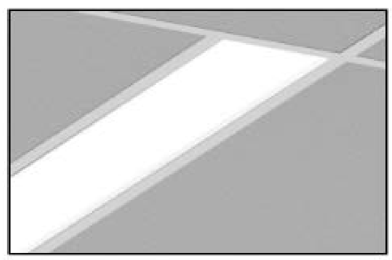
Angle In Degrees	Average 0-Deg	Average 45-Deg	Average 90-Deg
45	11217	10095	9128
55	9632	8440	7438
65	7960	6924	6018
75	6129	5389	4649
85	4080	3765	3452

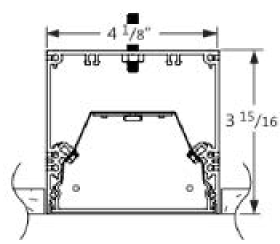
LUMINANCE OVER 7,000 CD/M^2
BETWEEN 45 AND 90 DEGREES

*IES file used: Axis Lighting, Beam 2
BRLED-500-80-35-FL-4
Source: https://www.axislighting.com/families/beam-2

CANDELA ARRAY

4 1/8" lens width, 500 lumens/foot output





LUMINANCE DATA (cd/sq.m)

Angle In Degrees	Average 0-Deg	Average 45-Deg	Average 90-Deg
45	5663	5301	4953
55	5035	4638	4265
65	4380	4017	3698
75	3648	3414	3163
85	2721	2561	2455

*IES file used: Axis Lighting, Beam 4
BBRLED-500-80-35-FL-4
Source: https://www.axislighting.com/families/beam-4

- Alternate Path 1: Luminance values greater than 650 cd/ft^2 (7,000 cd/m^2) between 45 and 90 degrees from nadir are allowed when continuous dimming is provided and accessible to occupants.
- Alternate Path 2: Achieve a Unified Glare Rating (UGR) of <19 using software modelling calculations of the designed lighting calculated for the space.

2-1.4.2 Disability Glare.

Avoid disability glare caused by using bright luminaire components such as visible light sources or bright lenses that can reflect in the surface of tasks with glossy or specular finishes.

2-1.4.3 Luminance of Room Surfaces.

Illuminate surfaces to control the contrast between an occupant's task and the surrounding surface in the field of view. Avoid dark backgrounds when an occupant views a bright computer screen in the foreground. Control high luminance ratios for daylight fenestrations when direct sun is allowed to penetrate.

2-1.4.4 Uniformity.

Uniformly illuminate the task plane as well as room surfaces to avoid shadows or distracting patterns of light. Avoid large, backlighted translucent surfaces such as floors or walls that may be disorienting, especially for people with vision impairments.

2-1.4.5 Shadowing.

Minimize contrast with ambient and task lighting to fill in harsh shadows, especially for work surfaces where people are performing detail-oriented tasks. Shadows are beneficial when distinguishing between stair treads and risers.

2-1.4.6 Color Appearance.

Minimize contrast with ambient and task lighting to fill in harsh shadows, especially for work surfaces where people are performing detail-oriented tasks. Shadows are beneficial when distinguishing between stair treads and risers.

2-1.4.6.1 Color Temperature.

Provide light sources with a correlated color temperature (CCT) of no greater than 4100 K as stated on the manufacturer's luminaire information sheet for all interior spaces. Maintain one CCT in an area and maintain one CCT throughout the entire building where possible. The recommended CCT for most interior applications is 3500 K. For residential and hospitality applications, a CCT of 2700 K is recommended.

2-1.4.6.2 Tunable White Lighting.

Provide tunable white or dim-to-warm light sources in applications where the desired color temperature of light is variable. Residential, hospitality, and childcare applications are the most common recommended uses of adjustable color temperature. Use tunable white light if the quantity of light must remain constant. Use dim to warm light if warmer color temperatures are desirable only when there is also a reduction in light levels.

Tunable white lighting is not a substitute for spectral tuning and does not provide circadian rhythm-specific lighting conditions. For more information on circadian rhythm lighting, refer to APPENDIX D.

2-1.4.6.3 Color Rendering Index.

Use LED light sources with a color rendering index (CRI) of 80+ for all interior applications to accurately render the color of accent walls, architectural features, and artwork. In many high and low bay applications, a CRI of 70+ is acceptable unless a higher CRI is required for the task occurring in the space.

For applications where color identification is of high importance, such as copy/print rooms, command and control centers, kitchens, and areas with art installations, use light sources with a fidelity index greater than or equal to 80 ($R_f \geq 80$), and a gamut index between 97 and 110 ($97 \leq R_g \leq 110$), as defined in IES TM-30. If gamut and fidelity indices are not available, provide light sources with a CRI of 90+ with an R_9 value of at least 50 ($R_9 > 50$). Point(s) of Interest.

2-1.4.7 Modeling of Faces or Objects.

Include indirect lighting from multiple directions and angles for ambient lighting. Use multiple systems such as sconces, pendants, and wall washers to ensure the proper appearance of three-dimensional forms.

Focus visual attention and provide wayfinding with accent lighting. Create visual interest in special spaces as well as guidance through transitional areas with lighting highlights on wall displays and accenting signs.

2-1.4.8 Source/Task/Eye Geometry.

Locate luminaires in response to task areas to avoid shadows and direct and reflected glare.

2-1.4.9 Appearance of Space and Luminaires.

Use creative lighting design with aesthetic appearance of the space and of the luminaires for public building areas.

2-1.4.10 Surface Characteristics.

Review finish selection with Architect and Interior Designer. Coordinate selected surface characteristics with lighting calculations.

2-2 INTERIOR LIGHTING EQUIPMENT.

2-2.1 Light Source Technology.

Provide SSL/LED systems unless there is no equivalent SSL/LED product for the application. If another light source other than SSL/LED is specified, provide documentation regarding the selection of that light source in the project's Basis of Design. Refer to UFC 4-510-01 for specific medical applications that require alternatives to SSL/LED systems.

2-2.1.1 SSL/LED Drivers.

Provide lighting systems with accessible and replaceable drivers. Prioritize drivers that are integral to the luminaire. Use dimmable drivers compatible with standard dimming control circuit of 0-10V, DALI dimming, or DMX dimming. All dimming protocols must comply with cybersecurity requirements in paragraph 1-6.

2-2.1.2 Retrofit LED Lamps.

Provide linear LED lamps that are UL Type A. The datasheet must comply with ANSI C78.54. Use linear LED lamps with a beam angle of 270 degrees. When acceptable products with a 270-degree beam angle are not available, products with a beam angle of at least 180 degrees are allowable.

Retrofit LED light source replacements (screw base) are only permitted for the replacement of incandescent or compact fluorescent light sources. These must be NEMA SSL 7A[1] compliant and provided with a NEMA SSL 7A compliant dimmer to ensure that the electrical infrastructure is adequate to dim the lamps without flicker or dropouts in dimming range.

2-2.1.3 Incandescent and Tungsten-Halogen.

Do not use incandescent or tungsten halogen light sources, unless specifically required for medical applications where alternatives such as SSL/LED are unavailable.

2-2.2 Surge Protection Device.

Provide metal oxide varistor (MOV) surge protection devices at panel boards for all lighting panels or all circuits feeding interior lighting systems. For lighting circuits fed

[1] Department of Energy. *Dimming LEDs with Phase-Cut Dimmers: The Specifier's Process for Maximizing Success.* October 2013.

from load centers, surge protection devices are not required if surge protection is provided by the upstream panelboard.

2-3 LUMINAIRE BRACING AND SUPPORT.

Provide redundant supports to ensure that failure of a single supporting component does not result in luminaire falling. Mount overhead luminaires weighing more than 20 pounds (9 kilograms) with either rigid or flexible systems to reduce the likelihood that they will fall and injure building occupants or damage equipment. Ensure luminaires do not move horizontally in any direction more than 1 inch (25 mm) when subjected to force specified herein. Design equipment mountings to resist forces of 0.5 times the equipment weight in any horizontal direction and 1.5 times the equipment weight in the downward direction. This does not preclude the need to design equipment mountings for forces required by other criteria such as seismic design criteria of non-structural systems.

2-3.1 Luminaires Subject to Wind Loads.

In interior areas with a wind load, such as aircraft hangar bays or vehicle maintenance facilities with drive through maintenance bays, mount luminaires with stem hangers. If a single stem is used, provide a secondary means of support to ensure that failure of the stem does not result in luminaire falling.

2-4 INTERIOR LIGHTING CONTROLS.

Refer to CHAPTER 3 for control requirements specific to common applications and space types. Provide commissioning per ASHRAE 90.1 requirements, except for low-rise residential. Refer to ANSI/IES LP-6 for additional considerations for lighting control systems and ANSI/IES LP-8 for commission guidance for specific applications.

2-4.1 Control Strategies.

Provide a combination of control strategies per space as required in each Application page in CHAPTER 3. Indicate the control strategy for each space or subspace in the contract documents.

2-4.1.1 Manual Control.

Locate manual control devices at all room entries unless manual control devices are not required for the application. Locate manual control devices at the latch side of doors rather than the hinge side if space permits. Provide all required scenes at main entrances and exits, with secondary devices at secondary entrances and exits. Secondary devices are not required to provide full dimming and scene control, but they must provide at least one ON scene and one full OFF scene for the entire space. Provide additional manual control devices as required for specific applications as noted in CHAPTER 3.

Manual control devices consist of scene wallstations, wallbox switches, and wallbox dimmers. Provide clear labeling for scene wallstations, with buttons for each scene required for the application. If using wallbox dimmers instead of scene wallstations, provide wallbox dimmers for each luminaire type in the room, unless otherwise noted. Wallbox dimmers must allow for full range of dimming down to 10% minimum. Some applications, such as auditoriums and briefing rooms, may require dimming down to 1% or less.

2-4.1.2 Occupancy and Vacancy Sensing.

Provide occupancy and vacancy sensors to control lighting within a space or zone by detecting human activity. Occupancy mode is set for auto-on/auto-off, which is mostly utilized in large spaces, corridors, and spaces with no daylight. Vacancy mode is set for manual-on/auto-off, which is utilized in smaller spaces and spaces with daylight. This allows occupants to choose to turn lights on when entering the space, depending on surrounding light, daylighting, and individual activity.

Some applications allow for full or partial automatic on when occupancy is detected. This can be achieved either by turning all lights on to no more than 50% of full light output, or by turning on select luminaires, such as task-oriented luminaires, while leaving other luminaires off.

2-4.1.3 Ramped Dimming.

When automated dimming is required, program a gradual dimming rate so occupants of the space do not perceive a sudden change in light levels. This is especially important in maintenance spaces such as aircraft hangar bays and maintenance shops where personnel may be working in close proximity to energized equipment or running motors.

2-4.1.4 Time Schedules.

Time schedules built into centralized and distributed systems to allow for scheduled OFF and ON scenes, based on time of day. Provide time scheduled shutoffs for spaces that do not allow or require full OFF with vacancy sensors. In some networked lighting control systems, time schedules can be used to change response profiles for occupancy/vacancy controls. These profiles may include changes in time-delay, occupancy or vacancy mode, or associated control zones as defined in paragraph 2-3.3.6.

2-4.1.5 Daylighting Control.

Provide automatic control of the ambient electric lighting in response to daylight as defined in ASHRAE 90.1 for all spaces with access to daylight unless otherwise noted for the specific application. For spaces that receive daylight from windows, curtain walls, or any other sidelight area, the primary and secondary sidelighted areas must be controlled independently of each other. For spaces that receive daylight from skylights or roof monitors, the lighting control system must control the ambient electric lighting in response to daylight. For spaces that receive daylight from toplighting and sidelighting, the ambient lighting in overlapping zones must be controlled together. Consider daylighting modeling and analysis for determining daylighting control zones in complex spaces.

Provide automatic response to daylight with the following functionality:

- Ambient electric lighting with continuous dimming capable of dimming to 10% of full output or lower.
- Program a ramp dimming so occupants of the space do not perceive a sudden change in light levels.
- Photocontrol sensors. Layout, quantity, and programming of photocontrol sensors vary by manufacturer and strategy.
- Refer to APPENDIX B for additional daylighting control information.

2-4.1.5.1 Automated Shading.

When automated shading is provided to control glare and unwanted heat gain from daylighting, coordinate daylighting controls with automated shading controls. Refer to APPENDIX B Daylighting Controls Best Practices for additional information.

2-4.1.6 Zoning.

Areas of control are divided into separate zones for larger spaces, typically above 250 square feet (23 square meters). The specific zoning requirements will vary depending on the application. Provide separate, independent control for each zone. When required for the application, provide separate control for each luminaire type, within each area. Unless otherwise noted, follow control zone square footage requirements as outlined in ASHRAE 90.1.

Zoning may differ depending on control strategy, even within the same area. Establish occupancy and vacancy control zones based on tasks performed in each area. Establish daylighting control zones based on proximity and access to daylight, according to Daylighting Control Best Practices discussed in APPENDIX B.

2-4.1.6.1 Associated Control Zones.

In large spaces containing multiple zones, provide associated control zones where required for the application. Associated control zones connect adjacent zones that are visible and less than 600 square feet (56 square meter), such that activity in an occupied zone will trigger nearby unoccupied zones to provide a reduced level of light by turning on adjacent zones for comfort and security. Utilize associated control zones in regularly occupied spaces during hours of darkness to illuminate egress paths and adjacent unoccupied zones to a reduced level.

2-4.2 Controls for Means of Egress.

Comply with NFPA 101 for the lighting and controls in Means of Egress. Provide UL924 compliant lighting controls that interface with the fire alarm system where required by NFPA 101.

2-4.3 Controls for Electrical Workspaces.

Comply with NFPA 70 when controlling luminaires in working spaces around electrical equipment. Do not use occupancy sensors, vacancy sensors, or timers to control luminaires that provide illumination of the working space around electrical equipment such as service equipment, switchboards, switchgear, panelboards, or motor control centers. To reduce energy consumption, luminaires in the adjacent space that do not provide illumination of the working space may be dimmable a maximum of 50% of full light output and cannot be stepped dimmed. For this application, the luminaires may be controlled by an integrated or separate occupancy or vacancy sensor.

2-4.4 Wireless Networks.

The use of wireless networks must be pre-approved by the System Owner (SO) and the Authorizing Official (AO) as part of the Control System Impact Rating determination defined in UFC 4-010-06.

Coordinate wireless networks with base spectrum manager prior to specification in case of restrictions for wireless usage within the installation.

2-5 DAYLIGHTING.

Refer to UFC 1-200-02 and UFC 3-101-01 for Daylighting requirements. Coordinate architectural daylight design and lighting contribution into electrical lighting and controls design.

Refer to APPENDIX B for daylighting controls best practices.

2-6 ELECTRICAL ENERGY MONITORING.

For construction and renovation of buildings greater than 25,000 SF (2,322 m^2), terminate lighting branch circuits in dedicated lighting panelboards.

2-7 ELEVATORS.

Provide lighting in accordance with UFC 3-490-06.

2-8 ILLUMINATION FOR MEANS OF EGRESS.

Provide in accordance with NFPA 101.

2-8.1 Emergency Lighting.

Emergency lighting units must be LED. For renovation and retrofit projects, replacement of emergency lighting units with LED units is highly encourage but not required.

Install emergency lighting equipment in conspicuous and accessible locations to facilitate the periodic testing requirements.

2-8.2 Exit Signs.

Internally illuminated signs must be LED type and comply with UFC 3-600-01.

2-9 LIGHTING SYSTEM ALTERATIONS.

Alterations occur when luminaires are added, replaced, removed, when more than 10% have been relocated, or when ballasts or lamps are replaced with anything other than the original ballast or lamp. This does not include routine maintenance. Provide alterations to the lighting system to achieve the following benefits:

- Reduce energy through technology selection, providing appropriate illuminance levels and implementing control strategies. Energy savings in commercial applications of 47% on average is achieved by a combination of LED adoption and Networked Lighting Controls implementation.[2]

- Reduce maintenance through decreasing equipment quantities (luminaires), replacing obsolete light source technology with SSL/LED light sources, and implementing control strategies.

- Improve lighting quality through improved photometric distribution and glare reduction. Refer to IES LP-9 Upgrading Lighting Systems in Commercial and Institutional Spaces for additional information.

2-9.1 Lighting System Alteration Requirements.

Comply with the lighting power density (LPD) and control requirements of ASHRAE 90.1 as well as the control requirements in this UFC. Provide computer-generated photometric plans based on ANSI/IES LM-79 data for each space to verify proposed lighting alteration meets the required performance criteria using the applicable light loss factor (LLF). See 3-2 for more information on lighting calculations.

[2] DesignLights Consortium. *Energy Savings Potential of DLC Commercial Lighting and Networked Lighting Controls*. July 2018.

2-9.2 Types of Lighting System Alterations.

Lighting system alterations include redesign, luminaire replacement, luminaire conversion kits to light source retrofits. Redesign will maximize the long-term energy and sustainment savings while improving the lighting quality in existing spaces.

Only provide alternatives to redesign when a full redesign is either not necessary or not feasible.

2-9.2.1 Redesign.

Redesign includes new luminaires, luminaire layout, electrical circuits, and controls designed to meet current lighting criteria. Redesign lighting systems when the existing:

- Illuminance levels are not within 20% below or 50% above the illuminance levels listed in the specific application's performance requirements
- Lighting does not illuminate perimeter surfaces in regularly occupied spaces or shelving in warehouses and storage
- Lighting does not produce uniform illumination
- Luminaire spacing is too wide, or partition height obstructs light distribution
- Luminaires (or luminaire layout) are for when the tasks or physical layout of the space has changed or partition height obstructs light distribution
- Luminaires are in poor condition
- Lighting controls are inadequate

2-9.2.2 Luminaire Replacement.

Luminaire replacement is when existing luminaires are replaced with new luminaires. Luminaire replacement is acceptable when:

- Illuminance levels are within 20% below or 50% above the illuminance levels listed in the specific application's performance requirements
- Lighting produces excessive glare
- Lighting illuminates perimeter surfaces in regularly occupied spaces or shelving in warehouses and storage
- Lighting layout produces uniform illumination
- Luminaires (or luminaire layout) are appropriate for the tasks or physical layout of the space

2-9.2.3 Luminaire Conversion Kit.

Luminaire conversion kits replace reflectors, lampholders, ballast and light source within the housing of an existing luminaire. Conversion kits must meet UL 1598C and the resulting system must produce light levels and uniformity equivalent to the existing system or meet the lighting levels and uniformity required in the current criteria, whichever is lower. Luminaire conversion kits are only acceptable when:

- Illuminance levels are within 20% below or 50% above the illuminance levels listed in the specific application's performance requirements
- Lighting illuminates perimeter surfaces in regularly occupied spaces or shelving in warehouses and storage
- Lighting layout produces uniform illumination
- Luminaires (or layout) are appropriate for the tasks or physical layout of the space

Direct replacement of an incandescent, fluorescent, induction, or HID lamp to LED lamp, without any electrical or mechanical changes, is not considered a luminaire conversion. Linear LED lamp or tubular LED (TLED) are not allowed in luminaire conversion kits.

2-9.2.4 Lighting Source Retrofit.

Light source retrofit, sometimes referred to as a direct lamp replacement, is a system designed in the same form factor as the existing light source. An example is a linear LED lamp, or TLED, which is a direct replacement for a linear fluorescent lamp. Light source retrofit is only acceptable when no modifications to the existing luminaire are required (direct replacement) and when:

- Existing luminaires and lamp holders are in good condition
- Existing luminaires do not produce excessive glare
- Existing luminance levels are within 20% below or 50% above the illuminance levels listed in the specific application's performance requirements
- Existing lighting illuminates perimeter surfaces in regularly occupied spaces or shelving in warehouses and storage
- Existing lighting layout produces uniform illumination
- Existing luminaires (or layout) are appropriate for the tasks or physical layout of the space

- Existing lighting control systems function as intended without flicker and in full dimming range

2-9.2.5 Lighting Source Retrofit Requirements.

Do not use LED retrofit light sources or LED lighting modules that have been designed and constructed to be installed in existing HID or mercury vapor luminaire enclosures. LED retrofits are approved for replacement of CFL or incandescent sources (A-Type lamp replacements with Edison bases). Inserting a LED retrofit in an existing luminaire may void the luminaire’s warranty.

Linear LED lamp retrofits are allowed with the following criteria:

- UL 1993 Type A Certification.
- Type A is designed to operate with the existing fluorescent ballast and does not require mechanical or electrical changes to the luminaire. Dual Mode Lamps (UL Type A/Type B) designed to operate off the existing fluorescent ballast and line voltage are not acceptable.
- Compatible with existing ballast type. Do not bypass or remove the ballast of the existing luminaire. If the linear LED lamps are not compatible with the existing ballast, the existing ballast may be replaced with a compatible fluorescent lamp ballast suitable for ASHRAE 90.1 compliant lighting controls.
- Resulting glare from the luminaire is not increased
- Has been manufactured within one year of installation
- Dimmable without flicker fade outs
- Frosted or diffuse optic with a minimum beam angle of 270 degrees.
- Resulting system must produce light levels equivalent to the existing system or meet the lighting levels and uniformity required in the current criteria, whichever is lower.
- Inserting a linear LED lamp in an existing luminaire may void the luminaire’s warranty.

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CHAPTER 3 INTERIOR LIGHTING APPLICATIONS

3-1 INTRODUCTION.

This chapter identifies typical interior facility applications. Each application details a conceptual lighting design example. The requirements for each application are for general ambient lighting. Coordinate accent and specialty lighting with architect and interior designer. Designs must meet the lighting performance and controls requirements defined in the application details, but layout, luminaire selection, and time schedules may vary.

Verify special lighting equipment requirements in hazardous (classified) locations.

3-2 LIGHTING CALCULATIONS.

Provide computer-generated photometric plans for each space to verify proposed lighting design meets the required performance criteria using the applicable light loss factor (LLF). Luminaire photometric files used in calculations must be derived from ANSI/IES LM-79 test results. Typical LLF is 0.81 for an office with luminaires that are L80 at 60,000 hours, and a 25-year life cycle. LLF varies based on environment, application, LED lumen depreciation, and building life cycle. It is understood that designers can use their discretion and experience to determine exactly where to draw calculation grids to provide informative calculations that meet the intent of the recommendations.

Target illumination levels are provided for each Interior Application. Depending on the application and the recommendations provided by the IES, values are given as one of the following:

- Minimum: No values anywhere on the calculation grid may be less than this value, within a 10% margin of error.

- Average: An average, taken over the entire general area for the application, may not be less than this value, within a 10% margin of error.

- Maximum: No values anywhere on the calculation grid may be greater than this value, within a 10% margin of error.

- Uniformity: Unless otherwise noted, uniformity is calculated as a ratio of the average calculated illuminance over the minimum calculated illuminance of the calculation grid.

3-2.1 Schematic Design and Concept Design.

For schematic and concept design phases prior to 60%, provide narrative indicating the following:

- Target average maintained illuminance level.

- Target lighting power density (watts per square foot or per square meter).

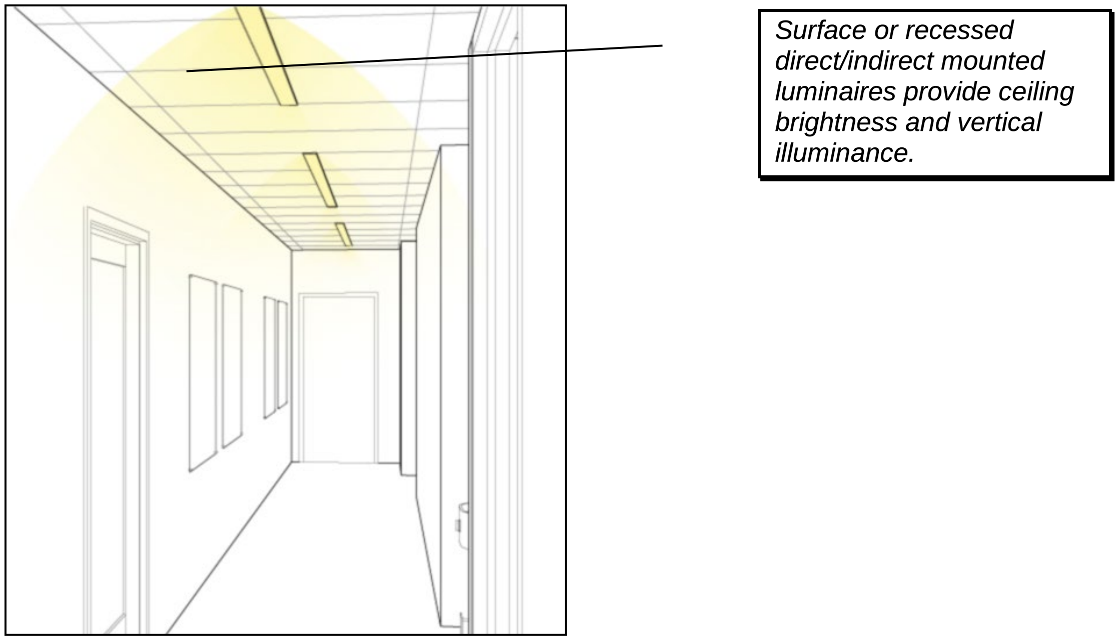
3-2.2 Designs at 60% or later.

For designs submitted at 60% or later, provide photometric plan calculations to include the following:

- The point by point spacing of the calculation grid of horizontal illuminance measurements at the workplane or other designated height above finished floor. The point spacing must be 1/3 of the luminaire mounting height, taken across the general area.
- Where applicable, vertical illuminance measurements at designated surface, taken at a maximum of every one foot (305 mm) across task area.
- Minimum and maximum maintained illuminance levels.
- Average maintained illuminance level.
- Average to minimum and maximum to minimum ratios for horizontal illuminance.
- Lighting power density (watts per square foot or per square meter).
- Where applicable, model the furniture, partitions in the lighting calculations with the proper reflectances, to accurately calculate the light levels of the space.
- Calculate the egress illuminance levels per NFPA 101 requirements.

3-3 GENERAL BUILDING SPACES.

3-3.1 Corridors.



3-3.1.1 Control Requirements.

Manual Control	None required if remote local control device is installed per ASHRAE 90.1
Occupancy/Vacancy	Automatic ON to 100% unless daylight is present Automatic full OFF after 20 minutes vacancy OR Automatic dimming to a maximum of 50% of full output after 20 minutes vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Per ASHRAE 90.1 requirements

3-3.1.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	5 fc (50 lux) at floor
Horizontal Illuminance Uniformity	3:1 average to minimum

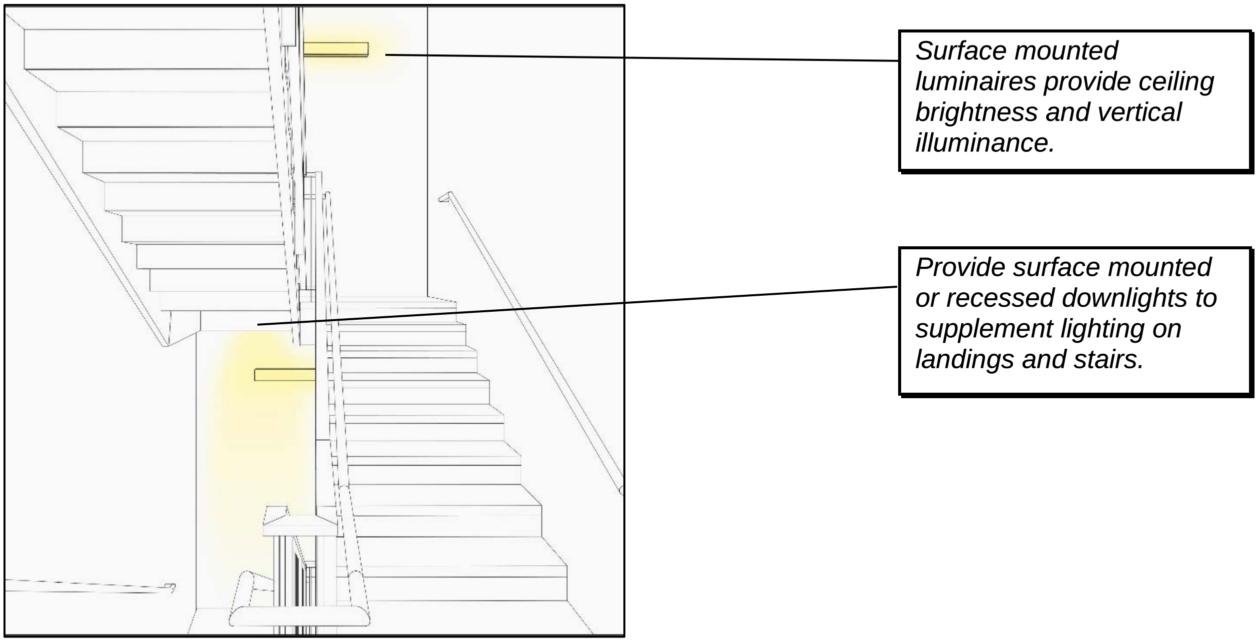
3-3.1.3 Critical Design Issues.

- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the corridor is means of egress, automatic off is allowable when control requirements are met. If area adjacent to corridor is lighted to illuminances greater than 50 fc, then immediate adjacent corridors may be lighted to a 1:10 ratio to minimize visual transition from brightly lighted area to darker corridor.

- When a corridor is adjacent to the open and visually accessible work or task areas, the illuminances of the passageway proper should be no less than 20% of the nearby task illuminances (ANSI/IES RP-1).

- Illuminate feature artwork and/or feature wall finishes.

3-3.2 Stairways.



3-3.2.1 Control Requirements.

Manual Control	None required if remote local control device is installed per ASHRAE 90.1
Occupancy/Vacancy	Automatic ON to 100% unless daylight is present Automatic dimming to a maximum of 50% after 20 minutes vacancy
Time Schedule	None required.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

3-3.2.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Minimum Illuminance	10 fc (100 lux) at walking surface (includes stair treads)
Horizontal Illuminance Uniformity	2:1 average to minimum

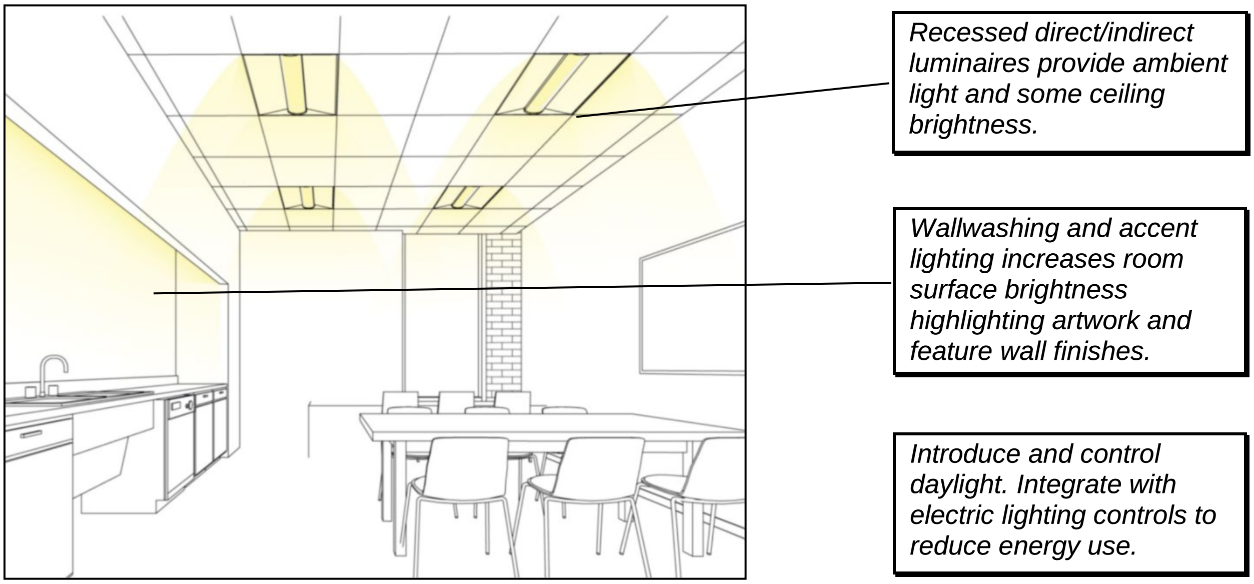
3-3.2.3 Critical Design Issues.

- Horizontal illuminance is calculated on stair treads and landings.

- Do not locate luminaires on the ceiling above the treads. Locate luminaires where they are easily accessible for maintenance.

- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the corridor is means of egress, automatic off is allowable when the NFPA 101 control requirements are met.

3-3.3 Lounge Areas/Breakroom.



3-3.3.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire control zone
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	None required
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for task lighting and ambient lighting

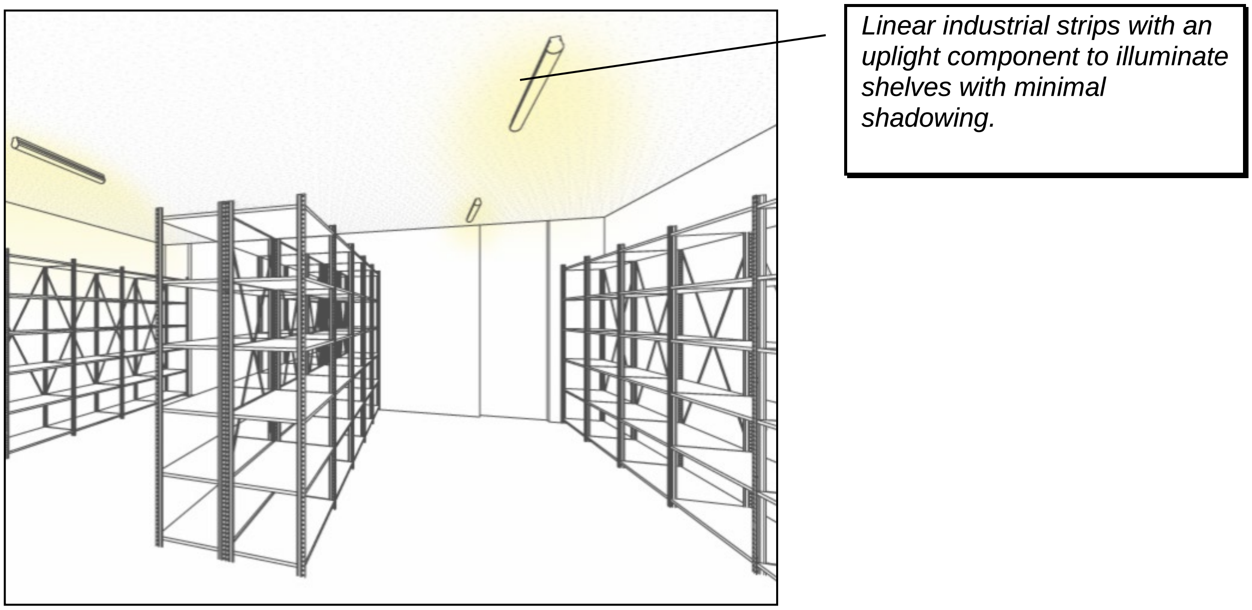
3-3.3.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance, Dining area, social	10 fc (100 lux) at 2’-6” (762 mm) AFF
Average Horizontal Illuminance, Leisure reading	20 fc (200 lux) at 2’-6” (762 mm) AFF
Average Horizontal Illuminance, Food prep, clean up, work areas	30 fc (300 lux) at 2’-6” (762 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-3.3.3 Critical Design Issues.

- Illuminate feature artwork and/or feature wall finishes.
- Illuminate sink areas and/or food prep areas.

3-3.4 Storage Rooms.



3-3.4.1 Control Requirements.

For storage rooms under 50 square feet:

Manual Control	A minimum of one wallbox switch
Occupancy/Vacancy	Automatic full ON Automatic full OFF after 20 minutes of vacancy
Time Schedule	None required
Daylight	No daylight sensing required
Zoning	None

For storage rooms greater than 50 square feet:

Manual Control	At least one wallbox switch or dimmer
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to 50% of general lighting power Automatic full OFF after 10 minutes of vacancy
Time Schedule	None required
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

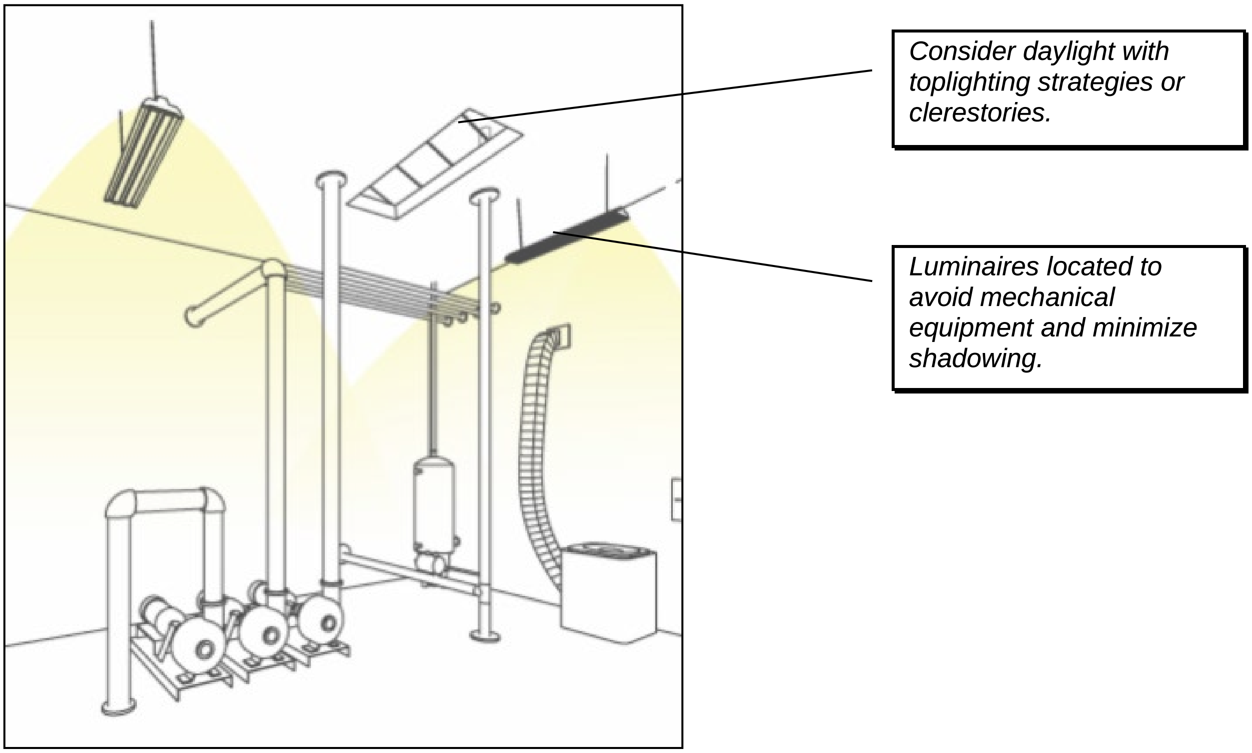
3-3.4.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	10 fc (100 lux) at floor
Average Vertical Illuminance	7.5 fc (75 lux) at 4’-0” (1219 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-3.4.3 Critical Design Issues.

- Lighting controls, including occupancy and vacancy sensors, should account for the shelving and layout of the room.

3-3.5 Mechanical Rooms.



3-3.5.1 Control Requirements.

Manual Control	A minimum of one wallbox switch at each room entrance
Occupancy/Vacancy	None required
Time Schedule	None required
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None required

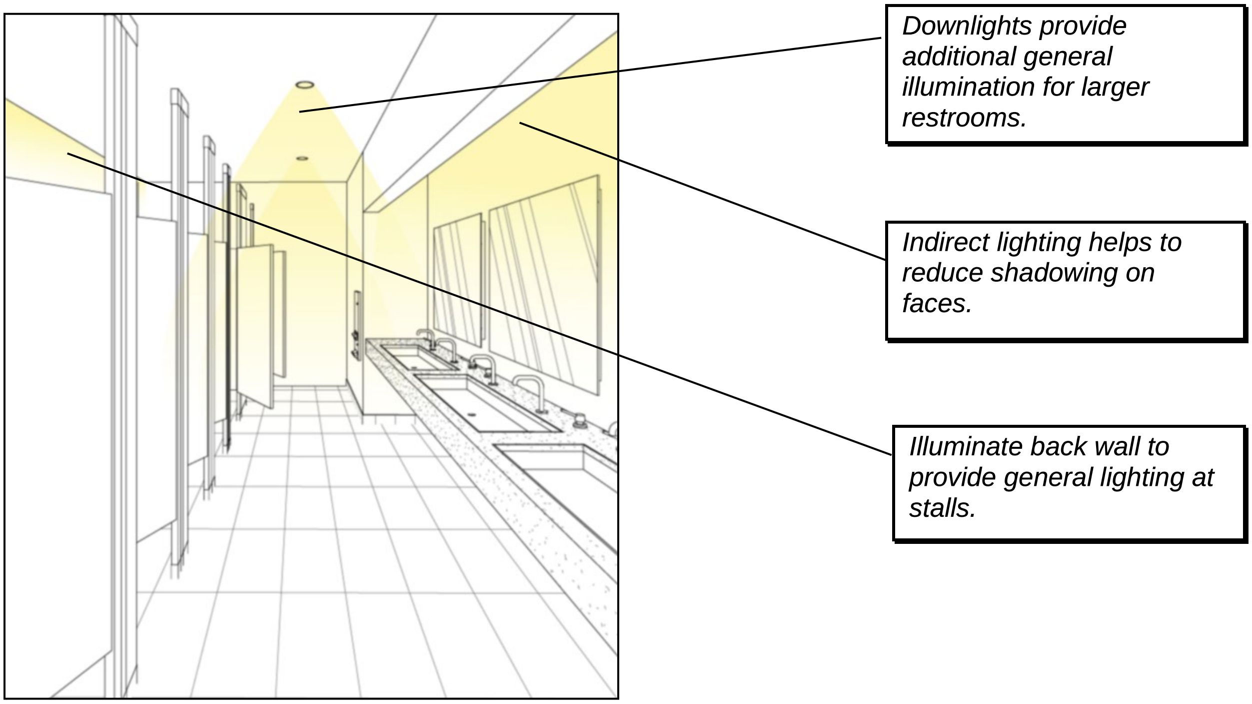
3-3.5.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	20 fc (200 lux) at 3’-6” (1067 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-3.5.3 Critical Design Issues.

- Coordinate luminaire locations with equipment.
- Calculation points within the equipment footprint may be removed.

3-3.6 Restrooms.



3-3.6.1 Control Requirements.

Manual Control	For single-occupancy restrooms only: one wallbox switch
Occupancy/Vacancy	Automatic ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None required

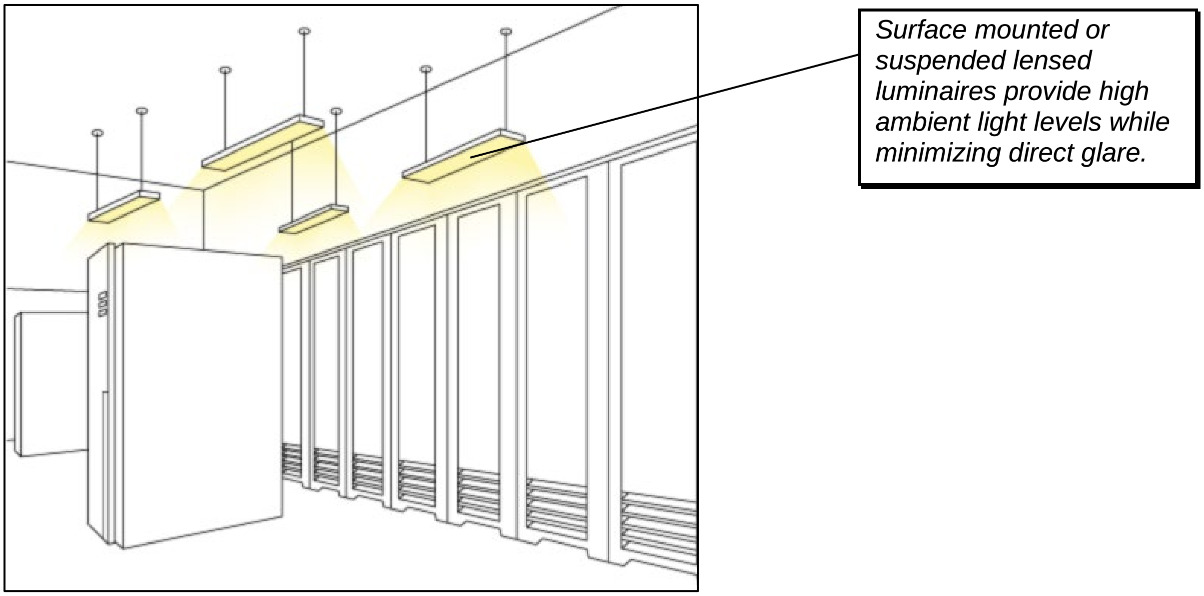
3-3.6.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance, General	5 fc (50 lux) at floor
Average Horizontal Illuminance, Fixtures and vanities	15 fc (150 lux) at vanity surface
Average Horizontal Illuminance, Showers	10 fc (100 lux) at floor
Horizontal Illuminance Uniformity	3:1 average to minimum

3-3.6.3 Critical Design Issues.

- Utilize ultrasonic or dual-tech occupancy sensors.
- Locate occupancy sensors so that activity at restroom entrance and within stalls will trigger sensors.
- No local control required for multi-occupant restrooms.

3-3.7 Telecommunication/Equipment Rooms.



3-3.7.1 Control Requirements.

Manual Control	One wallbox switch
Occupancy/Vacancy	None
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

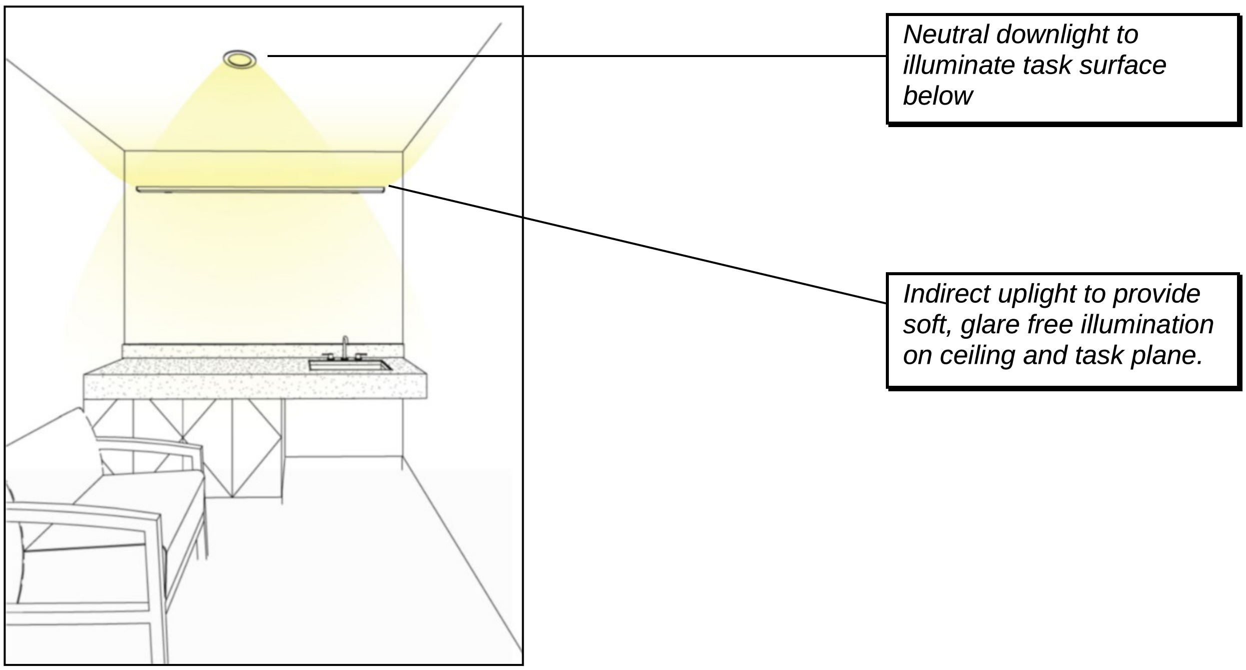
3-3.7.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Minimum Horizontal Illuminance	50 fc (500 lux) at 3’-0” (914 mm) AFF
Minimum Vertical Illuminance	30 fc (300 lux) at 3’-0” (914 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-3.7.3 Critical Design Issues.

- Coordinate luminaire locations with ceiling obstructions and cable trays. Do not mount luminaires directly above cable trays.

3-3.8 Nursing and Lactation Rooms.



3-3.8.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 50% of full lighting power OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for downlight and ambient uplight

3-3.8.2 Performance Requirements.

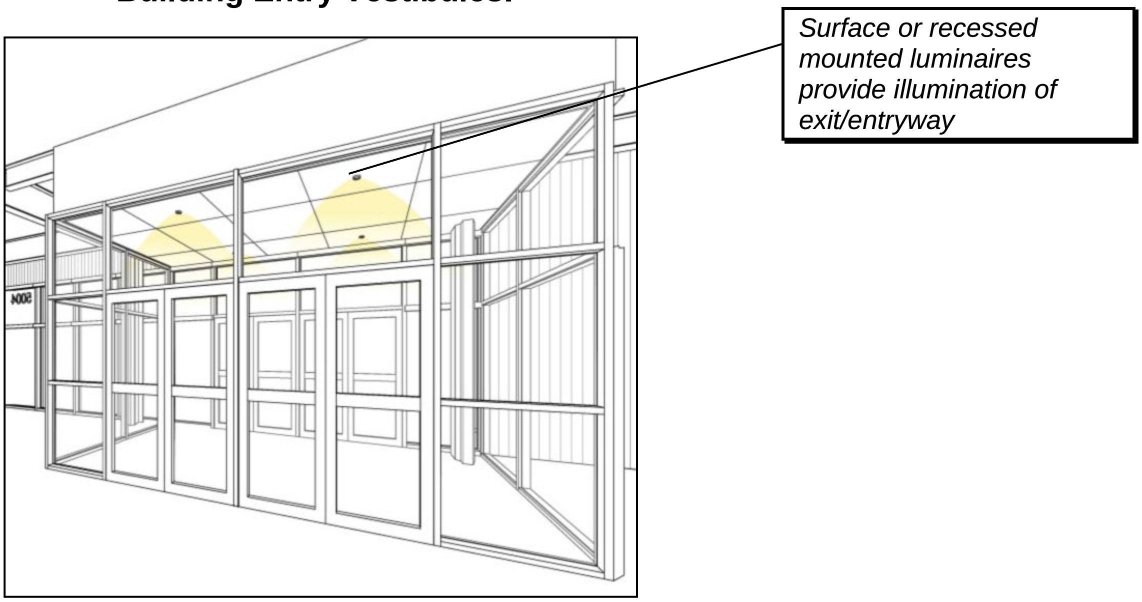
Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	20 fc (300 lux) at 2'-6" (762 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-3.8.3 Critical Design Issues.

- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.

- Light room surfaces to balance luminance ratios.

3-3.9 Building Entry Vestibules.



3-3.9.1 Control Requirements.

Manual Control	None required if remote local control device is installed per ASHRAE 90.1
Occupancy/Vacancy	Automatic ON to 100% unless daylight is present Automatic full OFF after 20 minutes vacancy OR Automatic lighting reduction by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when corridor is scheduled to be vacant, only if occupancy sensing does not utilize full OFF noted above
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Per ASHRAE 90.1 requirements

3-3.9.2 Performance Requirements.

Target Criteria	**Daytime**	**Nighttime**
Average Horizontal Illuminance, Main building entrance	15 fc (150 lux) at floor	4 fc (40 lux) at floor
Average Horizontal Illuminance, Secondary building entrance	10 fc (100 lux) at floor	5 fc (50 lux) at floor
Average Horizontal Illuminance, Interior vestibule	4 fc (40 lux) at floor	N/A
Horizontal Illuminance Uniformity	4:1 average to minimum	

3-3.9.3 Critical Design Issues.

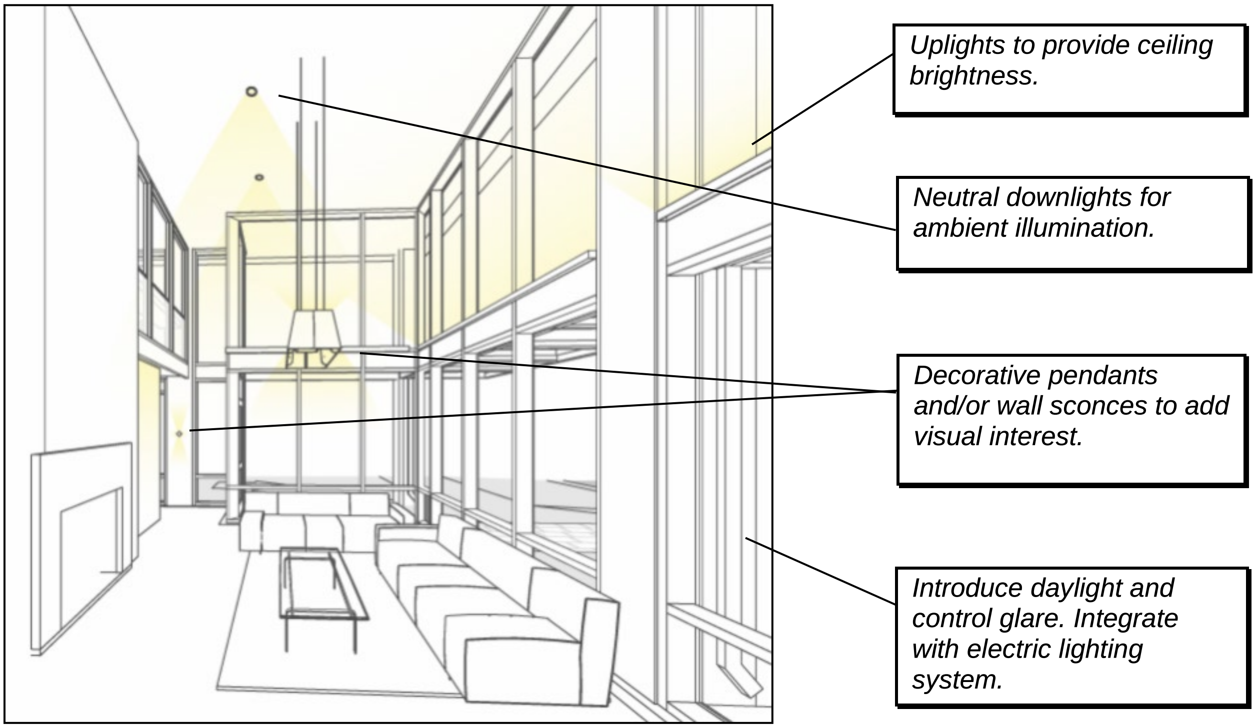
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the vestibule is means of egress, automatic off is allowable when control requirements are met.

- Illuminate feature artwork and/or feature wall finishes.

- For buildings unoccupied at night, nighttime light level adjustments are not required.

3-4 ADMINISTRATIVE SPACES.

3-4.1 Large Lobbies.



3-4.1.1 Control Requirements.

Manual Control	Scene wallstation OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Automatic ON to 100% of daytime illuminance criteria unless daylight is present. During the night, automatic ON to 100% of nighttime illuminance criteria. Automatic dimming to a maximum of 50% after 20 minutes vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for each luminaire type

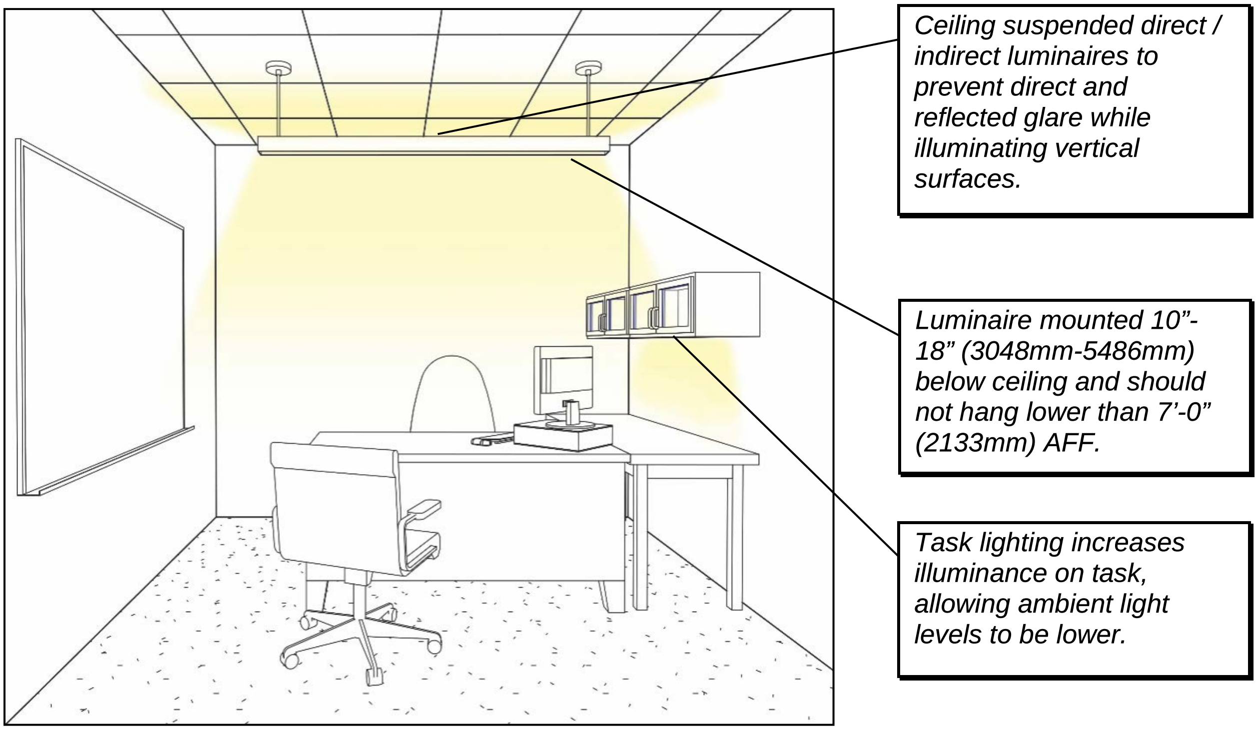
3-4.1.2 Performance Requirements.

Target Criteria	Daytime	Nighttime
Average Horizontal Illuminance, Social, waiting	10 fc (100 lux) at floor	5 fc (50 lux) at floor
Average Horizontal Illuminance, Reception desk	15 fc (150 lux) at 3'-6" (1067 mm) AFF	
Average Horizontal Illuminance, Security screening	20 fc (200 lux) at 3'-0" (910 mm) AFF	
Horizontal Illuminance Uniformity	3:1 average to minimum	

3-4.1.3 Critical Design Issues.

- Avoid visual clutter by selecting luminaires that are aesthetically pleasing.
- Eliminate harsh shadows by lighting surfaces within the space.
- Provide wayfinding guidance such as path to reception desk and elevators.
- Light room surfaces to balance luminance ratios.
- Illuminate feature walls.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the lobby is means of egress, automatic off is allowable when control requirements are met.
- Lighting controls must be within the lobby or easily accessible in order for building personnel to manually override controls.
- For elevator lobbies, the light levels should be approximately 1.5 times greater than the average horizontal illuminance of the adjacent corridor or equal to the average horizontal illuminance of the adjacent corridor with added vertical surface brightness (ANSI/IES RP-1).

3-4.2 Individual Offices.



3-4.2.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire type Task lighting may be toggle switch on luminaire
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy Task lighting may be automatic ON
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for ambient lighting and task lighting

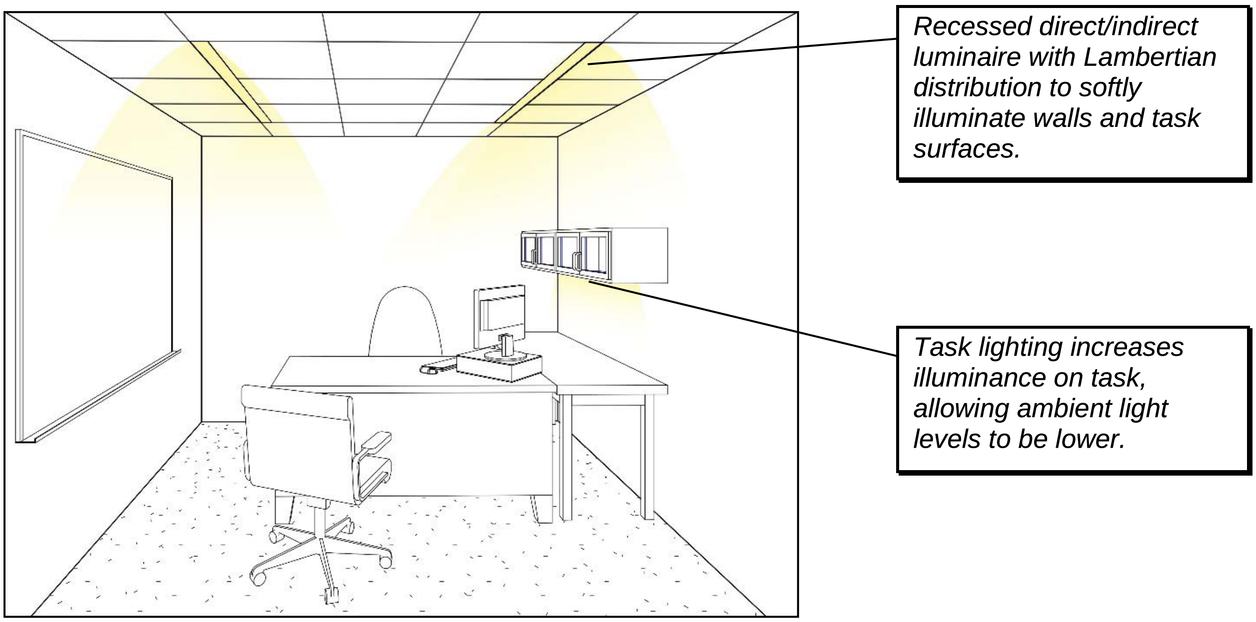
3-4.2.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	30 fc (300 lux) at 2’-6” (762 mm) AFF
Horizontal Illuminance Uniformity	2:1 average to minimum

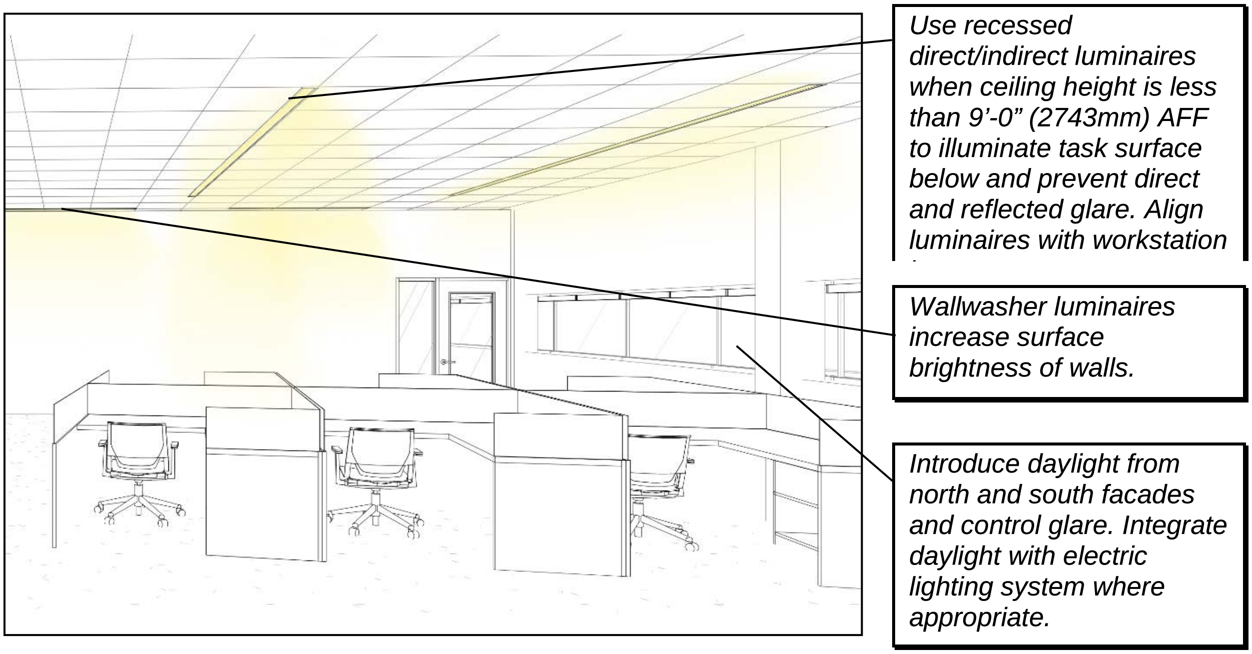
3-4.2.3 Critical Design Issues.

- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.
- Light room surfaces to balance luminance ratios.
- Coordinate luminaire mounting with ceiling obstructions.
- Provide illumination for vertical writing surfaces mounted on walls.
- Task lighting provided for each work area.

3-4.3 Individual Offices (Alternative Scheme).



3-4.4 Open Offices.



3-4.4.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire type Task lighting may be toggle switch on luminaire
Occupancy/Vacancy	Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy Task lighting may be automatic ON
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present. Activate associated control zones if applicable when daylight is not present.
Zoning	Zones must be a minimum of 600 square feet (56 square meters) and a maximum of 2,500 square feet (232 square meter) Provide associated control zones for zones under 250 square feet (23 square meter). Provide separate control for ambient lighting and task lighting

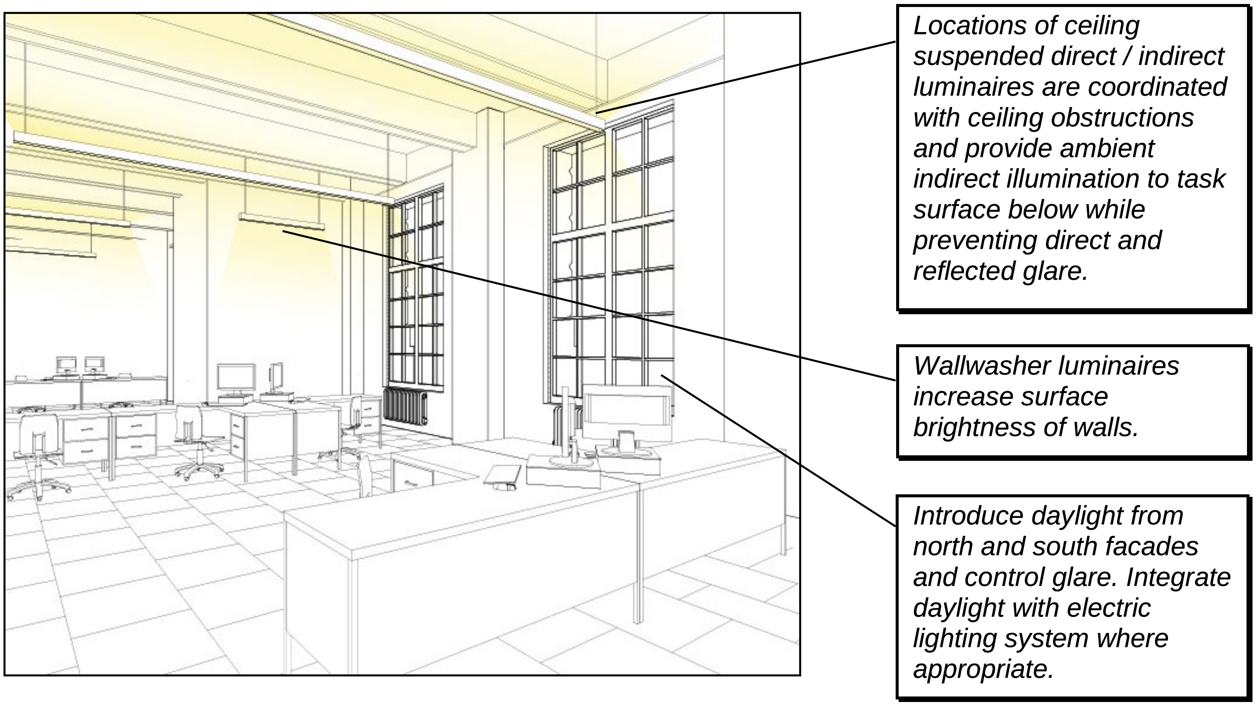
3-4.4.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	30 fc (300 lux) at 2’-6” (762 mm) AFF
Horizontal Illuminance Uniformity	2:1 average to minimum

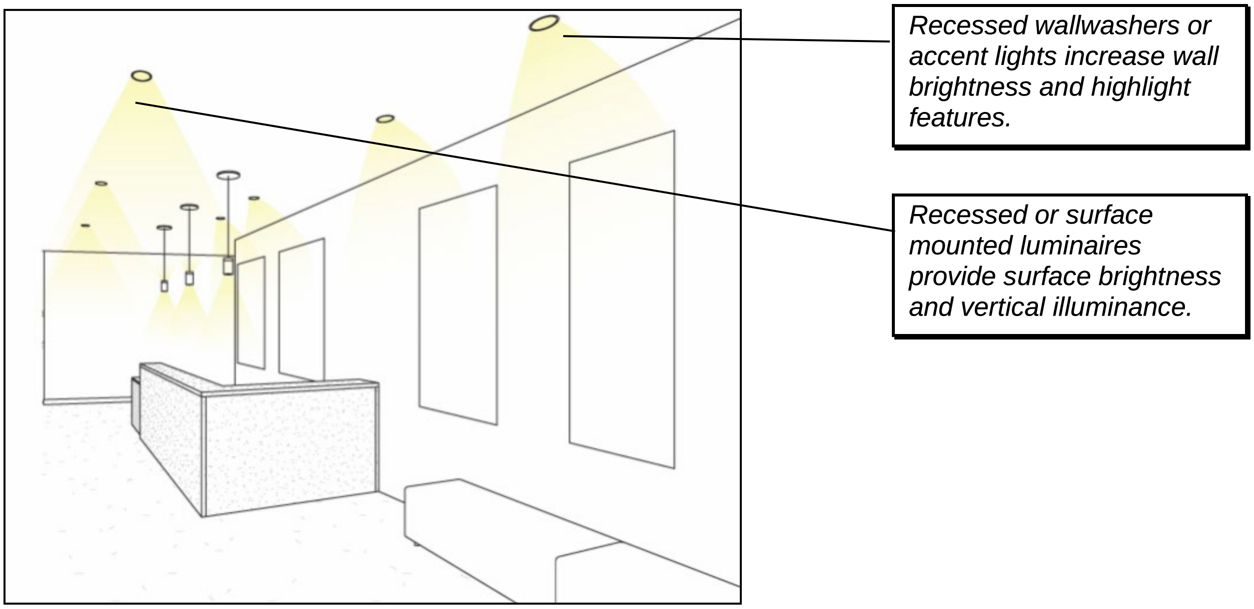
3-4.4.3 Critical Design Issues.

- Coordinate luminaire locations with ceiling obstructions such as structure, HVAC, and fire suppression systems.
- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.
- Light room surfaces to balance luminance ratios.
- Luminaire mounted 10”-18” (3048 mm - 5486 mm) below ceiling and should not hang lower than 7’-0” (2133 mm) AFF.
- In retrofit applications, ensure that heat management of luminaires is adequate and does not compromise rated life of luminaire.
- Provide undercabinet or desk mounted task lights to increase illuminance on task surface. Task lights must have occupancy sensor.
- Provide lighting control zones no larger than 2,500 square feet (232 square meter).
- Means of egress must comply with NFPA 101 for aisles and passageways leading to an exit.

3-4.5 Open Offices (Alternative Scheme).



3-4.6 Waiting Areas and Lobbies.



3-4.6.1 Control Requirements.

Manual Control	Scene wallstation OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 70% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for each luminaire type

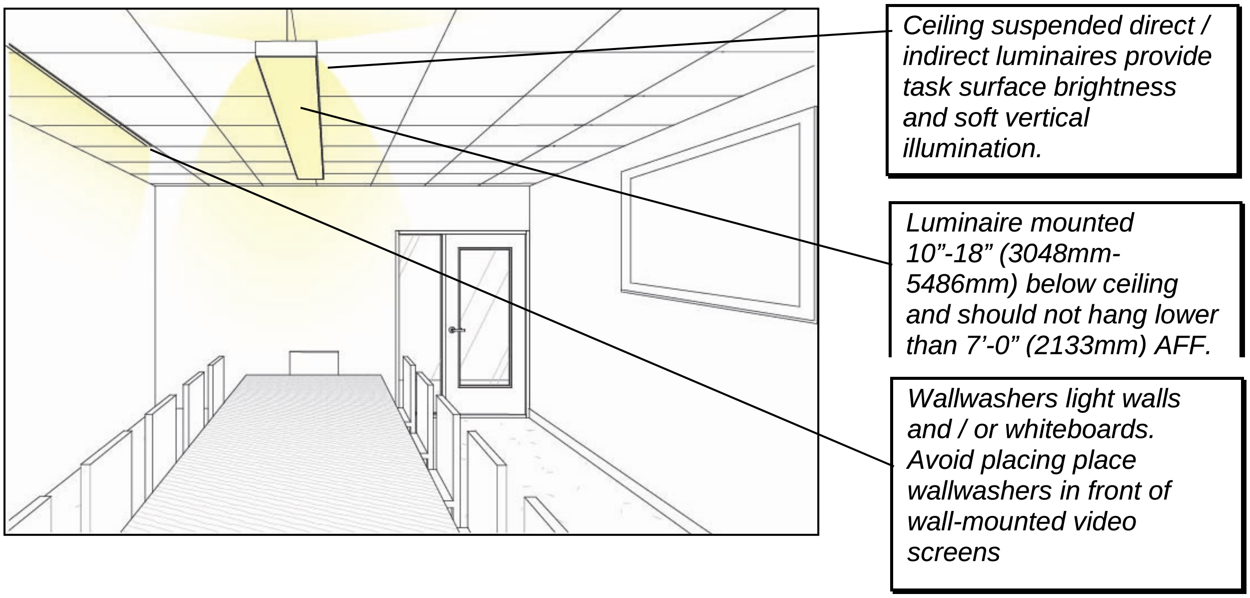
3-4.6.2 Performance Requirements.

Target Criteria	Daytime	Nighttime
Average Horizontal Illuminance, Social, waiting	10 fc (100 lux) at floor	5 fc (50 lux) at floor
Average Horizontal Illuminance, Reception desk	15 fc (150 lux) at 3’-6” (1067 mm) AFF	
Average Horizontal Illuminance, Security screening	20 fc (200 lux) at 3’-0” (910 mm) AFF	
Horizontal Illuminance Uniformity	3:1 average to minimum	

3-4.6.3 Critical Design Issues.

- Select aesthetically pleasing luminaires.
- Light room surfaces to balance luminance ratios.
- Provide task lighting for reception desk and security screening areas to meet performance requirements.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the waiting area and lobbies are means of egress, automatic off is allowable when control requirements are met.
- For circulation spaces, the light levels should be approximately 1.5 times greater than the average horizontal illuminance of the adjacent corridor or equal to the average horizontal illuminance of the adjacent corridor with added vertical surface brightness (ANSI/IES RP-1).

3-4.7 Small Meeting Rooms.



3-4.7.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power and continuous dimming capabilities OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for ceiling luminaires and wallwash luminaires

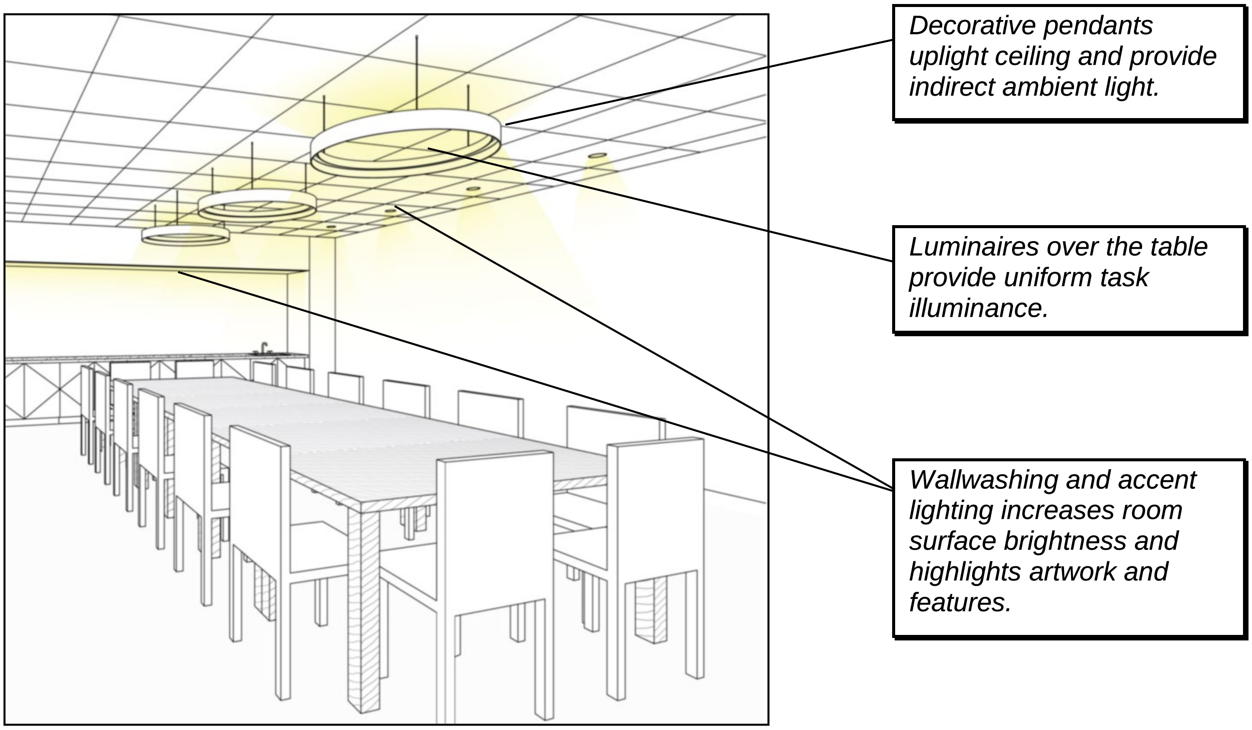
3-4.7.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	30 fc (300 lux) at 2'-6" (762 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-4.7.3 Critical Design Issues.

- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.
- Select aesthetically pleasing luminaires.
- Light room surfaces to balance luminance ratios.
- Coordinate luminaire locations with ceiling mounted AV equipment.
- Use recessed or surface mount direct/indirect luminaires if ceiling height is too low for suspended luminaires.
- Luminaires immediately adjacent to a display monitor should be on a separate control zone. This would allow those luminaires to be OFF while the display monitor is in use and allow the rest of the lighting in the room to be raised and lowered independently.
- In rooms used for video teleconferencing, use indirect lighting as much as possible to illuminate vertical surfaces such as faces to reduce shadowing and increase uniformity.

3-4.8 Multipurpose / Boardrooms / Large Conference Rooms.



3-4.8.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power and continuous dimming capabilities OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for each luminaire type Provide an additional zone for luminaires that are illuminating a whiteboard, projection screen, or television

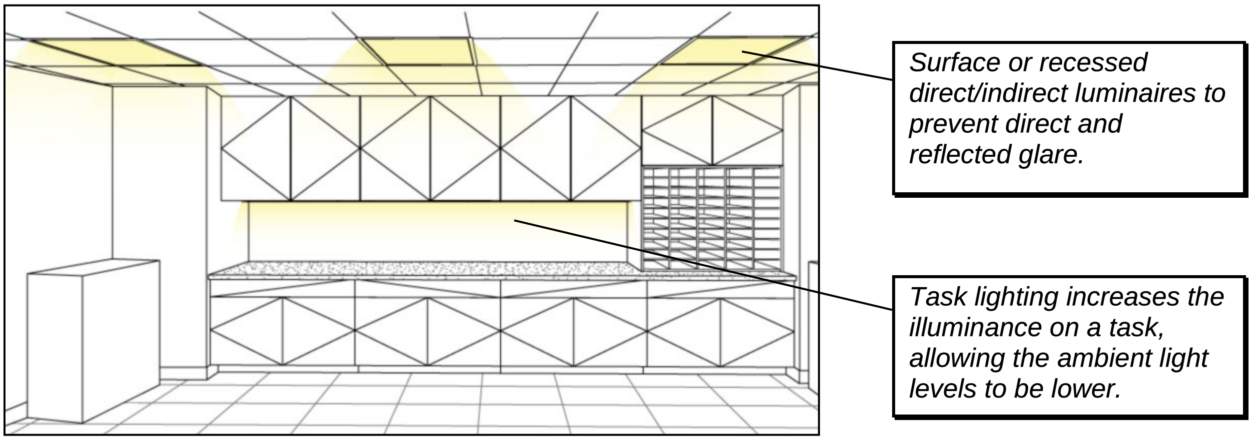
3-4.8.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	30 fc (300 lux) at 2'-6" (762 mm) AFF
Average Vertical Illuminance	15 fc (150 lux) at 4'-0" (1524 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-4.8.3 Critical Design Issues.

- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.
- Select aesthetically pleasing luminaires.
- Light room surfaces to balance luminance ratios.
- Coordinate luminaire locations with ceiling mounted AV equipment.
- Consider means of egress requirements if the conference room is over 300 sq ft and has multiple entrances.

3-4.9 Copy/Print and Office Support Areas.



3-4.9.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy for all lighting, including undercabinet. OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy for all lighting, including undercabinet.
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for task lighting and ambient lighting

3-4.9.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance, General (ambient)	10 fc (400 lux) at 0’-0” (0 mm) AFF
Average Horizontal Illuminance, Machines (task)	30 fc (300 lux) at task surface
Average Horizontal Illuminance, Printed material inspection (task)	50 fc (500 lux) at task surface
Horizontal Illuminance Uniformity	3:1 average to minimum

3-4.9.3 Critical Design Issues.

- Illuminate task surfaces with task lighting.
- Light room surfaces to balance luminance ratios.

3-4.10 Command and Control / Operation Centers.

Suspended indirect luminaires to prevent direct and reflected glare.

Task lighting increases the illuminance on a task, allowing the ambient light levels to be lower or remain off.

3-4.10.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power and continuous dimming to 1% OR One wallbox dimmer per luminaire type with dimming to 1% Task lighting may be toggle switch on luminaire
Occupancy/Vacancy	None
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for ambient lighting and task lighting

3-4.10.2 Performance Requirements.

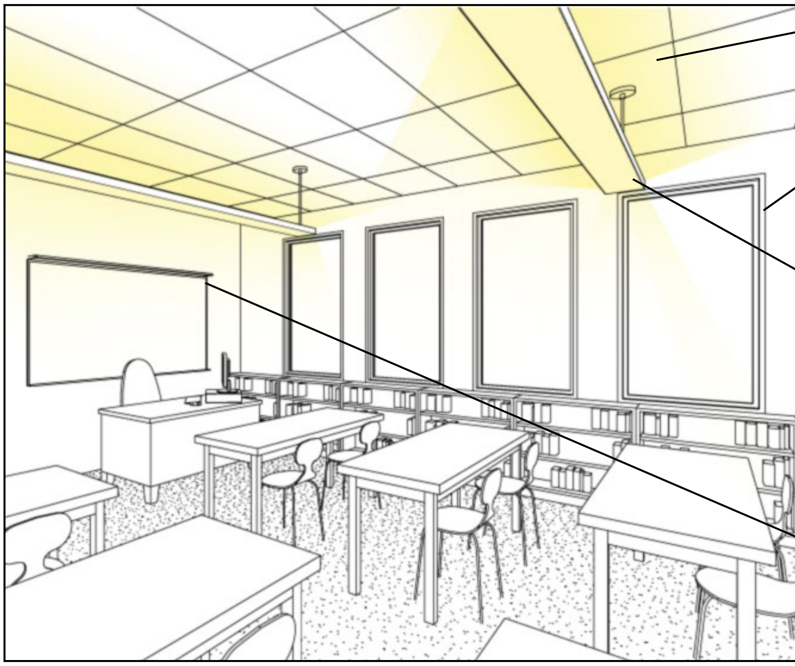
Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	30 fc (300 lux) at 2'-6" (762mm) AFF
Horizontal Illuminance Uniformity	2:1 average to minimum

3-4.10.3 Critical Design Issues.

- Eliminate direct and reflected glare.
- Luminaires may have to dim to lower than 1% due to special circumstances or tasks performed in the space.
- Task lighting should be shielded and directed so as not to disturb other occupants in the room.
- Only use recessed direct/indirect luminaires when ceilings are less than 9' or less.
- Ceiling reflectance can be no less than 80%.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the space is designated as a means of egress, automatic off is allowable when control requirements are met.
- Operation centers operate on 24-hour schedules, therefore no occupancy sensing needed.
- Consider spectral tuning luminaires when designing for spaces that routinely operate 24-hour schedules.

3-5 EDUCATIONAL SPACES.

3-5.1 Classroom / Training Rooms.



3-5.1.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power and continuous dimming capabilities OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide a separate zone for luminaires that are illuminating a white board, projection screen, or television

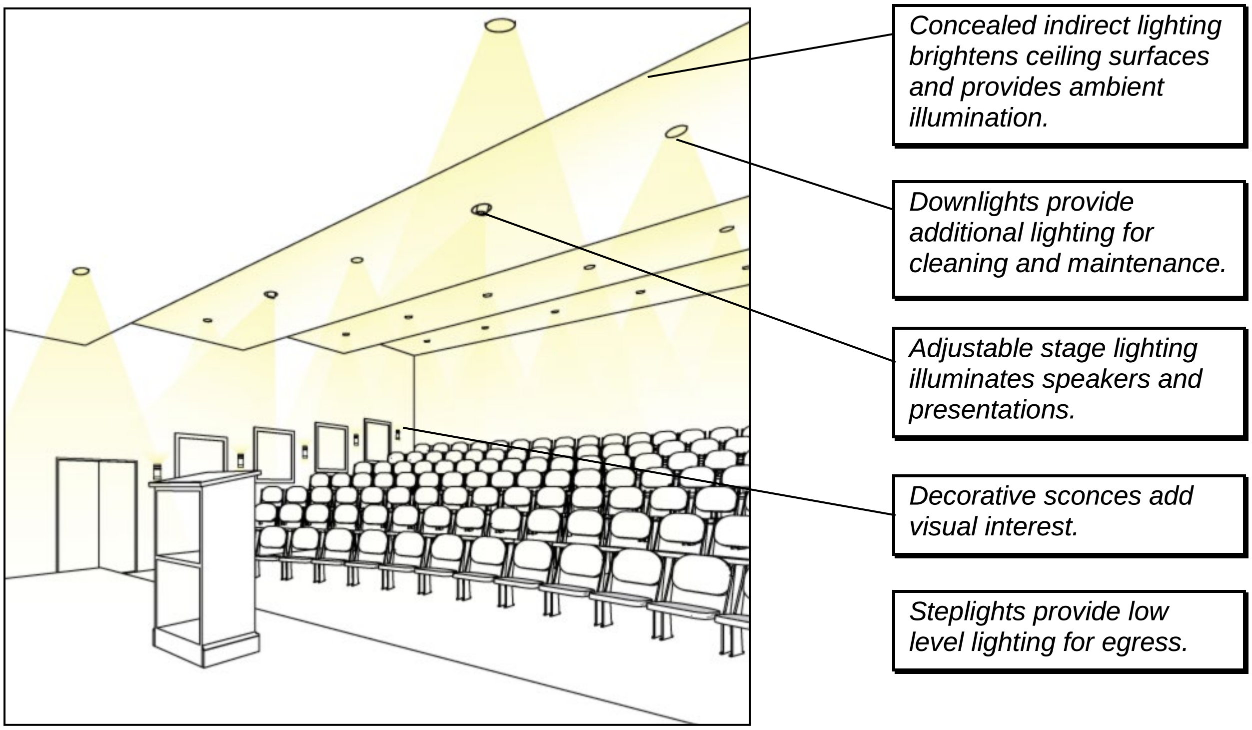
3-5.1.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	40 fc (400 lux) at 2’-6” (762 mm) AFF
Average Vertical Illuminance	15 fc (150 lux) at 4’ (1,219 mm) AFF on presentation wall
Horizontal Illuminance Uniformity	2:1 average to minimum

3-5.1.3 Critical Design Issues.

- Control glare from windows and clerestories.
- Provide even illumination (both electric and daylight) to the space.
- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.
- Light room surfaces to balance luminance ratios.
- Ceiling suspended direct/indirect luminaire mounted 10” - 18” (3048 mm - 5486 mm) below ceiling and should not hang lower than 7’-0” (2133 mm) AFF.
- Use recessed or surface mount direct/indirect luminaires if ceiling height is too low for suspended luminaires.
- Coordinate luminaire locations with ceiling mounted AV equipment.
- Additional guidance provided in ANSI/IES RP-3, Recommended Practice Lighting Educational Facilities.
- Luminaires may have to dim lower than 10% due to special circumstances.
- Provide scene wallstation near instructor’s desk at the front of the classroom.

3-5.2 Auditoriums.



3-5.2.1 Control Requirements.

Manual Control	At least one scene wallstation with: At least one preset “Presentation” scene At least one preset “All On” scene for cleaning Continuous dimming to 10% for all luminaires.
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for each luminaire type Provide an additional zone for luminaires that are illuminating a speaker podium or stage.

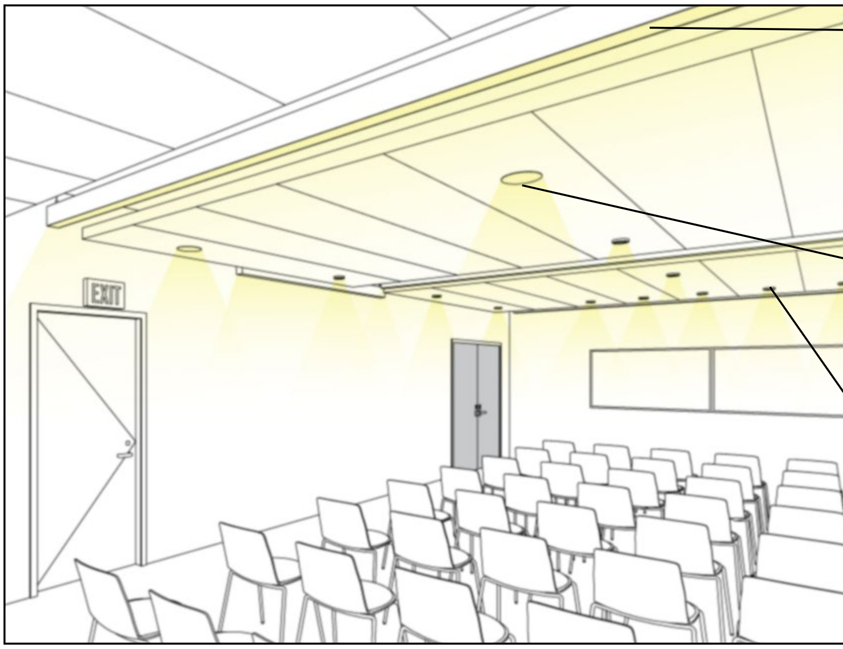
3-5.2.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance, Audience (ambient)	5 fc (50 lux) at 2'-0" (910 mm) AFF
Average Horizontal Illuminance, Panel Speaker (task)	30 fc (300 lux) at 2'-6" (762 mm) AFF
Average Horizontal Illuminance, Stage Demonstration (task)	50 fc (500 lux) at 3'-0" (1067 mm) AFF
Horizontal Illuminance Uniformity	2:1 average to minimum
Average Vertical Illuminance, Stage	20 fc (200 lux) at 5'-0" (1524 mm) AFF

3-5.2.3 Critical Design Issues.

- Minimize glare with solutions such as a diffuse lens, regressed lens, indirect optics, and/or shielded louvers.
- Use downlights with specular cones to minimize glare.
- Allow for low ambient lighting through zoning and dimmable controls.
- Provide accent lighting on speaker.
- Avoid harsh shadows by lighting the speaker from both sides.
- Provide egress lighting along the edge of the aisles per NFPA 101.
- Light room surfaces to balance luminance ratios.
- Coordinate luminaire locations with ceiling mounted AV equipment.
- Provide lighting for front of room vertical writing surfaces.
- Provide Scene Wallstation close to Podium and locate at Podium if possible. Provide additional scene control at all primary entrances.

3-5.3 Large Presentation and Briefing Areas.



Ambient illumination provides ceiling and vertical surface brightness.

Neutral downlights for additional layer of lighting control.

Adjustable accent lights highlight speaker or presentation.

3-5.3.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power and continuous dimming capabilities OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for each luminaire type Provide an additional zone for luminaires that are illuminating a speaker podium, projection screen, or television

3-5.3.2 Performance Requirements.

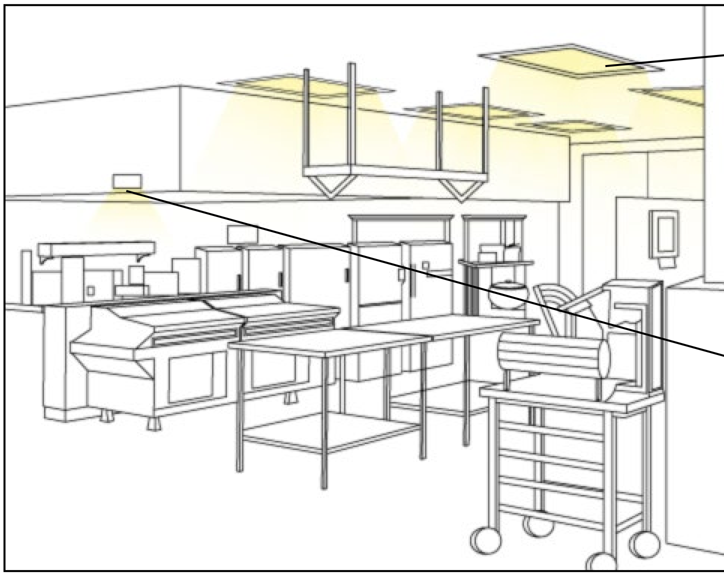
Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	10 fc (100 lux) at 2'-6" (762 mm) AFF
Average Horizontal Illuminance, Panel Speaker (task)	30 fc (300 lux) at 2'-6" (762 mm) AFF
Average Horizontal Illuminance, Stage Demonstration (task)	50 fc (500 lux) at 3'-0" (1067 mm) AFF
Horizontal Illuminance Uniformity	2:1 average to minimum
Average Vertical Illuminance, Stage	20 fc (200 lux) at 5'-0" (1524 mm) AFF

3-5.3.3 Critical Design Issues.

- Allow for low ambient lighting through zoning and dimmable controls.
- Provide dimming capabilities down to 10% for all lighting in the space.
- Provide accent lighting on speaker.
- Light room's surfaces to balance luminance ratios.
- Coordinate luminaire locations with ceiling mounted AV equipment.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the space is designated as a means of egress, automatic off is allowable when control requirements are met.

3-6 FOOD SERVICE SPACES.

3-6.1 Commercial Kitchens.



3-6.1.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON OR Automatic ON to a maximum of 50% of full lighting power
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for task lighting and ambient lighting

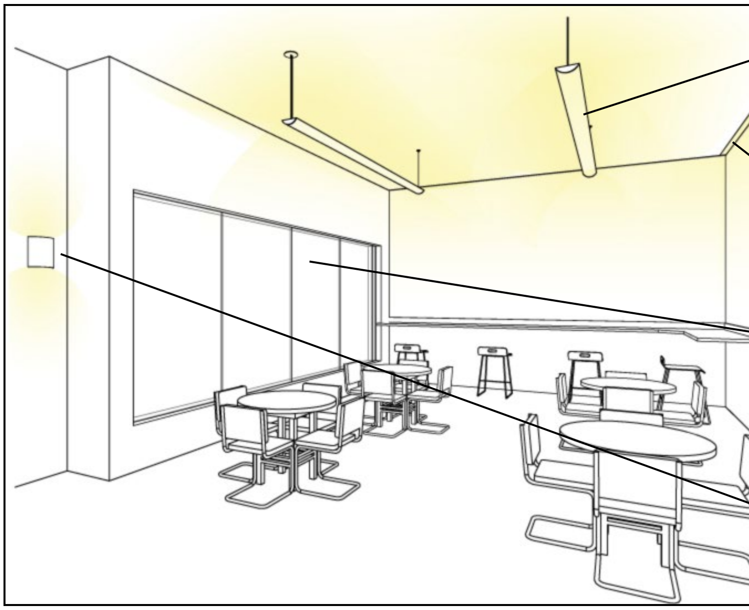
3-6.1.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance, Food prep, handling, cleaning (task)	50 fc (500 lux) at food preparation surface
Average Vertical Illuminance, Food prep, handling, cleaning (task)	20 fc (200 lux) at food preparation surface
Horizontal Illuminance Uniformity	3:1 average to minimum at food preparation surface
Average Horizontal Illuminance, Dishwashing, pot washing (task)	20 fc (200 lux) at task surface
Average Vertical Illuminance, Dishwashing, pot washing (task)	10 fc (100 lux) at 4’-0” (1219 mm) AFF

3-6.1.3 Critical Design Issues.

- Locate luminaires to minimize shadows.
- Select luminaires designed for food processing facilities.
- Use high, 90+ CRI light sources in kitchen for proper rendering of food color.

3-6.2 Cafeterias.



3-6.2.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for task lighting and ambient lighting

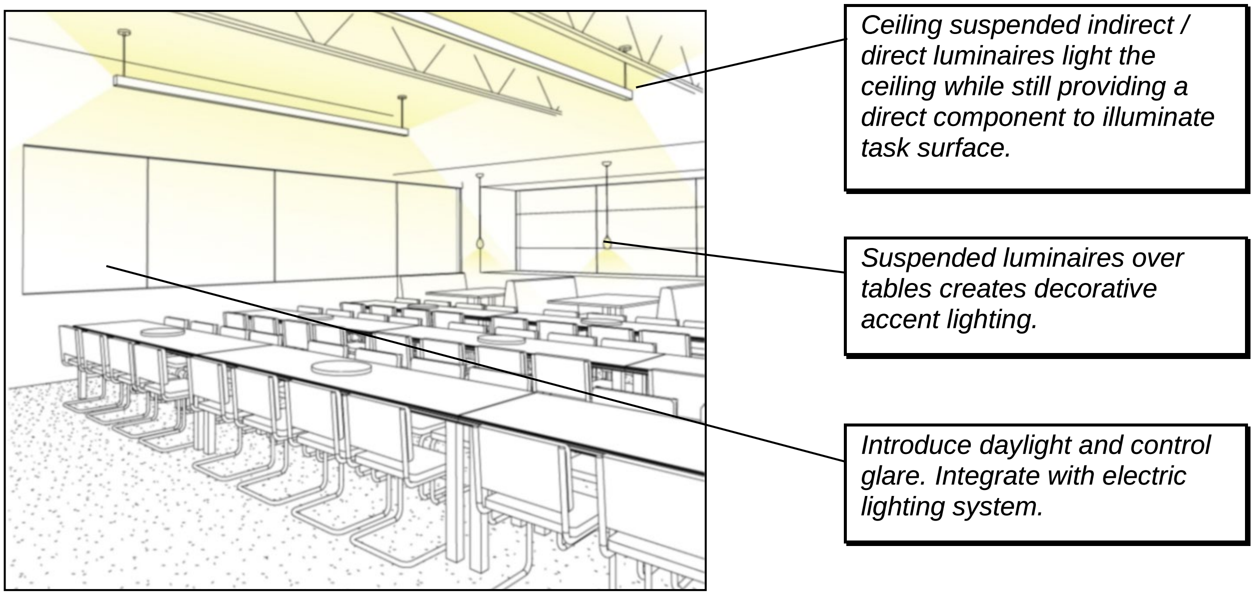
3-6.2.2 Performance Requirements.

Target Criteria	**Ambient**	**Food Display**	**Food Servery**
Average Horizontal Illuminance	15 fc (150 lux) at 2'-6" (762 mm) AFF	50 fc (500 lux) at food preparation surface	20 fc (200 lux) at task surface
Average Vertical Illuminance	NA	20 fc (200 lux) at food preparation surface	20 fc (200 lux) at task surface
Horizontal Illuminance Uniformity	3:1 average to minimum		

3-6.2.3 Critical Design Issues.

- Use accent lighting to provide wayfinding.
- Light room surfaces to balance luminance ratios.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the space is designated as a means of egress, automatic off is allowable when control requirements are met.
- Areas of food preparation do not have to have occupancy sensors.

3-6.3 Enlisted Dining Rooms.



3-6.3.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control for task lighting and ambient lighting

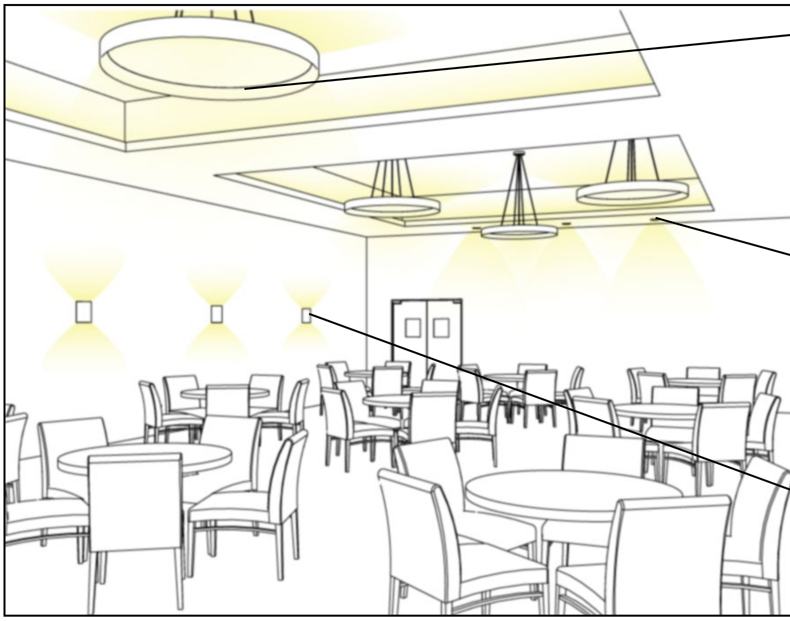
3-6.3.2 Performance Requirements.

Target Criteria	Ambient	Food Display
Average Horizontal Illuminance	15 fc (150 lux) at 2'-6" (762 mm) AFF	50 fc (500 lux) at food preparation surface
Average Vertical Illuminance	NA	20 fc (200 lux) at food preparation surface
Horizontal Illuminance Uniformity	3:1 average to minimum	

3-6.3.3 Critical Design Issues.

- Use accent lighting to provide wayfinding.
- Provide luminaires with low lumen output and dimming to avoid excessive brightness.
- Light room surfaces to balance luminance ratios.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the space is designated as a means of egress, automatic off is allowable when control requirements are met.

3-6.4 Officer Dining Rooms.



3-6.4.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power and continuous dimming capabilities OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	None
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate control zone for each luminaire type.

3-6.4.2 Performance Requirements.

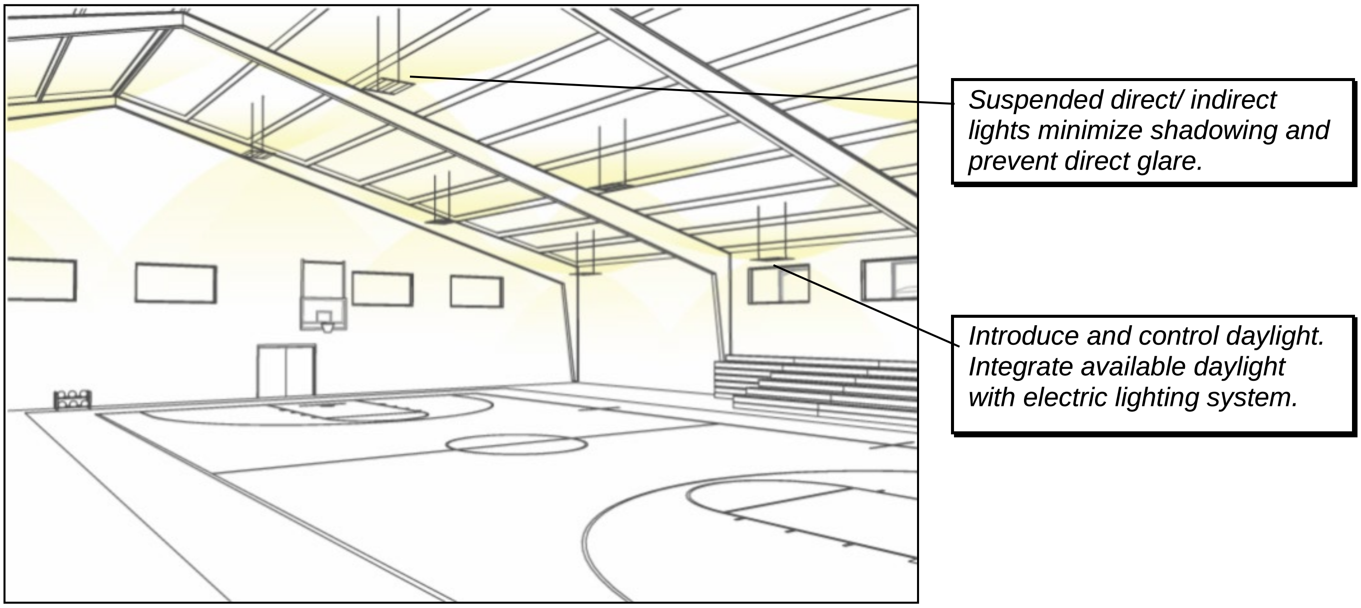
Target Criteria	**Ambient**	**Food Display**
Average Horizontal Illuminance	10 fc (100 lux) at table plane	50 fc (500 lux) at food preparation surface
Average Vertical Illuminance	NA	20 fc (200 lux) at food preparation surface
Horizontal Illuminance Uniformity	3:1 average to minimum	

3-6.4.3 Critical Design Issues.

- Select aesthetically pleasing luminaires.
- Provide luminaires with low lumen output and dimming to avoid excessive brightness.
- Light room surfaces to balance luminance ratios.
- Means of egress must comply with NFPA 101 control requirements and minimum light level requirements. When the space is designated as a means of egress, automatic off is allowable when control requirements are met.

3-7 RECREATIONAL SPACES.

3-7.1 Indoor Multi-use Gymnasiums.



3-7.1.1 Control Requirements.

Manual Control	Scene wallstation with preset scenes: - All lights on to 10% -40% (normal) - All lights on to 50% - 70% (recreation) - All lighting on to 80% - 100% (league play)
Occupancy/Vacancy	Automatic ON to a maximum of 50% of full lighting power with automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide separate zones for each defined activity space, if more than one.

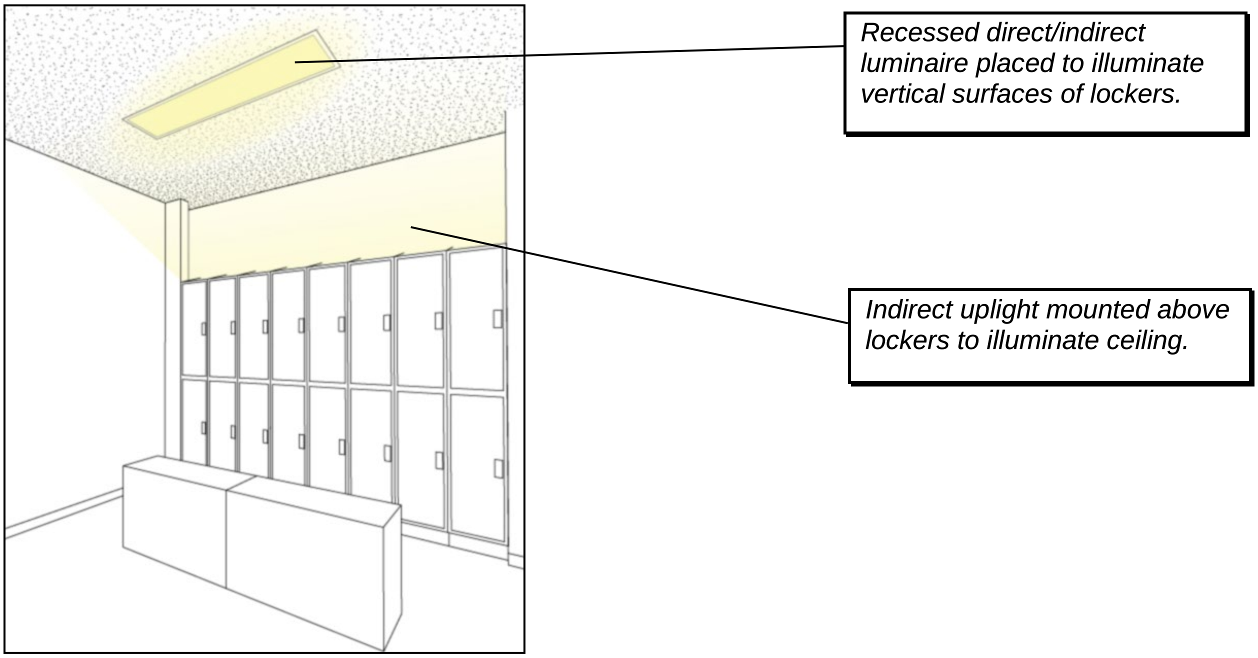
3-7.1.2 Performance Requirements.

Target Criteria	**Recreational**
Average Horizontal Illuminance	Refer to ANSI/IES RP-6 for specific indoor sport
Horizontal Illuminance Uniformity	Refer to ANSI/IES RP-6 for specific indoor sport

3-7.1.3 Critical Design Issues.

- Provide luminaires with lenses or louvers to minimize glare.
- Refer to ANSI/IES RP-6, *Recommended Practice: Lighting Sports and Recreational Areas* for specific criteria for different indoor sports. Use Class IV for all recreation lighting criteria. If more than one type of sport is intended to be played in the gymnasium, design the light levels for the sport requiring the most light.
- Refer to ANSI/IES RP-6, *Recommended Practice: Lighting Sports and Recreational Areas* for direction in luminaire placement to avoid glare.
- Provide uniform illuminance on the court.
- Minimize shadows to enhance view of objects and people.
- Light room surfaces to balance luminance ratios.
- Coordinate luminaire locations with ceiling equipment such as HVAC, and sports equipment.
- Use wire guards or polycarbonate lens where appropriate to protect luminaire.
- Refer to UFC 4-740-02 for additional requirements and considerations regarding recreational spaces in fitness centers.
- Provide keyed box for lighting controls near main entrance.

3-7.2 Locker Rooms.



3-7.2.1 Control Requirements.

Manual Control	At least one scene wallstation or wallbox dimmer
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

3-7.2.2 Performance Requirements.

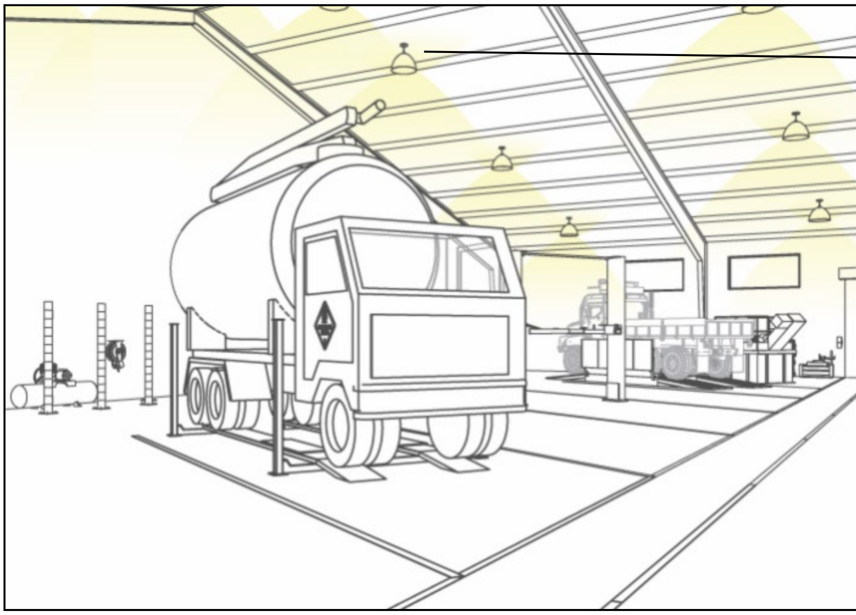
Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	5 fc (50 lux) at floor
Average Vertical Illuminance	10 fc (100 lux) at locker faces
Horizontal Illuminance Uniformity	3:1 average to minimum

3-7.2.3 Critical Design Issues.

- Provide luminaires with translucent, non-breakable, protective covers.
- Provide luminaires that are damp rated if they are located in close proximity to showers, pools, or other humid spaces.
- Light room surfaces to balance luminance ratios.
- Minimize shadows by providing diffuse lighting, especially at lockers and counters.
- Refer to UFC 4-740-02 for additional requirements and considerations regarding recreational spaces in fitness centers.
- For locker rooms greater than 300 square feet, means of egress must comply with NFPA 101 for passageways leading to an exit.

3-8 MAINTENANCE SPACES.

3-8.1 Vehicle Maintenance Areas.



Direct / indirect luminaires reduce direct glare.

Luminaire spacing provides uniform illuminance on task plane.

3-8.1.1 Control Requirements.

Manual Control	Manual OFF with scene wallstation with at least three preset scenes: full ON, lights dimmed between 30% and 70% of full lighting power, and OFF.
Occupancy/Vacancy	Manual ON Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled Full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Zone each service bay separately.

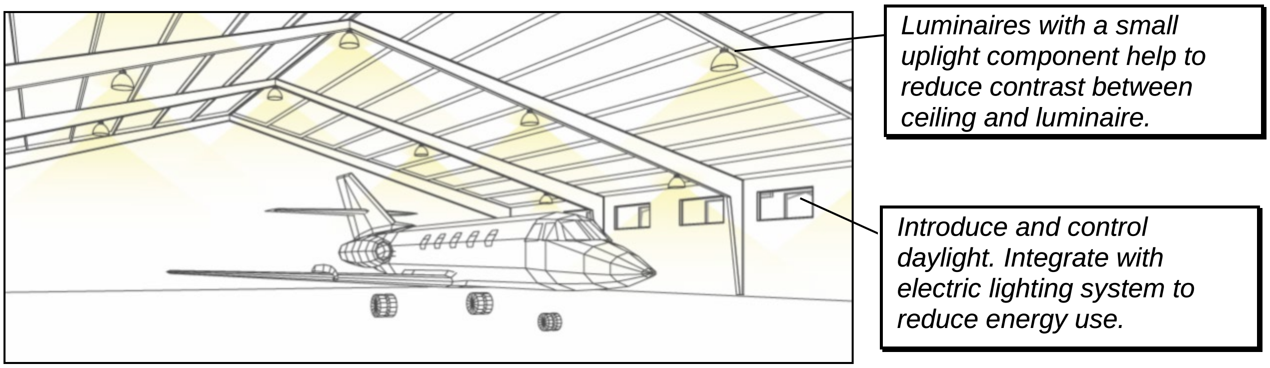
3-8.1.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	30 fc (300 lux) at floor
Average Vertical Illuminance	7.5 fc (75 lux) at 4’-0” (1219 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-8.1.3 Critical Design Issues.

- Use stem mounted luminaires in all drive through vehicle maintenance bays.
- Provide redundant supports to ensure that failure of a single supporting component does not result in luminaire falling.
- Locate lighting equipment to minimize shadows.
- Automated dimming must be ramped.
- Light room surfaces to balance luminance ratios.
- Uniformly light the work plane.
- Verify special lighting equipment requirements in hazardous (classified) locations.
- These service facilities employ ambient and task lighting systems. The two primary lighting strategies are:
- Wall-mounted luminaires to illuminate tasks (the bench and vehicle hood areas) or
- Strategically located luminaires at the ceiling at the tasks (hood areas).
- White ceilings and walls are necessary to maximize efficiency and diffusion.
- Target illuminance requirements are applicable when all luminaires are energized.
- Occupancy/Vacancy automatic OFF is not allowed.
- Manual control override of scheduled shutoff will not turn the lighting on for more than 2 hours during scheduled off periods.

3-8.2 Aircraft Hangar Bay.



3-8.2.1 Control Requirements.

Manual Control	Manual OFF with scene wallstation with at least three preset scenes: full ON, lights dimmed between 30% and 70% of full lighting power, and OFF.
Occupancy/Vacancy	Manual ON Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled dimmed to 20% or user defined level when hangar bay is scheduled to be vacant unless occupants enter the bay, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming per zone when daylight is present.
Zoning	Each aircraft maintenance area is a separate lighting control zone. ASHRAE 90.1 does not apply to aircraft maintenance areas.

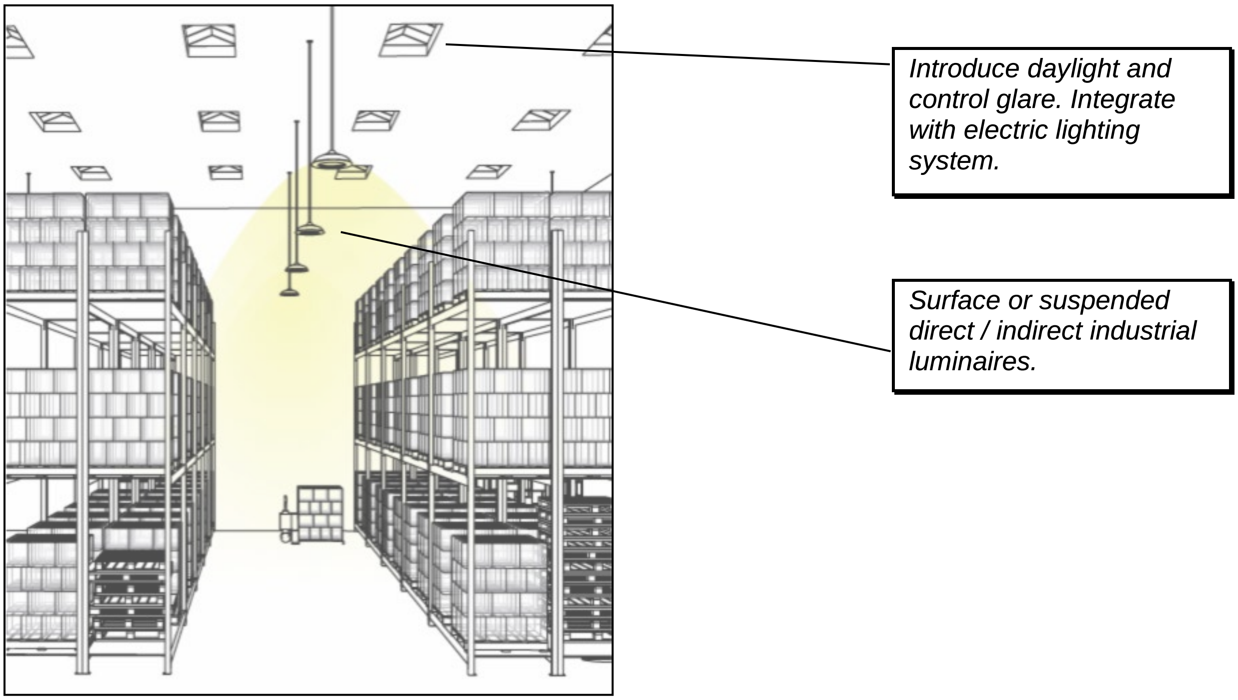
3-8.2.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	50 fc (500 lux) at 2'-6" (762 mm) AFF
Average Vertical Illuminance	50 fc (500 lux) at aircraft surface
Horizontal Illuminance Uniformity	3:1 average to minimum

3-8.2.3 Critical Design Issues.

- If there are no afterhours security requirements, the lights in the hangar bay may be shut off via Time Schedule. Coordinate security lighting requirements with security officer.
- Use stem mounted luminaires in aircraft hangar bays.
- Provide redundant supports to ensure that failure of a single supporting component does not result in luminaire falling.
- Locate lighting equipment to minimize shadows.
- Uniformly light the work plane.
- Automated dimming must be ramped.
- Occupancy/Vacancy automatic OFF is not allowed.
- Verify special lighting equipment requirements in hazardous (classified) locations.
- Refer to ANSI/IES RP-7 for additional considerations.
- Account for permanent illuminance-reduction installation features, such as instances where luminaires are installed above bird netting. 10% performance reduction is assumed in these situations. Ensure that luminaires be accessible for maintenance when bird netting is installed.
- UFC 4-211-02 requires 100 fc average for corrosion control hangar bays.
- Coordinate skylight and clerestory locations with aircraft control to ensure no visual light trespass conflicts with control tower night operations.

3-8.3 Warehouses.



3-8.3.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 70% of full lighting power OR One wallbox dimmer per zone
Occupancy/Vacancy	Manual ON Automatically dimmed by at least 50% after 20 minutes of vacancy OR Automatic ON to 50% of general lighting power Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	Provide zones that are no larger than 2,500 square feet, unless space is over 10,000 square feet, then larger zones can be used.

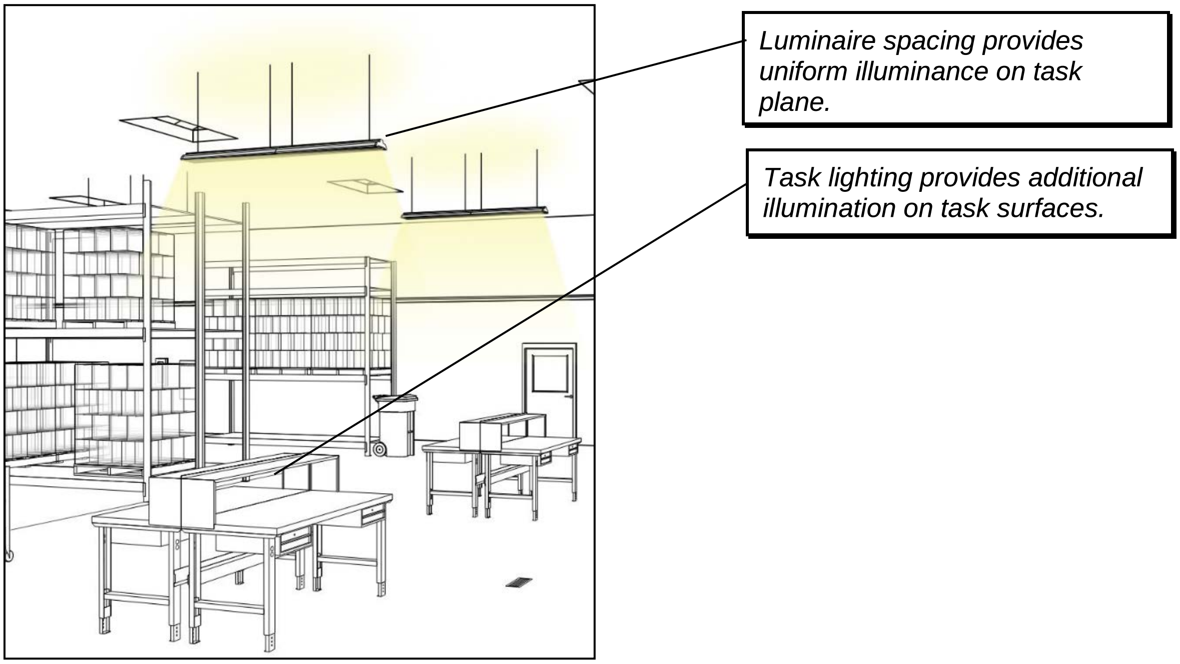
3-8.3.2 Performance Requirements.

Target Criteria	Small items	Medium items	Large items, infrequent use
Average Horizontal Illuminance	20 fc (300 lux) at floor	10 fc (100 lux) at floor	5 fc (50 lux) at floor
Average Vertical Illuminance	10 fc (100 lux) at 4'-0" (1220 mm) AFF	7.5 fc (75 lux) at 4'-0" (1220 mm) AFF	2 fc (20 lux) at 4'-0" (1220 mm) AFF
Horizontal and Vertical Illuminance Uniformity	3:1 average to minimum		

3-8.3.3 Critical Design Issues.

- Locate lighting equipment to minimize shadows.
- Coordinate lighting equipment locations with permanent shelving
- Light room surfaces to balance luminance ratios.
- Uniformly light the work plane.
- Distribution of luminaire to illuminate vertical surfaces of shelving.
- When spaces are larger than 10,000 square feet, zones can be larger in accordance with ASHRAE.
- Recommended occupancy zoning by aisle.
- Manual control override of scheduled shutoff will not turn the lighting on for more than 2 hours during scheduled off periods.

3-8.4 Maintenance Shops.



3-8.4.1 Control Requirements.

Manual Control	Manual OFF with scene wallstation with at least three preset scenes: full ON, lights dimmed between 30% and 70% of full lighting power, and OFF. Individual control for task lighting at work benches.
Occupancy/Vacancy	Manual ON Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled full OFF when building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

3-8.4.2 Performance Requirements.

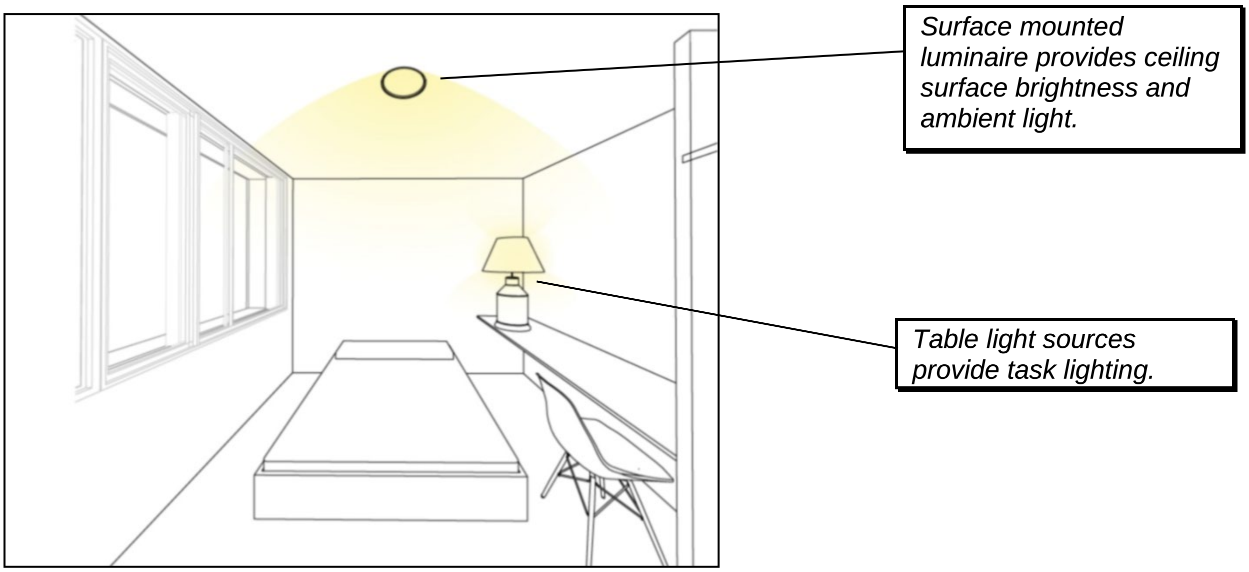
Target Criteria	**Ambient**	**Task**
Average Horizontal Illuminance	30 fc (300 lux)	50 fc (500 lux) at 3’-6” AFF
Horizontal Illuminance Uniformity	3:1 average to minimum	

3-8.4.3 Critical Design Issues.

- Maintenance shops are often located within other space types. Design lighting in the maintenance shop areas to be on own control zone and design to the light levels listed in the performance requirements.
- Locate lighting equipment to minimize shadows.
- Automated dimming must be ramped.
- Light room surfaces to balance luminance ratios.
- Uniformly light the work plane.
- Verify special lighting equipment requirements in hazardous (classified) locations.
- Manual control override of scheduled shutoff will not turn the lighting on for more than 2 hours during scheduled off periods.

3-9 HOUSING.

3-9.1 Bedrooms.



3-9.1.1 Control Requirements.

Manual Control	At least one wallbox dimmer with continuous dimming for ambient lighting.
Occupancy/Vacancy	None
Time Schedule	None
Daylight	None
Zoning	Provide separate switching for ambient lighting and task lighting.

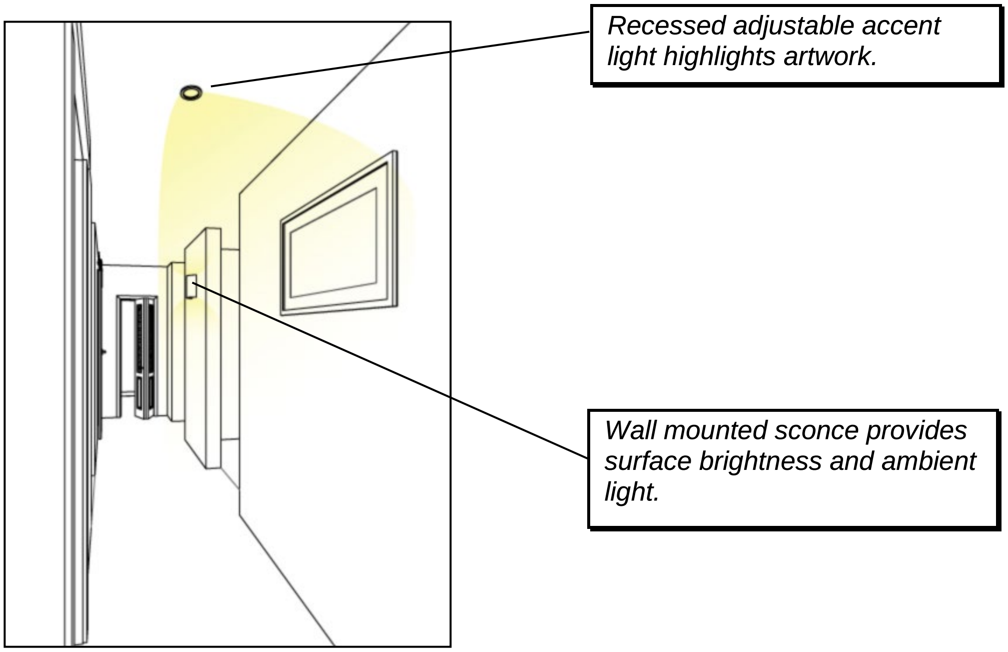
3-9.1.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	5 fc (50 lux) at 2'-0" (610 mm) AFF
Horizontal Illuminance Uniformity	5:1 average to minimum

3-9.1.3 Critical Design Issues.

- Light room surfaces to balance luminance ratios.
- Provide three-way switches at Unit/Room entrance and bedroom(s) doors.
- Provide overhead ambient lighting in bedrooms, separately switched and dimmed for each occupant side of the room.
- Per FC 4-721-10N Unaccompanied Housing, no “cloud type” light luminaires are allowed.
- Refer to FC 4-721-10N Unaccompanied Housing and UFC 3-353-1 for further guidance.

3-9.2 Hallways.



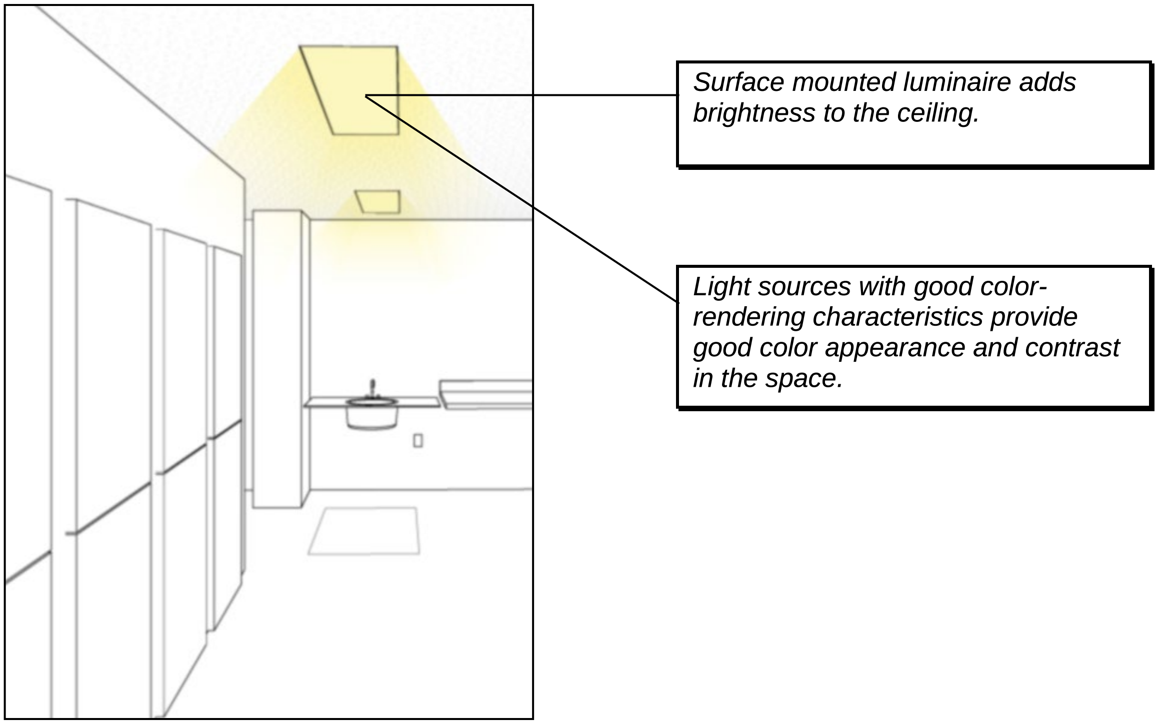
3-9.2.1 Control Requirements.

Manual Control	At least one wallbox dimmer or scene wallstation
Occupancy/Vacancy	Manual ON Automatically dimmed between 30% and 70% after 5 minutes of vacancy OR Manual ON Automatic OFF after 5 minutes of vacancy
Time Schedule	None
Daylight	None
Zoning	Provide separate switching for ambient lighting and accent lighting

3-9.2.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	3 fc (30 lux) at floor
Horizontal Illuminance Uniformity	5:1 average to minimum

3-9.3 Laundry Rooms.



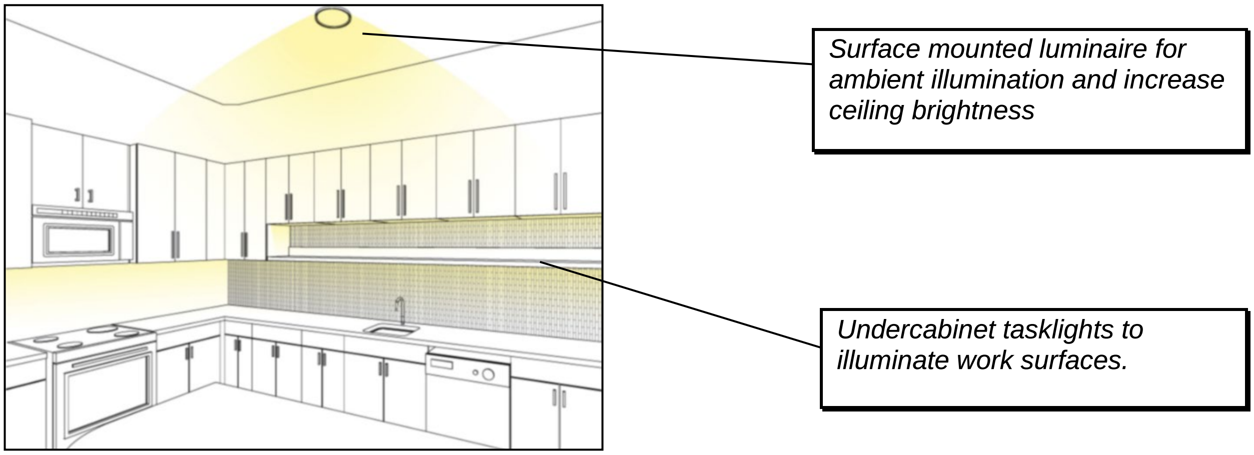
3-9.3.1 Control Requirements.

Manual Control	At least one wallbox dimmer or scene wallstation
Occupancy/Vacancy	Manual On Automatic full OFF after 5 minutes of vacancy
Time Schedule	None
Daylight	None
Zoning	None

3-9.3.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	20 fc (200 lux) at 3’-0” (914 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-9.4 Kitchens.



3-9.4.1 Control Requirements.

Manual Control	At least one wallbox dimmer or scene wallstation per luminaire type
Occupancy/Vacancy	None
Time Schedule	None
Daylight	None
Zoning	Provide separate switching or scene control for ambient lighting and task lighting. Provide separate switch for task lighting above sink and/or work surfaces.

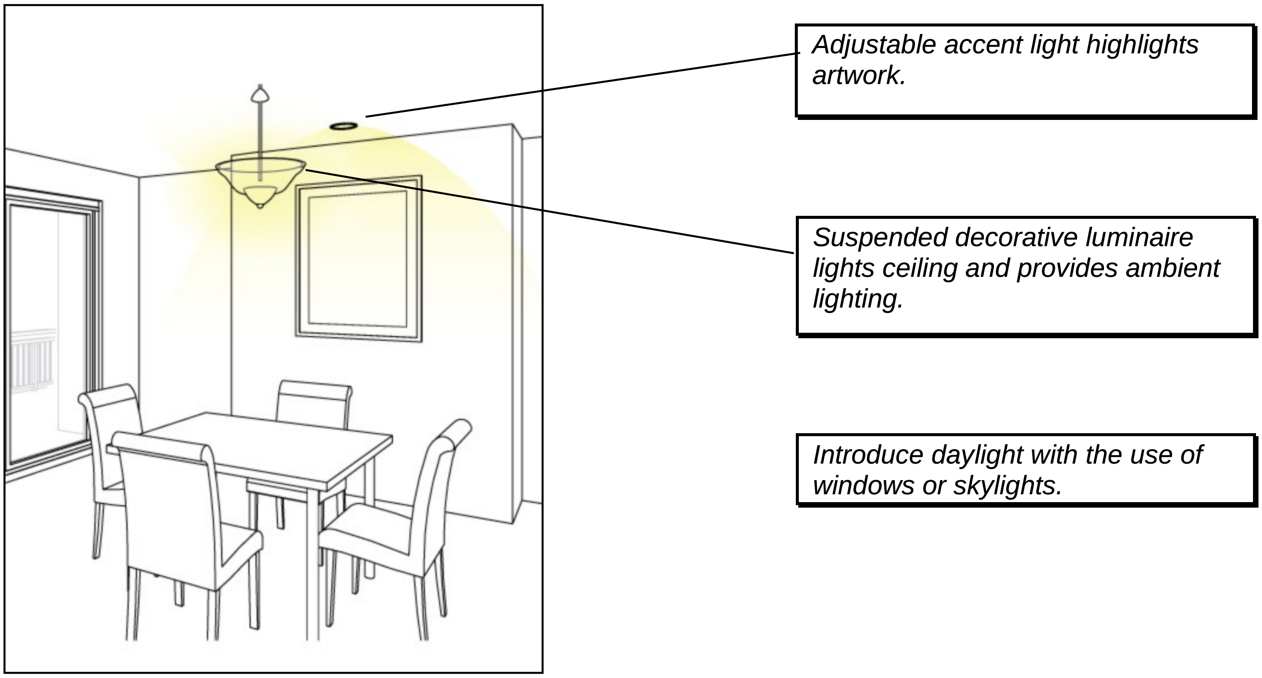
3-9.4.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance, General	5 fc (50 lux) at floor
Average Horizontal Illuminance, Task Surface	30 fc (300 lux) at cooking surface
Horizontal Illuminance Uniformity	3:1 average to minimum

3-9.4.3 Critical Design Issues.

- Locate lighting equipment to minimize shadows.
- Light room surfaces to balance luminance ratios.
- Illuminate work surfaces.

3-9.5 Dining Rooms.



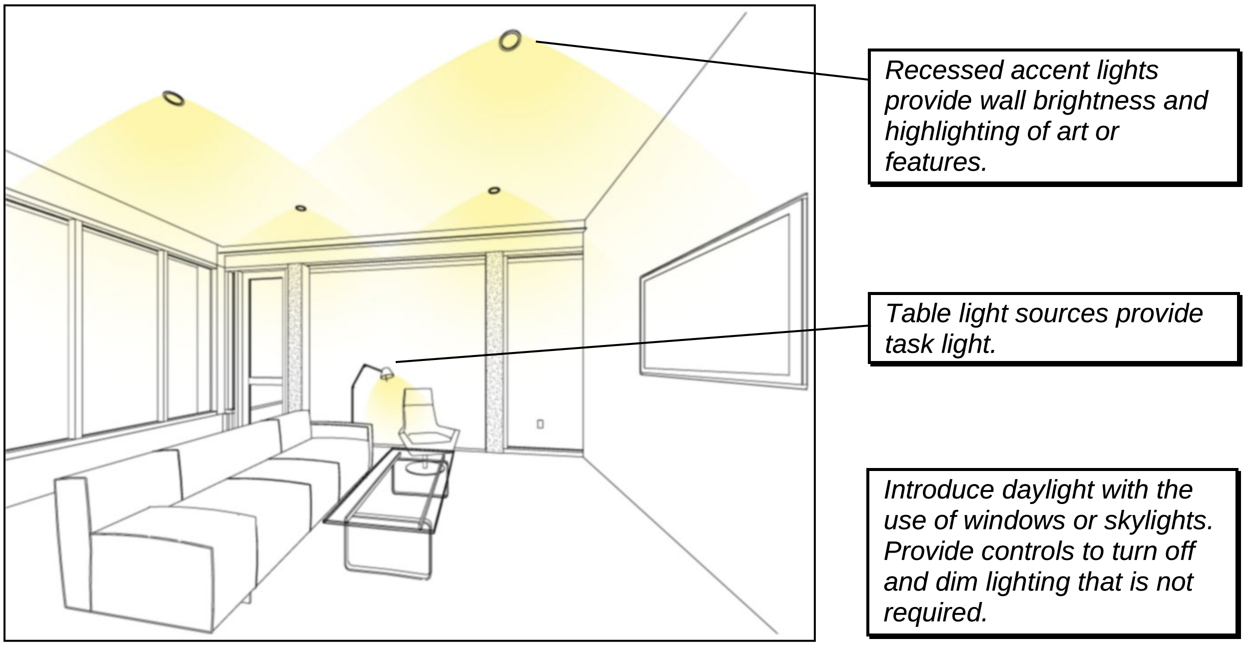
3-9.5.1 Control Requirements.

Manual Control	Local ON/OFF control device AND At least one scene wallstation or wallbox dimmer with continuous dimming
Occupancy/Vacancy	None
Time Schedule	None
Daylight	None
Zoning	Provide separate switching for ambient lighting and accent lighting. Each lighting type may dim as separate zone or part of scene controller

3-9.5.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	5 fc (50 lux) at table plane
Horizontal Illuminance Uniformity	4:1 average to minimum

3-9.6 Living Rooms.



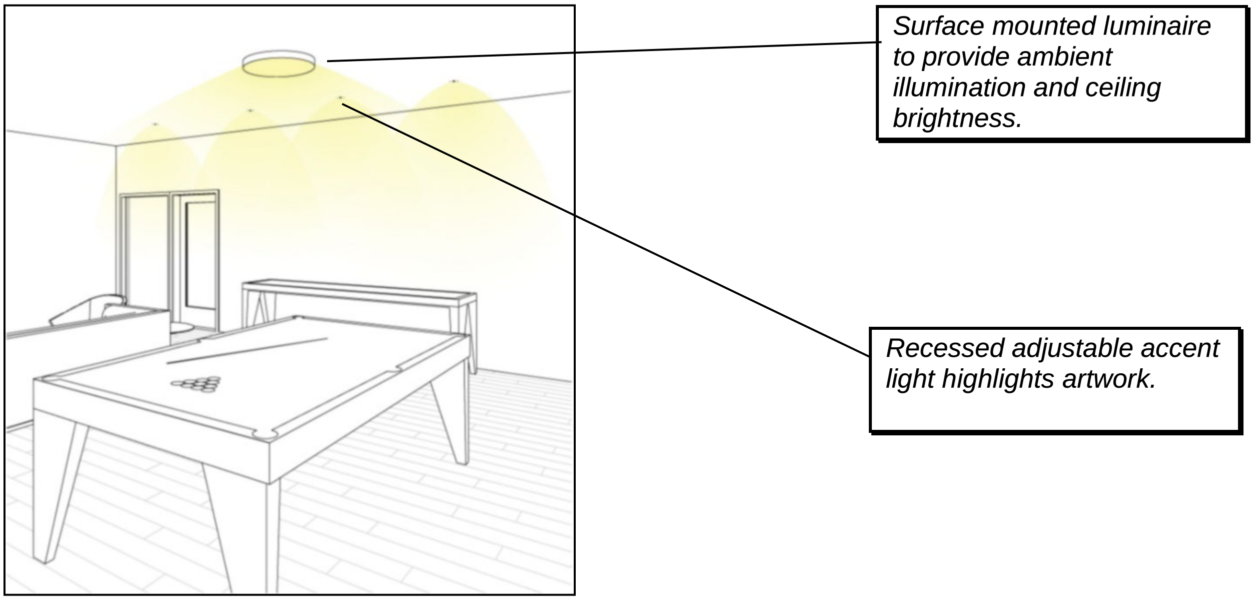
3-9.6.1 Control Requirements.

Manual Control	At least one wallbox dimmer or scene wallstation
Occupancy/Vacancy	None
Time Schedule	None
Daylight	None
Zoning	Provide separate switching or scene control for ambient lighting and task lighting

3-9.6.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	3 fc (30 lux) at floor
Horizontal Illuminance Uniformity	5:1 average to minimum

3-9.7 Rec Rooms.



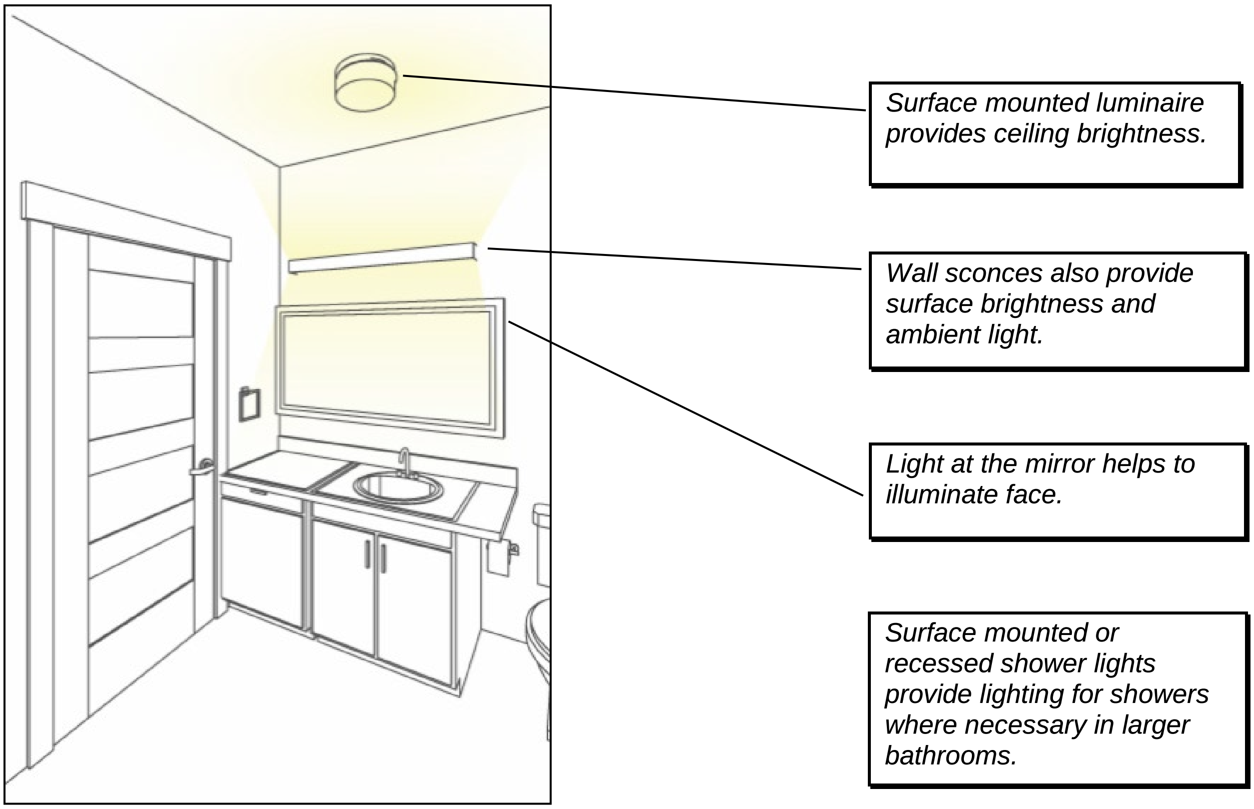
3-9.7.1 Control Requirements.

Manual Control	At least one wallbox dimmer or scene wallstation
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy OR Automatic ON to a maximum of 50% of full lighting power Automatic full OFF after 20 minutes of vacancy
Time Schedule	None
Daylight	None
Zoning	Provide separate switching or scene control for ambient lighting and accent lighting

3-9.7.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	20 fc (200 lux) at 2’-6” (762 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-9.8 Bathrooms.



3-9.8.1 Control Requirements.

Manual Control	At least one wallbox dimmer or scene wallstation per luminaire type
Occupancy/Vacancy	Manual ON Automatic full OFF after 20 minutes of vacancy
Time Schedule	None
Daylight	None
Zoning	None

3-9.8.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	30 fc (300 lux) at 3'-0" (914 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-9.9 Garages.

3-9.9.1 Control Requirements.

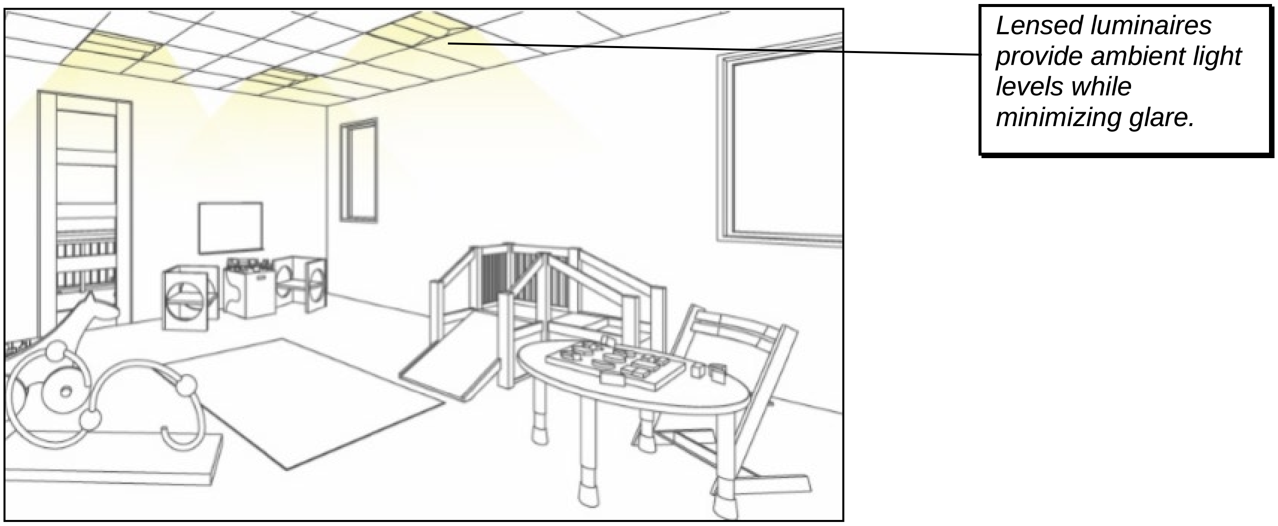
Manual Control	At least one wallbox switch or scene wallstation
Occupancy/Vacancy	Manual ON Automatic full OFF after 10 minutes of vacancy
Time Schedule	None
Daylight	None
Zoning	None

3-9.9.2 Performance Requirements.

Target Criteria	**Daytime/Nighttime**
Average Horizontal Illuminance	20 fc (200 lux) at 3’-0” (914 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-10 CHILDCARE SPACES.

3-10.1 Daycare Indoor Play Areas.



3-10.1.1 Control Requirements.

Manual Control	Scene wallstation with at least one preset scene with all lights dimmed between 30% and 50% of full lighting power OR One wallbox dimmer per luminaire type
Occupancy/Vacancy	Manual ON Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled shutoff for all lights in the space when the building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

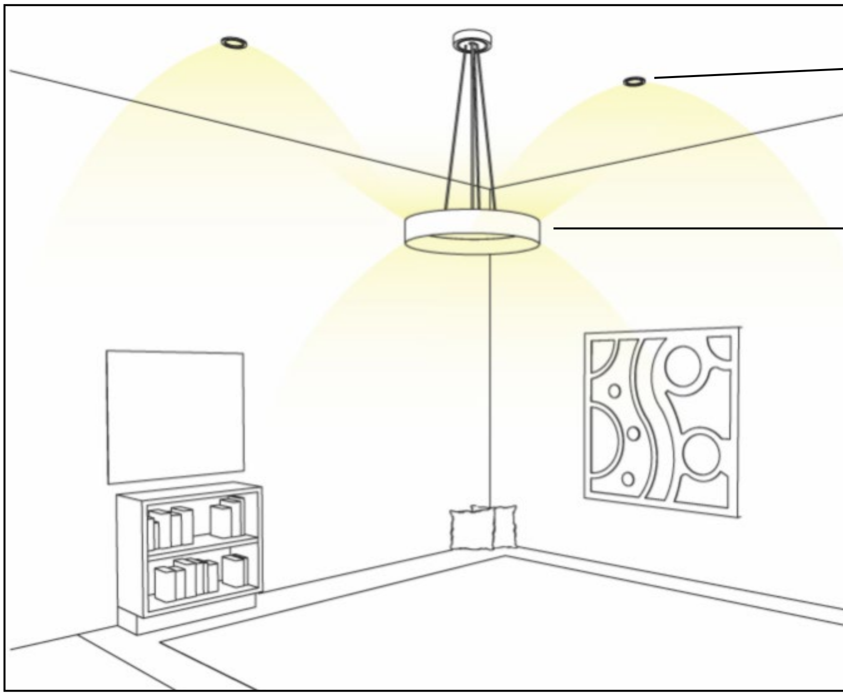
3-10.1.2 Performance Requirements.

Target Criteria	Daytime/Nighttime
Average Horizontal Illuminance	30 fc (300 lux) at 2'-0" (910 mm) AFF
Horizontal Illuminance Uniformity	3:1 average to minimum

3-10.1.3 Critical Design Issues.

- Light room surfaces to balance luminance ratios.
- Provide wall sconces to add decorative interest and illuminate wall surfaces.
- Refer to UFC 4-740-14 and FC 4-740-14N for additional requirements and considerations regarding child development centers.

3-10.2 Daycare Indoor Rest Areas.



Neutral surface mounted or recessed downlights for ambient illumination and cleaning.

Suspended luminaire lowers the "perceived ceiling" and helps to create a space within a larger space.

3-10.2.1 Control Requirements.

Manual Control	Scene wallstation with continuous dimming and preset scene for rest time
Occupancy/Vacancy	Manual ON Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled shutoff for all lights in the space when the building is scheduled to be vacant unless occupants enter the building, then use Manual Control and Occupancy/Vacancy sensor criteria.
Daylight	Automatic responsive daylight dimming when daylight is present
Zoning	None

3-10.2.2 Performance Requirements.

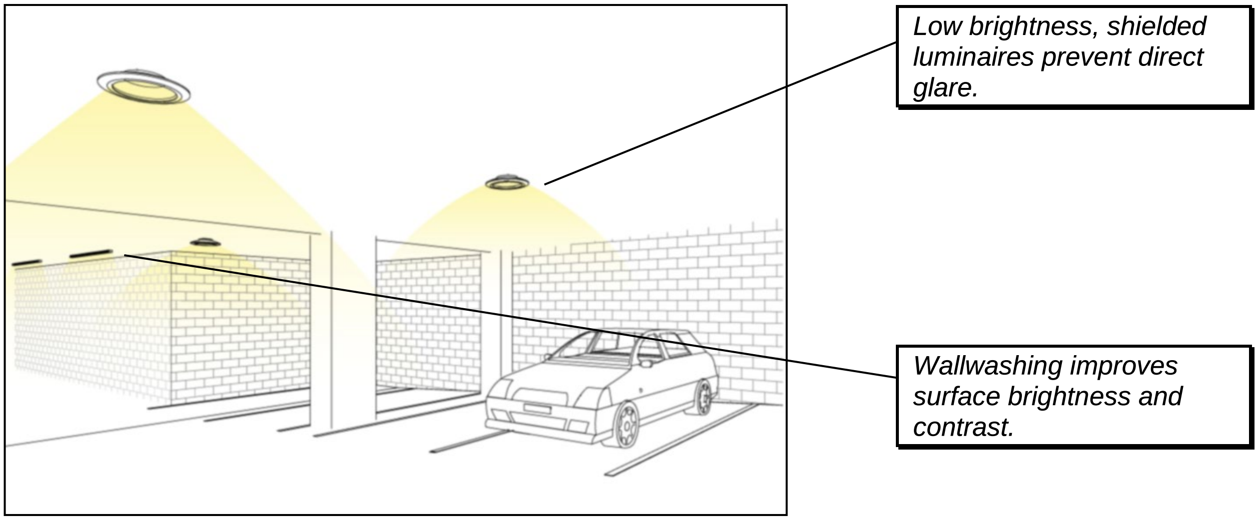
Target Criteria	**Daytime/Nighttime**
Minimum Horizontal Illuminance	1 fc (10 lux) at 2'-0" (910 mm) AFF (at all times)
Maximum Horizontal Illuminance	5 fc (50 lux) at 2'-0" (910 mm) AFF (during rest time)
Average Horizontal Illuminance	20 fc (200 lux) at 2'-0" (910 mm) AFF (outside of rest time)

3-10.2.3 Critical Design Issues.

- Provide dimmable lighting zones to reduce light levels during rest periods.
- Use dim-to-warm LED light sources to provide a warm CCT suitable for areas of rest.
- Provide layout of ambient lighting for cleaning.
- Refer to UFC 4-740-14 and FC 4-740-14N for additional requirements and considerations regarding child development centers.

3-11 PARKING.

3-11.1 Parking Structures.



3-11.1.1 Control Requirements.

Manual Control	None
Occupancy/Vacancy	Automatic ON with detected motion Automatically dimmed by at least 50% after 20 minutes of vacancy
Time Schedule	Scheduled shutoff for all lights in the space when the space is scheduled to be vacant
Daylight	Automatic reduction of daylight transition lighting to general light levels from Sunset to Sunrise Responsive continuous daylight dimming of luminaires within 20 feet of large perimeter wall openings
Zoning	Zones must be 3,600 square feet or less

3-11.1.2 Performance Requirements.

Target Criteria	Daytime	Nighttime
Minimum Horizontal Illuminance, General areas, active	1 fc (10 lux) at floor	1 fc (10 lux) at floor
Minimum Vertical Illuminance, General areas, active	0.5 fc (5 lux) at 5’-0” (1524mm) AFF	0.5 fc (5 lux) at 5’-0” (1524 mm) AFF
Minimum Horizontal Illuminance, General areas, inactive	0.2 fc (2 lux) at floor	0.2 fc (2 lux) at floor
Minimum Vertical Illuminance, General areas, inactive	0.1 fc (1 lux) at 5’-0” (1524 mm) AFF	0.1 fc (1 lux) at 5’-0” (1524 mm) AFF
Minimum Horizontal Illuminance, Vehicular entries and exit	50 fc (500 lux) at floor	1 fc (10 lux) at floor
Minimum Vertical Illuminance, Vehicular entries and exit	25 fc (250 lux) at 5’-0” (1524 mm) AFF	0.5 fc (5 lux) at 5’-0” (1524 mm) AFF
Minimum Horizontal Illuminance, Stairway	10 fc (100 lux) at walking surface	10 fc (100 lux) at walking surface
Minimum Vertical Illuminance, Stairway	25 fc (250 lux) at 5’-0” (1524 mm) AFF	1.2 fc (12.5 lux) at 5’-0” (1524 mm) AFF
Horizontal and Vertical Illuminance Uniformity	10:1 maximum to minimum	

3-11.1.3 Critical Design Issues.

- Provide daylight transition lighting at parking structure entrances.
- Stairs not on path of egress should use IES light levels in RP-8.

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CHAPTER 4 EXTERIOR LIGHTING

4-1 PRIORITIES FOR EXTERIOR LIGHTING SYSTEMS.

Design exterior lighting systems to minimize energy consumption, reduce maintenance costs, improve lighting quality on DoD Installations, at the lowest life cycle cost.

4-1.1 Energy Reduction.

Provide SSL/LED systems for all exterior lighting. SSL/LED systems are established technologies for exterior lighting applications that have been proven to save energy over traditional light sources.

Minimize energy consumption by providing energy efficient technologies, maintaining effective luminance and illuminance levels, and implementing control strategies. Maintain illumination level prescribed averages as closely as possible, in order to provide sufficient light levels without contributing to excessive energy usage.

4-1.2 Maintenance Reduction.

Reduce maintenance by technology selection, reducing equipment quantities, and implementing controls strategies.

Select light sources, drivers, and controls that are rated and warranted for long useful lives to increase the amount of time between maintenance cycles. Match light sources in adjacent areas when appropriate.

4-1.3 Luminaire Placement.

Locate luminaires to reduce impact to adjacent properties. This is particularly important when lighting areas adjacent to residential neighborhoods and environmentally sensitive areas, including waterways.

4-1.4 Lighting Quality.

Apply the following to ensure the priority of lighting quality is achieved.

4-1.4.1 Direct Glare.

Avoid direct glare from luminaires and excessive contrast of surfaces. Use shielded light sources and as low a lumen output as possible. When using ANSI/IES TM-15 BUG ratings, a low ‘G’ rating would provide reduced glare.

4-1.4.2 Light Pollution / Trespass.

Use ANSI/IES TM-15 U0 luminaires to eliminate direct light above the horizontal plane. Refer to maximum allowable uplight (U) and backlight (B) ratings in specific lighting zones.

4-1.4.3 Modeling of Faces and Objects.

Provide light from multiple directions to accurately render objects and people.

4-1.4.4 Reflected Glare.

Select and locate luminaires to minimize wet surface reflected glare and polished surface reflection of a light source.

4-1.4.5 Shadows.

Locate poles such that the light from the luminaires minimizes shadows that could conceal potential hazards.

4-1.4.6 Vertical Illuminance.

Provide vertical illuminance on individuals' faces as well as potential hazards.

4-1.4.7 Appearance of Space and Luminaires.

Carefully select luminaires to match the aesthetic character of the building and contribute to a welcome designation to the building entry. Refer to the base-wide architectural plan to consolidate luminaire types.

4-1.4.8 Light Distribution on Surfaces.

Illuminate the walkway uniformly to avoid dark patches.

4-1.4.9 Point(s) of Interest.

Provide lighting for wayfinding and indicate points of interests, such as the building entry.

4-2 EXTERIOR LIGHTING EQUIPMENT.

4-2.1 Light Source Technology.

Provide SSL/LED systems unless there is no equivalent SSL/LED product for the application. If another light source other than SSL/LED is specified, provide documentation regarding the selection of that light source in the project's Basis of Design.

4-2.1.1 SSL/LED Light Sources.

Provide light sources with a CCT of no greater than 3000 K as stated on the manufacturer's specification information to reduce skyglow in exterior applications and minimize impact to human and animal circadian rhythms.[3 & 4] Use monochromatic amber LEDs in place of low pressure sodium (LPS) for sensitive environments such as wildlife habitat, wildlife nesting, or to meet dark sky requirements (observatories). Incorporate Fish and Wildlife, State, and local governing authority recommendations for lighting systems design and installation.

4-2.1.2 CCT and CRI.

Use a color rendering index (CRI) of no less than 70 for exterior applications. In some applications, where motorists' vision is of high importance, such as areas with high speeds and high vehicle conflicts, a CCT of 4000 K may be used.

4-2.1.3 SSL/LED Drivers.

Provide lighting systems with accessible and replaceable drivers. For current and future dimming requirements (smart grid, curfew, adaptive), use dimmable drivers compatible with standard dimming control circuit of 0-10V or DALI. Other dimming protocols must comply with cybersecurity requirements.

4-2.2 Surge Protection.

Provide MOV type surge protection devices at panelboards for all circuits feeding exterior lighting systems. LED luminaires require integral metal oxide varistors (MOV) type surge protection device with elevated 10-kVA surge protection.

4-2.3 Over Current Protection Device.

Provide in-line fuse in pole base or splice box for street and area lights.

4-2.4 Poles.

Do not use square poles. Provide compatible poles with all pole-mounted luminaires. Provide breakaway bases for poles adjacent to vehicle traffic in accordance with the American Association of State Highway and Transportation Officials (AASHTO) GL-6. Non-breakaway poles must be protected by a barrier or be barrier-mounted.

4-3 EXTERIOR LIGHTING CONTROLS.

Refer to CHAPTER 5 for control requirements specific to common applications. Refer to ANSI/IES LP-6 for additional considerations for lighting control systems, and ANSI/IES LP-8 for commission guidance for specific applications.

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[3] IES TM-12-12, Lamp Spectral Effects at Mesopic Lighting Levels. The Illuminating Engineering Society. New York, NY.
[4] IES TM-18-18, Light and Human Health. The Illuminating Engineering Society, New York, NY.

4-3.1 Control Strategies.

Indicate in the contract documents the control strategy for each area type in accordance with required strategies in CHAPTER 5.

4-3.1.1 Manual Control.

The lights are manually turned on and manually turned off. This approach can only be used when other control strategies cannot be implemented due to operational requirements.

4-3.1.2 Motion Sensing.

Upon sensing vacancy, the lights dim to 30% of full light output. Do not provide motion sensing that fully turns off all lighting within a control zone.

4-3.1.3 Time Schedule.

Time scheduling controls the light based on a preset schedule. This is most beneficial when lights are controlled based on business hours. Time scheduling may be used in place of photosensing, for turning lights on when there is no longer sufficient daylight, and for turning lights off during hours of daylight. Use an astronomical timeclock when controlling exterior lighting using this method to ensure the schedule adjusts as sunrise and sunset shifts throughout the year.

When using time scheduled controls that are based on operating business hours, provide at least 15 minutes of luminaire operation before business open, when before dawn, and at least 15 minutes of luminaire operation after business close, when after dusk. Do not use time scheduled controls to completely turn off exterior lighting if occupants regularly occupy the building after officially scheduled hours.

4-3.1.4 Photosensing.

Photosensing measures the amount of daylight currently available and controls luminaires according to this. Typically, at sunset or shortly after, the lights automatically turn on. At sunrise or shortly before, the lights automatically turn off. Photocells may be located on each luminaire individually or located at the lighting control center. Photocells are typically used for exterior lighting systems that are not connected to a building lighting control system.

Provide photosensors with zero-cross technology to withstand severe in-rush current and extend relay life.

4-3.1.5 Zoning.

Provide separate control circuits for each luminaire application. For example, area lights may be on the same control circuit. However, area lights and step lights should not be on the same control circuit. Provide separate control zones for each use area.

4-3.2 Wireless Networks.

Coordinate wireless networks with base spectrum manager prior to specification in case of restrictions for wireless usage within the installation.

4-3.3 Control Equipment.

Provide lighting control equipment capable of meeting the strategies described in the contract documents. Control equipment must be designed to control the specific light sources and luminaires specified for each application. Provide photocells which meet elevated 10-kV/10-VA requirements per IEEE designed to operate exterior LED luminaires in order to eliminate inrush current system malfunction.

4-3.3.1 Multi-pin Receptacle.

Provide streetlights and parking lot lighting that are installed with an ANSI C136.41 seven-pin receptacle which accepts a standard three-pin photocell or shorting cap. This allows streetlights and parking lot lighting to be connected to a wireless control system in the future, since many wireless control system nodes are compatible with seven-pin receptacles.

4-4 EXTERIOR LIGHTING ZONES.

Lighting zones reflect the base (or ambient) light levels desired for an area. Adopt the lowest possible lighting zone. Lighting zones are best implemented as an overlay to the established zoning especially on installations where a variety of zone districts exist within a defined area or along an arterial street. Where zone districts are cohesive, it may be possible to assign lighting zones to established land use zoning. It is recommended that the lighting zone includes churches, schools, parks, and other uses embedded within residential communities or to any land assigned to a lower zone.

For DoD installations, it is important to consider all activities of an area's land use. Lighting zones must consider the surrounding areas as well. For example, adjacent lighting zones must not hinder nighttime operations. Additionally, outside the United States and its territories, it is important that the installation does not stand out as an exceptionally bright area compared to the adjacent development. Figure 4-1 and Table 4-1 show examples of how lighting zones from the IDA-IES *Model Lighting Ordinance* may be applied to DoD installations.

Figure 4-1 Example Lighting Zones on a Sample Installation

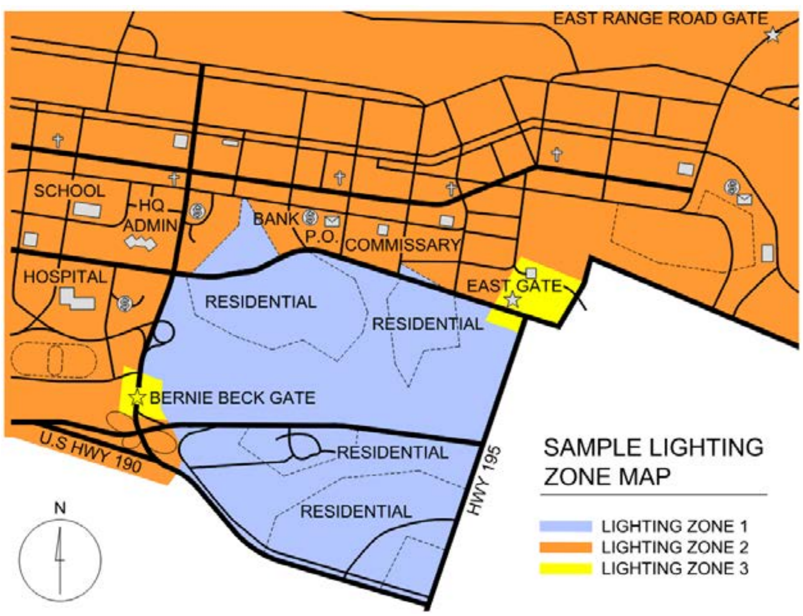


Table 4-1 Lighting Zones and DoD Applications.

MLO Lighting Zones	**Title**	**DoD Installation/Application**	
LZ0	No Ambient Lighting	**Training areas** Night vision training areas, endangered waterfront areas and other areas where there is expected no nighttime activity.	INCREASING NIGHTTIME ACTIVITY
LZ1	Low Ambient Lighting	**Personnel Support Districts** Unaccompanied quarters, single and multi-family residential, campgrounds, administration, and other non-nighttime use areas, golf course, exercise fields and paths **Airfield** (Nearby facilities may be higher zone)	
LZ2	Moderate Ambient Lighting	**Waterfront or Airfield Facilities** Administrative areas, common areas, service areas, parking. **Training Facilities** Academic instruction, educational services, applied instruction, reserve training, operational simulators **Administrative Facilities** Offices, conference centers, command centers, parking **Personnel Support Districts** Officer clubs, lodge, food service, fire and security, ITT, medical and dental clinics, family services, schools, childcare facilities, youth programs, religious facilities, banks, exchange, commissary, libraries, morale, welfare and recreation, hobby shops, theaters, gyms indoor sport facilities, outdoor pools, sports (tennis, basketball) courts, baseball and football fields **Industrial Facilities** Shipyards, ordinance handling/storage, manufacturing facilities, maintenance shops, depots	
LZ3	Moderately High Ambient Lighting	**Waterfront Facilities** Wharf and pier areas **Airfield Facilities** Aircraft hangars, air operations and headquarters, line shacks, terminal facilities, training areas, utility service areas **Entry Control Facilities** **Access Control Points**	
LZ4	High Ambient Lighting	No areas qualify for this lighting zone.	

4-5 ELECTRICAL ENERGY MONITORING.

For new construction buildings greater than 25,000 SF (2,322 m^2), terminate exterior lighting branch circuits in dedicated lighting panelboards. Provide metering requirements as required by UFC 1-200-02.

4-6 SOLAR LIGHTS.

Solar lights are permitted for use when:

- Electric utility services do not exist in the desired location of lighting.
- Centralized solar panels can be deployed to provide power to the lights.
- Sufficient battery capacity is provided to meet illumination requirements.
- Used with curfew controls to maximize battery life.

Solar lights are not permitted for use for security lighting or safety applications.

4-7 LIGHTING SYSTEM ALTERATIONS.

4-7.1 Types of Lighting System Alterations.

4-7.1.1 Redesign.

Redesign includes new luminaires, circuits, and controls designed to meet current lighting criteria. A new design must ensure reduced energy consumption, reduced maintenance, and lighting quality is improved at the lowest life cycle cost. Lighting redesign is required when a renovation involves changing lighting technologies such as fluorescent to LED and when renovation involves changing lighting with more efficient lighting within the same technology. Redesign lighting systems when existing:

- Illuminance levels are too low or too high
- Lighting produces glare
- Luminaire layout produces non-uniform illumination
- Luminaires are in poor condition
- Lighting control systems are inadequate
- Luminaires (or luminaire layout) is not appropriate because the physical layout of the area has changed

4-7.1.2 One-for-One Luminaire Replacement.

A luminaire replacement consists of the entire luminaire being replaced, including the housing. A luminaire replacement may be considered when the lighting design is sufficient, but more efficient luminaires are available. In instances where the existing luminaire is operating under dimming control, the lighting controls must be upgraded to be compatible with the operating characteristics of the replacement luminaire. Luminaire replacement is only acceptable when the resulting illuminance levels, glare, and distribution meet the current criteria.

4-7.1.2.1 Pole Modifications.

SSL/LED luminaire replacements have a different weight and Effective Projected Area than legacy luminaires, which impacts the structural performance of the pole. Most frequently, a reduction in weight at the top of the pole increases wind-induced vibration or pole galloping. Impact dampers reduce this phenomenon. Design and implementation of impact dampers must be coordinated with pole manufacturer or structural engineer.

4-7.1.2.2 Control Equipment Modifications.

Provide upgraded photocell replacements for all SSL/LED luminaire replacements that are controlled by photocell. Provide photocells which meet elevated 10 kV/10-VA requirements per IEEE designed to operate exterior LED luminaires in order to eliminate inrush current system malfunction.

4-7.1.3 Light Source Retrofit.

A light source retrofit is the replacement of the light source within the luminaire housing or the lighting module that has been designed to be installed in existing luminaire enclosures.

Do not use LED retrofit light sources or LED lighting modules that have been designed and constructed to be installed in existing HID, mercury vapor, or linear fluorescent luminaire enclosures. LED retrofits are only approved for replacement of CFL or incandescent sources (A-lamp replacements) with Edison bases.

4-8 SITE DESIGN COORDINATION.

Coordinate the design, luminaire selection, and placement with the location of trees, shrubs, and other site furnishing.

4-9 AIRFIELDS.

UFC 3-260-01 limits light emissions – either directly or indirectly (reflected) – that may interfere with pilot vision in runway clear zones. Exterior lighting must meet all FAA and airfield operational regulations. These regulations restrict the height, location, and technology of lighting located near airfields. Certain light sources may also interfere with night vision technologies. Obtain approval of lighting from installation's airfield safety office.

Use luminaires with a U0 rating to reduce glare and uplight which may affect airfield operations. If U0 rated luminaires are unable to satisfy lighting levels and performance criteria, utilize interior and external shielding to minimize glare and uplight. Do not exceed a glare rating of G2. Refer to UFC 3-535-01 for additional information.

CHAPTER 5 EXTERIOR LIGHTING APPLICATIONS

5-1 INTRODUCTION.

This chapter identifies typical exterior facility applications. Each application details a conceptual lighting design example. Designs must meet the lighting performance and controls requirements defined in the application details.

5-2 CALCULATIONS OF LIGHTING FOR EXTERIOR AREAS.

Computer-generated photometric plans for each area are required to verify proposed luminaires and locations meet the required performance criteria of the design using the applicable light loss factor (LLF).

Target illumination levels are provided for each Exterior Application. Depending on the application and the recommendations provided by the IES, values are given as one of the following:

- Minimum: No values anywhere on the calculation grid may be less than this value, within a 10% margin of error.
- Minimum Average: An average, taken over the entire task area for the application, may not be less than this value, within a 10% margin of error.
- Maximum: No values anywhere on the calculation grid may be greater than this value, within a 10% margin of error.
- Maximum Average: An average, taken over the entire task area for the application, may not be greater than this value, within a 10% margin of error.
- Uniformity: Unless otherwise noted, uniformity is calculated as a ratio of the average calculated illuminance over the minimum calculated illuminance of the calculation grid.

5-2.1 Schematic and Concept Design.

For Schematic and concept design phases prior to 60%, provide narrative indicating the following:

- When listing target criteria, include lighting zone in basis of design.
- Average maintained illuminance (or luminance for roadways) level.
- Lighting power density (watts per square foot or per square meter).

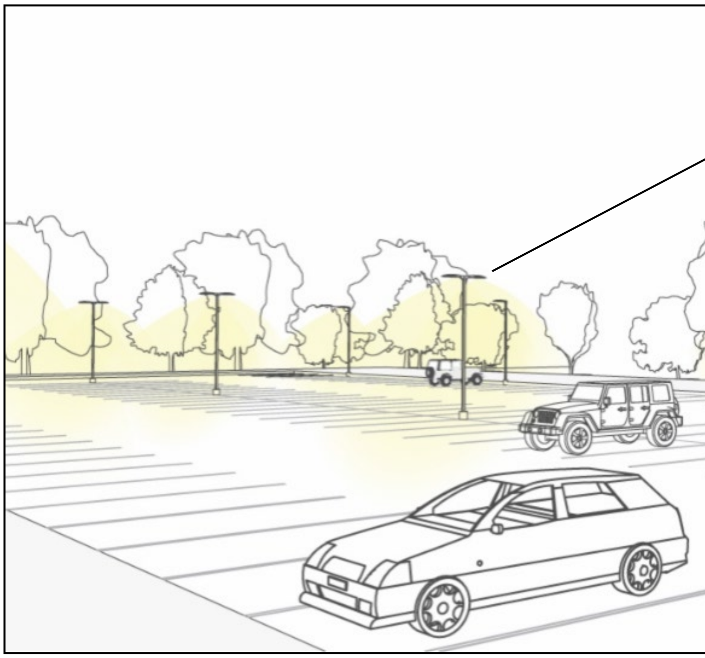
5-2.2 Designs submitted at 60% or later.

For designs submitted at 60% or later, provide photometric plan calculations to include the following:

- The point spacing of the calculation grid of horizontal illuminance (or luminance for roadways) measurements at finished grade, are to be 1/3 of the luminaire mounting height taken across the general area.
- Where applicable, vertical illuminance measurements at designated surface, taken at a maximum of every one foot (305 mm) across task area.
- Minimum and maximum illuminance (or luminance for roadways) levels.
- Average maintained illuminance (or luminance for roadways) level.
- Average to minimum and maximum to minimum ratios for horizontal illuminance (or luminance for roadways).
- Lighting power density (watts per square foot or per square meter).

5-3 PARKING FACILITIES.

5-3.1 Parking Lots.



Pole mounted luminaires with U0 rating control glare and reduce light pollution and trespass.

Spacing of luminaires provides uniform horizontal illuminance in parking areas.

5-3.1.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	Automatic dimming to 30% within 15 minutes after business close and automatic full ON within 15 minutes before business open Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	None

5-3.1.2 Performance Requirements.

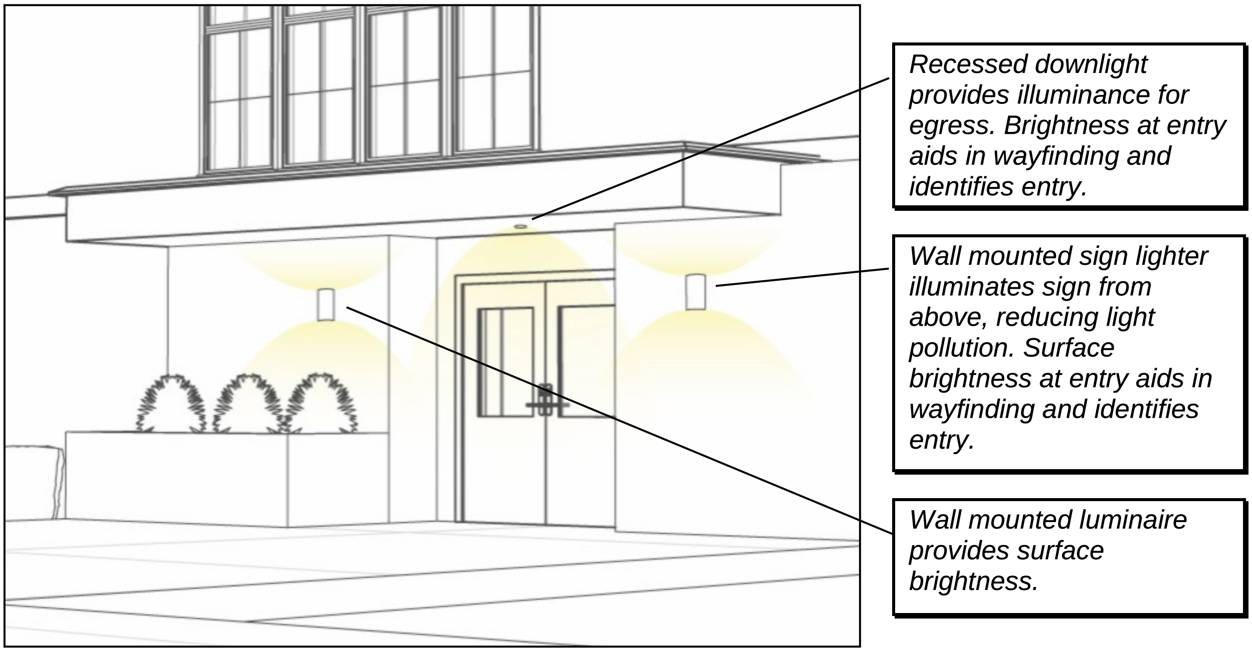
Target Criteria	All Lighting Zones
Minimum Horizontal Illuminance	0.2 (2 lux) at grade
Minimum Vertical Illuminance in center of drive lane, in direction of traffic flow	0.1 (1 lux) at 5’-0” (1524 mm) AFF
Horizontal Illuminance Uniformity	20:1 maximum to minimum

5-3.1.3 Critical Design Issues.

- Provide no greater than G2 and U0 rated luminaires with low lumen output to minimize glare and light pollution.
- Provide Type V distributions for luminaires within the center of parking areas. Use Type III and IV distributions along the perimeters to minimize light trespass on a neighboring property or building unless luminaires are intended to illuminate adjacent property or building.
- Use photocells specifically designed to operate SSL/LED lighting.
- Use an ANSI 7-pin photocell receptacle.

5-4 BUILDING LIGHTING.

5-4.1 Primary Entrances.



5-4.1.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 30% after 10 minutes of no detected motion
Time Schedule	Automatic dimming to 30% within 1 hour after business close and automatic full ON within 1 hour before business open Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	None

5-4.1.2 Performance Requirements.

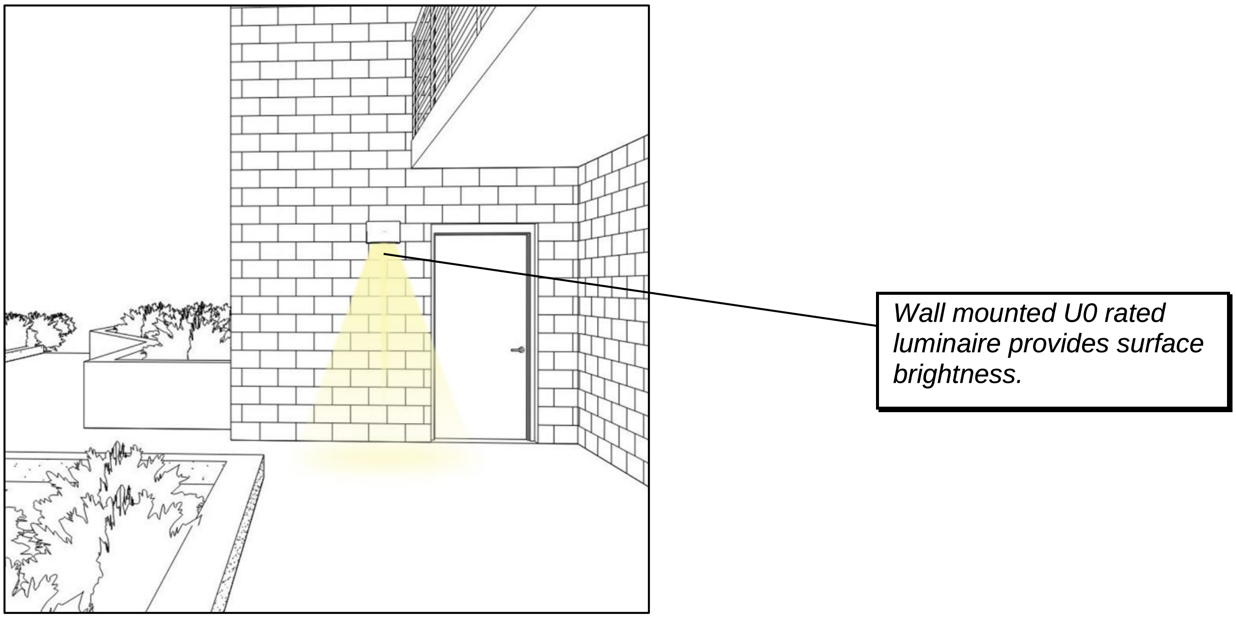
	LZ1 Low ambient	**LZ2 Moderate ambient**	**LZ3 Moderately high ambient**
Average Horizontal Illuminance	1 fc (10 lux) at grade*	Between 1 fc (10 lux) and 2 fc (20 lux) at grade	Between 2 fc (20 lux) and 4 fc (40 lux) at grade
Uniformity	5:1 average to minimum		

*If exit is in path of egress, meet LZ2 criteria.

5-4.1.3 Critical Design Issues.

- Select luminaires to match the aesthetic character of the building and contribute to a welcome designation to the building entry.
- Comply with NFPA 101 lighting requirements for each exit discharge.
- All luminaires must use shielded optics and/or low lumen light sources to minimize glare and light pollution.
- Select and locate lighting to eliminate shadows near entries and provide wayfinding.
- Exterior building mounted luminaires are to match the aesthetic design of the building.
- Luminaires may remain on to assist with building security and law enforcement.

5-4.2 Exits.



5-4.2.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 30% after 10 minutes of no detected motion
Time Schedule	Automatic full OFF within 1 hour after business close and automatic full ON within 1 hour before business open Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	None

5-4.2.2 Performance Requirements.

	LZ1 Low ambient	**LZ2 Moderate ambient**	**LZ3 Moderately high ambient**
Average Horizontal Illuminance	Between 0.5 fc (5 lux) and 2 fc (20 lux)* at grade	Between 1 fc (10 lux) and 3 fc (30 lux) at grade	Between 1 fc (10 lux) and 5 fc (50 lux) at grade
Uniformity	5:1 average to minimum		

*If exit is in path of egress, meet LZ2 criteria.

5-4.2.3 Critical Design Issues.

- Select luminaires to match the aesthetic character of the building.
- Comply with NFPA 101 lighting requirements for each exit discharge.
- All luminaires must use shielded optics and/or low lumen light sources to minimize glare and light pollution.
- Luminaires may remain on to assist with building security and law enforcement.

5-4.3 Housing Areas.

The use of U0 rated wall mounted luminaires, area lights, and downlighting on the façade (rather than uplighting) minimizes light pollution.

5-4.3.1 Control Requirements.

Manual Control	Wall-mounted LED luminaires at individual unit entries and patios are controlled by local control within the housing unit.
Motion Sensing	For lighting not at individual unit entries: Automatically dim lights to 30% after 15 minutes of no detected motion
Time Schedule	For lighting not at individual unit entries: Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	For lighting not at individual unit entries: ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	Zone building-mounted lighting separately from site area lighting

5-4.3.2 Performance Requirements.

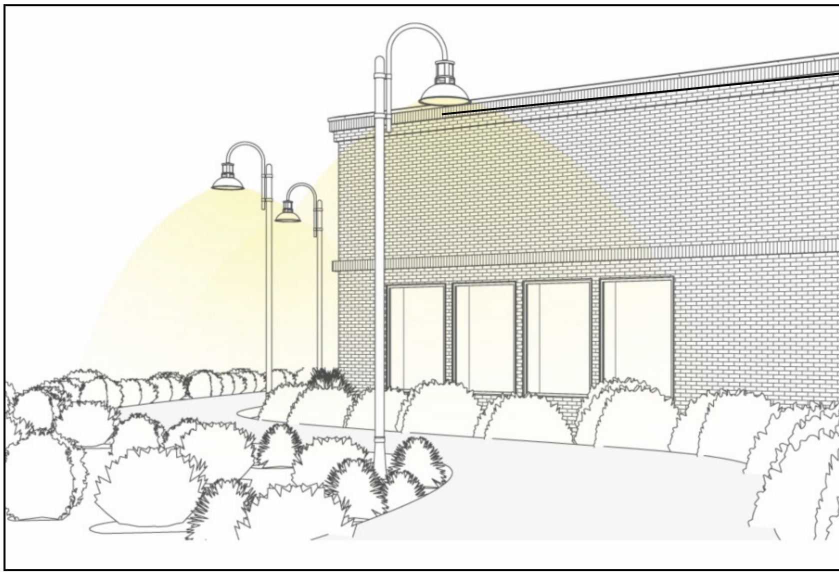
See requirements for Building Entries.

5-4.3.3 Critical Design Issues.

- Use U0 or U1 rated luminaires.
- Use G0 or G1 rated luminaires
- All luminaires must use shielded optics and/or low lumen light sources to minimize glare and light pollution.
- In locations underneath covered balcony or walkway, utilize indirect lighting solutions to provide vertical illumination of surfaces and occupants passing through the space.

5-5 PEDESTRIAN AREAS.

5-5.1 Walkways.



Luminaires with low lumen output reduce direct glare and provide adequate vertical illuminance while minimizing light pollution and trespass.

5-5.1.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 30% after 15 minutes of no detected motion
Time Schedule	Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	None

5-5.1.2 Performance Requirements.

	LZ1 Low ambient	**LZ2 Moderate ambient**	**LZ3 Moderately high ambient**
Average Horizontal Illuminance, adjacent to landscape	Between 0.2 fc (2 lux) and 0.4 fc (4 lux) at grade	Between 0.4 fc (4 lux) and 0.8 fc (8 lux) at grade	Between 0.5 fc (5 lux) and 1.5 fc (15 lux) at grade
Average Horizontal Illuminance, adjacent to architecture, exits, hardscapes, and waterfronts	Between 0.5 fc (5 lux) and 1.0 fc (10 lux) at grade	Between 1 fc (10 lux) and 2 fc (20 lux) at grade	Between 1 fc (10 lux) and 3 fc (30 lux) at grade
Uniformity	10:1 average to minimum		

5-5.1.3 Critical Design Issues.

- Match aesthetics of decorative poles to that of adjacent buildings.
- All luminaires must be U0 or U1 and must use shielded optics, such as a lens or louver.
- Use G0 or G1 low wattage light sources to minimize glare and light pollution.
- Place poles at potential conflict locations, such as intersections.

5-5.2 Plazas.

5-5.2.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 30% after 15 minutes of no detected motion
Time Schedule	Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing When associated with business, automatic full OFF within 1 hour after business close and automatic full ON within 1 hour before business open For landscape and façade lighting, automatically turn OFF the lighting at midnight or close of business (whichever is later)
Photosensing	ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	Provide separate control for each luminaire type

5-5.2.2 Performance Requirements.

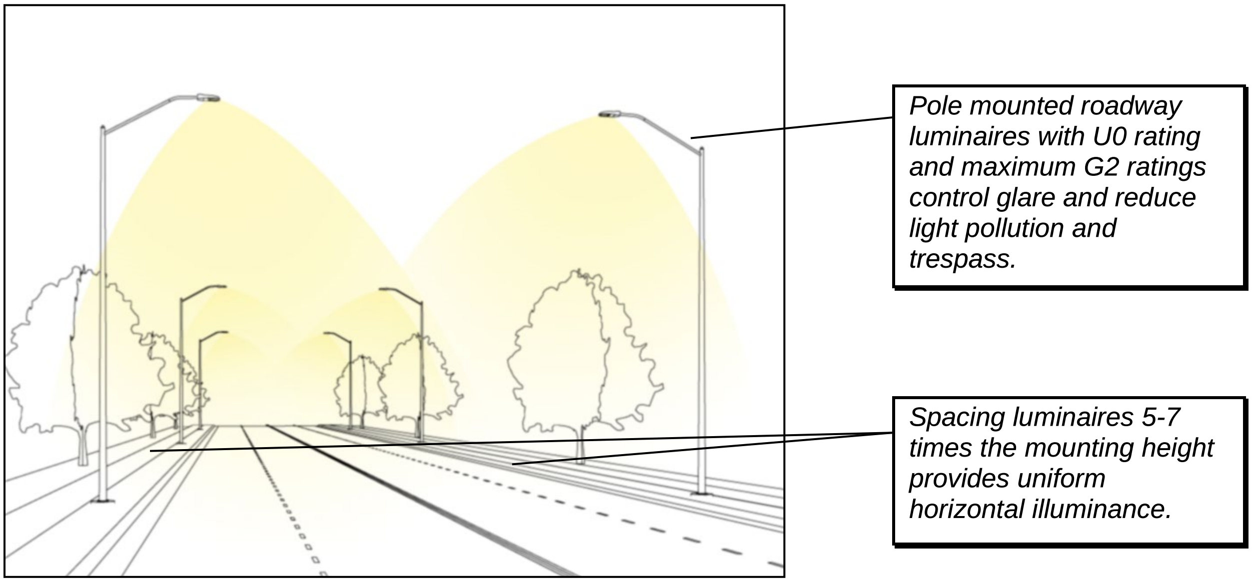
	LZ1 Low ambient	**LZ2 Moderate ambient**	**LZ3 Moderately high ambient**
Average Horizontal Illuminance	Between 0.5 fc (5 lux) and 1.0 fc (10 lux) at grade	Between 1 fc (10 lux) and 2 fc (20 lux) at grade	Between 1 fc (10 lux) and 3 fc (30 lux) at grade
Uniformity	10:1 average to minimum		

5-5.2.3 Critical Design Issues.

- Use U0 or U1 rated luminaires.
- Use G0 or G1 rated luminaires.

5-6 VEHICLE TRAFFIC AREAS.

5-6.1 Roadways and Streets.



5-6.1.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

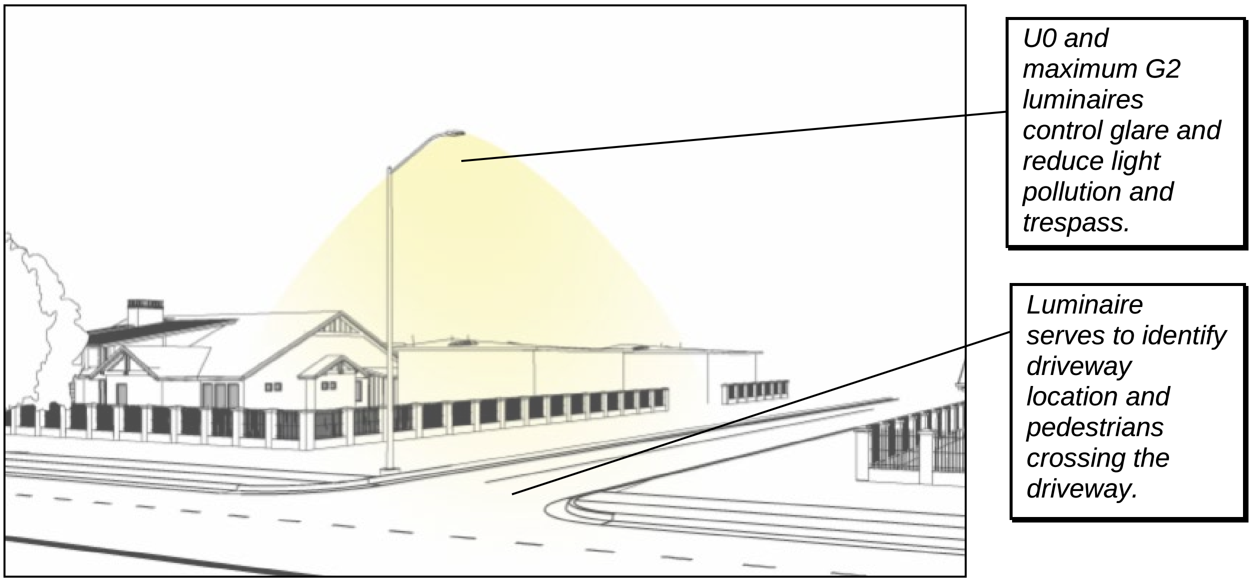
5-6.1.2 Performance Requirements.

Target Criteria	**All Lighting Zones**
Average Horizontal Luminance	ANSI/IES RP-8, *Recommended Practice: Lighting Roadway and Parking Facilities*
Uniformity (Average to Minimum)	

5-6.1.3 Critical Design Issues.

- Use U0 and maximum G2 luminaires to minimize glare and reduce light pollution.
- Locate poles in an opposite pattern versus a staggered pattern to increase visibility.
- Provide luminaires and poles to match installation standard.
- Use photocells specifically designed to operate SSL/LED lighting.
- Use an ANSI 7-pin photocell receptacle.
- Use breakaway bases in accordance with AASHTO GL-6 unless there are sidewalks adjacent to the street where pedestrians could be present.
- Follow ANSI/IES RP-8, Recommended Practice: Lighting Roadway and Parking Facilities for crosswalks located on roadways.

5-6.2 Driveways.



5-6.2.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

5-6.2.2 Performance Requirements.

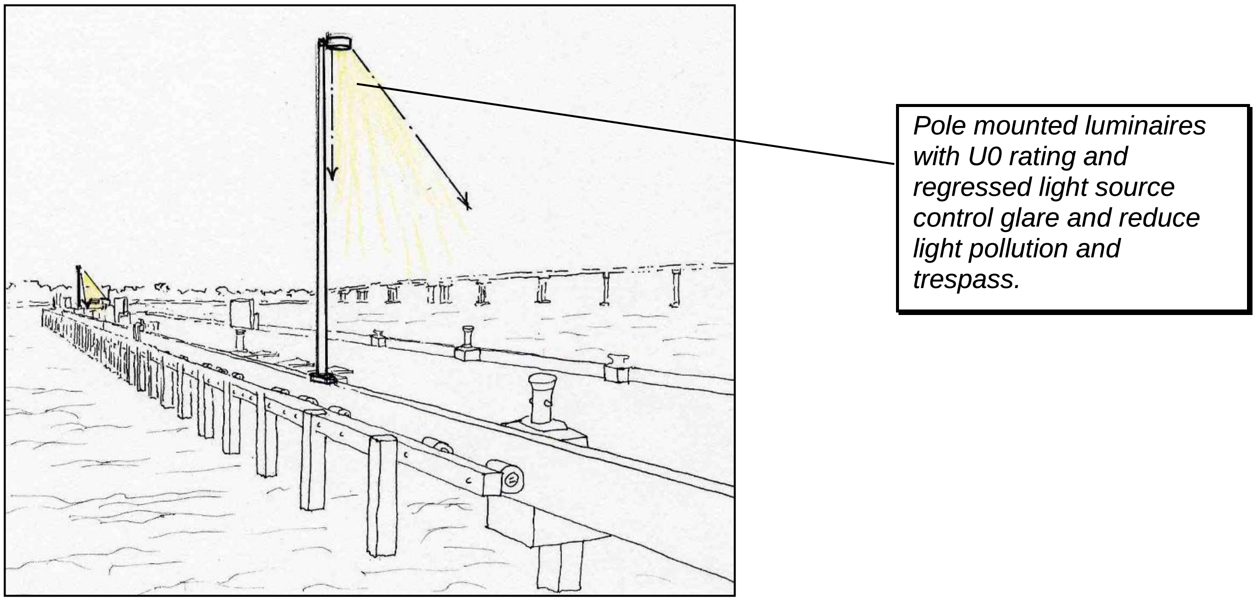
Install one pole mounted, U0 and maximum G2 rated roadway luminaire at the entrance to the driveway. Applies to all lighting zones.

5-6.2.3 Critical Design Issues.

- Use U0 and maximum G2 luminaires to minimize glare and reduce light pollution.
- Use photocells specifically designed to operate SSL/LED lighting.
- Use an ANSI 7-pin photocell receptacle.

5-7 OUTDOOR ACTIVIY AREAS.

5-7.1 Marinas.



5-7.1.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 30% after 10 minutes of no detected motion, if not dimming by Time Schedule
Time Schedule	Automatic dimming to 30% within 1 hour of business close and automatic full ON within 1 hour of business open, if not utilizing motion sensing Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability, if not using astronomical timeclock
Zoning	None

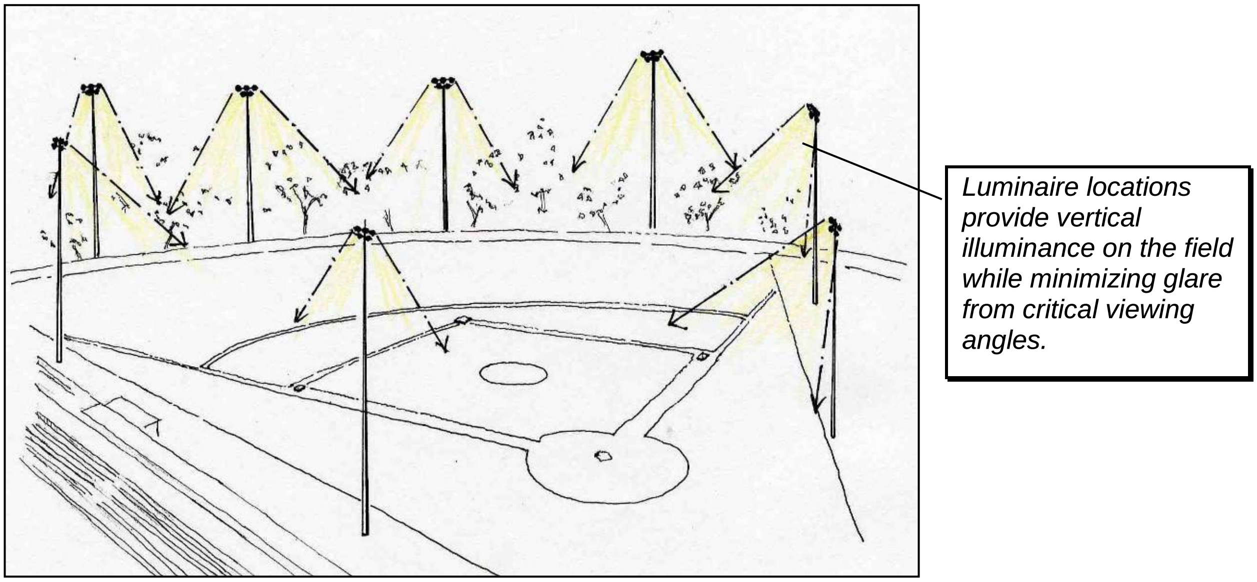
5-7.1.2 Performance Requirements.

Target Criteria	All Lighting Zones
Average Horizontal Illuminance	0.5 fc (5 lux) at grade

5-7.1.3 Critical Design Issues.

- Use U0 luminaires to minimize glare and to reduce light pollution. Use luminaires with regressed lenses to reduce glare, especially in environmentally sensitive areas.
- Use G0 or G1 rated luminaires
- Use luminaires with appropriate light distributions to eliminate light reflecting off of the water
- Use monochromatic LEDs for sensitive environments such as wildlife habitat, observatories, wildlife nesting, or to meet Dark Sky requirements.
- In instances where cranes are used, coordinate pole location and height with portal crane clearances.

5-7.2 Baseball and Softball Fields.



5-7.2.1 Control Requirements.

Manual Control	Manual on
Motion Sensing	None
Time Schedule	Automatic partial ON to 50% within 1 hour before field scheduled to be open Automatic full OFF within 1 hour after field scheduled to be closed. Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability
Zoning	Provide separate zones per field

5-7.2.2 Performance Requirements.

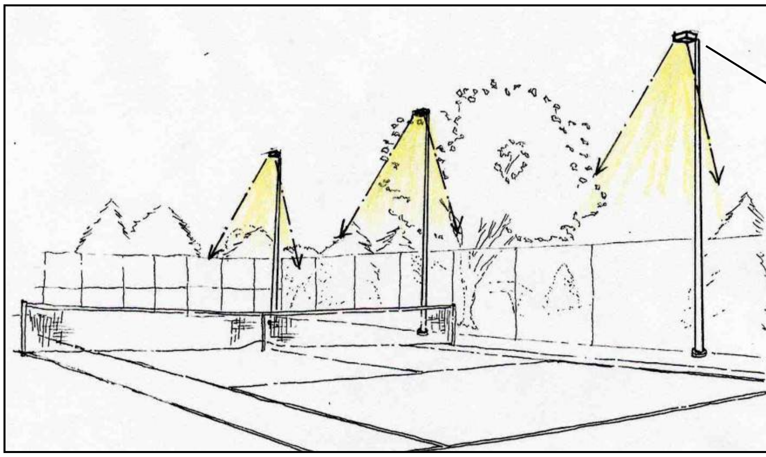
Target Criteria **(Class IV – Recreational*)**	**Infield**	**Outfield**
Average Horizontal Illuminance	30 fc (300 lux) at 3’-0” (910 mm) AFF	20 fc (200 lux) at 3’-0” (910 mm) AFF
Uniformity (Maximum to Minimum)	2.5:1	3:1

*For other classes of play, see ANSI/IES RP-6. Criteria apply to all lighting zones.

5-7.2.3 Critical Design Issues.

- Locate lighting poles outside of critical glare zones.
- Refer to ANSI/IES RP-6, Recommended Practice: Lighting Sports and Recreational Areas.
- Provide uniform illuminance on the field.
- Coordinate aiming of luminaires to minimize light trespass and glare.

5-8.1 Tennis Courts.



Pole mounted U0 area lights provide minimum glare and uniform illuminance on the court.

5-8.1.1 Control Requirements.

Manual Control	Manual On
Motion Sensing	None
Time Schedule	Automatic partial ON to 50% within 1 hour before courts scheduled to be open Automatic full OFF within 1 hour after courts scheduled to be closed. Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability
Zoning	Provide separate zones per court

5-8.1.2 Performance Requirements.

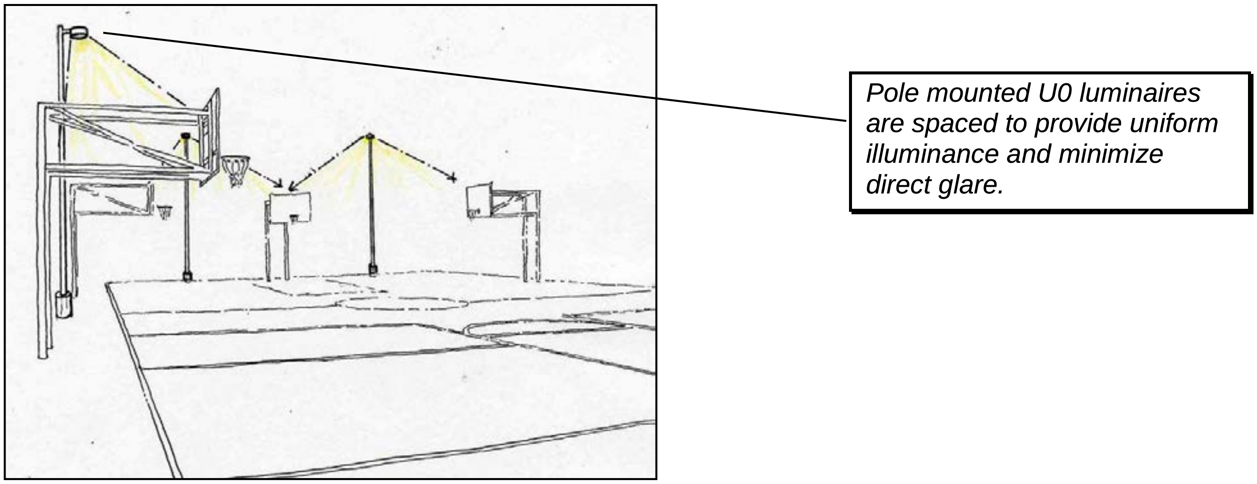
Target Criteria (Class IV – Recreational*)	**All Lighting Zones**
Average Horizontal Illuminance	30 fc (300 lux) at 3'-0" (910 mm) AFF
Uniformity (Maximum to Minimum)	2.5:1

*For other classes of play, see ANSI/IES RP-6. Criteria apply to all lighting zones.

5-8.1.3 Critical Design Issues.

- Use U0 luminaires to minimize glare and to reduce light pollution.
- Locate luminaires parallel to the direction of play.
- Locate lighting poles outside of critical glare zones.
- Refer to IES RP-6 for additional information on sports and recreational area lighting.
- Coordinate aiming of luminaires to minimize light trespass and glare.
- Provide uniform illuminance on the field.

5-8.2 Basketball Courts.



5-8.2.1 Control Requirements.

Manual Control	Manual On
Motion Sensing	None
Time Schedule	Automatic partial ON to 50% within 1 hour of courts scheduled to be open Automatic full OFF within 1 hour of courts scheduled to be closed. Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability
Zoning	Provide separate zones per court

5-8.2.2 Performance Requirements.

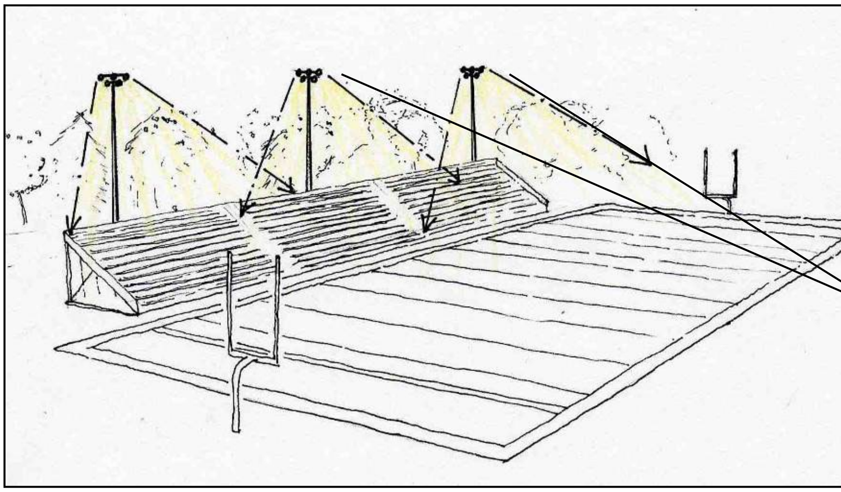
Target Criteria (Class IV – Recreational*)	**All Lighting Zones**
Average Horizontal Illuminance	20 fc (200 lux) at 3'-0" (910 mm) AFF
Uniformity (Maximum to Minimum)	4:1

*For other classes of play, see ANSI/IES RP-6. Criteria apply to all lighting zones.

5-8.2.3 Critical Design Issues.

- Use U0 luminaires to minimize light trespass and glare.
- Provide uniform illuminance on the court.
- Locate lighting poles outside of critical glare zones.
- Refer to ANSI/IES RP-6, for additional information on sports and recreational area lighting.
- Coordinate aiming of luminaires to minimize light trespass and glare.

5-8.3 Football Fields.



Pole mounted modular rack of adjustable sports lighting with internal and external shielding. Luminaire spacing provides uniform illuminance on the field.

5-8.3.1 Control Requirements.

Manual Control	Manual On
Motion Sensing	None
Time Schedule	Automatic partial ON to 50% within 1 hour before field scheduled to be open Automatic full OFF within 1 hour after field scheduled to be closed. Astronomical timeclock ON at dusk and OFF at dawn, if not using photosensing
Photosensing	ON and OFF based on daylight availability
Zoning	Provide separate zones per field

5-8.3.2 Performance Requirements.

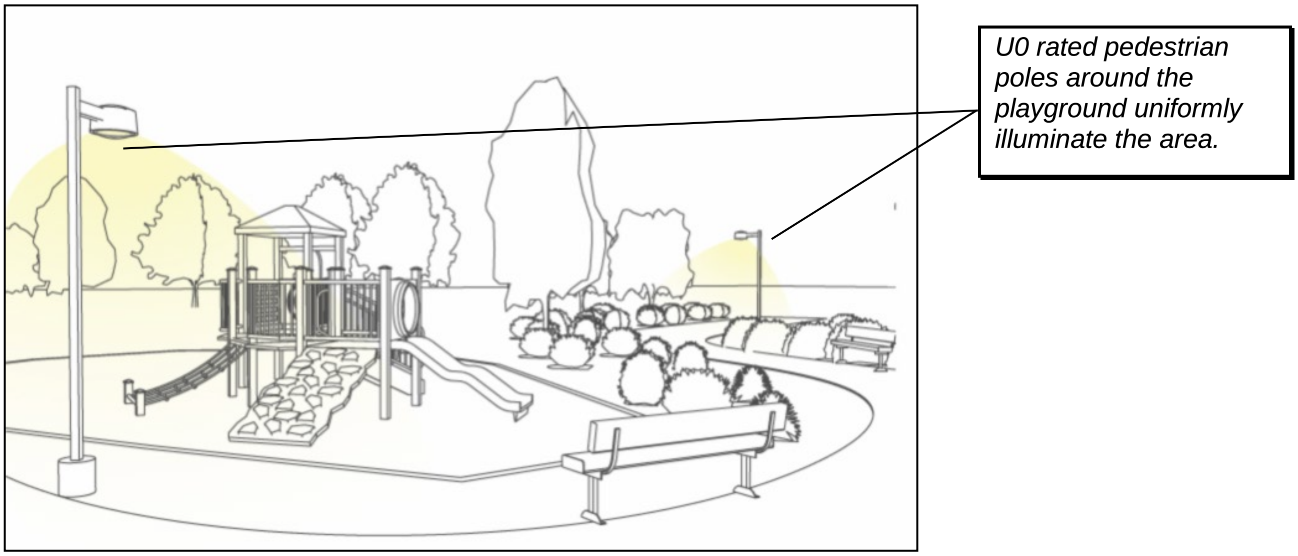
Target Criteria (Class IV – Recreational*)	**All Lighting Zones**
Average Horizontal Illuminance	20 fc (200 lux) at 3’-0” (910 mm) AFF
Uniformity (Maximum to Minimum)	4:1

*For other classes of play, see ANSI/IES RP-6. Criteria applies to all lighting zones.

5-8.3.3 Critical Design Issues.

- Locate lighting poles outside of critical glare zones.
- Refer to ANSI/IES RP-6 for additional information on sports and recreational area lighting.
- Provide uniform illuminance on the court.
- Coordinate aiming of luminaires to minimize light trespass and glare.

5-8.4 Playgrounds.



5-8.4.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

5-8.4.2 Performance Requirements.

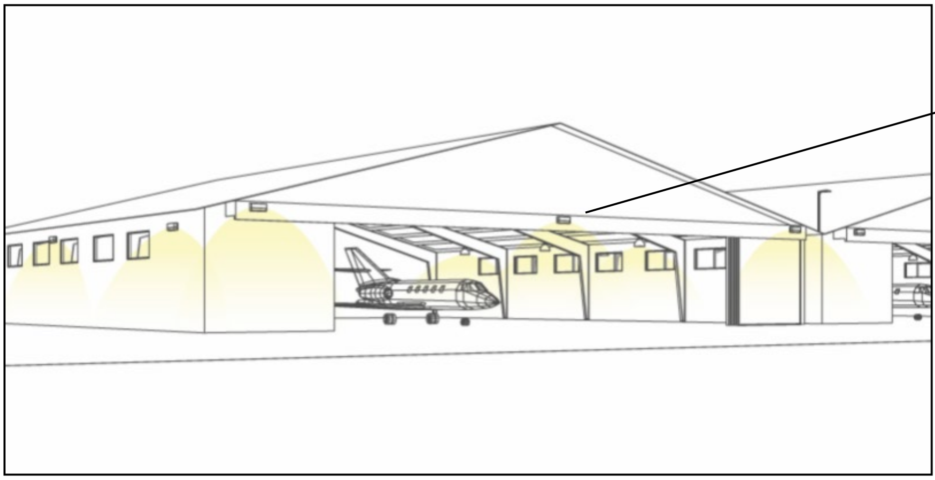
Target Criteria	All Lighting Zones
Average Horizontal Illuminance	1 fc (10 lux) at grade
Uniformity	5:1 average to minimum

5-8.4.3 Critical Design Issues.

- Provide uniform illuminance on the area surrounding the playground.
- Use U0 and maximum of G1 rated luminaires.
- All luminaires must use shielded optics and/or low lumen light sources to minimize glare and light pollution.

5-9 OTHER AREAS.

5-9.1 Airfields (Hangar Exterior).



Wall mounted U0 area luminaires illuminate both the hangar walls and the adjacent area. The U0 and G2 or less rating eliminates glare for approaching aircraft.

5-9.1.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	Control separately from other building mounting lighting systems

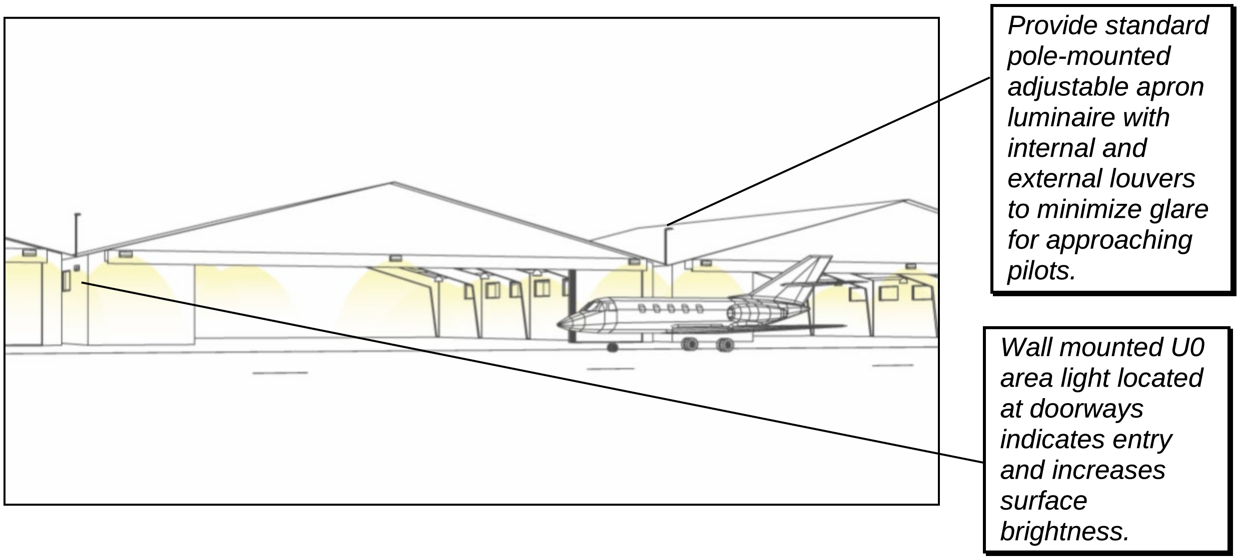
5-9.1.2 Performance Requirements.

Target Criteria	**All Lighting Zones**
Average Horizontal Illuminance	1 fc (10 lux) at grade
Uniformity	5:1 maximum to minimum

5-9.1.3 Critical Design Issues.

- Provide U0 and G2 rated luminaires with low lumen output to minimize glare and light pollution.
- Refer to section 4-9 for additional airfield lighting requirements.

5-9.2 Airfields (Apron).



5-9.2.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	Control separately from other building mounting lighting systems

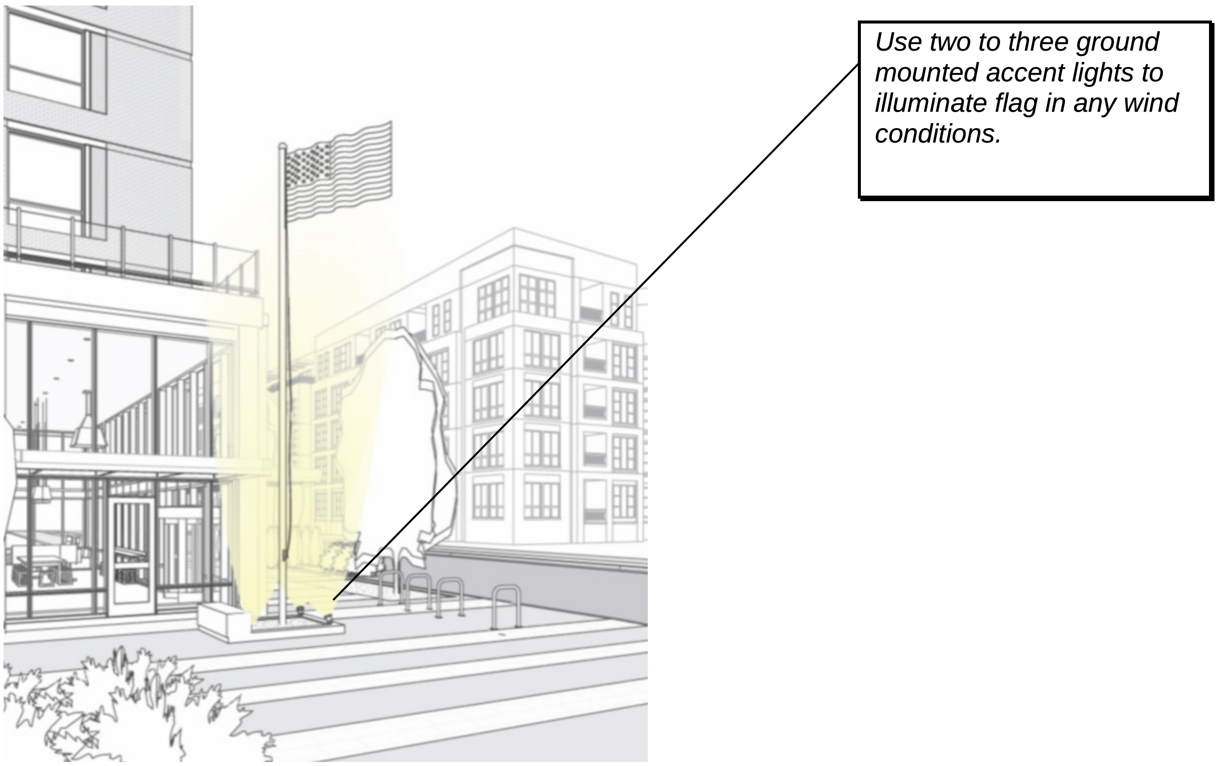
5-9.2.2 Performance Requirements.

Target Criteria	**Maintenance and service**
Average Horizontal Illuminance, Maintenance and service	2 fc (20 lux) at grade
Average Horizontal Illuminance, Aircraft parking	0.5 fc (5 lux) at grade
Average Horizontal Illuminance, Loading and unloading	2 fc (20 lux) at grade
Average Horizontal Illuminance, Other apron areas	1 fc (10 lux) at grade
Uniformity	4:1 average to minimum

5-9.2.3 Critical Design Issues.

- Coordinate with airfield manager for control methodologies.
- Provide U0 and maximum G2 rated luminaires with low lumen output to minimize glare and light pollution.
- Refer to section 4-9 for additional airfield lighting requirements.
- Reference UFC 3-535-01, Table 10-1, for uniformity criteria and apron area.

5-9.3 Flagpoles.



5-9.3.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	Automatic full OFF within 1 hour after business close and automatic full ON within 1 hour before business open Astronomical timeclock ON at dusk and OFF at dawn
Photosensing	None
Zoning	None

5-9.3.2 Critical Design Issues.

- Ground mounted accent lights experience less water intrusion than in-grade uplights.
- In environmental sensitive areas and Lighting Zones 0 and 1, use integrated flagpole downlighting to eliminate uplight.
- If flags are removed at dusk, lighting is not required.

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CHAPTER 6 TECHNICAL REQUIREMENTS – SECURITY LIGHTING

6-1 INTRODUCTION.

Exterior security lighting is an important issue for many facilities and not all of the specific criteria are addressed in this section. For lighting requirements, this UFC supersedes MIL-HDBK-1013/1A*, Design Guidelines for Physical Security of Facilities*. Security lighting provides illumination during periods of darkness or in areas of low visibility to aid in the detection, assessment, and interdiction of aggressors by security forces. Security lighting is sometimes referred to as protective lighting.

Refer to CHAPTER 2 and CHAPTER 4 for addition requirements for interior and exterior lighting and controls.

6-2 PHYSICAL SECURITY.

Physical security describes the part of security concerned with physical measures designed to safeguard personnel; to prevent or delay unauthorized access to equipment, installations, material, and documents; and to safeguard them against espionage, sabotage, damage, and theft.

6-2.1 Physical Security System.

A physical security system is comprised of people, equipment, and operational procedures that control access to critical facilities or assets. Security lighting is one of the elements that comprise the equipment component of a physical security system.

6-2.2 Security Lighting Objectives.

Security lighting is one component of a larger physical security system. While the level of protection may vary, the lighting must supplement and facilitate other measures taken to ensure the security of an asset. These other measures may take the form of security forces at an entry control point, sensitive inner areas, boundaries, or the use of video cameras. In all cases, the lighting enhances visibility for either an individual or device and facilitates their performance.

In the simplest form, security lighting provides a clear view of an area for security personnel while reducing concealment opportunities for aggressors. A physical security system must be able to detect a threat, assess the threat, and then neutralize the threat.

6-2.3 Deterrent Value.

Security lighting at a site may deter lesser threats and aggressors. While a security lighting system does not deter sophisticated criminals or terrorists, it may influence unsophisticated criminals or vandals. The mere presence of light increases the probability of detection or capture and may induce these types of aggressors to look for an easier target.

Similarly, the effective use of lighting can enhance the perception of security, which is important to the personnel who work within a secure area. This can be accomplished with glare reduction, lighted surfaces, proper uniformity, and adequate illuminance.

6-2.4 Defining Requirements.

Defining the requirements of a physical security system and its components involves an interdisciplinary planning team. The team considers all interests relating to a project to determine how security fits into the total project design.

Base the specific membership of the planning team on local considerations, but in general, the following functions are to be represented: facility user, antiterrorism officer, operations, security, logistics, engineering, life safety, and others as required. Use the process in UFC 4-020-01 to identify the design criteria, which includes the assets to be protected, the threats to those assets (the Design Basis Threat), and the levels of protection to be provided for the assets against the identified threats. In addition to those criteria elements, the team must also identify user constraints such as appearance, operational considerations, labor requirements or limitations, energy conservation and sustainment costs. Some areas such as water boundaries that cannot be patrolled do not require lighting.

6-2.5 Security Lighting Design.

The security lighting system must aid in the detection of aggressors and assist personnel in the assessment and response to potential threats. All security lighting designs must be coordinated with Security Forces. The type of site lighting system provided depends on the installation environment and intended use.

6-2.5.1 Continuous Lighting.

The most common security lighting system is a series of fixed lights arranged to illuminate a given area continuously.

6-2.5.2 Standby.

With this system, the luminaires are either automatically or manually turned on at times when suspicious activity is detected by security personnel or an intrusion detection system. A standby system creates the impression of activity and may offer a deterrent value while also achieving energy conservation. Use LED light source systems in lieu of light sources that require re-strike.

6-2.6 Controlled Lighting.

Controlled lighting is best used when it is necessary to limit the width of the lighted strip along the perimeter due to adjoining property. Minimize or eliminate silhouetting or illuminating security personnel on patrol. Illumination levels for controlled lighting must be adequate to detect a moving aggressor, either visually or by use of video cameras. Provide U0 rated luminaires mounted in the horizontal plane to minimize glare. Glare may hinder security personnel visibility and interfere with authorized activities or activities outside the installation. Figure 6-1 and Figure 6-2 show different configurations of controlled lighting.

Figure 6-1 Example of controlled lighting: single fence line

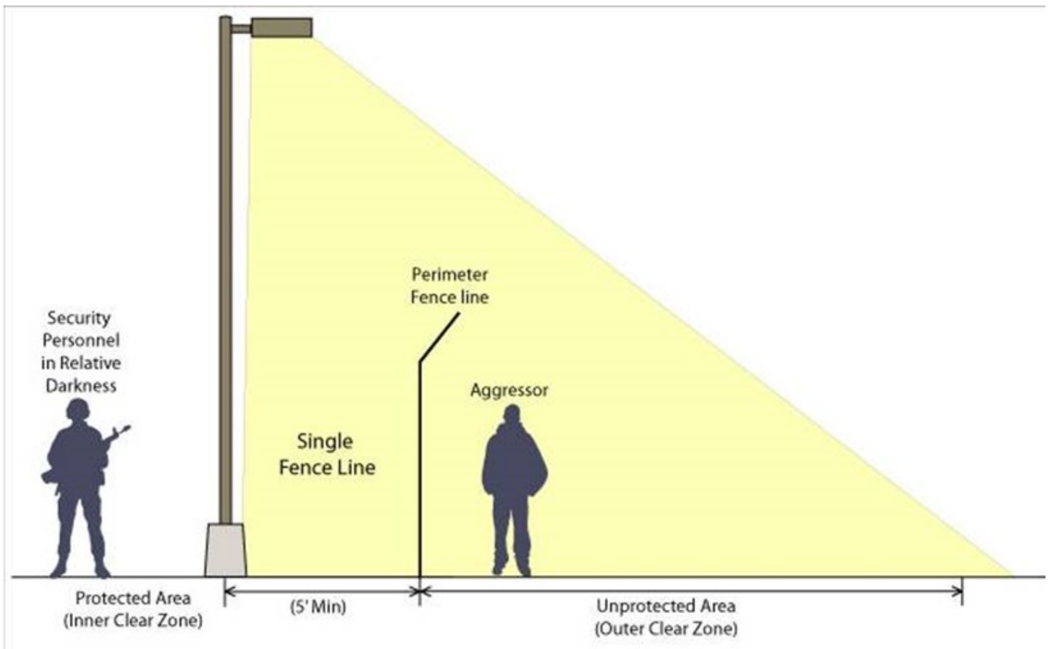
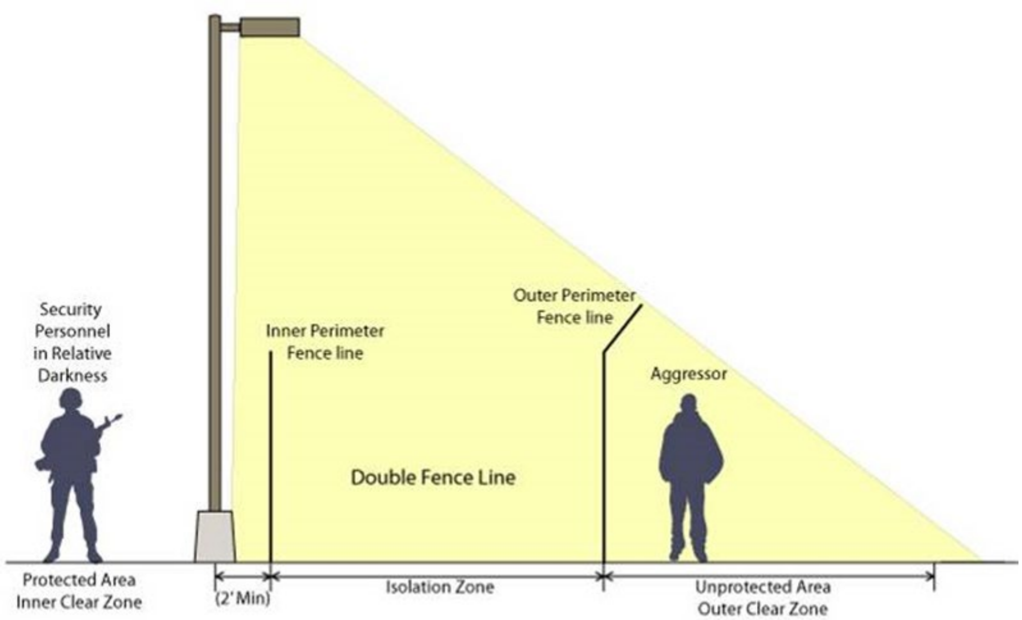


Figure 6-2 Example of controlled lighting: double fence line



6-2.6.1 Glare Projection.

Glare projection is a lighting strategy used in isolated or expeditionary locations to increase the assessment zone by illuminating large flat areas outside the fence line. One technique for glare projection lighting is to place lights slightly inside a security perimeter and directed outward. Glare projection may be a deterrent to potential intruders because it makes it difficult to see inside the area being protected. It also protects security personnel by keeping them in comparative darkness and enabling them to observe intruders at a considerable distance beyond the perimeter. Figure 6-3 and Figure 6-4 show examples of glare projection

Figure 6-3 Example of glare projection: single fence line

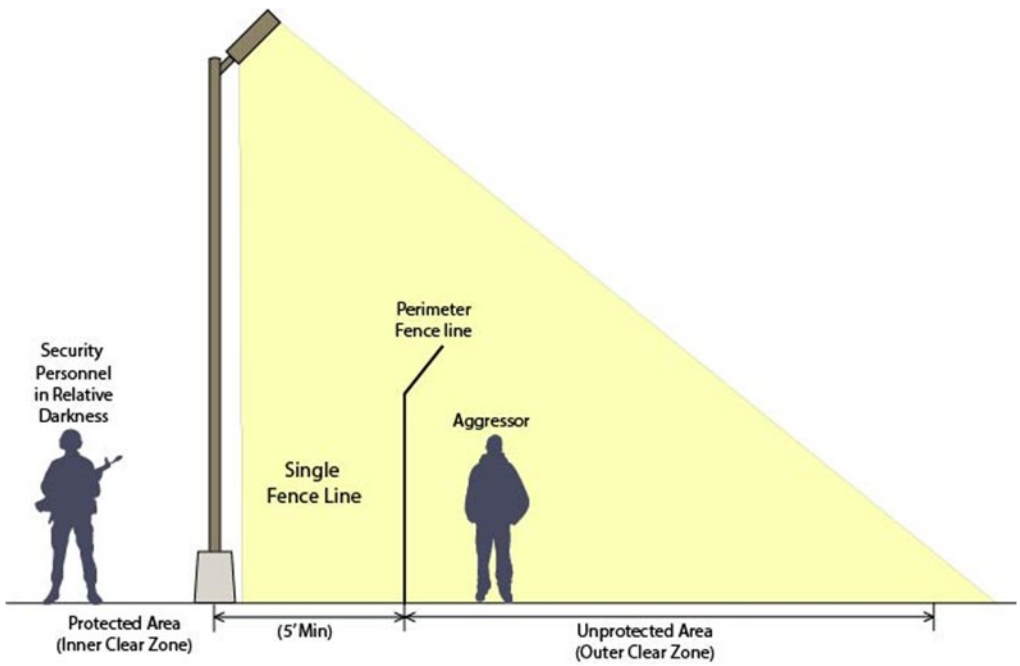
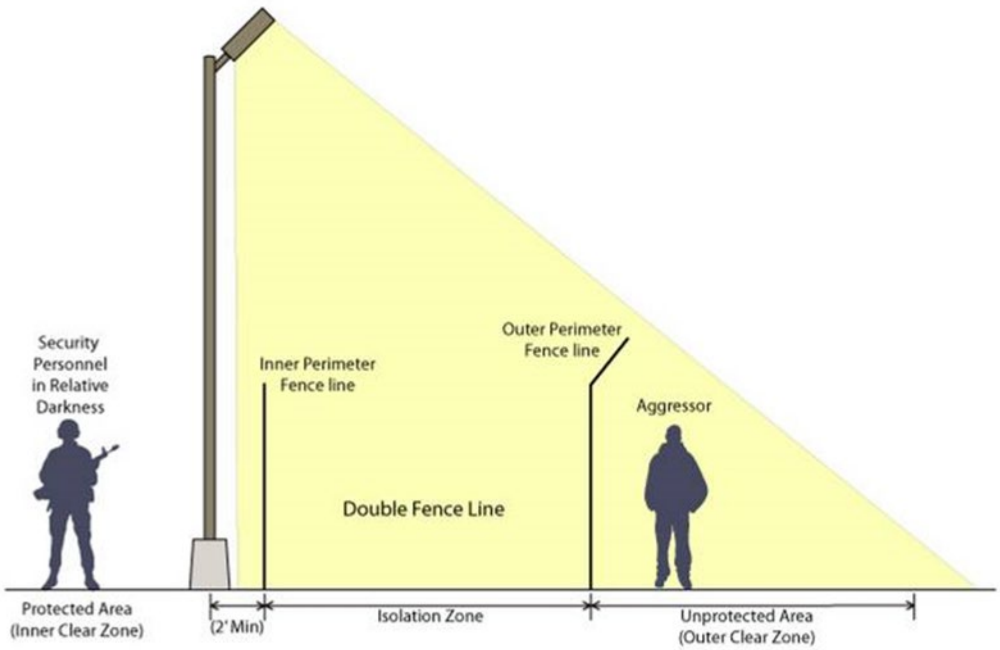


Figure 6-4 Example of glare projection: double fence line



6-2.7 Security Lighting Criteria.

In all cases, mission safety or operational requirements govern over security lighting requirements. For example, if security lighting requires 0.2 fc (2 lux), and a lighting level of 5 fc (50 lux) is required to perform a task or operation, then 5 fc (50 lux) is the requirement. Illuminance values appropriate for security personnel may range from a minimum of 0.1 fc (1 lux) for large open areas to a minimum of 10 fc (100 lux) in area of ID checks for entry control points. If guards must perform any written task (such as inside a guardhouse), the illuminance on the task plane may reach an average 30 fc (300 lux). Illuminance values in excess of this may inhibit the individual's ability to adapt to lower lighted areas outside.

6-2.7.1 Low Level of Protection (LLOP).

Illumination is only required at building entries and exits. Use low brightness and well shielded luminaires so that it does not become a glare source in the much darker surroundings.

6-2.7.2 Medium Level of Protection (MLOP).

Requires LLOP criteria and illumination of the building exterior. U0 rated luminaires mounted on the building wall can illuminate the exterior of the building without adding light to the surrounding area or cause light trespass to neighboring properties.

6-2.7.3 High Level of Protection (HLOP).

Requires MLOP criteria and illumination of the area around the facility. This lighting may still be accomplished with wall mounted lighting on the building. By using a different luminaire distribution, light can be directed to the surrounding area rather than just at the building. For larger areas, poles may be necessary to light further from the building. With U0 rated luminaires, a perimeter width of 2-3 times the mounting height can be illuminated. When a perimeter fence is required for security, HLOP would dictate illumination of the perimeter fence including any required clear or isolation zones to aid in the detection, assessment, and interdiction of aggressors by security forces. Use controlled lighting, except when dictated by local threat environment.

6-3 SECURITY LIGHTING APPLICATIONS.

Refer to the CHAPTER 7 on Security Lighting Applications for additional information.

6-3.1 Building Entrances and Exits.

Increasing the lighting level at the building entrance guides visitors and other personnel to the appropriate building entry. It also serves as exit lighting to guide individuals out of a building for life safety in case of an emergency. The security lighting at these locations protects against forced entry and provide enough light for threat assessment. Building entrances and exits must be lighted for all levels of protection. Use concealed, U0 rated luminaires and/or low brightness sources to limit glare while still providing adequate illumination.

6-3.2 Building Exterior.

Lighting of the building frequently includes some area lighting as well. By using U0 rated, wall mounted luminaires; both the building and the adjacent area can be illuminated. Mounting luminaires at the top of the facade and aiming the light down increases the facade brightness and reduces light trespass and light pollution.

6-3.3 Perimeter Lighting.

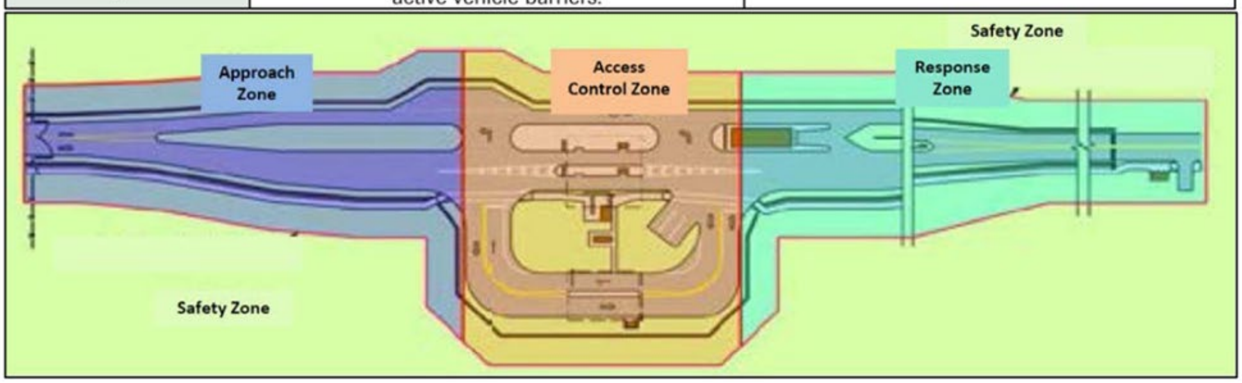
Illumination of a restricted area perimeter when required includes the exterior and interior clear zones adjacent to the fence or, in some applications, the area between a dual fence line (isolation zone). Provide poles, power circuits, and transformers within the protected area. Coordinate pole locations with the user to ensure that the applicable egress requirements and patrol routes of the clear zone are not violated. Provide poles that are not less than 5 feet (1.5 meters) from a single fence line, or less than 2 feet (0.6 meters) for a dual fence line. This 5-foot (1.5 meter) separation may not apply to a perimeter that is a solid wall. In the case of a solid wall, the designer needs to coordinate with the local security and service to determine the best approach. Provide perimeter lighting that is either continuous or standby, controlled or glare projection depending on the application and local threat environment. See Table 6-2 for additional criteria.

6-3.4 Entry Control Facilities, Access Control Points.

Refer to UFC 4-022-01 for Entry Control Facility/Access Control Points (ECF/ACP) Criteria and *Entry Control Facility/Access Control Point Lighting Analysis* for additional information. Entry Control Facilities/Access Control Points are separated into several zones, see Figure 6-5. These zones can be further subdivided into lighting zones, see Figure 6-6**.**. The lighting design for each zone is described in the following paragraphs.

Figure 6-5 ECF/ACP Zones*

Zone	Location	Goals
Safety	Extends in all directions beyond passive and active barriers.	Protect assets and personnel from explosions.
Approach	Installation boundary to a point just before the ID checkpoint.	Reduce speed, sort vehicles, provide stacking room, identify potential threats.
Access Control	A point just before and after the ID checkpoint.	Identify vehicles and personnel; provide surveillance, random inspection, visitor processing, and rejection capabilities.
Response	A point just after the ID checkpoint to the active vehicle barriers.	Provide measures to react to and resist a threat.



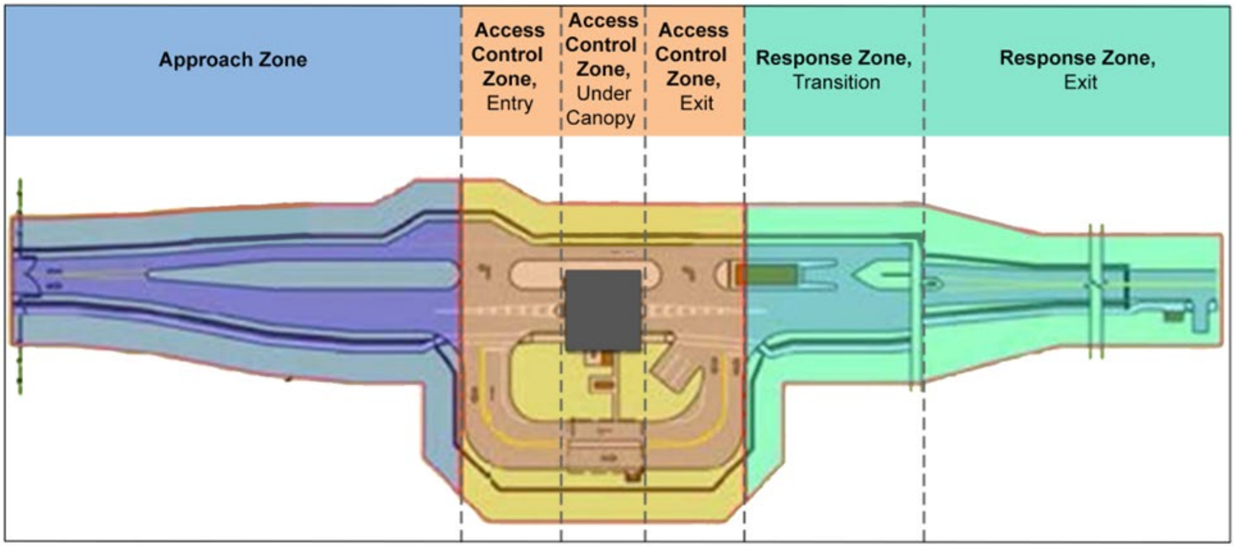
*Source: UFC 4-022-01.

6-3.4.2 Approach Zone.

Illuminate the Approach Zone to lead motorists safely to the Access Control Zone. Use U0 rated luminaires mounted in the horizontal plane to minimize glare. Glare rating not to exceed G2. To reduce glare for security personnel, provide signage to instruct motorists to turn off headlights as they approach the Access Control Zone.

To reduce adaptation issues for the motorist, gradually increase (transitional lighting) lighting levels as the motorist approaches the Access Control Zone, which has the highest light levels. Motorist’s eyes take time to adjust to sudden changes in light level, especially high to low. Extensive discussion of transitional lighting can be found in ANSI/IES RP-8. Typically, a minimum Approach Zone of 200 ft. (61 m) is adequate to achieve acceptable transitional lighting in the Approach Zone.

Figure 6-6 ECF/ACP Lighting Zones



6-3.4.3 Access Control Zone.

Lighting in the Access Control Zone/Access Control Points provides the highest light levels in the Entry Control Facility/Access Control Points. To provide the proper lighting adaptation levels for drivers and security personnel, the Access Control Zone is broken into three areas, see Figure 6-6. Increased light levels in the Access Control Zone, Entry allows the motorist to adapt to the brightness. Decreased light levels in the Access Control Zone, Exit, allows the motorist to adapt to lower light levels upon exit of the Access Control Zone.

The lighting system must provide for identification and inspection. For most of the Access Control Zone, U0 rated luminaires provide adequate lighting for most of these visual tasks. However, vertical illuminance on motorists' faces can be improved with the use of low brightness light sources (less than 3500-lumen light source output). Luminaires mounted to the side and behind security personnel improves identification tasks. Use a glare rating not to exceed G2.

6-3.4.4 Response Zone.

From the Access Control Zone, gradually return roadway lighting to lower light levels (transitional lighting) while still providing adequate uniformity; see Figure 6-6. Provide U0 rated luminaires mounted in the horizontal plane to minimize glare for motorists and security personnel in the Response Zone. Use a glare rating not to exceed G2. In addition, provide signage to instruct motorists to turn headlights back on after leaving the Access Control Zone.

6-3.4.5 Pedestrian Access.

Pedestrian zones must provide light for both pedestrians and security personnel. Pedestrians must have a clear view of gates and card access readers and security personnel must be able to see pedestrians approaching the ECF/ACP. Provide U0 rated luminaires mounted in the horizontal plane to minimize glare. Use a glare rating not to exceed G2.

6-3.4.6 Vehicle Inspection.

In areas where security personnel must identify visitors, check credentials, and read shipping manifests, provide lighting that does not interfere with the operations while vehicles approach, stop for inspection, and proceed. Having to continually adapt to different illuminance and brightness levels could lead to eyestrain and reduced performance by security personnel. Provide additional task lighting from behind the guard and light the person to identify or the vehicle to inspect.

6-3.4.7 Gatehouse/Guard Booth.

Inside the gatehouse, task lighting must be provided for reviewing identifications, paperwork, and possibly computer tasks. However, the interior light levels must be kept at a lower ambient light level than the exterior. Otherwise, the security personnel will have reduced visibility and those approaching the shack will have a clear view of the interior. While the ambient light level may be very low, task lighting at a desk or workstation can still be increased to a higher level. The location and shielding of interior lighting must minimize the chance of veiling reflections on the glass that may limit visibility to the outside. All luminaires must be dimmable to adjust inside lighting levels. Do not use colored light for task lighting when color is to be distinguished in the task.

6-3.4.8 Overwatch Position.

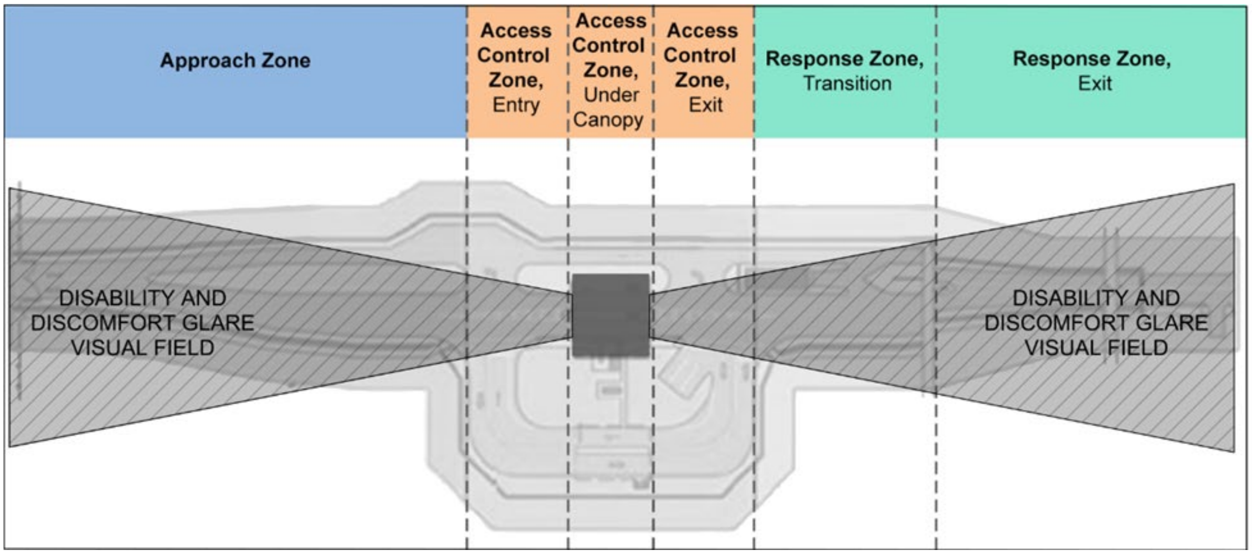
These locations must maintain an unobstructed view through the access and Response Zones. Additionally, inside the overwatch itself, lighting must be kept to extremely low levels or eliminated entirely to prevent the lighting of the security personnel. All luminaires must be dimmable to adjust lighting levels. While red colored light has been used in such applications to maintain the eye’s dark adaptation, do not use colored light for task lighting when color is to be distinguished within the Overwatch position.

6-3.4.9 Disability and Discomfort Glare Visual Field.

The Disability and Discomfort Glare Visual Field is the visual coverage of security personnel stationed at an ECF/ACP, located within the Access Control Zone. Luminaires within this field are most likely to cause disability and discomfort glare for Security Personnel.

Figure 6-7 overlays the Disability and Discomfort Glare Visual Field on the typical ECF/ACP layout. This figure is an example layout. ECF/ACP layout must consider the impact of the Disability and Discomfort Glare Visual Field on the lighting layout. See the *Entry Control Facility/Access Control Point Lighting Analysis* for more information.

Figure 6-7 ECF/ACP Disability and Discomfort Glare Visual Field



All luminaires placed within this visual field must take glare as a consideration in design:

- Minimize light source visibility from the security personnel position.
- The glare rating should be no greater than G1.
- Use Table 6-1 to establish maximum luminaire mounting heights per distance from security personnel position.

Table 6-1 Maximum Luminaire Mounting Height in the Disability and Discomfort Glare Visual Field

Distance from Security Personnel Position	At 20' (6 m)	At 30' (9 m)	Between 40' (12 m) and 60' (18 m)	Between 60' (18 m) and 80' (24 m)	Between 80' (24 m) and 100' (34 m)	>100' (34 m)
Maximum Luminaire Mounting Height*	14' (4 m)	18' (5 m)	Between 22' (7 m) and 32' (10 m)	Between 32' (10 m) and 40' (12 m)	Between 40' (12 m) and 50' (15 m)	>50' (15 m)

*Maximum luminaire mounting height is measured to the underside of luminaire.

6-3.5 Waterfront.

Refer to UFC 4-025-01 for Waterfront Security Criteria. Waterfront areas consist of a defined perimeter (landside and waterside), restricted area, Entry Control Facilities at the entrance into the waterfront area, access control points located at each pier, and pedestrian access control points along the perimeter. In waterfront areas, utilize high mast lighting to reduce the number of poles minimizing obstructions to waterfront operations and maintaining clear paths for equipment and vehicles. Provide U0 rated luminaires mounted in the horizontal plane to limit direct and reflected glare. Use a glare rating not to exceed G2. In some regions, white light sources may interfere with the marine environment. Coordinate marine issues with the local environmental authority.

Security lighting can visually interfere with lighting used as aids to navigation (ATON) by ships. Lighting ashore can camouflage, outshine, or otherwise conceal ATON. Ensure that lighting ashore and in the waterfront compound does not conflict with or otherwise conceal the ATON lights. Coordinate security lighting requirements with Port Operations.

6-3.5.1 Piers, Wharves and Shipyards.

Provide U0 rated luminaires to limit glare and uplight. Use a glare rating not to exceed G2. In general, high mast lighting provided for waterfront operations supply adequate illuminance for security requirements. Coordinate number, height, and location of poles and the associated concrete pedestals to minimize obstructions to pier, wharf and shipyard operations. Refer to UFC 4-152-01 for Pier and Wharf operational lighting requirements. Refer to for the minimum lighting intensity requirements for shipyards.

6-3.5.2 Pierhead and Wharf Guard Towers.

Lighting inside the guard towers must not degrade security personnel’s nighttime visibility. All luminaires must be dimmable and mounted at or near desk level. Switch task and general lighting separately. When colors are not used to distinguished tasks (colored lights or controls for alarm annunciations), consider red light sources for task lighting to reduce adaptation problems. Manually operated searchlights may be required to assist security personnel to locate and assess waterside threats within the restricted zone. Lighting controls must be under the direct control of security personnel. Coordinate lighting requirements with security personnel.

6-3.5.3 Water Surface.

High mast lighting on pier and wharves provides adequate illuminance for security requirements. Glare, poor distribution, and excessive light levels reduce security personnel’s ability to assess surface and subsurface threats.

6-3.5.4 Underwater Lighting.

Underwater lighting is not normally required for detection of subsurface threats and is discouraged due to limited benefit, high installation cost, and maintenance issues.

6-3.5.5 Underdeck Lighting.

Dedicated luminaires located beneath the pier are not normally required and are discouraged due to limited benefit, high installation cost, and maintenance issues.

6-3.5.6 Lower Deck Lighting.

On the lower deck of a double deck pier, provide utility and work areas with illuminance levels based on the tasks performed. Lower deck lighting in roadway and open areas must be multilevel and divided into sections to localize lighting control. Alternate control of luminaires between photocell and manual light switch or implement an intelligent control system. Provide an average of 0.5 fc (5 lx) with luminaires under photocell control. To reduce energy consumption, consider occupancy or vacancy sensors for control of lighting in enclosed spaces.

6-3.6 Video Cameras.

Cameras respond to a luminous environment differently than the human eye. The field of view of a camera refers to the extent of the scene that can be viewed at one time. Some devices may use motorized swivels to pan across a scene and increase the viewing area. Cameras adjust the view based on the brightest point in this field. If it must adjust for a hot spot, areas under low illuminance levels may not be visible at all. Uniform illuminance and U0 rated luminaires are vital to limit hot spots and improve video camera system performance. **Figure 6-8** illustrates how a large portion of the camera's view may be washed out if it must adjust to an excessively bright light source. Any luminaire that falls within the camera's field of view at any time must be shielded. If a light source can be seen directly by the camera, the glare and high contrast limit the visibility of the entire scene. Therefore, the source of illumination is best located above the level of the camera. Refer to UFC 4-021-02 *Electronic Security Systems* for additional information.

Figure 6-8 Video camera's view of scene with excessive glare

6-3.6.2 Color Rendering Index.

For color cameras, the color rendering index of the sources lighting the area must be above 80. Color rendering is less important for monochrome systems.

6-3.6.3 Uniform Vertical Illuminance.

Video cameras typically record objects and people in elevation. Therefore, the security lighting system must provide adequate and uniform vertical illuminance. As in many security lighting applications, the amount of vertical illuminance is far more important than horizontal. Vertical illuminance criteria average is 0.2 to 0.5 fc (2 to 5 lux) at 5 feet (1524 mm) above the ground. Uniformity criteria is 4:1 average to minimum. These criteria refer to vertical illuminance values measured in the same direction of the camera line of sight. Vertical illuminance does not need to be this high in all directions. Color cameras may require higher light levels than monochrome cameras. Review camera manufacturer recommendations and coordinate with the security system designer when designing the lighting system.

6-3.6.4 Infrared (IR) Cameras.

IR cameras utilize IR sources to illuminate the field of view. Light in the IR spectrum is not visible to the human eye. IR cameras then pick up the reflections of these wavelengths from objects in the area.

6-3.6.5 Thermal Imaging.

Devices using thermal technology do not require any light source to operate. They create images based on the heat differences between humans, vehicles, the ground, and foliage. Unlike other camera technologies, thermal imagery is not affected by glare from headlights or light sources. While this technology can indicate the presence of people and objects in complete darkness, they do not provide the detailed images obtainable from visible light or IR cameras.

6-3.6.6 Specific Lighting Criteria.

The specific lighting criteria and design issues may vary with application. Table 6-2 summarizes the minimum (not average) horizontal and vertical illuminance levels for typical facility applications. The inner clear zone noted in the table refers to the area along a perimeter fence line within the facility or installation. The isolation zone refers to the area between a double fence line. The outer clear zone describes the area along the perimeter fence on the outside of the protected area. Isolation and clear zones are typically 30 feet (9.1 meters) in width. It is important to note, however, that over-lighting and glare can cause just as many visibility problems as underlighting.

Table 6-2 Minimum Lighting Criteria for Unaided Guard Visual Assessment

Application				**Minimum or Average Illuminance (All Lighted Areas)**		**Maximum Uniformity**
Type	Lighting	Area	Width Feet (m)	Locations to Light	Footcandles (lux)[a]	(Avg:Min)
Perimeter	Controlled	Inner Clear Zone	20-30 (6.1-9.1)[c]	Outer edge fence	0 (0)[e] min	10:1
	Controlled	Outer Clear Zone	30 (9.1)[d]	Outer edge	0.2 (2) or 0.4 (4)[g] min	10:1
	Controlled	Isolation Zone[f]	30 (9.1)	Between fence lines	0.5 (5) or 1.0 (10)[b] min	6:1
Building Lighting	Controlled	LLOP	--	Building Entry and Exits	Refer to 5-4.1 and 5-4.2	20:1
	Controlled	MLOP	--	Same as LLOP and exterior walls.	0.2 to 0.5 (2 to 5) min	15:1
	Controlled	HLOP	30 (9.1)	Same as MLOP and area around facility.	0.5 to 1.0 (5 to 10) min	10:1

a. Horizontal plane at 3 feet (914 mm) above finished grade unless otherwise noted.
b. Vertical illuminance 6 inches (152 mm) above finished grade.
c. Width of inner clear zone is asset dependent. Refer to Service guidance for asset being protected.
d. Width of outer clear zone is asset dependent (typical clear zones is 30 feet (9144 mm). Refer to Service guidance for asset being protected. Glare projection may be required in areas with larger clear zones such as forward areas or high threat environments or when the assessment zone is extended beyond the clear zone.
e. Minimize illuminance in inner clear zone to prevent illuminating security personnel. Some applications may require illumination of inner clear zone (backlighting).
f. Only applies to dual fence line applications.
g. Vertical illuminance 3 feet (0.9 meters) above finished grade, at outer edge.

6-4 LIGHTING CONTROLS.

Refer to CHAPTER 7 for control requirements specific to common applications. Refer to CHAPTER 2 and CHAPTER 4 for information on lighting controls and control strategies.

6-5 ELECTRICAL REQUIREMENTS.

Backup power is not required for all security lighting systems. The results from assessment of risk and asset value determine this need. For critical security lighting systems, several different types of systems are available for providing backup power in the event of a power outage. All offer various advantages and disadvantages. They vary in amount of time that they can provide power, amount of downtime between a power outage and backup power, and cost. Refer to service specific guidance regarding facilities and equipment authorized backup power.

6-5.1 Generators.

Generators are commonly used to provide backup power but have some downtime between the outage and when the generator restores power. Minimum downtime can be as low as seconds. While this is one of the least expensive solutions, operations must be able to sustain the short period of darkness.

6-5.2 Uninterruptible Power Supply.

An uninterruptible power supply (UPS) is a battery source that provides instantaneous power in case of a power loss. UPS systems have a high initial cost and are expensive to maintain. Therefore, only provide a UPS for security lighting systems associated with the protection of critical assets or security operations when continuous, full brightness lighting is required.

6-5.3 Flywheels.

Flywheels provide instantaneous power in the case of power loss in the form of the kinetic energy in a constantly rotating wheel. This energy can be harnessed immediately in the event of a power outage and used to power critical lighting. These devices vary widely in price and capacity.

6-5.4 Battery Backup.

Individual battery packs are available for some luminaires. In the event of a power outage, these packs can power the lighting for times ranging from five minutes to two hours, depending on the battery capacity. For LED light sources, the battery powers the driver directly although the light source may not provide full light output.

6-5.5 Circuiting Techniques.

To minimize security degradation during faults, divide lighting system into two or more circuits. Circuiting luminaires onto separate circuits in the same space does not provide backup power but limits vulnerabilities during a fault or circuit failure. If the lighting system is divided onto two or more circuits, the loss of one does not affect the entire lighting system. Install multiple circuits, except where their use is clearly impractical. Locate the overcurrent devices, transformer, and wiring within the protected area. Locate circuits underground to minimize the possibility of sabotage or vandalism.

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CHAPTER 7 SECURITY LIGHTING APPLICATIONS

7-1 INTRODUCTION.

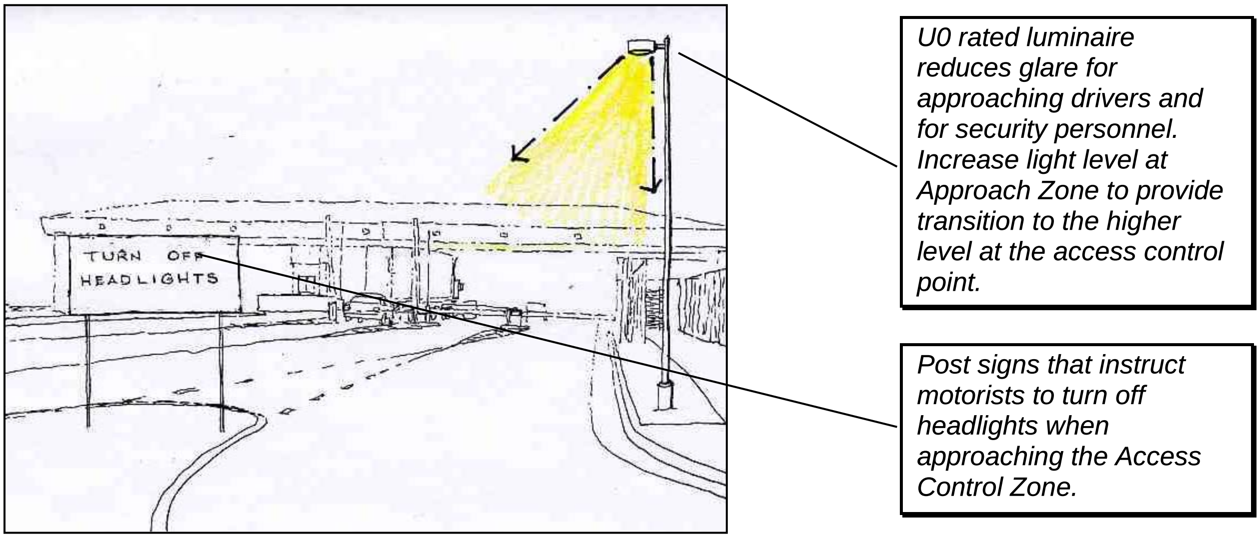
This section identifies typical security lighting applications. Each application details a conceptual lighting design example. Designers must meet the lighting performance and controls requirements.

7-2 CALCULATIONS FOR SECURITY LIGHTING.

Refer to CHAPTER 3 for lighting calculation requirements for interior lighting and CHAPTER 5 for calculations for exterior systems.

7-3 ENTRY CONTROL FACILITY/ ACCESS CONTROL POINTS.

7-3.1 Approach Zone.



7-3.1.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

7-3.1.2 Performance Requirements.

Target Criteria	**Minimum Distance**	**All Lighting Zones**
Average Horizontal Illuminance, Approach Zone	200' (61 m)	1.5 fc (15 lux) at grade
Uniformity	4:1 average to minimum	

7-3.1.3 Critical Design Issues.

- See Response Zone and UFC 4-022-01 for additional information on transition lighting.

- Refer to Figure 6-6 for diagram of ECF/ACP lighting zones.
- Provide transitional lighting between bright and dark regions for the Approach Zone of the gate to improve visual adaptation.
- Use luminaires with a G-Rating of G0 or G1, only use G2 for special conditions for roadway or area luminaires.
- For luminaires in the Discomfort and Disability Glare Visual Field, follow the design parameters outlined in section 6-3-4.1.

7-3.2 Access Control Zone Outside Canopy.

7-3.2.1 Control Requirements: Primary ECF/ACP.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

7-3.2.2 Control Requirements: Secondary ECF/ACP.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	Automatic dimming to 50% 1 hour after ECF/ACP closing and automatic full ON 1 hour before opening
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

7-3.2.3 Control Requirements: Limited Use ECF/ACP.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability with manual override

Zoning	None

7-3.2.4 Performance Requirements.

Target Criteria	Minimum Distance	All Lighting Zones
Average Horizontal Illuminance, Access Control Zone, Entry	40’ (12 m)	3 fc (30 lux) at grade
Average Horizontal Illuminance, Access Control Zone, Exit	40’ (12 m)	3 fc (30 lux) at grade
Uniformity	4:1 average to minimum	

7-3.2.5 Critical Design Issues.

- Refer to UFC 4-022-01 for additional criteria on signage.
- Refer to Figure 6-6 for diagram of ECF lighting zones.
- Use luminaires with a G-Rating of G0, G1, or G2 for roadway or area luminaires.
- For luminaires in the Discomfort and Disability Glare Visual Field, follow the design parameters outlined in section 6-3-4.1.

7-3.3 Access Control Zone Underneath Canopy.

Locate low brightness luminaire behind and to side of inspection personnel to light the approaching vehicle and driver. This also eliminates glare for the guard.

7-3.3.1 Control Requirements: Primary ECF/ACP.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

7-3.3.2 Control Requirements: Secondary ECF/ACP.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	Automatic dimming to 30% 1 hour after ECF/ACP closing and automatic full ON 1 hour before opening
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

7-3.3.3 Control Requirements: Limited Use ECF/ACP.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

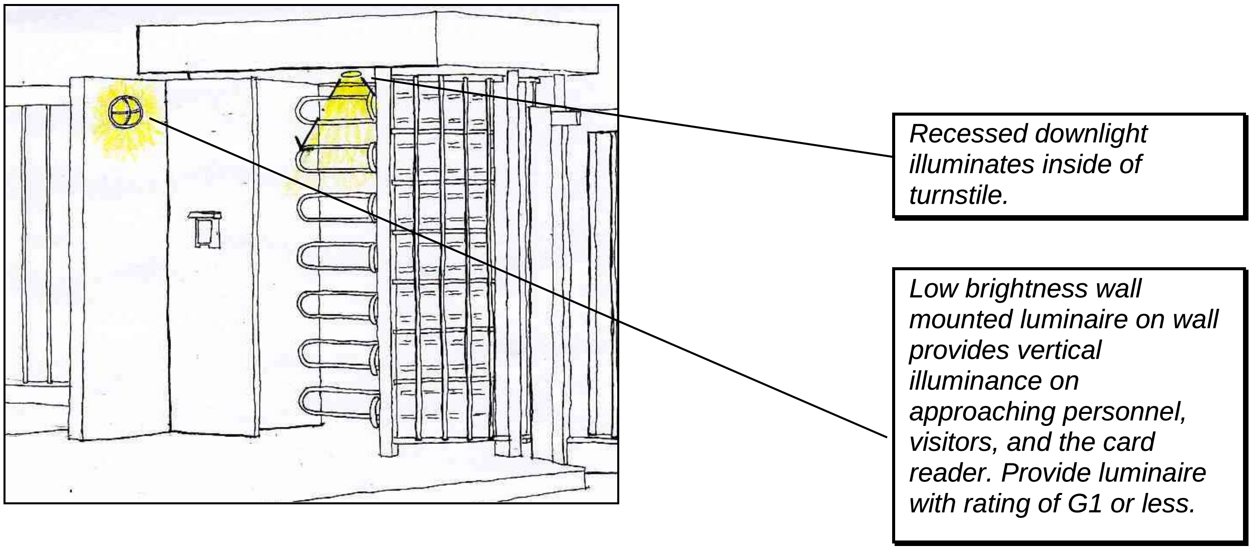
7-3.3.4 Performance Requirements.

Target Criteria	All Lighting Zones
Average Horizontal Illuminance under canopy at ID check	10 fc (100 lux) at grade
Uniformity under entire canopy	3:1 average to minimum

7-3.3.5 Critical Design Issues.

- Refer to Figure 6-6 for diagram of ECF/ACP lighting zones.
- Luminaires located on the wall must be less than 3500 initial light source lumens.
- Use luminaires with a G-Rating of G0 or G1 for canopy luminaires.
- Canopy luminaires should be semi-recessed or surface mounted with an uplight component. They will provide more illuminance onto the canopy ceiling surface, which improves uniformity and reduces contrast.
- Underneath the canopy, prioritize lighting at the ID check island, where ID Check is occurring.

7-3.4 Pedestrian Access.



7-3.4.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

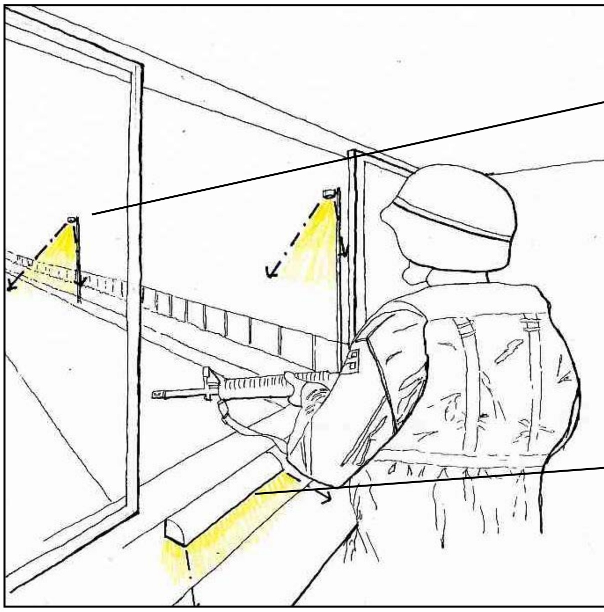
7-3.4.2 Performance Requirements.

Target Criteria	**All Lighting Zones**
Average Horizontal Illuminance	2 fc (20 lux)
Uniformity	3:1 average to minimum

7-3.4.3 Critical Design Issues.

- Luminaires located on the wall must be less than 3500 initial light source lumens.
- Locate luminaires to avoid harsh shadows.
- Refer to UFC 4-022-01 for additional criteria on signage.

7-3.5 Response Zone.



7-3.5.1 Control Requirements.

Manual Control	For interior task light, provide wallbox dimmer or scene wallstation with manual ON and manual OFF and manual dimming
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

7-3.5.2 Performance Requirements.

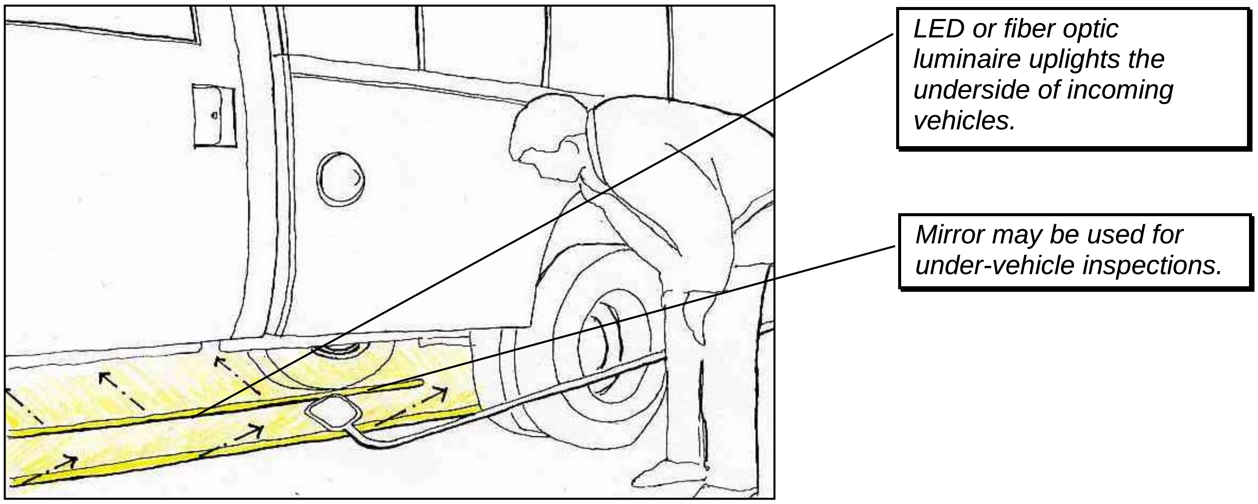
Target Criteria	Minimum Distance	All Lighting Zones
Average Horizontal Illuminance, Response Zone, Transition	60’ (18 m)	1.5 fc (15 lux) at grade
Average Horizontal Illuminance, Response Zone, Exit	80’ (24 m)	0.5 fc (5 lux) at grade
Uniformity	3:1 average to minimum	

7-3.5.3 Critical Design Issues.

- Refer to Figure 6-6 for diagram of ECF/ACP lighting zones.
- Use luminaires with a G-Rating of G0, G1, or G2 for roadway or area luminaires.
- Provide transitional lighting between bright and dark regions for the Response Zones of the gate to improve visual adaptation.
- For luminaires in the Discomfort and Disability Glare Visual Field, follow the design parameters outlined in section 6-3-4.1.

7-4 OTHER AREAS.

7-4.1 Under-Vehicle Inspection.



7-4.1.1 Control Requirements.

Manual Control	Wallbox switch or scene wallstation in nearby accessible location with manual ON and manual OFF
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

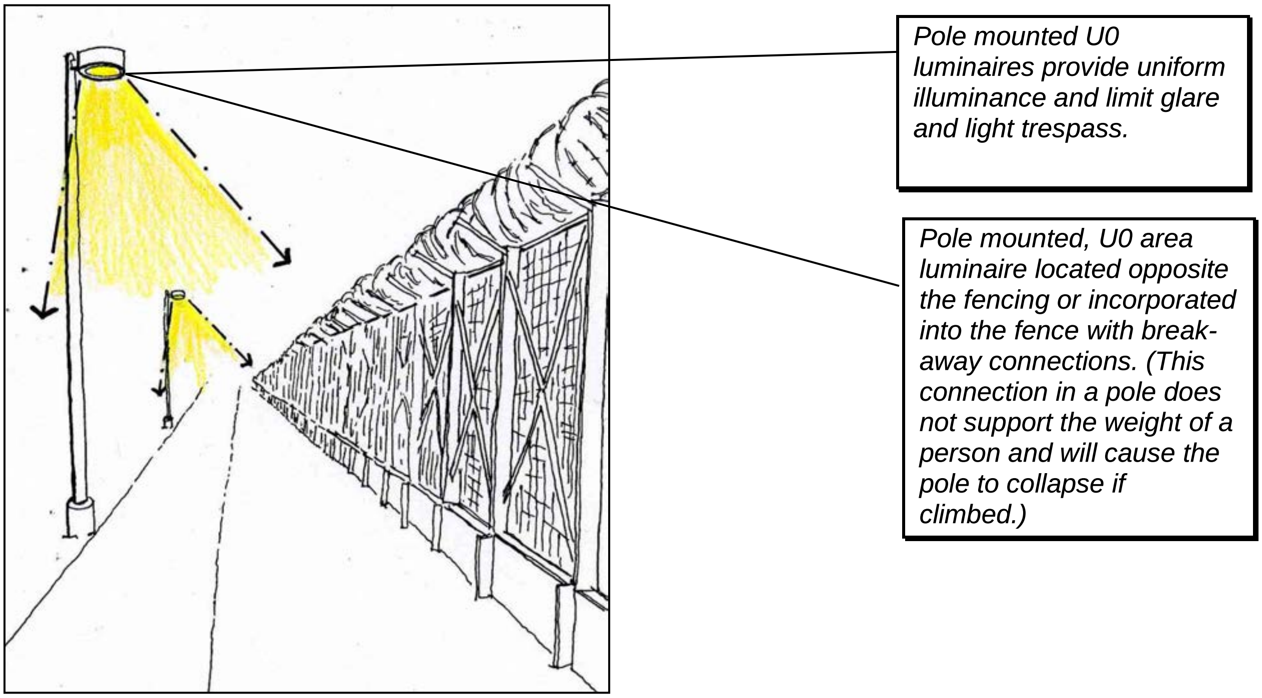
7-4.1.2 Performance Requirements.

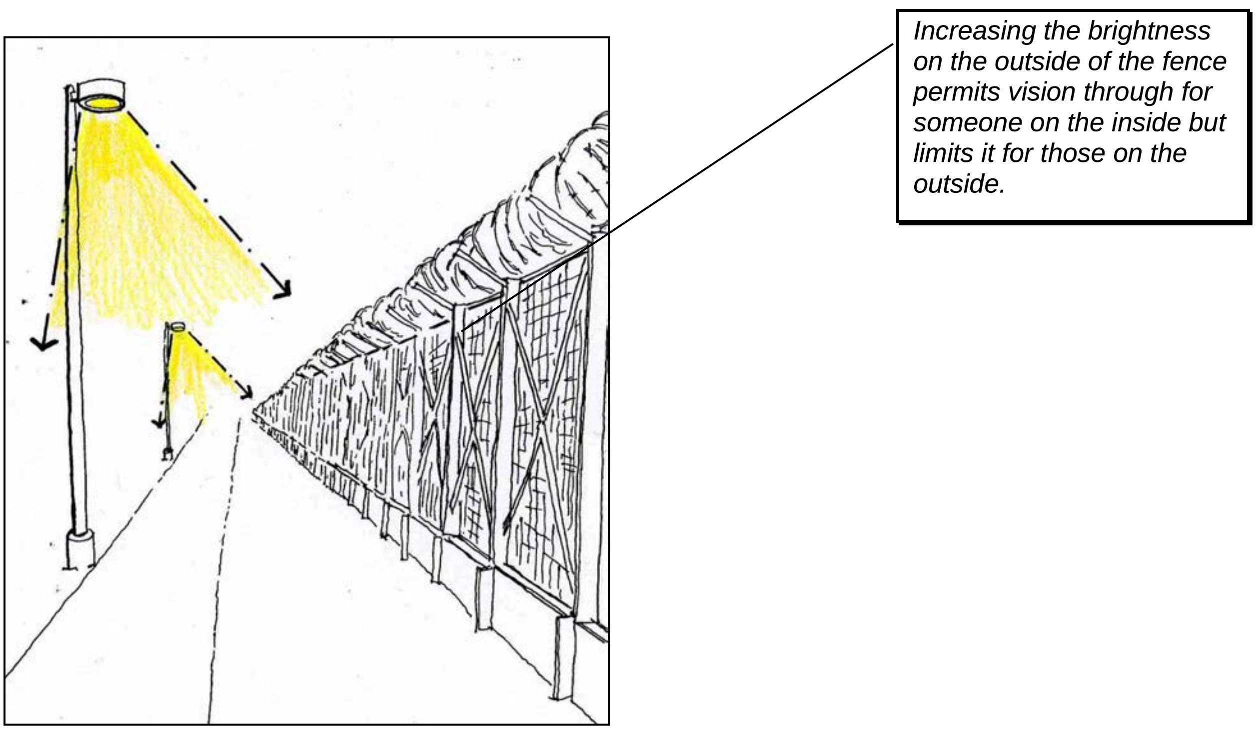
Target Criteria	**Daytime**	**Nighttime**
Minimum Horizontal Illuminance calculated from below	10 fc (100 lux) at 1’-0” (305 mm)	
Average Horizontal Illuminance at center of drive lane for surrounding parking and roadway	3 fc (30 lux)	
Uniformity	3:1 average to minimum	

7-4.1.3 Critical Design Issues.

- Luminaire brightness must be kept at a low level.
- Uniformly illuminate the underside of the vehicle.

7-4.2 Controlled Perimeters – Single Fence Line.





7-4.2.1 Control Requirements.

Manual Control	None
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on availability of daylight with manual override
Zoning	None

7-4.2.2 Performance Requirements.

Target Criteria	**All Lighting Zones**
Minimum Horizontal Illuminance	Between 0.2 and 4 fc (2 and 40 lux)
Uniformity	10:1 maximum to minimum

7-4.2.3 Critical Design Issues.

- Provide U0 rated and G2 or less luminaires with low lumen output to minimize glare and light pollution.
- Uniformly illuminate the area to minimize shadows along the perimeter.
- Coordinate lighting system with emergency backup power availability.

7-4.3 Restricted Area.

7-4.3.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 50% after 15 minutes of no detected motion
Time Schedule	None
Photosensing	ON and OFF based on daylight availability
Zoning	None

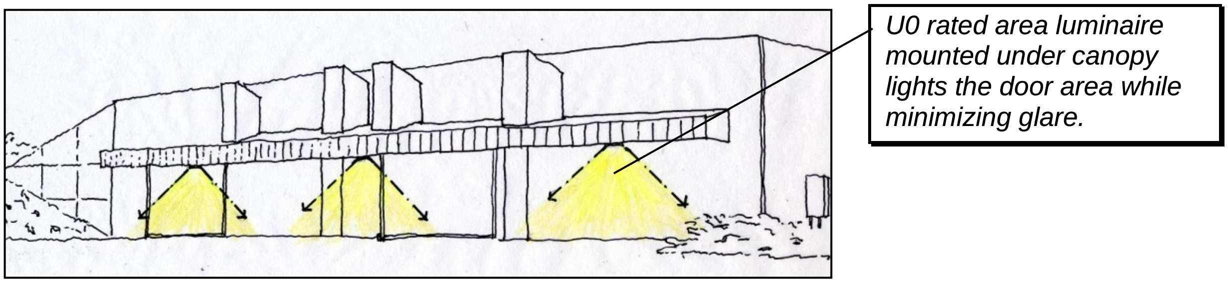
7-4.3.2 Performance Requirements.

Target Criteria	**All Lighting Zones**
Average Horizontal Illuminance	Between 2 and 5 fc (20 and 50 lux)

7-4.3.3 Critical Design Issues.

- Provide U0 rated and G2 or less luminaires with low lumen output to minimize glare and light pollution.

7-4.4 Magazines.



7-4.4.1 Control Requirements.

Manual Control	None
Motion Sensing	Automatically dim lights to 50% after 15 minutes of no detected motion
Time Schedule	None
Photosensing	ON and OFF based on daylight availability with manual override
Zoning	None

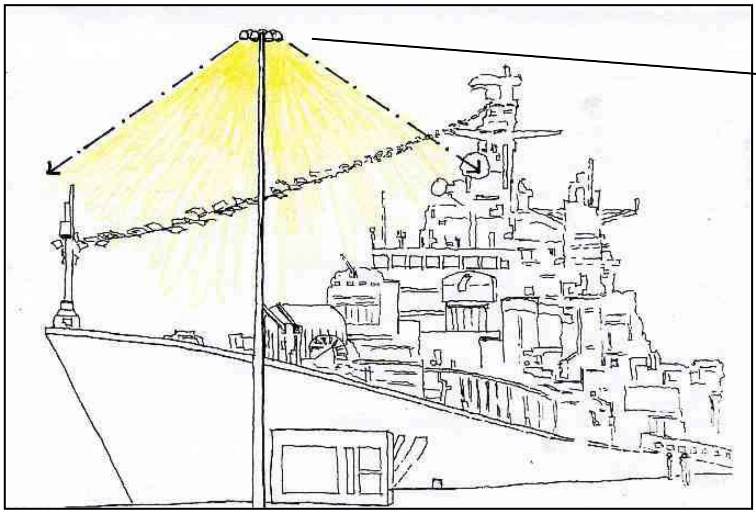
7-4.4.2 Performance Requirements.

Target Criteria	**All Lighting Zones**
Average Horizontal Illuminance	Between 0.2 and 5 fc (2 and 50 lux)

7-4.4.3 Critical Design Issues.

- Provide U0 and G2 or less luminaires with low lumen output to minimize glare and light pollution.
- Coordinate lighting system with emergency backup power availability.
- Reference UFC 4-420-01 for specific lighting requirements.

7-4.5 Piers and Wharves.



High mast luminaires provide uniform illuminance and minimize the number of poles necessary.

7-4.5.1 Control Requirements.

Manual Control	Optional: Two levels, operational and non-operational Switch location – guard position?
Motion Sensing	None
Time Schedule	None
Photosensing	ON and OFF based on daylight availability Turn lights to most recent manual setpoint
Zoning	None

7-4.5.2 Performance Requirements.

Target Criteria	**Active Work Areas**	**Other Areas**
Average Horizontal Illuminance	Between 3 and 5 fc (30-50 lux)	0.5 fc (5 lux)

7-4.5.3 Critical Design Issues.

- Provide U0 rated luminaires.
- Use the minimum number of high mast lighting poles and luminaires that provide uniformity.
- Refer to 29 CFR 1915.82 for the minimum lighting intensity requirements for shipyards.
- Refer to UFC 4-152-01 for Pier and Wharf operational lighting requirements.

APPENDIX A BEST PRACTICES: INTERIOR LIGHTING

A-1 MAINTENANCE.

Refer to ANSI/IES LP-9 Section 3.6 Service and Maintenance Issues, for maintenance best practices.

A-2 VISIBILITY.

Large tasks generally require less illuminance, brightness, and contrast to be performed. Small, detailed tasks may require task lighting to increase the light level significantly. Knowing a description of the task is essential to designing the lighting for that task. The luminance or brightness of a task increases the task visibility. Brighter tasks are easier to see, so long as it is not so much brighter than its surroundings that it becomes uncomfortable or a source of direct glare. As task contrast decreases, the light level required to see it increases. If the contrast is too low, it is difficult to distinguish various components of the task, reducing visibility.

A-2.1 Glare.

Direct glare can be minimized with careful equipment selection and placement. Indirect or reflected glare is caused by light reflecting off the task in such a manner that the contrast is “washed out.” Many work situations position the light directly in front of the task, producing reflected glare. See Figure A-1 for examples of direct glare.

Like direct glare, indirect glare can be minimized with the type and layout of lighting equipment. Locate direct light to the side or behind a critical task. Use semi-indirect light to bounce light off surfaces in order to provide uniform low glare light with less reflected disability glare. Direct luminaires that are immediately over an individual can cause glare even though the light source is not in the field of view. This type of glare can produce the same negative effects as direct or reflected glare including eye strain and headaches.

Figure A-1 Examples of Direct Glare

A-2.1.2 Considerations to Minimize Glare.

- Indirectly light the ceiling and walls for interior ambient lighting systems.
- Use direct light only in limited amounts for task and accent light.

A-2.2 Uniformity.

Lighting level or illuminance uniformity is important on work surfaces where sustained tasks are performed as well as on wall and ceiling surfaces that make up a significant portion of the field of view. See Figure A-2 and Figure A-3 for examples of uniformity. Poor uniformity can cause adaptation problems. It is very important to prevent “spotty” lighting especially in interior areas where people are working.

Figure A-2 Uniform ceiling brightness

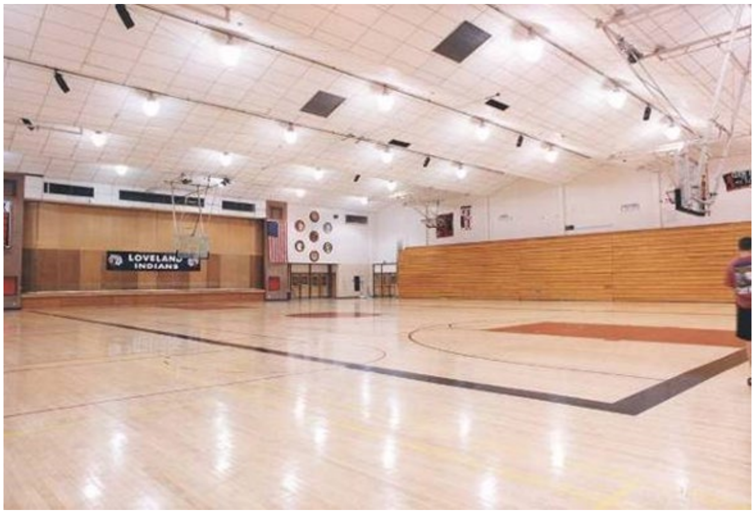


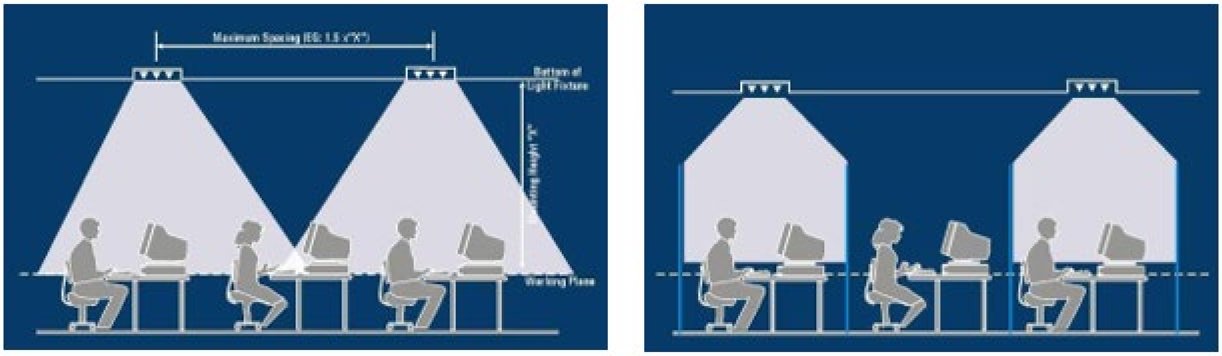
Figure A-3 Uniform illuminance

A-2.3 Maintaining Uniformity.

Carefully consider changes in lighting systems and furniture systems so that lighting uniformity is not compromised. As shown in Figure A-4, a lighting system that provides uniform illuminance on the work-plane in one furniture configuration may not provide the same uniformity in a different configuration.

In the case shown, an additional luminaire is required to adequately light the center workstation. This increases the amount of energy required to light the same area. In such a condition, the use of a semi-indirect, pendant system provides better uniformity and at the same time allow for flexibility in the workstation layout.

Figure A-4 Task plane illuminance uniformity[5]



A-2.3.2 Considerations for Uniformity.

- In office areas, uniformity should not exceed 5:1 average to minimum in immediate work surrounds, not including accent lighting.

A-2.4 Illuminance.

In many cases illuminance is no longer a top priority. Lighting wall and ceiling surfaces is usually more important than providing high levels of horizontal illuminance. In order to provide flexibility and interest in a space, light ceiling and wall surfaces with lower ambient lighting levels. Provide higher illuminance levels with individualized task lighting.

A-2.4.1 Considerations for Adequate Illuminance.

- Design ambient lighting levels to 1/3 to 1/2 task lighting levels. Add task lighting to increase light level at the task.
- Use white light for exterior lighting.

A-2.5 Surface Brightness.

Traditionally, illuminance has been the basis of lighting design; however, we see brightness. We do not see lighting levels. There are three different types of visual responses: Photopic or our day vision (5 cd/m² and higher), Scotopic or our night vision (0.001 cd/m² and below) and mesopic or a combination of night and day vision (0.001 cd/m² to 5 cd/m²). (ANSI/IES LS-1-21).

We “see” brightness (luminance); we don’t see lighting levels or (footcandles or lux). Our perception of spaces depends on how surfaces are lighted. The factors that lead to brightness as a response are object luminance, surround luminance, state of

[5] Used with permission. Hayden McKay Lighting Design.

adaptation, gradient, and spectral content.[6] It is important to light vertical surfaces such as walls and building facades as a first priority, then horizontal surfaces such as ceilings and canopies. The least effective surfaces to light are floors. Downlighting results in spaces feeling dark and "cave-like", see Figure A-5. Lighting surfaces improves the feel of the space, see Figure A-6.

Figure A-5 Downlighting only

Figure A-6 Improved surface brightness

A-2.6 Low Ceiling Applications.

In some applications, the ceiling height may be low and cannot be increased to accommodate pendant mounted lighting equipment. In these cases, the lighting design should still try to address the issue of surface brightness. One way to achieve surface brightness with low ceiling conditions is with recessed downlight/wallwash luminaires. The reflector on these luminaires looks similar to a standard downlight, but also uses a modification to light adjacent walls evenly. It is also designed to put light high on the wall next to the ceiling.

[6] ANSI/IES LS-8-20, Lighting Science: Vision – Perceptions and Performance. (New York: Illuminating Engineering Society; 2021.)

A-2.6.1 Indirect lighting.

Indirect lighting provides better visibility for offices and computer tasks than parabolic luminaires. Additionally, the installation cost of pendants can be lower than recessed direct/indirect troffer luminaires due to the reduced number of connection points. In low ceiling applications where a semi-indirect pendant system is not feasible, consider semi-indirect recessed for lighting the interior of the space. Downlight/wallwashers around the perimeter of the space increase the surface brightness of the walls. This strategy is a better choice to eliminate glare than the use of lensed troffers. However, avoid troffers designed to spread the light. These achieve wide distributions by lowering the light sources in the luminaire and thereby increasing the glare.

A-2.6.2 Semi-indirect pendant.

Semi-indirect pendant manufacturers offer short pendant luminaires for low ceiling applications. These luminaires use refined optics to spread light out and light the ceiling with a pendant length of under 12 in (0.3 m). These luminaires allow semi-indirect lighting systems in spaces with a ceiling height of 8 ft (2.4 m).

A-2.7 Considerations for Surface Brightness.

- Provide high surface reflectances for walls (60% minimum) and ceilings (85% minimum).
- Light ceilings with semi-direct wall or pendant mounted lighting.
- Light walls with wall washers.
- Direct daylight to ceilings and walls.
- For exterior applications, light vertical surfaces that are in pedestrians’ field of view.

A-3 LIGHT SOURCES.

A-3.1 Technical Considerations.

Refer to ANSI/IES LP-4-20, *Lighting Practice: Electric Light Sources – Properties, Selection, and Specification*.

A-3.2 Light Source Efficacy.

Refer to ANSI/IES LP-4-20, *Lighting Practice: Electric Light Sources – Properties, Selection, and Specification*.

A-3.3 Material Issues.

Fluorescent, metal halide, induction, and high-pressure sodium light sources contain liquid mercury to produce the mercury vapor necessary for operation. When light sources are broken or incinerated the mercury may be released into the soil or the atmosphere. Mercury has been linked to potential health risks. Some light source manufacturers offer product series that feature reduced mercury content.

A-3.4 Recycling.

Traditional light source types except incandescent sources contain some level of mercury. These light sources should be recycled to avoid release of any mercury into landfills. The cost of recycling light sources should be included in any life-cycle cost analysis.

A-4 EQUIPMENT PERFORMANCE.

A-4.1 Flicker.

Most light sources flicker but remain mostly imperceptible. SSL luminaires are particularly sensitive to noticeable flicker when dimmed, especially with incompatible dimming controls and inadequate electrical infrastructure. Utilizing 0-10V and DALI dimming protocols are recommended to reduce flicker across dimming ranges. For applications where these dimming protocols are not available, such as screw-base lamp replacements, provide dimmer compatible with SSL luminaires and ensure that electrical infrastructure is adequate to operate SSL luminaires.

A-4.2 Noise.

Provide LED drivers with a Class A noise rating.

A-4.3 Interference.

LED drivers have the potential to cause electromagnetic interference (EMI) and radio frequency interference (RFI) when operated near other high frequency electronic equipment. This can be a significant issue when installed near electronic medical equipment. LED drivers should be selected and rated for use near sensitive equipment, complying with FCC Title 47 Part 15.

A-4.4 Effects of Temperature.

Ambient air temperature affects the performance and output of fluorescent, SSL, and induction light sources. Low temperature has a positive effect on SSL sources, improving their life. For SSL luminaires, ANSI/IES LM-79 and ANSI/IES LM-80 testing reports show the lumen depreciation over time and temperature.

A-4.5 Life.

The operating temperature of drivers and power control units directly affects the life. The luminaire housing or enclosure should provide for adequate dissipation of heat. When drivers operate at excessive temperatures, the insulation degrades, resulting in a shortened driver life. High operating current in SSL luminaires can also shorten life. Review ANSI/IES LM-80, ANSI/IES LM-79, and ANSI/IES TM-21 data to determine actual life with designated operating current.

The life expectancy data given by LED light source manufacturers refers to the approximate operating time over which the LED light source will maintain 70% (L_{70}) of its initial light output.

A-5 CONTROL APPROACHES.

Lighting controls have the benefit of reducing energy use when lighting is not required. Lighting controls are required in meeting ASHRAE 90.1 energy codes. It is important to note that electric lighting controls should be incorporated with a daylight design to gain any energy savings from the daylight.

A-5.1 Occupancy Based Controls.

Occupancy sensors automatically turn the lights on when an occupant enters a space and automatically turn the lights off after a predetermined period in which no human activity is sensed. Vacancy sensors automatically turn the lights off after a predetermined period in which no human activity is sensed. The occupant manually turns on the lights when he or she enters the space. The operating technologies behind either an occupancy or vacancy sensor are passive infrared, ultrasonic, or dual technology.

Occupancy based controls may be ceiling mounted to cover large spaces or they may be integrated with wall switches for smaller spaces. Occupancy based controls are ideal for areas of convenience such as storage rooms where individuals often have their hands full when entering or leaving. For private offices without daylight, it may be ideal to have an auto-on occupancy sensor that turns the lights on to a preset light level, such as 50% with a manual 100%, and then automatically turns the lights off. Manual override may be necessary in spaces where the lights occasionally need to be turned off with occupants such as classrooms and conference rooms. It may also be useful to group luminaires and control with a single occupancy or vacancy sensor. Controls should have a time delay that can be adjusted up to 30 minutes. If the sensor fails, local override control should be available, or the system should revert to the ON position. Table B-1 summarizes strategies for selecting the appropriate occupancy-based control sensor.

A-5.2 Bilevel and Multi-level Switching.

Bilevel switching is less prevalent with SSL sources. It is most commonly seen today in direct/indirect luminaires with two circuits: one circuit controls the indirect, or uplight, component, and the other controls the direct, or downlight, component. It is also occasionally used to provide step dimming in areas, without requiring dimming controls. However, as SSL sources are less expensive to dim than their fluorescent predecessors, step dimming is seen less frequently. Bilevel switching should be used in stairwells and similar low occupancy spaces such as hallways to reduce energy consumption without the use of dimming controls. Controls should fail in the full-on position. Spaces should be equipped with bilevel luminaires controlled by an integrated or separate occupancy sensor. When the space is unoccupied; lighting should be reduced by a minimum percentage of 50% and maintain the minimum life safety code requirement for egress when the building is occupied. When utilizing bilevel switching in Means of Egress, the lighting and controls must comply with NFPA 101.

A-5.3 Daylight Dimming.

Daylight dimming is used to reduce the light output and energy usage of the electric lighting in spaces with daylight. This is achieved with the placement of photosensors to measure the amount of light on a task surface or the amount of available daylight outside. Electric light is either dimmed or shut off in response to the amount of light detected and the programming on the control system. Best practices of daylight dimming are discussed in detail in Appendix C.

A-5.4 Light Level Tuning.

Light level tuning is used to adjust the maximum light level to precisely set the lighting requirements based on the preference of the occupants in the space and the color of the carpets, office furniture, cubicles, and walls. Different spaces can have different maximum light levels and the ability to adjust the high-end output of the luminaire can offer typical lighting energy savings of 20% or more.

A-5.5 Scene Based Dimming.

One button touch allows multiple zones of light within a space to go to the appropriate light levels, known as a scene, for a specific task or use. Scene-based control should allow the integration of AV controls, shading, and lighting to work seamlessly with one button touch (lights dim, projection screen lowers, and shades go down).

A-5.6 Manual Switching.

Manual switching may be an ideal strategy where automatic control is not allowed, such as electrical rooms. The energy savings is diminished though, so a switch should be integrated with an occupancy-based sensor, where allowed.

A-5.7 Timeclocks.

Timeclocks control larger areas or groups of luminaires. They automatically adjust lighting levels based on the time of day or astronomical events such as sunrise and sunset. This type of control may be applicable in spaces where there is constant occupancy, limited daylight, and minimal activity in non-peak hours of the day.

A-5.8 Personal Control.

This provides an occupant with the ability to control and dim their own lighting even in an open office configuration. Personal controls may be accomplished with personal control over task lighting at a workstation.

A-5.9 Network Control Systems.

A network control system is required to integrate into a building automated, energy management system. Even in cases where integration with a building management system is not feasible, it may be appropriate to have a stand-alone network lighting control system. There are varying methods to create a network control system. A network-based system may provide the greatest flexibility and configuration options because zones can be created through software for spaces that may be reconfigured over time. A network control system with the capability of controlling each luminaire allows maximum flexibility for energy savings and reconfiguration of the spaces. When possible, a network control system will also allow use of control devices like occupancy sensors by other systems, such as controlled receptacle circuits.

A-6 CONTROL EQUIPMENT.

A-6.1 Sensors.

A-6.1.1 Occupancy Based Controls.

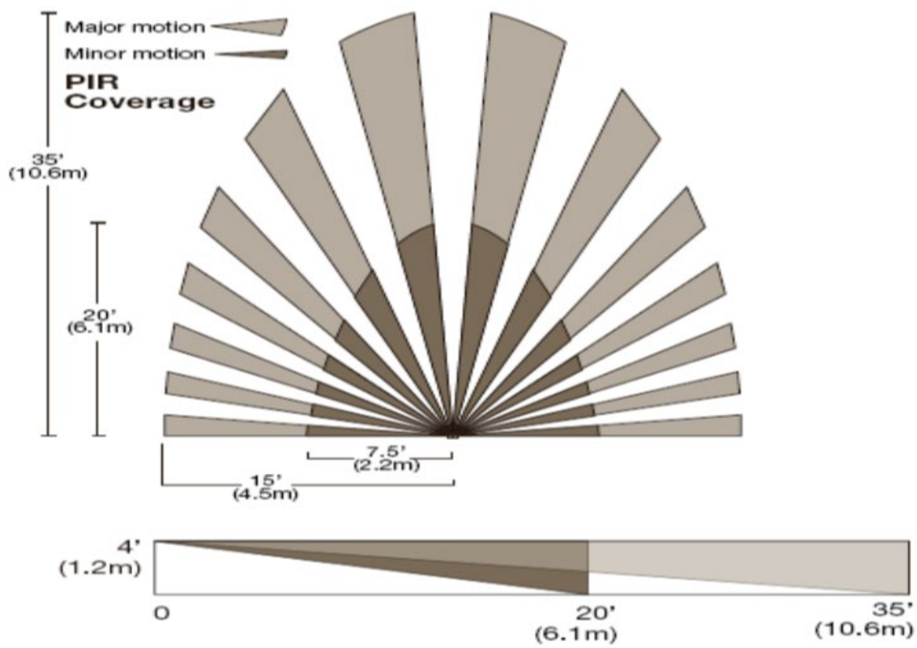
An occupancy sensor is used for interior applications to automatically turn the lights on when an occupant enters the space and automatically turn the lights off after a period of undetected occupancy.

A vacancy sensor requires the occupant to manually turn the lights on when they enter the space, and the sensor automatically turns the lights off after a period of undetected occupancy. More energy is saved when using vacancy sensors as occupants may not always require electric lighting when entering a space.

A-6.1.1.1 Passive Infrared.

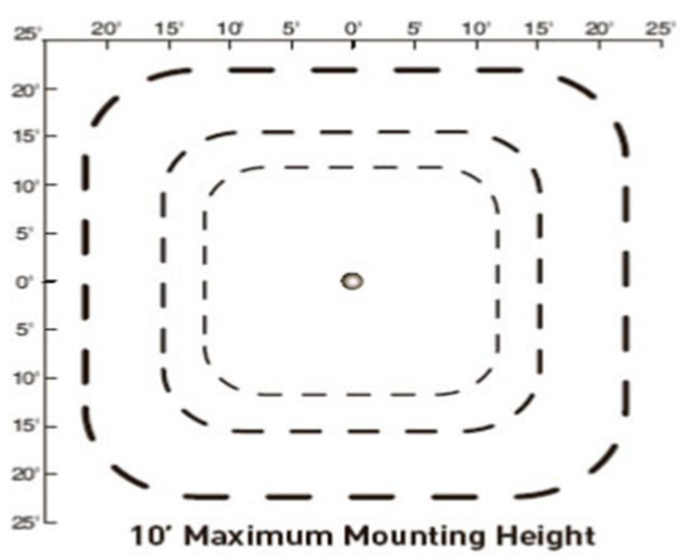
Passive infrared (PIR) sensors detect the difference in heat between a human and the surroundings. Because of this, the sensor has to be able to “see” the entire space and any obstruction such as partitions, shelves, or cabinets block detection. Changes in ambient temperature also reduce the effectiveness of the infrared sensors. The pattern of occupancy is dispersed in a fan shape where the distance between fan blades is small near the sensor but increases as the fan blades are directed away from the sensor, see Figure A-7.

Figure A-7 Coverage Pattern of PIR Sensor



Ultrasonic technology relies on high frequency sound waves to detect movement in the space, see Figure A-8 for typical coverage pattern. This movement could be a person moving, or air movement created by a person's activity. This type of sensor is therefore appropriate for spaces that have partitions such as restrooms or open office areas. Such sensors need to be located so that they do not sense the "false-occupancy" of an air vent or a passer-by in an adjacent space. Room finishes such as carpeting may absorb the ultrasonic waves and reduce effectiveness.

Figure A-8 Coverage Pattern of Ultrasonic Sensor

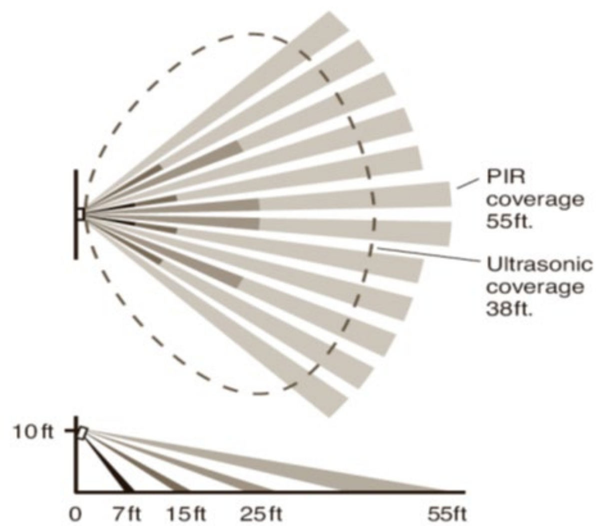


A-6.1.1.2 Dual Technology.

Dual technology sensors combine both the capabilities of PIR and ultrasonic to detect occupancy. See Figure A-9 for coverage pattern. Both an ultrasonic and PIR detection of occupancy is required for the lights to turn on but only one sensor technology is required for the lights to remain on. This type of sensor is best used in large spaces with low occupant activity levels.

Figure A-9 Coverage Pattern of Dual Technology Sensor

(Courtesy of Wattstopper/Legrand)



A-6.1.1.3 Microphonic.

Microphonic passive occupancy sensors are available with dual sensors. These sensors use PIR technology to first detect motion in the space and then use a microphone to monitor sounds to indicate continued occupancy.

Micophonic sensor technology is not recommended for most spaces since noise from HVAC, refrigerators, traffic, radios, telephones, and other systems may cause false occupancies detection.

A-6.1.1.4 Sensor Considerations.

See Table A-1 for guidance on where to use sensor types. Each type of occupancy or vacancy sensor should be equipped with a time delay. This time delay leaves the lights on for a predetermined amount of time after the last occupant has been detected. The purpose of the time delay is to ensure that occupants are not left without lighting and to reduce the number of on/off cycles. Since occupancy patterns vary with time of day as well as day of the week, and are not easily scheduled, it is best to select a time delay that works for both periods of increased and decreased occupant activity.

Manufacturers typically have preset time delays at 5, 10, 15, 20, or 30 minutes. It is recommended that a time delay setting of 20 minutes be used for most spaces. Should another time delay setting be selected, consideration should be given to the increased energy consumption, driver type, and increased life of the light source due to the reduced number of on/off cycles.

In addition to the time delay, there should also be a setting for the sensitivity. The sensitivity needs to be calibrated appropriately according to the activity in the space. For example, if there is limited movement in the space, the sensitivity should be calibrated to detect very slight movement.

Table A-1 Guide for Using Sensors

DO	**DON'T**
Use ultrasonic sensors in large open areas with partitions or furniture	Use ultrasonic sensors where there is high air flow.
Place sensors in proximity to where the main activity in the space will occur.	Install an in-wall sensor where it is blocked by furniture or behind the door.
Use PIR in enclosed spaces.	Use ultrasonic sensors in small, enclosed spaces where they may react to activity outside the space.
For large areas, create zones of light to manage light.	Install ultrasonic or dual tech sensors higher than 12 feet.
Overlap sensor coverage patterns by at least 20% to ensure adequate coverage.	Install sensors within 6 feet of an HVAC vent.
Ensure PIR line of sight does not extend out doorways. This can be achieved by either sensor placement or lens masking.	Use PIR sensors when there are multiple obstructions (furniture, partitions) which prevent line of sight of the sensor.

A-6.1.1.5 Self-Adapting.

Self-adapting technologies “learn” how the space is used by occupants and adjusts the lights as necessary. The technology responds in real-time and automatically adjusts both the sensitivity of the sensor and the delay time. Self-adapting sensors are best used in spaces where neither the occupants nor the activities vary from day to day. Self-adapting technology is not recommended for classrooms and conference rooms but may be ideal for private offices.

A-6.2 Manual Controls.

Considerable energy savings can be achieved by allowing occupants to control (on/off) or vary the light levels.

Energy savings from dimming lights is nearly linear. Furthermore, users seldom require maximum light levels and studies show that allowing users to adjust illuminance for different tasks saves 35% - 42% lighting energy.

A-6.2.1 Switches.

Manual controls for occupants can be a good way to increase worker autonomy and give occupants greater control ability, although the energy savings is not as great as automatic controls and is not allowed by the energy code in most regularly occupied spaces.

A-6.2.2 Dimmers.

Manual dimming occurs with a control action initiated by the occupant. This type of dimming may be useful in spaces where several different activities can take place. A conference room is an example where the lights may need to be dimmed for an A/V presentation, but also may need to be full output for meetings. Manual dimming also results in high satisfaction rating for occupants and should be encouraged for regularly occupied areas.

A-6.3 Time Controls.

A-6.3.1 Time Switch.

Automatic switching takes place in conjunction with occupancy controls when the space becomes unoccupied. The lights turn off after a designated period of inactivity.

A-6.3.2 Timeclock.

A timeclock is a device that automatically adjusts the lights at a specific time or based on astronomical events such as sunrise or sunset. Manufacturers typically allow the preset time to vary between 5 minutes and 12 hours. This type of control may be applicable in spaces where there is constant occupancy, limited daylight, and minimal activity in non-peak hours of the day.

A-6.3.3 Schedule.

A preset schedule can be programmed to automatically turn the lights on or off based upon trends in occupancy. Different schedules are created for weekdays, weekends, evenings, and holidays.

A-7 NETWORK CONTROL SYSTEM.

A network control system can be connected in a number of different ways. Implementing addressable drivers provides digital addresses for all drivers and connects them as a system through network cabling. The digital addresses allow control over each driver individually and allow for flexibility of the system as the needs of the space evolve over time. A wireless system communicates with all devices (sensors, dimming drivers, and area controllers) over radio frequency. The zoning of such a system is configured through software and provides flexibility as the needs of the space evolve over time.

ANSI/IES LP-6 provides technical information regarding the varying architectures, topologies, and protocols that are currently available for lighting controls. The document may be useful especially when integrating one protocol with another or integrating a lighting control system with a building automation system. Typical uses are outlined along with limits/extents, interoperation with other protocols, and designer responsibilities specification recommendations.

A-8 EMERGENCY AND EXIT LIGHTING.

Mark and illuminate means of egress in accordance with NFPA 101. The purpose of emergency lighting is to ensure the continuation of illuminance along the means of egress from a building and provide adequate light for the orderly cessation of activities in the building. The purpose of exit lights is to identify the means of egress. Both types of lighting are powered from both a normal power source and an emergency source, with automatic switching from one to the other.

In some specific situations, emergency lighting might be required for specific spaces or work areas that are not on the means of egress. There are often areas where work of a critical nature has to continue regardless of loss of normal power, such as a computer server room. In health care facilities, including hospitals, skilled nursing homes, and residential custodial care facilities, lighting for the means of egress (including exit signs) and elevator cabs is considered “life safety” lighting and connected to the life safety branch of the facility’s emergency power system. Task illumination at anesthetizing locations, patient care areas, laboratories, intensive care units, recovery rooms, and other locations as required by NFPA 70, Article 517 are considered “critical” lighting and powered from the critical power branch of the facility’s emergency power system. In applications where the loss of light, even momentary, would endanger personnel or risk other loss or damage, provide lighting systems to maintain constant illumination through the use of an uninterruptible power supply of sufficient capacity to permit an orderly cessation of activity.

A-8.1 Testing of Emergency Lighting Equipment.

Because of the periodic testing requirements, accessibility of equipment is an important design consideration. Consider self-testing or self-diagnostic emergency lighting equipment.

A-9 REPLACEMENT OF LUMINAIRES.

A-9.1 Fluorescent Industrial Luminaires, Wraparound, Strip Lights, and Recessed Direct/Indirect Troffers.

Convert T-12 and T-8 lighting systems to dedicated LED luminaire. Properly dispose of fluorescent lamps that contain mercury.

A-9.2 Incandescent Downlights.

Where possible, replace incandescent downlights with dedicated LED luminaire replacements. If a full replacement is not possible, retrofit LED lamps are available for direct one-to-one replacement for most incandescent lamps. Confirm appropriate CCT selection, lumen output, and dimming capabilities. Many retrofit LED lamps are not rated for enclosed luminaires. Check lamp specifications prior to installation.

A-9.3 HID, Floodlights, Downlights and Other Luminaires.

Replace existing luminaires with LED systems. This replacement is especially appropriate for applications where switching or dimming could be encouraged to save energy in addition to improving visibility. LED retrofit kits are not a one-for-one replacement of HID luminaires but rather an alternate lighting system.

A-9.4 Exit Signs.

Retrofit incandescent exit signs with LED type.

A-9.5 Lighting Control System.

Consider lighting controls for a lighting replacement project to improve the energy efficiency of the space. Use the installed cost of the system when analyzing the life-cycle cost for a lighting replacement with controls. Integrate the lighting control system directly into the HVAC system to provide reduced HVAC load requirements and improve the buildings energy efficiency.

APPENDIX B BEST PRACTICES: DAYLIGHTING CONTROLS

B-1 INTRODUCTION.

Refer to ANSI/IES LP-3-20, *Lighting Practice: Designing and Specifying Daylighting for Buildings* for additional information.

B-2 SYSTEM INTEGRATION.

If the majority of areas are daylighted, then the electric lighting becomes supplemental during daytime periods. Since our appetite for light is less in the evening and nighttime hours, daylighting does not need to be duplicated with electric lighting. Design electric lighting to supplement the daylighting. For example, when daylight is plentiful, the electric lighting dims near the daylight source. In other areas where the daylight penetration is not as great, the electric lighting can be increased. Electric lighting controls (daylight, occupancy, and vacancy sensors) can typically save up to 50% of the lighting energy in existing buildings and up to 35% in new buildings.[7]

B-3 CONTROLS.

B-3.1 Daylight Sensor Technologies.

Open loop photosensors determine the light level by measuring the outside light availability. Based upon the light level measured, a signal is sent to the electric lighting to either increase or decrease the light level depending on the exterior daylight availability.

Closed loop photosensors determine the light level in a space by measuring the inside light availability. Based upon the light level measured, a signal is sent to the electric lighting to either increase or decrease the light level depending on the interior daylight availability. Table B-1 provides a summary of daylight sensor technologies.

B-3.1.1 Larger Areas.

In larger areas with one daylight zone adjacent to the same window wall and no corner windows, open loop sensor works well. In other spaces, with multiple zones, closed loop works well with one sensor per zone. Networked lighting control systems typically deploy closed loop sensors.

[7] New Buildings Institute, Inc. “Lighting Controls”, *Advanced Lighting Guidelines,* Chapter 8. 2001 Edition, p. 8-1

Table B-1 Summary of Daylight Sensors

Use This Equipment	In This Type of Space	And Be Aware for These Issues
Open loop	Spaces where the outside daylight availability gives an accurate representation of the daylight into the space.	- Sensor should be placed outside or inside pointed towards the daylight opening - Use multiple sensors for spaces with more than one daylight opening - Outside conditions are accounted for, but not space conditions (geometry and reflectance)
Closed loop	Spaces where a constant level of illumination is desired.	- Room surfaces (reflectances) and physical obstacles may affect the light level readings - More reliable and effective at measuring light levels than open loop photosensors

A hybrid adaptation of open loop and closed loop sensors is available. Open loop systems only measure changes in daylight, and not changes in electric lighting. This reduces the likelihood of system imbalance, but by locating these sensors outside of the space does not provide the most accurate daylight dimming but can cause some system imbalance. A hybrid system is located in the space for accurate daylight dimming, but by subtracting the electric lighting contribution to the sensor, system imbalance is not a problem.

B-3.2 Automatic Lighting Controls.

Continuous dimming provides a seamless transition of light level to occupants. The light level is adjusted over a period of typically several seconds does not distract occupants which is ideal for daylight availability dimming. Step dimming creates more abrupt changes in light level. The range of dimming is limited to a few preset light levels and does not allow for transitions and may be noticeable, even distracting, to occupants.

B-3.3 Task Dominant Areas.

Task dominant area examples include offices, conference rooms, classrooms, maintenance areas, and other regularly occupied areas. Daylight dimming provides the highest level of satisfaction since the lighting smoothly responds to daylight availability versus an abrupt on/off. Ideally, manual dimming with an upper daylight limit provides the greatest flexibility and highest acceptance since people have control over their areas. In addition, occupancy and vacancy sensors turn off the lighting if no one is in the area.

B-3.4 Non-task Dominant Areas.

Non-task dominant area examples include transition areas such as corridors, lobbies, atriums, or support areas such as cafeterias, restrooms, and storage areas. Exterior lighting is typically a non-task dominated area. Automatic daylight on/off or bilevel switching is acceptable in these areas, yet dimming is still preferred. Occupancy sensors in these public areas save the most energy, though lights can be turned off with an energy management system. If occupancy devices allow adequate time, especially in transition areas, then the lighting is not disrupted during normal hours of operation.

B-3.5 Control Strategies.

Luminaires in primary and secondary zones switch or dim in response to daylight. See Figure B-1 for layout of primary and secondary zones. Locate sensors according to manufacturer's recommendations. Integrate electric lighting with daylight controls. The electric lighting should begin to dim when the daylight contribution exceeds the target illuminance level on the task plane. Continuous dimming is recommended instead of step dimming to minimize visual disruption to occupants. Harvesting daylight is best suited in spaces that are frequently occupied and a significant amount of daylight enters the space.

When selecting daylight zones, consider the exterior environment in addition to the proximity to glazing. As Figure B-1 and Figure B-2 indicate, if exterior buildings or foliage are blocking some of the daylight contribution into the building, treat those zones as secondary, see Figure B-3. Note that the zoning changes depending on the floor level. Locate the electric lighting parallel to the daylight zones for dimming control.

Figure B-1 Daylight Control Zones

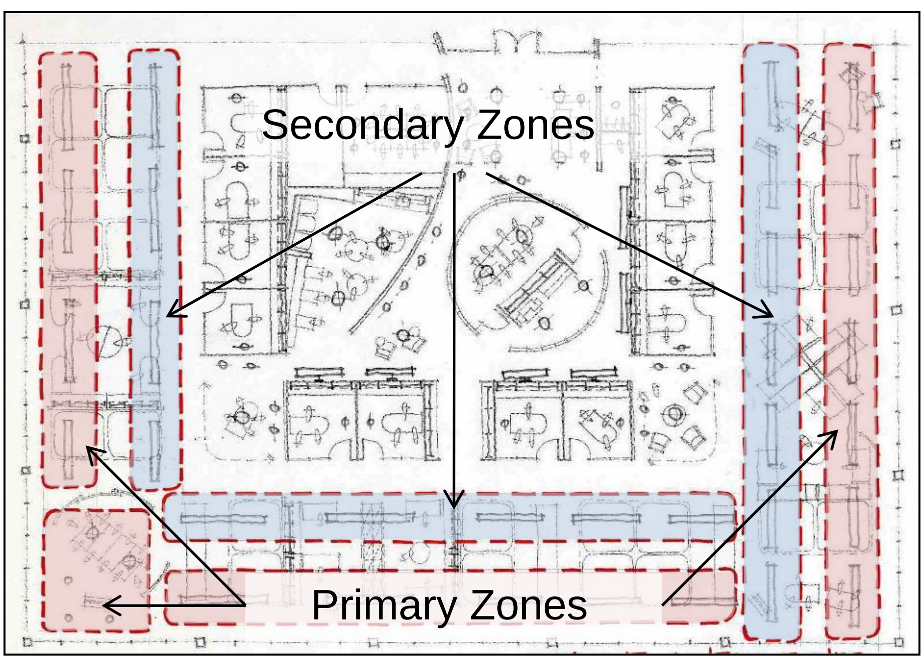


Figure B-2 Daylight Control Zones with Obstructions (Upper Floors)

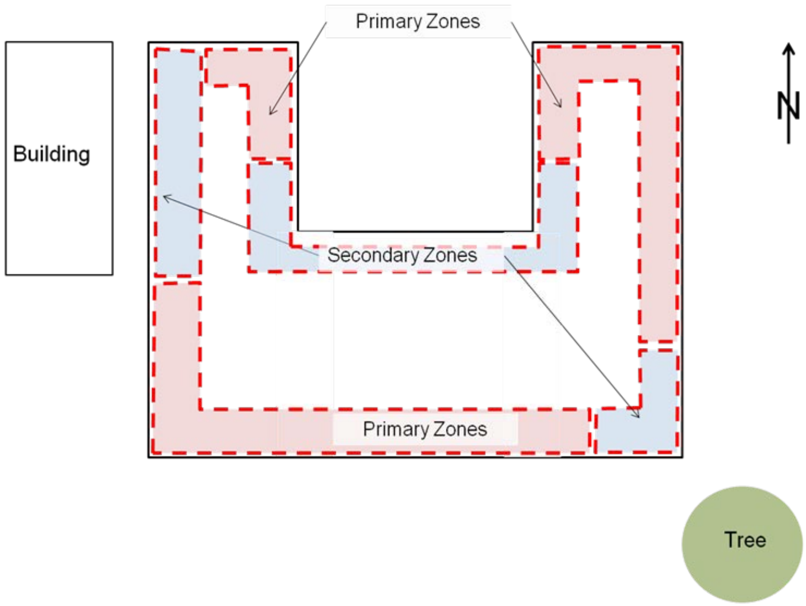
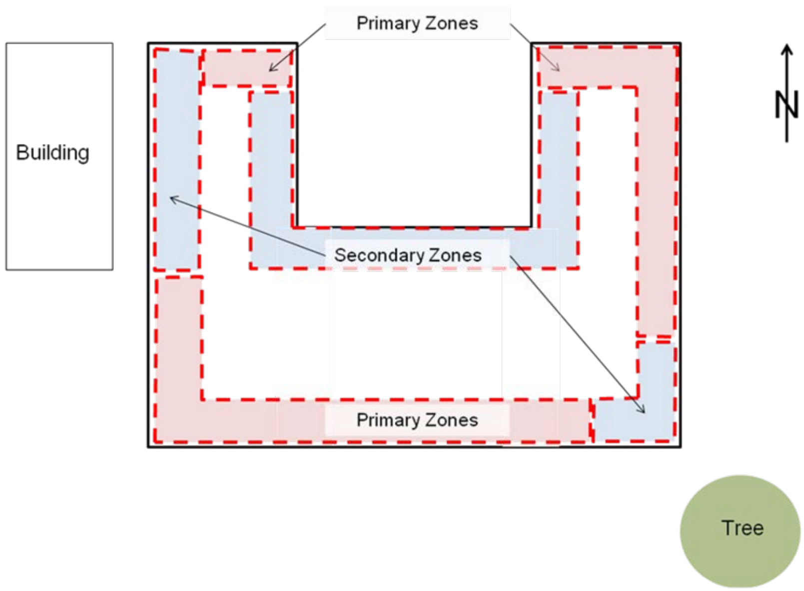


Figure B-3 Daylight Control Zones with Obstructions (Lower Floors)



B-4 AUTOMATED SHADING.

When utilizing automated shading, coordinate daylighting controls with automated shading controls.

APPENDIX C BEST PRACTICES: EXTERIOR LIGHTING

C-1 LIGHTING QUALITY.

C-1.1 Luminance.

There are three different types of visual responses: Photopic or our day vision (5 cd/m² and higher), Scotopic or our night vision (0.001 cd/m² and below) and mesopic or a combination of night and day vision (0.001 cd/m² to 5 cd/m²). Reference ANSI/IES LS-7-20, *Lighting Science: Vision – Eye and Brain*, Sections 5 through 5.4, for more on the ranges for photopic and scotopic vision. The majority of exterior lighting is designed in the mesopic range.

C-1.1.1 Mesopic.

Since light source lumen ratings are all based on photopic sensitivity, they need to be adjusted for nighttime applications. Photopic and mesopic lumens are determined from the spectral power distribution of the light source. In addition, photopic luminous efficiency function applies to visual fields 2 degrees or smaller. This means that only tasks that are on-axis or one that is focusing straight ahead apply to the photopic light source lumen ratings. Any task that is in our peripheral vision does not. Peripheral vision shifts to shorter wavelength sensitivity.

Mesopic multipliers may be used to account for the improved visibility provided by white light. The process for calculating mesopic multipliers can be performed with luminance values or with illuminance values that are converted to luminance values as a function of the background reflectance. Point-by-point mesopic multipliers, as outlined in CIE 191:*2010 Recommended System for Mesopic Photometry Based on Visual Performance* adjust not only the average luminance, but also the uniformity.

C-1.2 Light Pollution.

Light pollution or sky glow is caused by light aimed up into the sky and by light reflected off the ground or objects, see Figure C-1. Sky glow prevents the public and astronomers from seeing the night sky.

Floodlights, wall packs, and other un-shielded luminaires; see Figure C-2, are the major contributors to sky glow. Over-lighting, even with shielded luminaires, reflects unnecessary light back into the atmosphere and adds to the sky glow. This often occurs at outdoor areas such as motor pools and sports fields.

Figure C-1 Los Angeles, 1908 (left), Los Angeles, 2002 (right) [8]

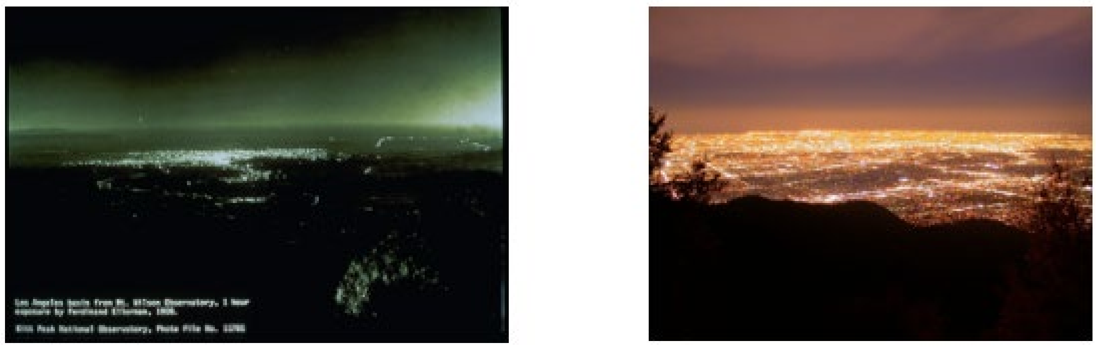
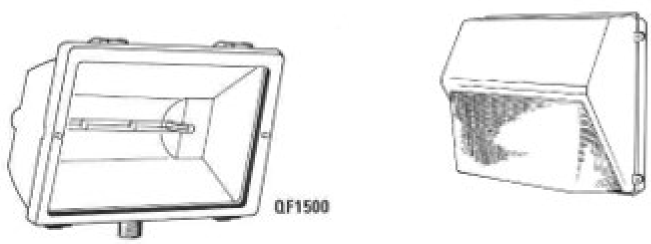
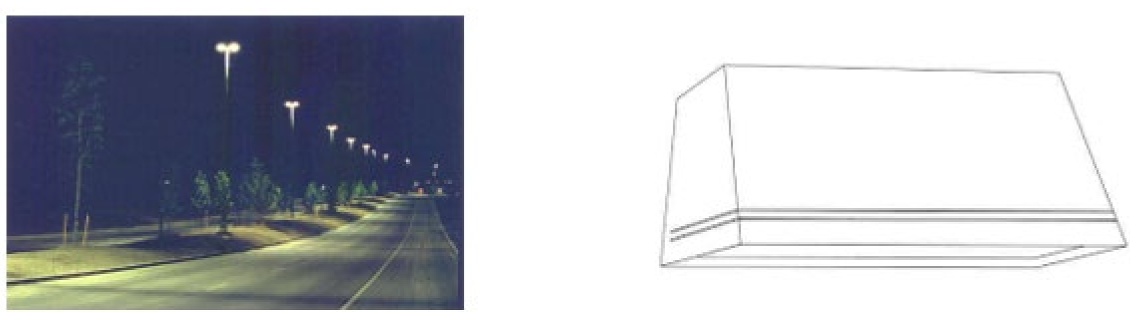


Figure C-2 Unshielded and Non-Cutoff Luminaires



To minimize light pollution, use U0 rated luminaires for area and roadway lighting as illustrated in Figure C-3. Provide uniform low glare lighting and do not over-light exterior areas. Also, control lighting with time clocks, photocells, and motion sensors such that lighting is only energized when needed.

Figure C-3 Examples of IES TM-15 U0 rated luminaires



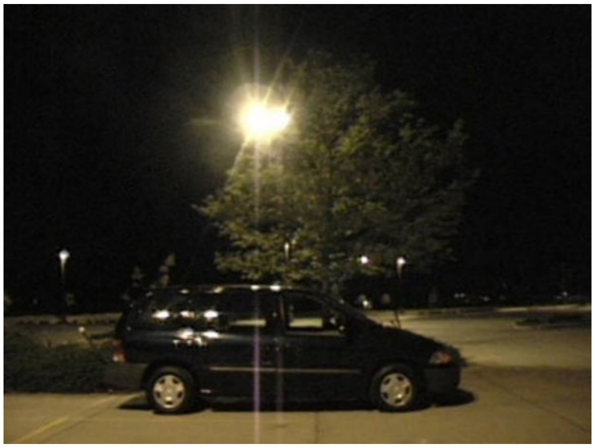
C-1.3 Light Trespass.

Light trespass is referred to as nuisance glare or the “light shining in my window” effect. It is usually caused by a glare source that is bright compared to the darker night surround, see Figure C-4. Since glare inhibits our ability to “see” tasks and decreases contrast, minimize glare. Uncontrolled light sources (floodlights) are usually the cause of

[8] © 2003 by Prof. Dr. Gerhard Eisenbeis University of Mainz/Germany

light trespass. Not only does light trespass cause neighbor annoyance, but it also increases light pollution.

Figure C-4 Uncontrolled Light Source



To minimize light trespass, use only U0 and a maximum of G1 rated luminaires for area lighting, see Figure C-5. When unshielded luminaires such as wall packs and decorative luminaires are used at low mounting heights, reduce the light source brightness to that of a 4,200-lumen light source or less. Do not over-light areas because reflected light can also result in complaints and poor visibility by increasing visual adaptation. Also, consider dimming or turning lighting off when not needed and activate with motion sensors or timers when activity occurs.

Figure C-5 IES TM-15 U0 Rated Luminaires

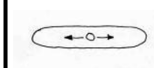
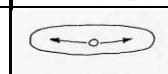
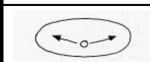
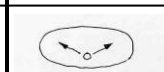
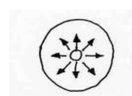
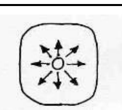
C-2 CLASSIFICATION SYSTEMS FOR OUTDOOR LUMINAIRES.

There are three systems in use today for categorizing outdoor light fixtures, two defined by the Illuminating Engineering Society (IES) and one by the National Electrical Manufacturers Association (NEMA). In two of the systems, the luminaires are categorized according to the distribution of light emitted from the luminaire, and in the third by the pattern of light produced on the ground.

C-2.1 The IES Categories.

The IES categorizes outdoor area and roadway luminaires (non-floodlights) according to the pattern of illumination they produce on the ground, from Type I, which doesn't project very far forward to backward but tends to be very wide from side to side, to Type V and Type VS, which have symmetric round and square-shaped distributions, respectively. Table C-3 shows these classifications and the general shape of each distribution's pattern of illumination.

Table C-1 Exterior Luminaire Distribution Classification.

Type	Description	Plan View
Type I	Narrow, symmetric illuminance pattern.	
Type II	Slightly wider illuminance pattern than Type I.	
Type III	Wide illuminance pattern.	
Type IV	Widest illuminance pattern.	
Type V	Symmetrical circular illuminance pattern.	
Type VS	Symmetrical, nearly square illuminance pattern.	

C-2.2 NEMA Classifications.

NEMA classifies floodlights, including those used for sports applications, according to the intensity distribution of the light within the beam, considering the "horizontal" and "vertical" parts of the beam separately. The categories range from 1 to 7, with the smaller numbers indicating tighter beams and thus a longer useful projection distance or "throw". Table C-2 shows the NEMA beam type categories. The broader the beam, the more difficult it is to control the light distribution and prevent stray light, including glare and unwanted uplight.

Table C-2 NEMA Beam Angle Classifications.

Beam Type	Beam Spread Degree Range	Projection Distance
1	10 to 18	240 ft and greater
2	18 to 29	200 to 240 ft
3	29 to 46	175 to 200 ft
4	46 to 70	145 to 175 ft
5	70 to 100	105 to 145 ft
6	100 to 130	80 to 105 ft
7	130 and up	under 80 ft

C-2.3 BUG Ratings.

The classification of exterior luminaires changed in a significant way in 2011. The former “cutoff” classification system was abandoned and was replaced by a new system, defined and explained in ANSI/TM-15, first published in 2007. In 2011, the Backlight-Uplight-Glare (BUG) rating system was added.

BUG ratings for luminaires are useful in evaluating optical performance in exterior environments. BUG ratings are based on zonal lumen output. It is difficult to compare the BUG ratings to the previously used cutoff classifications, as the cutoff classifications were determined from the luminaire’s luminous intensity values (measured in candelas) above 80 degrees, rather than luminaire lumens. Table C-3 illustrates the lack of correlation between the previous classification system and the current BUG ratings. The three components of BUG ratings are illustrated in Figure C-6 and Table C-4 and are explained further in the subsections that follow.

Table C-3 Correlation between BUG Ratings and Cutoff Classifications

BUG Rating	Full Cutoff	Cutoff	Semi-Cutoff	Non-Cutoff
B	B0-B5	B0-B5	B0-B5	B0-B5
U	U0	U1-U5	U1-U5	U1-U5
G	G0-G5	G0-G5	G0-G5	G0-G5

Figure C-6 Exterior Luminaire BUG Classification

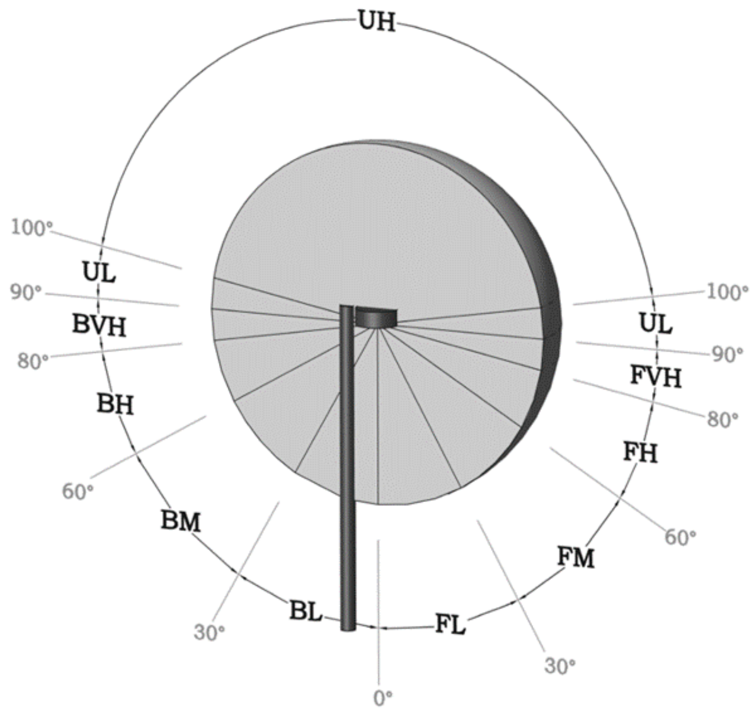


Table C-4 Exterior Luminaire BUG Classification Key

UH	Uplight High
UL	Uplight Low
BVH	Backlight Very High
BH	Backlight High
BM	Backlight Medium
BL	Backlight Low
FVH	Forward Light Very High
FH	Forward Light High
FM	Forward Light Medium
FL	Forward Light Low

C-2.3.2 Backlight (B) Rating.

Backlight from a luminaire can create light trespass if the luminaire is located near the edge of a property. The “B” rating takes into account the amount of backlight in the low (BL), medium (BM), high (BH), and very high (BVH) zones, which are generally to the “rear” of the luminaire. The closer to a property line a luminaire is located, the stricter, or lower, the “B” rating should be. If the luminaire is located more than two mounting heights from the property line, then a higher B rating may be appropriate.

C-2.3.3 Uplight (U) Rating.

Uplight is a significant source of sky glow. Uplight emitted at angles near horizontal (UL) cause the most sky glow and negatively affects professional and academic astronomy. Higher-angle uplight (UH) not reflected off a surface is mostly energy waste. The “U” rating defines the amount of light emitted into the upper hemisphere, with greater concern for the light at or near the horizontal (UL).

C-2.3.4 Glare (G) Rating.

Glare can be annoying or visually disabling. The “G” rating takes in to account the amount of forward-emitted light in the high (FH) and very high (FVH) zones and the amount of backward-emitted light in the high (BH) and very high (BVH) zones.

C-2.3.5 Considerations.

In general, a higher BUG rating means that more light is emitted in the relevant solid angles, and the allowable rating increases with higher-numbered lighting zones (see Section C-4). However, a higher “B” (backlight) rating simply indicates that the luminaire directs a significant portion of light behind the pole, so allowed “B” ratings are based on the location of the luminaire with respect to the property boundary. A high “B” rating maximizes the luminaire’s spread of light and is effective and efficient when used far from the property boundary. When luminaires are located near the property boundary, a lower “B” rating prevents unwanted light from interfering with neighboring properties.

C-3 LIGHTING ZONES.

C-3.1 LZ0: No Ambient Lighting.

LZ0 areas are those where the natural environment will be seriously and adversely affected by lighting. Impacts include disturbing the biological cycles of flora and fauna and/or detracting from human enjoyment and appreciation of the natural environment. In these areas, human activity is subordinate in importance to nature. The vision of human residents and users is adapted to the total darkness, and they expect to see little or no lighting. When not needed, lighting should be extinguished.

C-3.2 LZ1: Low Ambient Lighting.

LZ1 areas are those where lighting might adversely affect flora and fauna or disturb the character of the area. The vision of human residents and users is adapted to low light levels. Lighting may be used for safety, security, and/or convenience, but it is not necessarily uniform or continuous. After curfew, most lighting should be extinguished or reduced as activity levels decline.

C-3.3 LZ2: Moderate Ambient Lighting.

LZ2 areas are areas of human activity where the vision of human residents and users is adapted to moderate light levels. Lighting may typically be used for safety, security, and/or convenience but it is not necessarily uniform or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

C-3.4 LZ3: Moderately High Ambient Lighting.

LZ3 areas are areas of human activity where the vision of human residents and users is adapted to moderately high light levels. Lighting may typically be used for safety, security and/or convenience and is often uniform and/or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

C-3.5 LZ4: High Ambient Lighting.

LZ4 areas are areas of human activity where the vision of human residents and users is adapted to high light levels. Lighting is generally considered necessary for safety, security and/or convenience and it is mostly uniform and/or continuous. After curfew, lighting may be extinguished or reduced in some areas as activity levels decline.

C-3.6 Potential Reasons for Classifying an Area at a Lower Lighting Zone.

- Very low or no activity at night
- Adjacent lighting zone, either DoD or Civilian, is lower and has a low level of activity

C-3.7 Potential Reasons for Classifying an Area at a Higher Lighting Zone.

- Sensitive areas requiring a high level of security
- High level of activity at night as well as high number of users

C-4 CONTROL APPROACHES.

C-4.1 Manual Switching.

Manual switching is not ideal for controlling exterior lighting.

C-4.2 Photocontrol.

A photocell is a device that measures the illuminance level and is set to turn on or off the luminaire at a preset illuminance level. The light levels are set to ideally have the luminaires turn on before sunset and extinguish after sunrise.

C-4.3 Occupancy Based Controls.

The use of motion sensors in exterior applications is widely accepted in residential applications. In commercial or industrial applications, occupancy sensors can be implemented in some applications. It is important to ensure that the occupancy sensor being used does not leave any ‘dead’ zones where occupancy cannot be detected for safety concerns.

C-4.4 Adaptive Lighting.

Adaptive lighting is concept of adjusting the light levels to suit the activity level. This is accomplished with bilevel switching and motion sensors or preset continuous dimming. When no occupancy is detected in a zone, or late at night when traffic and pedestrian volumes are known to be minimal, lighting levels are reduced to a minimum of 30% full light output. Adaptive lighting is ideally suited for wall-mounted, roadway, area, pathway, parking lot, or pedestrian luminaires.

All street lighting luminaires are required to have a multipin receptacle that is capable of accepting a dimming control node. With a similar form factor to that of a standard photocell, a dimming control node is installed on top of the luminaire. The control node communicates through a networked control system to allow for two-way communication. See Section A-5.9 Network Control Systems for additional information.

C-5 CONTROL EQUIPMENT.

C-5.1 Sensors.

C-5.1.1 Photosensors.

Photosensors can be used as an exterior lighting control strategy. A single photosensor can be installed on each luminaire or on a lighting control center linking a group of luminaires together. Diligently maintain the photosensor.

C-5.1.2 Motion Sensors.

Motion sensors used for exterior luminaires are the same as for interior luminaires. As such, the coverage patterns can be too small and result in coverage gaps when used to control exterior luminaires.

C-5.2 Timeclocks.

Timeclocks or time switches are used to automatically turn the lights on or off on a daily basis. Typically, time clocks are programmed to turn on and off based on astronomical events such as sunset and sunrise or when activity has ceased. The astronomic time clock automatically keeps track of what day it is and geographic location of the luminaires. As the exact time of sunset and sunrise fluctuates throughout the year, the time clock adjusts accordingly.

C-5.3 Network Control Systems.

Exterior control systems are beginning to follow the same path as interior addressable systems. By communicating with the driver or power control unit of each roadway or area luminaire, a centralized control system can monitor a wide range of characteristics including energy consumption and outages. Additionally, this control strategy accommodates the concept of adaptive lighting standards. This concept recognizes that lighting criteria provides for the worst-case scenario – conditions that may only exist for a fraction of the night or year. With more advanced control systems and dimmable sources, exterior lighting can provide the appropriate amount of light for the time of day, time of year, and weather conditions, while significantly reducing energy use.

C-5.3.1 Power Line Frequency.

A power line carrier network system uses the physical electrical wiring to communicate between devices. Each luminaire has its own device and therefore its own unique address. The devices can then all be linked together to form a network that is adjustable through a software program. From the software, zoning can be established as well as scheduling. Additionally, maintenance issues can be identified. In order to dim, a separate dimming driver may be required.

C-5.3.2 Radio Frequency.

A radio frequency (RF) lighting control system uses embedded RF transmitters and receivers to connect devices (sensors, user controls, power equipment) to one another. These systems can be stand alone or part of a networked lighting control solution. Care should be taken to evaluate the RF lighting control solution on the frequency range it operates in (is it densely or sparsely populated?), how the system propagates and ensures proper RF communication between devices, RF device installation and cost, and whether the type of space being controlled supports the use of RF devices. A mockup of the RF lighting control system is a recommended best practice to ensure that the system will perform as expected in the application/operating environment.

APPENDIX D BEST PRACTICES: LIGHTING FOR CIRCADIAN RHYTHMS

D-1 INTRODUCTION

The human body operates on an approximately 24-hour sleep-wake cycle that regulates our natural biological processes. These variations are known as the human circadian rhythms (animals and plants have them also), and the primary driver of this cycle is light.[9] This process is called entrainment and involves the synchronization of different rhythmic cycles that interact with each other. Nearly every cell in the human body has a circadian clock. Correct entrainment has been shown to lower risk of cancer, neurodegenerative diseases, substance addiction, and obesity.[10]

Humans have evolved under the sun during the day and in darkness at night. For millennia, the presence of absence of daylight has informed our bodies of each day's start and end. In the modern world, people are no longer continuously exposed to daylight during daytime hours, but instead are often exposed to much lower light levels in our homes and workplaces. Regulating our circadian rhythms is more difficult with less sunlight exposure and with electric lighting operating during periods of what would normally be natural darkness.[11] [12] [13]

D-2 RECOMMENDATIONS.

The lighting recommendations in this appendix are based on the current known research of circadian lighting design. While human well-being is important, it is nearly impossible to predict the outcomes and changes due to a circadian lighting design, both positive and negative.

D-3 OVERVIEW.

Electric lighting systems that are designed to impact the human circadian rhythm are referred to as circadian lighting systems. The concept behind these systems is that electric light could be used to support human health and typically revolves around the potential for melatonin suppression using light. Circadian lighting systems and luminaires are designed by modulating the quantity and spectral distribution of the light source.

[9] Boyce PR. Human Factors in Lighting. 3rd ed. London, England: CRC Press; 2017.

[10] Roenneberg T, Merrow M. The circadian clock and human health. Curr Biol. 2016;26(10):R432–43.

[11] Wright KP Jr, McHill AW, Birks BR, Griffin BR, Rusterholz T, Chinoy ED. Entrainment of the human circadian clock to the natural light-dark cycle. Curr Biol. 2013;23(16):1554–8.

[12] Stothard ER, McHill AW, Depner CM, Birks BR, Moehlman TM, Ritchie HK. Circadian entrainment to the natural light-dark cycle across seasons and the weekend. Curr Biol. 2017;27(508–13):12 041.

[13] Chen S, Wei M, Dai Q, Huang Y. Estimation of possible suppression of melatonin production caused by exterior lighting in commercial business districts in metropolises. LEUKOS. 2020;16(137–44):1523013.

D-3.1 Light and the Human Circadian System.

Human circadian rhythms are mediated by the suprachiasmatic nuclei (SCN), which is the part of the brain that controls the internal daily clock.[14] Within the human eye, there are three known groups of photoreceptors. Two of these groups, the rods and cones, are image-forming photoreceptors while the third group, the intrinsically photoreceptive retinal ganglion cells (ipRGCs), are non-image-forming. ipRGCs are essential in converting neural signals from the retina to the SCN.

The ipRGCs contain a photopigment called melanopsin, also known as the "darkness hormone," which is a photopigment that is especially sensitive to blue wavelengths.[15] [16] Melatonin production begins at the retina and travels to the SCN which signals the pineal gland to release the hormone in nighttime conditions.[6] This photopigment is believed to be the main aspect of the non-image-forming system.[17] The research on these cells and how they operate is ongoing, but researchers have concluded that the ipRGCs respond best to blue light, and that the ipRGCs are not limited to circadian entrainment alone.[18]

D-3.2 Circadian Lighting Metrics

Current metrics have been developed, researched, and vetted to try and measure what spectrum, timing, duration, quantity, and distribution of light will elicit a circadian response. Current ways to measure circadian lighting include but are not limited to:

- Equivalent Melanopic Lux (EML, used by the WELL Building Standard)
- Melanopic Irradiance (CIE)
- Melanopic Equivalent Daylight Illuminance (mEDI, by CIE)
- Melanopic Daylight Efficacy Ratio (mDER, by CIE)
- Circadian Stimulus (CS, by LHRC)
- Circadian Bio-Active Blue (CIRCADIAN Light)

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[14] Boyce PR. Human Factors in Lighting. 3rd ed. London, England: CRC Press; 2017.

[15] Arendt J. Melatonin and the pineal gland: influence on mammalian seasonal and circadian physiology. Rev Reprod. 1998;3(1):13–22.

[16] Berson DM, Dunn FA, Takao M. Phototransduction by retinal ganglion cells that set the circadian clock. Science. 2002;295(5557):1070–3.

[17] Lasauskaite R, Hazelhoff EM, Cajochen C. Four minutes might not be enough for light colour temperature to affect sleepiness, mental effort, and light ratings. Light Res Technol. 2019;51(7):1128–38.

[18] Schmidt TM, Chen S-K, Hattar S. Intrinsically photosensitive retinal ganglion cells: many subtypes, diverse functions. Trends Neurosci. 2011;34(11):572–80.

- Melanopic/Photopic (M/P) ratio

D-4 INFLUENCING FACTORS FOR CIRCADIAN LIGHTING SYSTEMS.

Spectrum, timing, duration, quantity, and distribution at the retina are all critical components in creating a circadian lighting response.[19] A circadian lighting system must consider all of these components in the design.

D-4.1 Spectrum.

The relative light output from a luminaire across the visual spectrum is referred to as its spectral power distribution (SPD). The goal in circadian design is to link the SPD of a luminaire to the effectiveness of stimulating ipRGCs. The peak sensitivity of the ipRGCs is generally accepted to be 480 nm, with multiple studies suggesting different peak sensitivities between 477 nm and 480 nm.[20] These wavelengths are found in the blue region of the spectrum. Research to determine the peak spectral sensitivity of the ipRGCs remains inconclusive, since they are positioned in such a way that they receive input from the rods and cones as well.[21]

D-4.2 Timing.

Time of day is a contributing factor in determining the impacts that spectrum and quantity of light have on human well-being. Sunlight in the morning is the best solution for entraining and establishing a healthy circadian rhythm.[22,23] Sunlight not only contains the necessary wavelengths, but is also sufficiently bright to stimulate the ipRGCs.

Reducing the amount of light in the evenings is equally important. Depending on when someone is exposed to light, a delay or advancement in their biological clock may occur, which is known as phase shifting. Studies show that blue light can entrain or disrupt the circadian rhythm, depending on the time of day someone was exposed to it.[24]

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[19] Bommel WJM, Beld GJ. Lighting for work: A review of visual and biological effects. Light Res Technol. 2004;36(4).

[20] Bailes HJ, Lucas RJ. Human melanopsin forms a pigment maximally sensitive to blue light (λmax ≈ 479 nm) supporting activation of G(q/11) and G(i/o) signalling cascades. Proc Biol Sci. 2013;280(1759):20122987.

[21] Schmidt TM, Chen S-K, Hattar S. Intrinsically photosensitive retinal ganglion cells: many subtypes, diverse functions. Trends Neurosci. 2011;34(11):572–80.

[22] Münch M, Nowozin C, Regente J, Bes F, De Zeeuw J, Hädel S, et al. Blue-enriched morning light as a countermeasure to light at the wrong time: Effects on cognition, sleepiness, sleep, and circadian phase. Neuropsychobiology. 2016;74(4):207–18.

[23] Figueiro MG, Steverson B, Heerwagen J, Kampschroer K, Hunter CM, Gonzales K. The impact of daytime light exposures on sleep and mood in office workers. Sleep Health. 2017;3(204–15):03 005.

[24] Figueiro M, Steverson B, Heerwagen J, Kampschroer K, Rea M. Light, entrainment, and alertness: A case study in offices. In: PROCEEDINGS OF the 29th Quadrennial Session of the CIE. International Commission on Illumination, CIE; 2019.

D-4.3 Duration.

The phase-shifting effects of light is dependent on duration and pattern of light. Phase-shifts vary exponentially dependent upon duration.[25] Phase-shifting has a different response when the light exposure is continuous versus intermittent. Current research reveals that intermittent light at the eye induces a greater phase shift than predicted by a simple linear response to optical radiation duration.[17,26,27]

D-4.4 Quantity.

The quantity of light Illuminance) received at the eye influences the effect that the light will have on the human circadian rhythms. Studies have shown that luminaires with higher correlated color temperatures (CCT), such as 6500 K, can have little to no impact on melatonin suppression if they are under a certain threshold. For one specific study, the threshold was found to be 30 lux.[28] It has also been found that using the "nightshift" mode on self-luminous displays has little to no impact on melatonin suppression if the brightness is still high.[29]

D-4.5 Distribution.

Distribution of light at the retina also plays an important role. Most standards and guidelines for lighting are developed for lighting a horizontal plane, such as working surfaces and roadways, but vertical illuminance is important for circadian lighting. Light exposure on the lower retina (thus, coming from above) has been found to suppress melatonin at a higher rate than light hitting the upper or central retina (thus, coming from below or straight ahead).[18] From a design standpoint, this could mean that circadian disruption could be reduced if there were less light at night falling on the lower half of the retina. Research continues to uncover more information about how the different aspects of light can have an impact on human well-being.

D-5 CIRCADIAN LIGHTING LUMINAIRES.

Commercially available circadian lighting luminaires are marketed by lighting manufacturers as tools to be used to improve the well-being and productivity of workers in typical indoor environments. These luminaires differ from systems that are often referred to as "white-tuning" luminaires, which allow the user to change how the light

[25] Illuminated Engineering Society. (2018). Light and Human Health: An Overview of the Impact of Optical Radiation on Visual, Circadian, Neuroendocrine, and Neurobehavioral Responses.

[26] Gronfier, C., et al., "Efficacy of a single sequence of intermittent bright light pulses for delaying circadian phase in humans." American Journal of Physiology - Endocrinology and Metabolism, 2004. 287(1): p. E174-81.

[27] 149 Rimmer, D. W., et al., "Dynamic resetting of the human circadian pacemaker by intermittent bright light."

American Journal of Physiology- Regulatory, Integrative, and Comparative Physiology, 2000. 279(5): p. R1574-9.

[28] Mariana G. Figueiro MSR. A working threshold for acute nocturnal melatonin suppression from "white" light sources used in architectural applications. J Carcinog Mutagen [Internet]. 2013;04(03).

[29] Glickman G, Hanifin JP, Rollag MD, Wang J, Cooper H, Brainard GC. Inferior retinal light exposure is more effective than superior retinal exposure in suppressing melatonin in humans. J Biol Rhythms. 2003;18:71–9.

appears by modulating the correlated color temperature. Circadian lighting luminaires also change the appearance of the light, but as a result of modulating the spectrum of the light. The timing, duration, quantity, and distribution of the light from these luminaires is entirely dependent on the quantity and mounting locations of the luminaires, as well as the programming of the lighting control system.

D-5.1 Spectral Power Distribution.

The specific group of wavelengths that are emitted from a luminaire across the visible spectrum is referred to as its spectral power distribution (SPD). When the SPDs of red, green, and blue light are combined, white light is produced. Additionally, different CCTs of white light can be combined to allow for more variety of spectra. Within a luminaire, the higher number of different LEDs, the more options that are available for creating different spectra. Figure D-1 shows the normalized SPD of sunlight compared to a typical 3500-K LED luminaire.

D-5.1.1 White Tuning.

For example, a typical white-tuning LED luminaire that can fluctuate between 2700 K and 6500 K is a combination of two different LED diodes, 2700 K and 6500 K. The only spectra that can be produced by this luminaire is a combination of the SPDs of each of these diodes. Figure D-2 has the following diodes: 2700 K and 6500 K. This is considered a two-channel luminaire.

D-5.1.2 Multichannel.

To produce a wider variety of spectra, a multi-channel luminaire is used. Not only does this provide more options for different color temperatures, but it also allows designers to target specific wavelengths without drastically changing the color of the produced light. The luminaire in graph in Figure D-3 has the following diodes: red, green, blue, 2700 K, two 3500 K, and 6500 K.

D-5.1.3 Circadian.

Circadian lighting design attempts to recreate daylight, which changes in SPD throughout the day, by mixing the light from several different LED diodes within the luminaire. However, these luminaires are not able to perfectly replicate daylight.

Figure D-1 SPD of Sunlight and 3500-K LED Luminaire

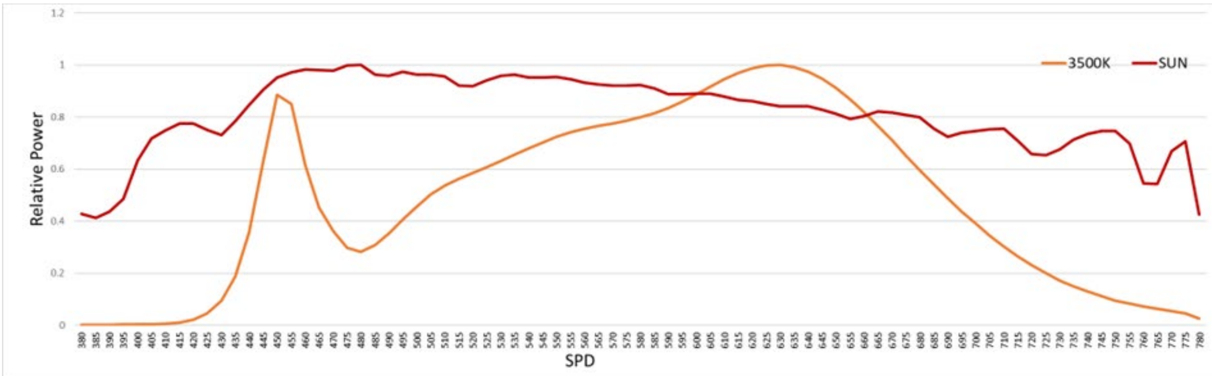


Figure D-2 SPD of a Two Channel Luminaire

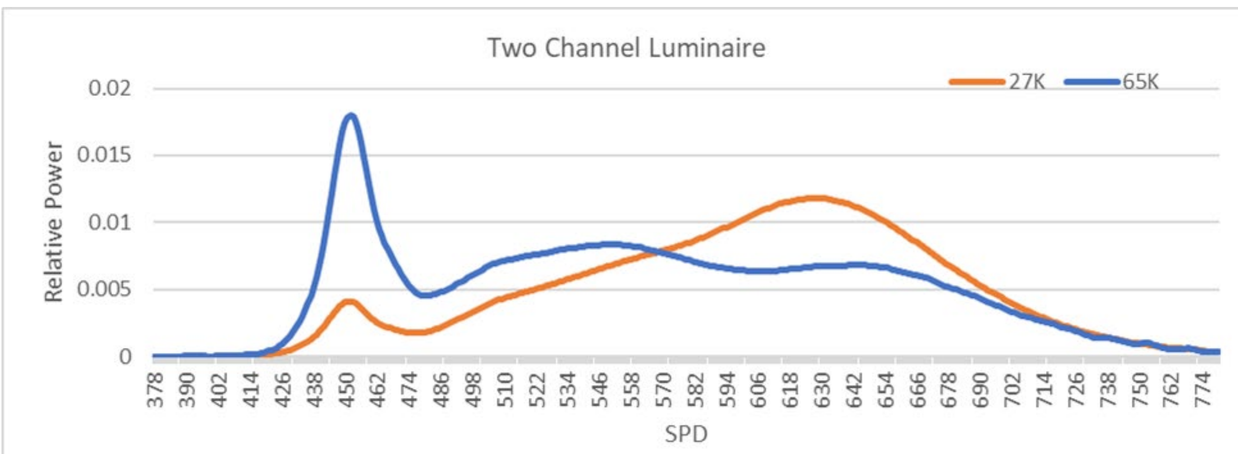
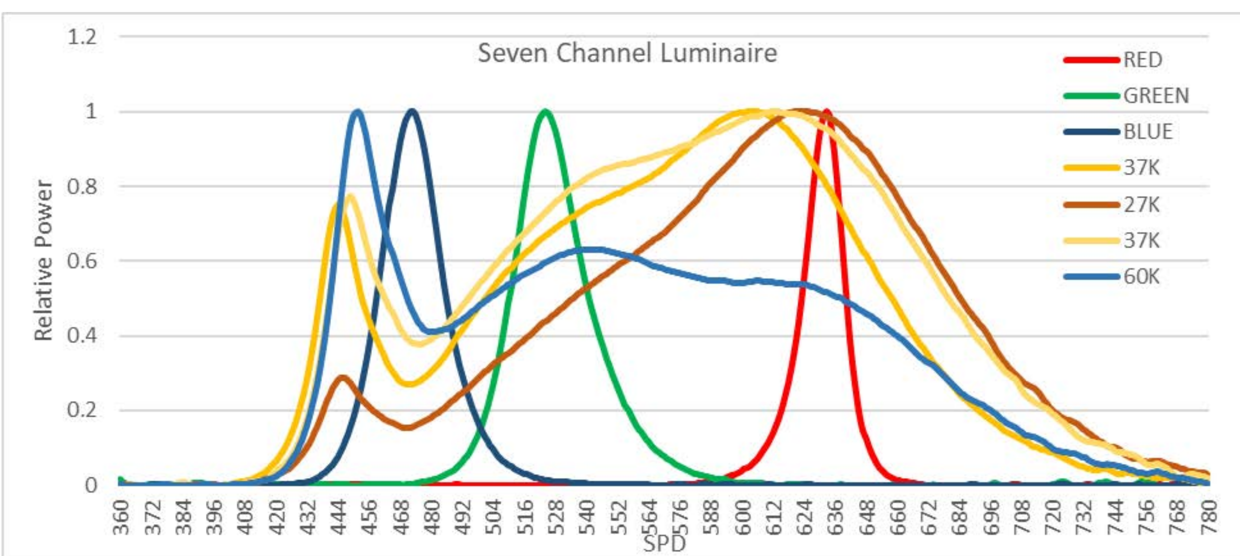


Figure D-3 SPD of a Six Channel Luminaire



D-6 DAYLIGHT AND VIEWS.

The daylighting and views in typical office spaces, where occupants work eight-hour shifts during daylight hours, will help workers maintain healthy circadian rhythms that are in synch with their home/work schedule. Harnessing the power of daylight reduces energy usage, provides daylight, and promotes a healthier condition for human well-being in an office environment.

Daylight and views in office spaces have been linked to improved sleep quality and mood among office workers.[30] Several elements influence how a worker can have better circadian entrainment, including location of workspace, the view of the outside, and window treatments.[31]

D-6.1 Harvesting the Benefits of Daylight.

To maximize the benefits of circadian lighting, workstations should be within 20 feet of a window. If the workstation is over 20 feet from a window, the view of the worker should be facing towards the nearest window. If there are any windows in the office space, blinds should be opened to let natural light into the space and allow workers to look outside. To maximize the circadian potential of daylight, high quality daylight and views should be present in the workspace. This requires coordinating with the architect and other members of the daylighting design team to optimize window placement, maximize views internal and external shade controls, while minimizing glare.

D-7 IMPLEMENTING CIRCADIAN LIGHTING SYSTEMS.

Circadian lighting metrics are all based on the assumption that it takes a certain combination of spectrum, timing, duration, quantity, and distribution of light to produce melatonin suppression, which will result in phase shifting. However, current research reveals that implementing a circadian lighting design in indoor environments can cause circadian disruption for some individuals more than others.[32] The other assumption is that melatonin suppression will cause a parallel phase shift in the circadian clock, but there is evidence of divergent phase shifting and melatonin response in humans.

The evidence is inconclusive that a certain dosage of light will create a phase shift and melatonin suppression in the indoor lighting environment. Most notably, it cannot be stated with assurance that all people will react in the same way to indoor lighting environments. Research has shown a wide range of results regarding the implementation of circadian lighting, both having positive and negative effects on human well-being. These inconsistencies cannot predict how human well-being will be

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[30] Figueiro MG, Steverson B, Heerwagen J, Kampschroer K, Hunter CM, Gonzales K. The impact of daytime light exposures on sleep and mood in office workers. Sleep Health. 2017;3(204–15):03 005.

[31] Altenberg Vaz N, Inanici M. Syncing with the sky: Daylight-driven circadian lighting design. LEUKOS. 2020;1–19.

[32] Vetter, C., Flynn-Evans, E., Phillips, A., Zeitzer, J.(2021, February 1). "Ask Me" Session: Connecting the Dots Between Light & Health Research and Practice [video file]. Retrieved from https://www.energy.gov/eere/ssl/2021-lighting-rd-workshop.

impacted on a large-scale by circadian lighting design. It is not recommended that universal approaches be applied at this time, since shifts to occupants' circadian cycles cannot be done with enough certainty and consistency.

D-7.1 Typical Work Environments.

Without more research, it is not recommended to install a lighting system specifically engineered to shift occupants' circadian cycles in typical workspaces, where occupants work the majority of their shift during the day. However, daylight and views may be used; this resource provides many benefits to indoor work environments, including natural impacts to circadian cycles.

D-7.2 Secure Environments.

Some work environments are unable to provide regular, continuous access to daylight due to the type of work or security of the facility. When possible, provide breakrooms with windows with clear views to exterior.

D-7.3 24-Hour Facilities.

In 24-hour facilities, occupants are not typically working a normal daytime shift, and therefore their circadian rhythms may not be in tune with a normal day. The goal of the lighting in these environments is to stimulate occupants during their shift to keep them alert without disrupting melatonin. Circadian disruption has been associated with increased risk for metabolic syndrome, diabetes, cardiovascular disease, and cancer.[33] However, there are inconsistencies and contradictions in different studies linking light at night to certain disease risks.[34] Therefore, broadly implementing circadian lighting systems is not recommended even in 24-hour facilities.

Electric lighting can provide both a positive and negative effect on human well-being, depending on how it is designed.[35] [36] [37] For a lighting system to be successful in a circadian lighting application, it must be able to adapt to the changing and evolving research on the spectral sensitivity of the ipRGCs and the recommendations made by experts in the field.

D-7.4 Circadian Lighting Luminaire Selection.

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[33] Mariana G. Figueiro. Lighting interventions to reduce circadian disruption in rotating shift workers. National Institute for Occupational Safety and Health. 2015;

[34] Hunter C.M., Figueiro M.G. Measuring Light at Night and Melatonin Levels in Shift Workers: A Review of the Literature. Biol. Res. Nurs. 2017;19:365–374.

[35] Chen S, Wei M, Dai Q, Huang Y. Estimation of possible suppression of melatonin production caused by exterior lighting in commercial business districts in metropolises. LEUKOS. 2020;16(137–44):1523013.

[36] Bellia L, Pedace A, Barbato G. Lighting in educational environments: an example of a complete analysis of the effects of daylight and electric light on occupants. Build Environ. 2013;68(50–65):04 00.

[37] Zielinska-Dabkowska KM. Make lighting healthier. Nature. 2018;553(7688):274–6.

If there is a desire to explore circadian lighting implementation in a specific room or area, select equipment that allows for flexibility and modifications as research evolves. Luminaires must have at least four channels: red, green, blue, and 3500 K. However, it is recommended that each luminaire should have at least six channels: red, green, blue, 2700 K, 3500 K, and 6500 K. Regardless of the number of channels, the control system must be adaptable to different light outputs and must be able to adjust the spectral power distribution throughout the day. By implementing a luminaire with more channels, more spectral power distributions are possible. The six-channel luminaire will be able to adapt to future recommendations more effectively.

Current findings do not recommend blue light at night because the risk it causes of disrupting the daily circadian rhythms. Research is being conducted to analyze the effectiveness in stimulating alertness by using red light, which does not cause circadian disruption.[38]

[38] Mariana G. Figueiro. Lighting interventions to reduce circadian disruption in rotating shift workers. National Institute for Occupational Safety and Health. 2015;

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APPENDIX E BEST PRACTICES: GERMICIDAL ULTRA-VIOLET LIGHTING

E-1 INTRODUCTION.

Germicidal ultraviolet (GUV) systems emit ultraviolet radiation (UVR) that inhibits microbial reproduction. They are used to sterilize surfaces, liquids, and air. GUV systems have generated significant interest due to their ability to kill antibiotic-resistant microbes. While GUV systems may be a step towards better disinfection when in conjunction with other Centers for Disease Control and Prevention (CDC) protocols, it is important to note the safety concerns and limitations of this equipment. There is limited industry consensus on the best and most appropriate way to use these systems, which is especially important to keep in mind as some lighting manufacturers are ready to produce and sell GUV products during the heightened concern for sanitizing spaces due to the Covid-19 pandemic. Without this consensus, widely implementing these strategies in DoD facilities is not currently recommended, but there are some limited applications and approaches that may be appropriate should decision-makers determine that GUV systems are to be deployed despite the risks. This appendix will explain GUV systems, review current known limitations and cautions, and discuss potential design applications.

In addition, refer to ANSI/IES RP-44-21 for specific guidance on the use of these kinds of systems.

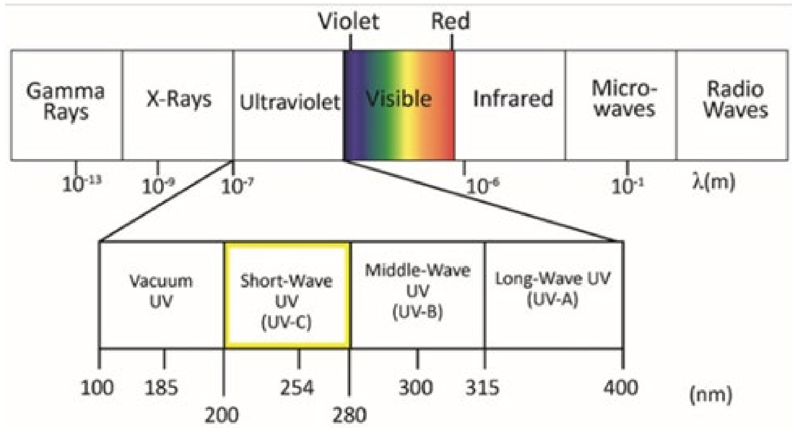
E-2 OVERVIEW.

E-2.1 Ultraviolet (UV) Interactions with Microbes.

There are three primary types of UVR, including ultraviolet A (UV-A), ultraviolet B (UV-B), and ultraviolet C (UV-C). UV-A radiation has the longest wavelengths of UVR, ranging from 315 nm to 400 nm, UV-B radiation falls in the middle, with wavelengths ranging from 280 nm to 315 nm, and UV-C radiation has the shortest wavelengths, ranging from 200 nm to 280 nm. UVR interacts with microorganisms through two primary mechanisms. UV-A excites photoreactive molecules, creating active species that damage DNA and other biological components.[39] UV-B and UV-C directly damage DNA, thus hindering reproduction.[40]

[39] Oguma, K., Katayama, H., & Ohgaki, S. (2002). Photoreactivation of Escherichia coli after low-or medium-pressure UV disinfection determined by an endonuclease sensitive site assay. Applied and environmental microbiology, 68(12), 6029-6035.
[40] Taylor, W., Camilleri, E., Craft, D. L., Korza, G., Granados, M. R., Peterson, J., ... & Mok, W. W. (2020). DNA damage kills bacterial spores and cells exposed to 222-nanometer UV radiation. Applied and Environmental Microbiology, 86(8).

Figure E-1 Spectrum of UV Light (www.ies.org)



UVR exposure is measured as “dosage” which is the product of the irradiance and the duration of exposure. Irradiance is a function of the source strength moderated by the distance from the target to the emitter and any attenuation that may occur along the way. The target’s material properties may also affect dosage, influencing how much energy is absorbed, reflected, or transmitted. While small amounts of UVR are reflected off of surfaces, for UVR to be an effective sterilizer direct exposure is required.

E-2.1.2 GUV Effectiveness.

Viruses and bacteria can only be inactivated by direct GUV, so the effectiveness varies based on which surfaces are exposed to GUV and whether water, air droplets, or humidity is present. Generally, shorter wavelengths are more effective than longer wavelengths, with a peak efficacy around 260 nm.[41,42] Far UV-C (< 222 nm) is nearly as effective as 254-nm UV-C. Some bacteria have the ability to repair themselves using the energy provided by UV-A and visible light, so short, intense exposures may be more effective than long, low-intensity applications.[43,44,45,46]

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[41] Gerchman, Yoram, Mamane, Hadas, Friedman, Nehemya, and Mandelboim, Michal. "UV-LED Disinfection of Coronavirus: Wavelength Effect." Journal of Photochemistry and Photobiology. B, Biology 212 (2020): 112044.

[42] Besaratinia, A., Yoon, J. I., Schroeder, C., Bradforth, S. E., Cockburn, M., & Pfeifer, G. P. (2011). Wavelength dependence of ultraviolet radiation-induced DNA damage as determined by laser irradiation suggests that cyclobutane pyrimidine dimers are the principal DNA lesions produced by terrestrial sunlight. The FASEB Journal, 25(9), 3079-3091.

[43] Harris, G. D., Adams, V. D., Sorensen, D. L., & Curtis, M. S. (1987). Ultraviolet inactivation of selected bacteria and viruses with photoreactivation of the bacteria. Water Research, 21(6), 687-692.

[44] Bohrerova, Z., Shemer, H., Lantis, R., Impellitteri, C. A., & Linden, K. G. (2008). Comparative disinfection efficiency of pulsed and continuous-wave UV irradiation technologies. Water research, 42(12), 2975-2982.

[45] Sommer, R., Haider, T., Cabaj, A., Pribil, W., & Lhotsky, M. (1998). Time dose reciprocity in UV disinfection of water. Water science and technology, 38(12), 145-150.

[46] Bowker, C., Sain, A., Shatalov, M., & Ducoste, J. (2011). Microbial UV fluence-response assessment using a novel UV-LED collimated beam system. Water research, 45(5).

E-2.1.3 UVR Dosage.

Currently, there are no specific industry standards or operation protocols defining the frequency and duration of UVR exposure with regard to its effectiveness. It is difficult to define standardized dose-response curves for different microbes in different mediums, but most of the literature suggest that relatively small dosages of UV-C radiation can eliminate microbial communities on surfaces and in the air.

This increased susceptibility to high dosages may explain why pulsed UV exposure appears to be more effective at neutralizing bacteria than continuous exposures of the same total dosage. Pathogens that are incapable of self-repair do not display this behavior.[47] Other studies, with different methodologies, have found no significant difference in the efficacy of pulsed vs. continuous exposure.[48] However, they do state that pulsed dosages can often be delivered in much shorter time frames, facilitating clinical applications and potentially limiting reactivation. In most cases, however, sterilization is a function of total dosage and is not impacted by dose rate.

E-2.1.4 Normal Solar Exposure.

Average annual UV dose from solar exposure ranges from 1,000 - 3,000 mJ/cm^2 in Europe and the U.S.[49] The spectral composition of this irradiance is heavily weighted toward UV-A, with a small UV-B component. UV-C radiation is completely filtered out in the upper atmosphere. In healthy adults, most UVR is filtered by the lens and the cornea, with very little reaching the retina. Children and adults who have undergone cataract surgery are at risk of increased exposure. UV-B radiation that does reach the retina can cause DNA damage and oxidative stress.[50] The current recommended daily maximum exposure is 32 mJ/cm^2 in an 8-hour period.[51] The effects of overexposure tend to be minor and short-lived.[52] However, repeated or long-term exposure can cause premature aging and increases the risk of cancer.[53] There is some evidence that

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[47] Bohrerova, Z., Shemer, H., Lantis, R., Impellitteri, C. A., & Linden, K. G. (2008). Comparative disinfection efficiency of pulsed and continuous-wave UV irradiation technologies. Water research, 42(12), 2975-2982.

[48] Wang, T., MacGregor, S. J., Anderson, J. G., & Woolsey, G. A. (2005). Pulsed ultra-violet inactivation spectrum of Escherichia coli. Water research, 39(13), 2921-2925.

[49] Godar, D. E. (2005). UV doses worldwide¶. Photochemistry and photobiology, 81(4), 736-749.

[50] Mahendra, C., Tan, L., Pusparajah, P., Htar, T.T., Chuah, L.H., Lee, V., Low, L., Tang, S.Y., Chan, K.G., & Goh, B. (2020). Detrimental Effects of UVB on Retinal Pigment Epithelial Cells and Its Role in Age-Related Macular Degeneration, Oxidative Medicine and Cellular Longevity, vol. 2020, 29 pages.

[51] International Commission on Non-Ionizing Radiation Protection. (2004). Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation). Health Physics, 87(2), 171-186.

[52] Andrea Trevisan, Stefano Piovesan, Andrea Leonardi, Matteo Bertocco, Piergiorgio Nicolosi, Maria Guglielmina Pelizzo, and Annalisa Angelini. "Unusual High Exposure to Ultraviolet-C Radiation." Photochemistry and Photobiology 82, no. 4 (2006): 1077-079.

[53] Matsumura, Yasuhiro, and Ananthaswamy, Honnavara N. "Toxic Effects of Ultraviolet Radiation on the Skin." Toxicology and Applied Pharmacology 195, no. 3 (2004): 298-308.

intermittent exposure patterns are correlated with an increased risk of skin cancer compared to more regular exposure patterns.[54]

E-3 LIMITATIONS OF GUV.

Even though GUV, and especially UV-C, technology is known to inactivate viruses and bacteria, it has not been widely implemented. Because of this, there are significant gaps in data and long-term research. True sterilization is difficult and may create undesired side effects, which are important to consider. GUV radiation affects microbial interactions, building occupants, and building materials, in addition to increasing energy usage. All of these concerns must be addressed when considering a GUV design.

E-3.1 Secondary Microbial Interactions.

While GUV systems show significant potential, there are a number of moderating factors to consider. 100% sterilization is difficult, and surviving microbes will adapt; both bacteria and viruses have been shown to develop UV resistance with repeated exposure. Recent research advocates for an approach in which the interior microbiome is considered as a living system that can be beneficially managed rather than something to be exterminated.[55,56]

GUV radiation kills or inactivates all microbes, good and bad, within its path, which could potentially harm our environment. The rise of antibiotic-resistant bacteria due to the overuse of antibiotics is rapidly becoming a global health crisis. GUV systems can be a useful tool in the fight against antibiotic-resistant bacteria, but care should be taken to avoid similar mistakes.[57,58] Many studies have shown that repeated exposure to UV

[54] Kricker, A., Armstrong, B. K., English, D. R., & Heenan, P. J. (1995). Does intermittent sun exposure cause basal cell carcinoma? A case-control study in Western Australia. International journal of cancer, 60(4), 489-494.
[55] Velazquez, S., Griffiths, W., Dietz, L., Horve, P., Nunez, S., Hu, J., ... & Van Den Wymelenberg, K. G. (2019). From one species to another: A review on the interaction between chemistry and microbiology in relation to cleaning in the built environment. Indoor air, 29(6), 880-894.
[56] Horve, P. F., Lloyd, S., Mhuireach, G. A., Dietz, L., Fretz, M., MacCrone, G., ... & Ishaq, S. L. (2019). Building upon current knowledge and techniques of indoor microbiology to construct the next era of theory into microorganisms, health, and the built environment. Journal of Exposure Science & Environmental Epidemiology, 1-17.
[57] Guo, M. T., Yuan, Q. B., & Yang, J. (2013). Microbial selectivity of UV treatment on antibiotic-resistant heterotrophic bacteria in secondary effluents of a municipal wastewater treatment plant. Water research, 47(16), 6388-6394.
[58] McKinney, C. W., & Pruden, A. (2012). Ultraviolet disinfection of antibiotic resistant bacteria and their antibiotic resistance genes in water and wastewater. Environmental science & technology, 46(24), 13393-13400.

radiation leads to the proliferation of bacteria and viruses that are more resistant to UV irradiation.[59,60,61]

E-3.2 Interactions with Building Occupants.

Exposure to UVR can have detrimental impacts on building occupants and, while these negative effects tend to heal quickly, there is a risk that repeated exposure could increase the risk of developing certain skin cancers. Far UV-C (<222 nm), which is nearly as effective as 254-nm UV-C, is of particular interest because it does not penetrate human skin or eye tissue.

E-3.2.1 Far UV-C Radiation.

Mice models and human clinical trials show that 222-nm far UV-C radiation, even in extreme doses, does not cause skin damage or irritation but does reduce bacterial counts on skin.[62,63] This suggests that it may be deployed in occupied spaces without causing direct harm to humans.[64,65] However, as far UV-C radiation is not naturally encountered within our atmosphere, there are potentially significant unknown consequences that could arise if it were widely deployed. The use of far UV-C radiation lessens the likelihood of direct harm to humans when compared to longer wavelengths of UVR, but the long-term effects are still unknown.

E-3.3 Interactions with Building Materials.

UVR impacts interior materials, causing visual degradation and structural damage that can reduce the lifespan of these materials and, if significant surface wear occurs, pathogens can potentially be harbored in the resultant pits or cracks. Surface properties also impact the efficacy of GUV systems. Rough surfaces can limit uniform exposure,

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[59] Carratala, A., Shim, H., Zhong, Q., Bachmann, V., Jensen, J. D., & Kohn, T. (2017). Experimental adaptation of human echovirus 11 to ultraviolet radiation leads to resistance to disinfection and ribavirin. Virus evolution, 3(2), vex035.

[60] Tom, E. F., Molineux, I. J., Paff, M. L., & Bull, J. J. (2018). Experimental evolution of UV resistance in a phage. PeerJ, 6, e5190.

[61] Goldman, R. P., & Travisano, M. (2011). Experimental evolution of ultraviolet radiation resistance in Escherichia coli. Evolution: International Journal of Organic Evolution, 65(12), 3486-3498.

[62] Yamano, N., Kunisada, M., Kaidzu, S., Sugihara, K., Nishiaki-Sawada, A., Ohashi, H., ... & Nishigori, C. (2020). Long-term effects of 222 nm ultraviolet radiation C sterilizing lamps on mice susceptible to ultraviolet radiation. Photochemistry and Photobiology.

[63] Fukui, T., Niikura, T., Oda, T., Kumabe, Y., Ohashi, H., Sasaki, M., ... & Matsumoto, T. (2020). Exploratory clinical trial on the safety and bactericidal effect of 222-nm ultraviolet C irradiation in healthy humans. PloS one, 15(8), e0235948.

[64] Nouji Narita, Krisana Asano, Keisuke Naito, Hiroyuki Ohashi, Masahiro Sasaki, Yukihiro Morimoto, Tatsushi Igarashi, Aki Nakane. (2020). 222-nm UVC inactivates a wide spectrum of microbial pathogens. Journal of Hospital Infection.

[65] Buonanno, Manuela, Ponnaiya, Brian, Welch, David, Stanislauskas, Milda, Randers-Pehrson, Gerhard, Smilenov, Lubomir, Lowy, Franklin D, Owens, David M, and Brenner, David J. "Germicidal Efficacy and Mammalian Skin Safety of 222-nm UV Light." Radiation Research 187, no. 4 (2017): 483-91.

while high-reflectance surfaces tend to scatter more visible light, potentially increasing bacterial photorepair.[66] Relative humidity has also been shown to moderate the impacts of UVR on certain bacteria and viruses in addition to influencing their transmission and survival characteristics.

- Polymers, plastics, and rubbers tend to chalk, crack, and lose strength.67,68
- Varnishes and coatings blister and crater.69
- Artificial flooring material treated with UV-resistant coatings displayed an increased formaldehyde release rate when exposed to UVR.70
- Wood becomes discolored even after brief UV exposure.71,72 Surface treatments can mitigate these effects, which are dependent on the surface grain patterns, with exposed end-grains being more susceptible to damage.73

E-3.3.1 Repeated Exposure.

Repeated exposure to UVR could cause surface damage to many common interior materials, potentially creating structures that may harbor pathogens and inhibit future disinfection efforts. Interestingly, both increased surface roughness and reflectivity have been shown to decrease sterilization efficiency.[74,75] The former is likely due to non-uniform 'clumps' of pathogens collecting in surface topological features, thereby

[66] Chinnis, D., Karlicek, R., Pfund, D. (2020, August 30). IALD Webinar: Lighting Design and GUV Technology [video file]. Retrieved from https://www.youtube.com/watch?v=prEFfrtQGjQ

[67] *Youn, B. H., & Huh, C. S. (2005). Surface degradation of HTV silicone rubber and EPDM used for outdoor insulators under accelerated ultraviolet weathering condition. IEEE Transactions on Dielectrics and Electrical Insulation, 12(5), 1015-1024.*

[68] Boubakri, A., Guermazi, N., Elleuch, K., & Ayedi, H. F. (2010). Study of UV-aging of thermoplastic polyurethane material. Materials Science and Engineering: A, 527(7-8), 1649-1654.

[69] Hu, J., Li, X., Gao, J., & Zhao, Q. (2009). UV aging characterization of epoxy varnish coated steel upon exposure to artificial weathering environment. Materials & Design, 30(5), 1542-1547.

[70] Kagi, N., Fujii, S., Tamura, H., & Namiki, N. (2009). Secondary VOC emissions from flooring material surfaces exposed to ozone or UV irradiation. Building and Environment, 44(6), 1199-1205.

[71] Timar, M. C., Varodi, A. M., & Gurău, L. (2016). Comparative study of photodegradation of six wood species after short-time UV exposure. Wood science and technology, 50(1), 135-163.

[72] Müller, Uwe, Rätzsch, Manfred, Schwanninger, Manfred, Steiner, Melanie, and Zöbl, Harald. "Yellowing and IR-changes of Spruce Wood as Result of UV-irradiation." Journal of Photochemistry and Photobiology. B, Biology 69, no. 2 (2003): 97-105.

[73] Chang, S. T., Hon, D. N. S., & Feist, W. C. (2007). Photodegradation and photoprotection of wood surfaces. Wood and Fiber Science, 14(2), 104-117.

[74] Ringus, D. L., & Moraru, C. I. (2013). Pulsed Ligh inactivation of Listeria innocua on food packaging materials of different surface roughness and reflectivity. Journal of food engineering, 114(3), 331-337.

[75] Stannard, C. J., Abbiss, J. S., & Wood, J. M. (1985). Efficiency of treatments involving ultraviolet irradiation for decontaminating packaging board of different surface compositions. Journal of food protection, 48(9), 786-789.

increasing the chance that some survive. The latter effect may be due to increased photoreactivation caused by reflected visible light.

E-3.4 Effectiveness.

As most materials reflect UVR less effectively than visible light, direct exposure is necessary to ensure effective sterilization.[76] Similarly, dirt or grime has the potential to shield pathogens from UVR, so sterilization efforts with UVR should be preceded by some form of surface cleaning. Increased relative humidity (RH) has been shown to increase the resistance of aerosolized bacteria to 254-nm UVR. As RH does not impact overall UV irradiance, this effect must be a result of interactions at the particle level. Certain bacteria may increase in size or water content as RH rises, potentially shielding their DNA from UVR.[77,78] The effect seems to be most pronounced as RH rises above 50%.[79]

E-3.5 Sustainability Concerns.

To reduce the increased energy and material usage, do not install a GUV system in every space, and do not schedule such systems to run continuously. If implemented, a GUV system must only be installed in spaces that have a high risk of disease transmission and must only operate periodically.

E-3.5.1 Energy Use.

The energy usage and cost of a building with installed GUV systems will be higher than the current baseline. As stated previously, it is not recommended that a GUV system be used in place of traditional sanitation practices. Therefore, there would be no direct cost savings by implementing this system. However, during periods of increased risk of infection from pathogens, buildings may integrate more features at the expense of increased energy usage, including improved HVAC systems with better filtration and increased airflow; utilizing pathogen detection tools in the building; and implementing a GUV system in certain areas.

Currently, North American energy codes do not provide guidance for GUV systems. This results in ambiguity for how GUV systems will impact energy code compliance at this time. GUV lamps are exempt from California’s Title 20 efficacy standards.

E-3.5.2 Lamp Replacement and Waste.

[76] Chinnis, D., Karlicek, R., Pfund, D. (2020, August 30). IALD Webinar: Lighting Design and GUV Technology [video file]. Retrieved from https://www.youtube.com/watch?v=prEFfrtQGjQ

[77] Ko, G., First, M. W., & Burge, H. A. (2000). Influence of relative humidity on particle size and UV sensitivity of Serratia marcescens and Mycobacterium bovis BCG aerosols. Tubercle and Lung disease, 80(4-5), 217-228.

[78] Peccia, J., Werth, H. M., Miller, S., & Hernandez, M. (2001). Effects of relative humidity on the ultraviolet induced inactivation of airborne bacteria. Aerosol Science & Technology, 35(3), 728-740.

[79] Riley, R. L., & Kaufman, J. E. (1972). Effect of relative humidity on the inactivation of airborne Serratia marcescens by ultraviolet radiation. Applied microbiology, 23(6), 1113-1120.

GUV systems will also require continuous maintenance, including lamp, ballast, or driver replacement. Many GUV systems utilize mercury vapor lamps, which require proper disposal to limit mercury contamination.

E-4 TYPES OF GUV LAMPS.

There are currently three primary types of GUV lamps: mercury vapor, light-emitting diodes (LED), and excimer lamps. Each lamp type has special considerations. It is important to note that all GUV lamps have relatively low lifetime hours, as listed below, compared to standard lamps and need to be replaced more often. While lamps used for general illumination are evaluated in terms of lumens per watt, GUV lamps cannot be defined with the same metric because they do not produce light in the visual spectrum (i.e., lumens) unless specifically engineered to do so as a safeguard. As such, efficiency for GUV lamps is defined as the percentage of the lamp's total input power that produces UVR.

- Low-pressure mercury vapor (LPM) lamps are the most efficient and most widely used GUV source currently available. These lamps emit monochromatically at a peak of 254 nm and are approximately 30% efficient, which is the highest among the three types. Their lifetime hours are approximately 10,000 hours, and they are the lowest cost GUV lamp.

- LEDs are the least efficient of this group, with efficiency around 3% to 7%. These lamps emit wavelengths that typically range from 265 nm to 280 nm, with an L_{70} of 5,000 to 10,000 hours. LED sources have been manufactured to produce far UV-C wavelengths. However, production of these shorter wavelengths is even less efficient than for longer wavelengths.

- Excimer lamps are slightly less efficient than LPM lamps, with a similar lifetime. Excimer lamps emit at a lower wavelength of 222 nm (far UV-C).

Conventional GUV systems use low-pressure lamps that emit monochromatically at a peak of 254 nm. Medium-pressure lamps that emit a broad range of UV light from 200 nm to 600 nm are also available and, more recently, UV LEDs and plasma-excimer lamps have been developed with emission peaks as low as 210 nm.[80]

E-5 TYPES OF GUV LIGHTING SYSTEMS.

GUV radiation has been proven effective for disinfection in multiple kinds of applications, including water treatment, hospitals, and HVAC integration. During the Covid-19 pandemic, many lighting manufacturers began creating and advertising new GUV systems. Some of these systems have been around for many years, with the intent of disinfecting environments such as surgical suites that require complete sterilization. There are also newer systems that have not been widely implemented.

[80] Taniyasu, Y., Kasu, M., & Makimoto, T. (2006). An aluminium nitride light-emitting diode with a wavelength of 210 nanometres. Nature, 441(7091), 325-328.

GUV systems are typically deployed in four different configurations: direct fixtures, indirect upper-room fixtures, moveable units, and lamps integral to HVAC equipment.

E-5.1 Building-Integrated GUV Fixtures.

Building-integrated systems use direct GUV luminaires for surface disinfection. These are permanent installations in the building. GUV radiation can be integrated into luminaires used for lighting the space or installed as independent luminaires for the sole purpose of GUV disinfection. This style, especially with UV-A and UV-B lamps, has been utilized for several years in select hospital spaces where sterilization is a priority. Direct, building-integrated UV-C luminaires have not been widely implemented and are a recent development. As such, there are no industry standards or specific recommendations that manufacturers must adhere to when designing and implementing these systems.

E-5.1.1 Uses.

Direct GUV fixtures can be effective against surface contamination, but the presence of shadows reduces the effectiveness of the installation. Direct GUV luminaires continue to be an effective option for healthcare settings when used selectively. They may also be an effective solution during times of increased risk of disease in office spaces with high-touch spaces like conference rooms and gathering spaces when used while the spaces are not occupied.

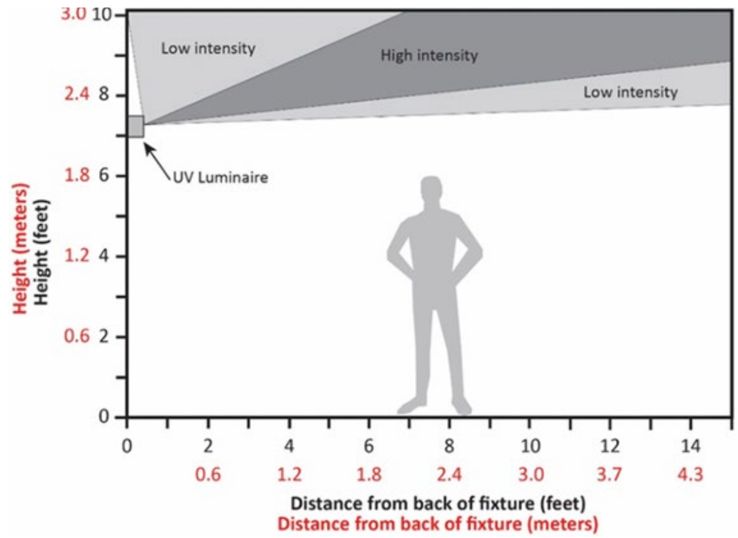
E-5.1.2 Additional Considerations.

Due to safety considerations, advanced controls must be implemented to guarantee that GUV luminaires are energized only when occupants are not present, especially with longer wavelength UV-A, UV-B, and some UV-C lamps. These systems pose a safety risk, which needs to be mitigated appropriately with adequate fail-safe measures. While far UV-C radiation does not currently show any risk to occupants, there are still too many unknowns to recommend continuous use while occupants are present. Further research is recommended, in addition to the development of industry standards.

E-5.2 Indirect Upper-Room GUV Systems.

Indirect upper-room systems are designed with GUV luminaires aimed toward the upper portion of the room, with no direct exposure in the occupied volume, see 0. This type of system can deactivate viral particles in the air, reducing the risk of airborne spread in occupied areas. Indirect upper-room GUV systems are functionally part of the HVAC system, and implementation should be coordinated with the mechanical engineer. A lighting engineer will likely not be involved with this system beyond controls integration.

Figure E-2 Upper-Air GUV Installation (www.ies.org)



E-5.2.2 Uses.

This design should be used in a room with high ceilings. There should be enough space such that a significant amount of air can pass over the system, while leaving the bottom of the system at 7 feet AFF, minimum. This design works best when the air is constantly moving via fans and the HVAC system. Extensive coordination with mechanical engineers is necessary. This system may operate in areas that are occupied, since it is indirect and above head height, but continuous operation is not recommended.

E-5.2.3 Additional Considerations.

This design heavily relies on the airflow within a room. To reduce odor and CO_2 in a room, a relatively low air change per hour (ACH) rate of 1-2 ACH needs to occur. When using an indirect upper-room GUV system, the ACH rate needs to be significantly higher, at 6-12 ACH.[81] The additional energy consumption and HVAC equipment needs to be noted.

The effectiveness of this type of system is highly dependent on the number of air changes per hour. The exact number depends on the desired level of risk mitigation. There are many variables that are specific to each space and HVAC configuration that impact pathogen distribution. In general, a higher ACH rate is generally better from a ventilation perspective.

E-5.2.4 Other Upper-Room Fixture Styles.

Similar to indirect upper-room systems, there are also luminaires with integrated fans and indirect GUV lamps. These are intended to operate similarly to indirect upper-room

[81] Illuminated Engineering Society. IES CR-2-20-V1, *Committee Report: Germicidal Ultraviolet – Frequently Asked Questions*. New York: IES; 2020.

GUV systems but are self-contained fixtures. Typically, these luminaires contain a UV emitter that is internal to the body of the fixture. These could be used to eliminate viral particles in the air and could be used to mitigate risk during occupied hours. However, these also require extensive coordination with mechanical engineers. Without industry standard protocols, designers must understand standard best practice based on current research and commonly used protocols. It is not recommended that designers rely on the manufacturer's claims regarding the system's effectiveness and deployment strategies. Therefore, these systems must be considered with caution but may be considered if upper-room GUV disinfection is desired but not implementable due to ceiling height.

E-5.3 Moveable GUV Units.

Moveable GUV systems are mounted in carts or handheld emitters and are temporarily transported into spaces to be used to sterilize surfaces as part of a cleaning regime. This system is best for disinfecting surfaces in areas that would not normally have permanent GUV installations, such as temporary medical shelters, emergency response areas, operating rooms, and other areas needing disinfection.

Movable GUV systems can be used to disinfect air or surfaces in rooms that do not have permanent systems. While this is an option, there still must be significant airflow within the room, just as in a permanent installation, and the room needs to be unoccupied during GUV operation to limit direct UVR exposure. If the UV emitter is internal to an enclosure or angled upward out of direct view, it could be used to eliminate viral particles in the air and could be used to mitigate risk during occupied hours.

E-5.3.1 Portable handheld devices.

Portable handheld devices may be used to disinfect surfaces in areas that do not have permanent direct GUV systems. The GUV emitted from the device needs to be applied to a surface area for several seconds to disinfect properly. If not applied long enough, the result may be only partially sanitized surfaces, which then contribute to a false sense of security, and this method must then be implemented in addition to traditional cleaning practices. Additionally, these systems rely on an operator to safely direct the UV source away from any humans.

E-5.3.2 Additional Considerations.

Moveable GUV systems that purify the air within a room require a high ACH rate, so their implementation must be coordinated with mechanical engineers. They are best suited for use in small rooms in order to be efficient. Since these are moveable devices, the user needs to make sure the proper controls are in place to protect the safety of the occupants and user. Movable units, especially handheld devices and self-contained home-use sterilization boxes, are not certified by UL.

E-5.4 Integral to HVAC System.

GUV systems that are integral to HVAC systems are installed within HVAC ductwork and kill or inactivate pathogens in the passing airstream. A lighting engineer would not be involved in selecting or implementing this kind of system, since this is the responsibility of the mechanical engineers. This use of GUV radiation has been around for many years as part of HVAC systems.

These systems have little effect on person-to-person pathogen transmission in a room and are no more effective than a simple HEPA air filter. Properly filtering air via the HVAC system is highly recommended, whether using physical or GUV filters, and will reduce airborne viral concentrations without interrupting occupancy. It is important to note that too much airflow will reduce the efficacy of these systems.

E-6 IMPLEMENTING GUV SYSTEMS.

The lack of standards for GUV systems makes it difficult to determine the best products to select and the most efficient use of them. Without standards, designers and engineers are given few resources with which to evaluate products that manufacturers market with few restrictions. With any new technology, claims around UV-C radiation should be considered with skepticism until industry standards have been developed, peer reviewed, and widely accepted by experts. The architectural engineering community has not reached consensus on the best type of GUV system, nor how widely it should be implemented.

E-6.1 Determining if a GUV System is appropriate.

Determining if any GUV system is right for a given space or building will not be determined solely by the lighting designer or electrical engineer. Selecting the correct disease mitigation strategy will require input from the building owner, project manager, public health officials, infectious disease experts, mechanical engineers, and lighting engineers. There are many recommended strategies that building designers can implement to reduce the potential spread of pathogens within the building. Many of these are modifications to the HVAC system design, including increased fresh air, filtration, and air flow. These modifications do not have any known complications, nor will they fully sterilize the environment which increases the risk of viral and bacterial mutations.

If improving the HVAC system is not feasible or is determined to be an insufficient measure on its own, then a GUV system may be considered if implemented correctly. The most effective GUV system is still unknown and varies widely by area type or building.

E-6.2 Selecting a GUV System.

Research indicates that far UV-C radiation is the preferred choice because it is at least as effective as UV-A or UV-B radiation, and it is safer for occupants. This will reduce the risk of exposure and complications if controls do fail. Even though it is not currently recommended to use a direct far UV-C system when occupants are present, further research may indicate that the unintended consequences are minimal, and deployment of the system could be modified to increase usage during times of occupation. UV-A, UV-B, and UV-C systems should never be used in this application.

E-6.2.1 Evaluating GUV Systems.

Many manufacturers are promoting UV-C technology as safe and effective solutions, but these systems are not without complications. Yet currently, there are no standards for GUV-system selection criteria and operation. As noted previously, continuous operation of far UV-C should not be implemented without extreme caution, since this range of wavelengths is not naturally present in our atmosphere and there remain many unknowns regarding long-term effects on humans and the environment. Designers must use caution when selecting a GUV system and must remain vigilant to manufacturers' assertions regarding their products, including but not limited to:

- Unrealistic claims about how frequently the system should be operated
- Disregarding unintended consequences and unknown long-term effects
- No mention of controls
- Stating that it is a catch-all disinfectant that can replace regular cleaning practices

Manufacturers that understand the limitations of GUV systems are likely to suggest a system that is a realistic strategy.

E-6.2.2 System Selection.

GUV systems are an integrated solution that needs input from specialists in HVAC, risk management specialists, and public health officials. Lighting manufacturers are promoting GUV technology since these systems have many shared properties with light. However, lighting designers and electrical engineers do not typically have the expertise to make decisions about the sanitation of facilities. Other disciplines must be involved, especially in the decision-making process. Heavy coordination is required with mechanical engineers to evaluate whether appropriate airflow can be achieved to effectively deploy indirect GUV systems.

Select far UV-C systems for the most flexibility in use: If control safeguards fail during operation, there will be no direct or immediate harm to any humans present in the space. Additionally, if far UV-C radiation is determined to be completely safe, even regarding long-term effects, then the system may potentially be used when the space is occupied in the future.

E-6.3 Deployment.

GUV radiation can be a useful addition to infection control options but should be deployed as part of a multi-pronged response to specific conditions and criteria. Ubiquitous, continuous deployment is not recommended, to minimize the risk of unknown potential side effects.

- Use surface-cleaning systems in addition to traditional sanitation procedures to increase their effectiveness.
- Use air-cleaning systems to mitigate spread, even in occupied spaces, during high-risk events.
- Coordinate with HVAC for potential GUV deployment in air handling units and/or fan coil units

As with any system, there are trade-offs that should be considered, weighing the needs of the moment against future hazards. If deployed carefully, GUV systems can significantly reduce the risk of disease transmission within buildings and help combat the spread of antibiotic-resistant bacteria. The use of a GUV system should not be continuous, and such a system should be used along with regular cleaning protocols, not instead of these protocols. These GUV systems may also be installed in the air handling units and/or fan coil units. The most successful and safe deployment will be heavily reliant on reliable controls, which will require that the GUV system communicates with both the building automation system (BAS) and the lighting control system. Refer to ANSI/IES RP-44-21, *Recommended Practice: Ultraviolet Germicidal Irradiation (UVGI)*, Section 9.0 Systems: Comparison, for details on how to select and compare systems based on application type. Also refer to Section 9.5 Summary Tables for comparisons of systems, including various systems' advantages and disadvantages.

E-6.3.1 GUV System Controls.

GUV systems must be controlled completely independently from the lighting systems within any given space. However, the GUV system controls must also communicate with the BAS and lighting control system to receive occupancy status, building occupancy schedules, and ACH data. For each space, control of GUV systems needs special consideration regarding the use of the space and the type of system installed in order to protect public safety and health. These control systems must be implemented in order to protect maintenance personnel from direct exposure during maintenance operations.

- The GUV system must be controlled independent of the lighting system.
- Each room or area that contains a GUV system must be controlled independently of any other room or area.

- Direct GUV systems must not operate when occupancy sensors detect that the room is occupied. This information can be obtained through the lighting control system. This is especially important for direct UV-A, UV-B, and UV-C systems, where exposure can be immediately harmful to humans.

- All GUV systems must have local, manual shut-off. Refer to ANSI/IES RP-44-21, *Recommended Practice: Ultraviolet Germicidal Irradiation (UVGI)*, Section 9.0 Systems: Comparison, for details on how to select and compare systems based on application type. Also refer to Section 9.5 Summary Tables for comparisons of systems including various systems' advantages and disadvantages.

- Moveable GUV units, which cannot be connected to the lighting control system, should be operated via a remote control.

- It is recommended that the GUV system be only turned on in association with a higher risk event, which should also coincide with increased fresh air and airflow.

E-6.3.2 System Maintenance.

Do not implement a GUV system without considering system commissioning and on-going maintenance. Without industry guidelines for deploying and maintaining these systems, specifiers must evaluate manufacturer's recommendations, if any, regarding the long-term use of these products. Do not consider manufacturers that do not address the longevity or maintenance of their systems.

Typically, Operations and Maintenance staff will not have the expertise or tools available to monitor, control, and update a GUV system. When specifying a GUV system, establish protocol for on-going maintenance, including continuous support from outside specialists. Specialists must:

- Verify that the system is functioning as intended with calibrated meters

- Utilize personal protective equipment (PPE) when working under energized UVR fixtures

- Maintain lamp replacement schedule to ensure proper function

E-6.3.2.1 Lamp Replacement.

GUV systems must provide a notification system indicating that the GUV lamp life has deteriorated and must be replaced. There are currently no standards for notification systems. Unless regular UV measurements are taken in-field, this notification system will be based on estimated lamp life by the lamp manufacturer.

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APPENDIX F GLOSSARY

F-1 ACRONYMS.

ACP	Access Control Point
AFF	above finished floor
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CCT	correlated color temperature
CRI	color rendering index
DoD	Department of Defense
ECF	Entry Control Facility
FC	Facilities Criteria
HID	high-intensity discharge
Hz	hertz
kW	kilowatts
kWh	kilowatt-hours
LEC	light-emitting capacitor
LED	light-emitting diode
LLD	lamp lumen depreciation
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
SF	square foot
SPD	spectral power distribution
SSL	Solid state lighting

THD total harmonic distortion

TLED tubular light-emitting diode

UFC Unified Facilities Criteria

UFGS Unified Facilities Guide Specifications

UL Underwriters Laboratories

V volt

W watt

F-2 DEFINITIONS OF TERMS.

The definitions of lighting terms are from ANSI/IES LS-1-21, *Lighting Science: Nomenclature and Definitions for Illuminating Engineering*.

Adaptation: The process by which the retina becomes accustomed to more or less light than it was exposed to during an immediately preceding period. It results in a change in the sensitivity to light.

Aircraft Maintenance Area: The full area designated for aircraft parking and maintenance area. Typically includes the depth from the hangar bay door to the back wall and width from the centerline boundary of the neighboring aircraft maintenance zones or to the side wall.

Altitude: The angular distance of a heavenly body measured on the great circle that passes perpendicular to the plane of the horizon, through the body and through the zenith. It is measure positively from the horizon to the zenith, from 0 degrees to 90 degrees.

Ambient Lighting: Lighting throughout an area that produces general illumination

Area Lighting Luminaire: A complete lighting device consisting of a light source and driver, where appropriate, together with its direct appurtenances such as globe, reflector, refractor, housing, and such support as is integral with the housing. The pole, post, or bracket is not considered part of the luminaire.

Luminance: Luminance is a property of a geometric ray. Luminance as measured by conventional meters is averaged with respect to two independent variables, area and solid angle; both must be defined for a complete description of a luminance measurement.

Azimuth: The angular distance between the vertical plane containing a given line or celestial body and the plane of the meridian.

Baffle: A single opaque or translucent element to shield a source from direct view at certain angles, to absorb or block unwanted light, or to reflect and redirect light.

Ballast: A device used with an electric-discharge light source to obtain the necessary circuit conditions (voltage, current, and waveform) for starting and operating.

Bollard: A type of luminaire having the appearance of a short, thick post, used for walkway and grounds lighting. The optical components are usually top-mounted.

Bowl: An open-top diffusing glass or plastic enclosure used to shield a light source from direct view and to redirect or scatter the light.

Bracket (mast arm): An attachment to a light source post or pole from which a luminaire is suspended.

BUG (Backlight, Uplight, Glare): Backlight – the amount of percent lamp lumens or the luminaire zonal lumens distributed behind a luminaire between zero degrees vertical (nadir) and 90 degrees vertical. Uplight – the percent lamp lumens or the amount of luminaire zonal lumens distributed above a luminaire between 90 and 180 degrees vertical. Glare – the amount of percent lamp lumens or the luminaire zonal lumens distributed 60 and 90 degrees vertical.

Candela, cd: The SI unit of luminous intensity, equal to one lumen per steradian (lm/sr).

Candlepower (cp): Another term for luminous intensity," expressed in candelas.

Clerestory: That part of a building that rises clear of the roofs or other parts and whose walls contain windows for lighting the interior.

Coefficient of Utilization (CU): The ratio of luminous flux (lumens) calculated as received on the work plane to the total luminous flux (lumens) emitted by the light sources alone. It is equal to the product of room utilization factor and luminaire efficiency.

Color Matching: The action of making a color appear the same as a given color.

Color Rendering: Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant.

Color Rendering Index (of a light source) (CRI): A measure of the degree of color shift objects undergo when illuminated by the light source as compared with those same objects when illuminated by a reference source of comparable color temperature.

Color Temperature (of a light source): See Correlated Color Temperature.

Contrast: *See Luminance Contrast.*

Correlated Color Temperature (of a light source) (CCT): The absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source.

Daylight Availability: The luminous flux from the sun plus sky at a specific location, time, date, and sky condition.

Diffused Lighting: Lighting provided on the work plane or on an object that is not incident predominantly from any particular direction.

Dimmer: A device used to control the intensity of light emitted by a luminaire or light source by controlling the voltage or current available to it.

Direct Component: That portion of the light from a luminaire that arrives at the work plane without being reflected by room surfaces.

Direct Glare: Glare resulting from high luminances or insufficiently shielded light sources in the field of view. It is usually associated with bright areas, such as luminaires, ceilings, and windows that are outside the visual task or region being viewed. A direct glare source can also affect performance by distracting attention.

Direct-Indirect Lighting: A variant of general diffuse lighting in which the luminaires emit little or no light at angles near the horizontal.

Direct Lighting: Lighting involves luminaires that distribute 90 to 100% of the emitted light in the general direction of the surface to be illuminated. The term usually refers to light emitted in a downward direction.

Directional Lighting: Lighting provided on the workplane or on an object, predominantly from a preferred direction.

Disability Glare: The effect of stray light in the eye whereby the contrast of the retinal image is reduced and, consequently, whereby visibility and visual performance are reduced. A direct glare source that produces discomfort can also produce disability glare by introducing a measurable amount of stray light in the eye.

Discomfort Glare: Glare that produces discomfort. It does not necessarily interfere with visual performance or visibility.

Downlight: A small direct lighting unit that directs the light downward and can be recessed, surface-mounted, or suspended.

Efficacy: See *Luminous Efficacy of a Source of Light.*

Efficiency: See *Luminaire Efficiency*.

Electroluminescence: The emission of light from a phosphor excited by an electromagnetic field.

Emergency Exit: A way out of the premises that is intended to be used only during an emergency.

Emergency Lighting: Lighting designed to supply illumination essential to the safety of life and property in the event of a failure of the normal supply. The system must be capable of providing minimum required illuminance specified in NFPA 101.

Exit Sign: A graphic device including words or symbols that indicates or identifies an escape route or the location of, or direct to, an exit or emergency exit.

Floodlight: A projector designed for lighting a scene or object to a luminance considerably greater than its surroundings.

Fluorescent Light Source: A low pressure mercury electric-discharge light source in which a fluorescing coating (phosphor) transforms some of the UV energy generated by the discharge into light.

Flush-mounted or Recessed Direct/Indirect Luminaire: A luminaire that is mounted above the ceiling (or behind a wall or other surface) with the opening of the luminaire level with the surface.

Footcandle, fc: A unit of illuminance equal to 1 lm/ft^2.

Glare: The sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance, and visibility. Direct glare is caused by excessive light entering the eye from a bright light source. The potential for direct glare exists anytime one has a direct view of a light source. With direct glare, the eye has a harder time seeing contrast and details. A system designed solely on lighting levels, tends to aim more light directly towards a task, thus producing more potential for glare. Direct glare can be minimized with careful equipment selection and placement.

Globe: A transparent or diffusing enclosure intended to protect a light source, to diffuse and redirect its light, or to change the color of the light.

High Ambient Temperatures: Above 50 degrees Celsius.

High-Intensity Discharge (HID) Light Source: An electric-discharge light source in which the light-producing arc is stabilized by bulb wall temperature, and the arc tube has a bulb wall loading in excess of 3 W/cm^2. HID light sources include groups of light sources known as mercury, metal halide, and high-pressure sodium.

High-Mast Lighting: Illumination of a large area by means of a group of luminaires that are designed to be mounted in a fixed orientation at the top of a high mast, generally 20 m (65 ft.) or higher.

High-Pressure Sodium (HPS) Light Source: A high intensity discharge (HID) light source in which light is produced by radiation from sodium vapor.

Illuminance: The areal density of the luminous flux incident at a point on a surface. Units: lux or footcandles.

Illuminance (footcandle or lux) Meter: An instrument for measuring illuminance on a plane. The instrument comprises some form of photodetector with or without a filter driving a digital or analog readout through appropriate circuitry.

Illumination: An alternative but deprecated term for illuminance. In this document, it is used in its more general sense of simply “lighting.”

Incandescent Filament Light Source: A light source in which light is produced by a filament heated to incandescence by an electric current.

Indirect Component: The portion of the luminous flux from a luminaire that arrives at the workplane after being reflected by room surfaces.

Indirect Lighting: Lighting involving luminaires that distribute 90 to 100% of the emitted light upward.

Induction Lighting: Lighting technology that uses electric current to induce an electromagnetic field within the phosphor coated light source. No filaments are used. Its advantages include instant on/off operation, white light with good color rendering characteristics, and a long light source life of 100,000 hours.

Intensity (candlepower) Distribution Curve: A curve, often polar, that represents the variation of luminous intensity of a light source or luminaire in the plane through the light center.

Isolux (Isofootcandle) Line: A line plotted on any appropriate set of coordinates to show all the points on a surface where the illuminance is the same.

Kelvin: The unit of absolute temperature used to designate the color temperature or correlated color temperature of a light source. Symbol: K.

Light Source: A generic term for a source created to produce optical radiation.

Light Source Lumen Depreciation (LLD) Factor: The fractional loss of light source lumens at rated operating conditions that progressively occurs during light source operation.

Lens: A glass or plastic element used in luminaires to change the direction and control the distribution of light rays.

Light: Radiant energy that is capable of exciting the retina and producing a visual sensation.

Light-Emitting Diode (LED): A p-n junction solid state diode whose radiated output is a function of its physical construction, material used, and exciting current.

Light Loss Factor (LLF): Formerly called maintenance factor. The ratio of illuminance (or exitance or luminance) for a given area to the value that would occur if light sources operated at their (initial) rated lumens and if no system variation or depreciation had occurred.

Light Meter: A common name for an illuminance meter.

Light Source Color: The color of the light emitted by a source.

Louver: An optical-control element, usually used in multiples, to shield a source from view at certain angles, to absorb or block unwanted light, or to reflect or redirect light.

Low-Bay Lighting: Interior lighting where the roof trusses or ceiling height is approximately 6.1 m (20 ft.) or less above the floor.

Low-Pressure Mercury Vapor (LPM) Light Source: A discharge light source (with or without a phosphor coating) in which the partial pressure of mercury vapor does not exceed 100 Pa during operation.

Low-Pressure Sodium (LPS) Light Source: A discharge light source in which light is produced by radiation from sodium vapor.

Lumen, lm: SI unit of luminous flux. Radiometrically, it is determined from the radiant power (see luminous flux). Photometrically, it is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela.

Lumen Depreciation: The decrease in lumen output that occurs as a lamp is operated, until failure.

Lumen Method: A procedure used to determine the relationship between the number and types of lamps, light sources and luminaires, the room characteristics, and the average level of illuminance on the work plane. It takes into account both direct and reflected flux.

Luminaire (light fixture): A complete lighting unit consisting of a light source or light sources and driver(s) (when applicable) together with the parts designed to distribute the light, to position and protect the light sources, and to connect the light sources to the power supply.

Luminaire Dirt Depreciation (LDD): The ratio of lumens emitted from a luminaire with dirt accumulated to the lumens emitted from the same luminaire when clean.

Luminaire Efficiency: The luminous flux emitted by a luminaire, divided by the luminous flux emitted by the source(s). Sometimes called light output ratio (LOR).

Luminance: The apparent brightness of a surface, measured in candelas per foot (cd/ft^2) or square meter (cd/m^2), sometimes called nits.

Luminance Contrast: The relationship between the luminances of an object and its immediate background.

Luminance Ratio: The ratio between the luminances any two areas in the visual field.

Luminous Efficacy of a Source of Light: The quotient of the total luminous flux emitted to the total light source power input. It is expressed in lumens per watt.

Luminous Flux: The time rate of flow of radiant energy, evaluated in terms of a standardized visual response. Units: lumens.

Matte Surface: A surface from which the reflection is predominantly diffuse, with or without a negligible specular component.

Means of Egress: An unobstructed and continuous way of exit from any point in a building or structure to a public way. It consists of three distinct parts: the exit access, the exit, and the exit discharge. A means of egress consists of the vertical and horizontal travel ways, including intervening room spaces, doorways, hallways, corridors, passageways, ramps, stairs, lobbies, horizontal exits, escalators, enclosures, courts, balconies, and yards.

Mercury Light Source: A high-intensity discharge (HID) light source in which the major portion of the light is produced by radiation from mercury operating at a partial pressure in excess of 10s Pa.

Mesopic Vision: Vision with fully adapted eyes at luminance conditions between those of photopic and scotopic vision.

Multi-level Switching: Multi-level switching allows multiple light sources within a luminaire to be switched independently. For example, a three light source luminaire would offer four light output settings: 100%, 66%, 33%, and OFF.

Orientation: The position of a building with respect to compass directions.

Overhang: In roadway lighting: the distance between a vertical line passing through a specified point (often the photometric center) of a luminaire and the curb or edge of a roadway.

Pendant Luminaire: *See Suspended* luminaire.

Peripheral Vision: The seeing of objects displaced from the primary line of sight and outside the central visual field.

Photometry: The measurement of quantities associated with light.

Photopic Vision: Vision mediated essentially or exclusively by the cones. It is generally associated with adaptation to a luminance of at least 5 cd/m^2.

Point-by-Point Method: A method of lighting calculation, now called the point method.

Point Method: A procedure for predetermining the illuminance at various locations in lighting installations by use of luminaire photometric data. The direct component of illuminance due to the luminaires and the interreflected component of illuminance due to the room surfaces are calculated separately. The sum is the total illuminance at a point.

Point Source: A source of radiation, whose dimensions are sufficiently small, compared with the distance between the source and the irradiated surface, that these dimensions can be neglected in calculations and measurements.

Pole (roadway lighting): A standard support generally used where luminaires are located.

Quality of Lighting: Pertains to the distribution of luminance in a visual environment. The term is used in a positive sense and implies that all luminances contribute favorably to visual performance, visual comfort, ease of seeing, safety, and aesthetics for the specific visual tasks involved.

Ramped Dimming: A gradual dimming rate that ensures occupants in the space will not perceive a sudden change in light levels.

Rated Light Source Life: The life value assigned to a particular type of light source. This is commonly a statistically determined estimate of average or of median operational life.

Reflected Glare: Glare resulting from reflections of high luminances in polished or glossy surfaces in the field of view.

Reflection: A general term for the process by which the incident flux leaves a (stationary) surface or medium from the incident side without change in frequency.

Reflector: A device used to redirect the flux from a light source by the process of reflection.

Scotopic Vision: Vision mediated essentially or exclusively by the rods. It is generally associated with adaptation to a luminance below about 0.001 cd/m^2.

Self-Ballasted Light Sources: Any arc discharge light source of which the current limiting devices is an integral part.

Solid State Lighting: Light sources that generate light through electroluminescence rather than filaments or gas discharge. SSL sources include light emitting diodes (LEDs), organic light emitting diodes (OLEDs), and polymer light emitting diodes (PLED).

Spacing: For roadway lighting, the distance between successive lighting units, measured along the centerline of the street.

Spacing-to-Mounting-Height Ratio: The ratio of the actual distance between luminaire centers to the mounting height above the horizontal ground or work plane.

Suspended (pendant) Luminaire: A luminaire that is hung from a ceiling by supports.

Table Lamp: A portable luminaire with a short stand, suitable for mounting on furniture.

Translucent: Transmitting light diffusely or imperfectly.

Transmission: A general term for the process by which incident flux leaves a surface or medium on a side other than the incident side, without change in frequency.

Transmittance: The ratio of the transmitted flux to the incident flux.

Transmittance, Visible (T_{vis}): The percentage of the visible spectrum transmitted.

Transparent: Having the property of transmitting rays of light through its substance so that bodies situated beyond or behind can be distinctly seen.

Troffer: A long recessed direct/indirect lighting unit usually installed with the opening flush with the ceiling.

Tungsten-Halogen Light Source: A gas-filled tungsten filament incandescent light source containing a certain proportion of halogens in an inert gas whose pressure exceeds 3 atm.

Uniformity: Lighting level or illuminance uniformity is important to work surfaces where sustained tasks are performed as well as on wall and ceiling surfaces that make up a significant portion of the field of view. Poor uniformity can cause adaptation problems. Flicker or strobing of luminaires can cause annoyances as well as headaches and fatigue.

Valance: A longitudinal shielding member mounted across the top of a window or along a wall (and is usually parallel to the wall) to conceal light sources, giving both upward and downward distributions.

Valance Lighting: Lighting comprising light sources shielded by a panel parallel to the wall at the top of a window.

Veiling Reflection: Regular (specular) reflection, superimposed on diffuse reflection from an object, that partially or totally obscures the details to be seen by reducing the contrast. This sometimes is called reflected glare. Another kind of veiling reflection occurs when one looks through a pane of glass. A reflected image of a bright element or surface may be seen superimposed on what is viewed through the glass pane.

Visibility: The quality or state of being perceivable by the eye. In many outdoor applications, visibility is defined in terms of the distance at which an object can be just perceived by the eye. In indoor applications, it usually is defined in terms of the contrast or size of a standard test object when observed under standardized viewing conditions and having the same threshold as the given object.

Volt: The difference in electrical potential between two points in a circuit.

Watt: The unit of power (rate of doing work). In electrical calculation, one watt is the power produced by a current of one ampere across a potential difference of one volt.

Workplane: The plane on which a visual task is usually done, and on which the illuminance is specified and measured. Unless otherwise indicated, this is assumed to be a horizontal plane 0.76 meters (30 inches) above the floor.

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APPENDIX G REFERENCES

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UFC 3-260-01, *Airfield and Heliport Planning and Design*

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Entry Control Facility/Access Control Point Lighting Analysis

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UFC 3-535-01
11 April 2017
Change 4, 25 April 2023

UNIFIED FACILITIES CRITERIA (UFC)

VISUAL AIR NAVIGATION FACILITIES

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

UFC 3-535-01
11 April 2017
Change 4, 25 April 2023

UNIFIED FACILITIES CRITERIA (UFC)

VISUAL AIR NAVIGATION FACILITIES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY (Preparing Activity)

Record of Changes (changes are indicated by **\4** ... /**4**/)

Change No.	Date	Location
1	7 March 2018	Paragraphs 1-6.4, 1-6.7, 12-1.4.17, and 12-1.8.3 modified; Chapters 13 and 14 deleted.
2	6 April 2021	Paragraphs 1-6.7, 1-11.1.1, 2-5.1.1, 2-5.1.2, 2-5.2, Figure 3-2, Appendix C, AFIC references throughout
3	21 May 2021	Paragraphs 1-7, 1-8.1.2, 1-8.2.2, Table 2-1A
4	25 April 2023	Chapter 14 inserted to relocate Landing Zone configuration from UFC 3-260-0 to UFC 3-535-01, for the purpose of having all lighting configurations in one UFC. Update for allowance of LEDs is included.

This UFC supersedes UFC 3-535-01, dated 11 April 2017, including Change 3.

This UFC will be formatted IAW the UFC Template upon next full revision.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
CHANGE SUMMARY SHEET

Subject: UFC 3-535-01, *Visual Air Navigation Systems*

Supersedes: UFC 3-535-01, 11 April 2017, including Change 3.

Description of Changes: This change brings requirements for new airfields into compliance with new FAA criteria for AC 150-5345-53 for LED criteria, adds a reference to AC 90-106, *Enhanced Flight Vision System Operations* , updates taxiway lighting to include allowance of LED type fixtures with various emitters or filters (Engineering Brief 67D), adds a chapter on Expeditionary Airfield Lighting (EALS), changed paragraph 1-17 title to Supplemental Criteria with added content provides guidance for navigational aids with integral LED obstruction lights at elevations under 35 feet in height, and provides guidance on replacement of approach light systems with LEDs, coordinated with AFFSA. Sign temperature requirements have been included IAW AC150-5345-44.

Reasons for Changes:

- Incorporate new FAA guidance and changes
- **\4** Incorporate changes in technology based on availability of parts from industry.
- Clarify Army- and Air Force-only requirements that Introduce Landing Zone light configuration.
- Introduce compensation configuration to be used for Aircraft with Head Up Displays, which do not detect LED lights.
- Introduce guidance on solar components of ALS. **/4/**
- Provide information on testing and inspection of systems prior to service and information on the characteristics of an airfield lighting system
- **\1** Chapters 13 and 14 were removed and converted to TSEWG TP-20, *Air Visual Air Navigation Facilities: Qualifying Equipment,"* and TSEWG TP-21, *Visual Air Navigation Facilities: Air Facility Equipment Inspection and Testing,* respectively (see Appendix A, "References"). **/1/**
- **\2** Update prohibited and allowed placements of LED fixtures based on industry progress. Clarify relationships between Air Force MAJCOMs and AFIMSC Detachments relative to Air Force waiver requests. Add guidance for solar powered airfield lighting fixtures. Revise terms to meet changes in FAA terminology. Update power requirements to modern technology requirements.

Revise Table 3-6, Visual Threshold Crossing Height Groups, to include C-130, C-17, and C-5. Update reference documents to account for renaming, rescissions, merges and cancellations. Add appendix of technological considerations and applications for design. **/2/**

- **\3** Clarify guidance regarding fixture outage thresholds. **/3/**

Impact: Cost impact is negligible. However, the following benefit should be realized:

- Designers may have a better understanding of the design requirements.

Unification Issues

- Paragraph 1-2 states the document scope and indicates that "Navy requirements are currently contained in Naval Air Systems Command (NAVAIR) 51-50AAA-2. When using the NAVAIR document, be certain that the complementary markings are installed and that no conflict occurs with the placement of light fixtures. The Navy should clarify what "…no conflict occurs" means, as it is unclear whether it references joint bases or only naval facilities.

- Paragraphs 1-5 and 1-6: This UFC applies to the Army and Air Force. Navy uses Naval Air Systems Command (NAVAIR) 51-50AAA-2, except for excerpts contained within this document which apply specifically to Navy and are not covered in NAVAIR 51-50AAA-2.

- Paragraph 1-7: The Army and the Air Force generally follow FAA standards that are primarily published as ACs, Engineering Briefs, handbooks, and specifications. However, when FAA documents are in conflict with the Air Force or Army requirements contained herein, this UFC takes precedence. When FAA documents are in conflict with Navy guidance included in this UFC or in NAVAIR 51-50AAA-2, UFC or NAVAIR 51-50AAA02 guidance takes precedence.

- Paragraph 1-8.2.1: NATO STANAGs apply at Army and Air Force facilities in NATO theater countries except the United States and Canada, or wherever NATO funding is provided for the work, regardless of location. Navy application of NATO Standardization Agreements is guided by NAVAIR 51-50AAA-2.

- Paragraph 1-10: The Army and Air Force have established tables within this document, which provide visual air navigation aids appropriate for operational requirements and associated electronic aids. See Table 2-1A for Air Force Airfield Visual Facilities Requirements. Note 18 was added to advise that outage thresholds for each system are established by FAA and must be followed for revised airfield operations during system outages; See Table 2-1B, for US Army Airfield Visual Facilities Requirements; or Table 2-3, Theater of Operations (TO) Airfield Heliport/Helipad Visual Requirements. For the Navy, NAVAIR 51-50AAA-2 identifies visual air navigation aids appropriate for operational requirements.

- Waivers: Paragraph 1-11 provides the Air Force process for obtaining waivers to requirements of visual air navigation aids. Paragraph 1-12 provides the Army process for obtaining waivers to requirements of visual air navigation aids. Navy waiver process is covered in NAVAIR 51-50AAA-2. These waiver processes are geared to the individual missions of these three services.

- Table 2-1A provides visual facilities requirements for Air Force airfields. Table 2-1B provides visual facilities requirements for Army airfields. Navy visual facilities requirements are provided in NAVAIR 51-50AAA-2. These visual facilities requirements are geared to the individual missions of these three services with the exception that Joint bases may have additional requirements. This issue has been resolved by Army-Air Force coordination on Table 2-1A. Navy-Air Force coordination has not been made on Table 2-1A.

- Table 3-6, Visual Threshold Crossing Height Groups, is modified and contains Army and Air Force coordinated information. Navy aircraft are not included.

- Figure 4-4A and Figure 4-4B provide threshold light configurations for Air Force and Army, respectively. They differ, based on mission.

- Figures 4-5A through Figure 4-5D provide threshold light circuiting for Air Force and Army, respectively. Interleaving is not recommended for Air Force airfields. (Twice the conductor lengths are necessary with one regulator for each circuit and specific outage thresholds for each system are established by FAA and must be followed for revised airfield operations during system outages. Interleaving may conflict with FAA revised airfield operations.)

- Para 12-3, “Siting PAPI”: For aircraft in height group 4 (Table 3-6) for Army airfields only, the PAPI is sited at the RPI plus an additional 300 feet (90 meters), +50 feet –0 feet (+15 meters –0 meters), from threshold.

- Para 12-3.1.2.2, Threshold Crossing Height (TCH): See Table 3-6. For the Air Force, the TCH is based on the most predominant aircraft using the runway (the MAJCOM will make this determination). For the Army, the TCH is based on the most demanding aircraft height group expected to use the runway (the aviation community will coordinate with US Army Aeronautical Service Agency (USAASA) for this determination).

CONTENTS

FIGURES

TABLES

CHAPTER 1 INTRODUCTION TO STANDARDS AND CRITERIA

1-1 PURPOSE.

This document provides guidance and detailed information on standard configurations and equipment for airfield lighting. Use this document when designing, planning, constructing, and installing new systems, for repairing and testing existing systems, and for introducing new aircraft technologies such as Head Up Display system lighting requirements.

1-2 SCOPE.

This document applies to Army and Air National Guard and to Army and Air Force Reserve bases with responsibility for maintaining their airfield facilities. Joint use with Civil Airport Authorities may require coordination. Existing systems and components are not required to be upgraded to these standards unless as part of a major rehabilitation. It is also important to note that the absence of a formerly FAA-approved NAVAID or piece of equipment from the current AC 150/5345-53, Appendix 3 Addendum is not an indication that this equipment is no longer approved for use. It means that particular NAVAID or piece of equipment is no longer manufactured. Much of this equipment is still supported for repairs by a sub-party of the former manufacturer and this NAVAID/piece of equipment may be more reliable and powerful than the one currently listed in the AC. Contact AFCEC/COSM if told that a NAVAID or piece of equipment is no longer approved for use. Beacons are one example of this situation.

This document contains the configuration standards, application and installation criteria, and a listing of applicable specifications for all visual air navigation facilities, except marking, at Air Force and US Army facilities.

Navy requirements are currently contained in Naval Air Systems Command (NAVAIR) 51-50AAA-2. When using the NAVAIR document, be certain that the complementary markings are installed and that no conflict occurs with the placement of light fixtures.

1-3 SUMMARY OF CHANGES.

This document aligns Air Force/Army airfield lighting requirements to be as close as possible to those of the FAA, with the exception of requirements that are unique to Air Force/Army facilities. FAA Advisory Circulars (AC) that are equivalent to Air Force/Army requirements are referenced. Specific requirements for the Air Force/Army are stated with appropriate data and figures provided.

a. Requirements for lightning protection (installation of a counterpoise) and equipment safety grounding systems are modified.

b. Figures and details are added to further clarify requirements.

c. In-paragraph FAA references are provided when context of a specific change is important.

d. References to other documents and guidance are updated due to cancellations or revisions.

e. The "Special Air Force Requirements" of Chapter 12 are now required for all installations.

f. Constant current regulators (CCR) are required to be ferro-resonant type. Silicon controlled rectifier (SCR) types are no longer approved for designs of new vault and lighting system installations. In-kind replacements of SCRs for existing systems and circuits may be approved under some circumstances (consult AHJ or designated individual of Service). ***/2/***

g. 50 kW and 70 kW constant current regulators (CCR) and 2400 VAC input regulators are no longer approved for new installations (A/C150-5345-10 details the requirements for constant current regulators (CCRs) and a monitor system for use with airport series lighting circuits.). The FAA objective is to transition to a 480 volt airfield lighting system for constant current systems. 30 kW is the maximum FAA-allowed CCR output. FOR AIR FORCE, 50kw and 70kW CCRs and the 2400 VAC system may remain in service with use of 2400V:480V transformers used to serve the vault additions/expansions, until funds are available for replacement of the existing service, generator and regulators.

h. Mixing of incandescent and light-emitting diode (LED) lighting technologies on a single taxiway is not permitted due to varying characteristics which affect light color, etc. In addition, mixing of fixtures by LED manufacturers on a single taxiway is not permitted for the same reason. If two taxiways are on a single circuit, fixtures for each taxiway must be uniform by type and manufacturer, not on the entire circuit, provided constant current regulator is not overloaded.

i. The FAA has changed specifications for light emitting diode (LED)-based red obstruction lights to make them visible to pilots using certain night vision goggle systems. Effective with the implementation of this change in FAA AC 150/5345-43, Specification for Obstruction Lighting Equipment, manufacturers will be required to meet the new specification for certified red LED-based obstruction lights.

1-4 BACKGROUND.

The term "visual air navigation facilities" refers to all lights (excluding ballpark-type lights for aprons and ramps which are covered in UFC 3-530-01), signs, symbols, and other visual aid devices located on and in the vicinity of an airfield. These facilities provide a visual reference and guidance to pilots when operating aircraft on the ground and in the air, and supplement the guidance provided by electronic aids such as Tactical Air Navigation (TACAN), Precision Approach Radar (PAR), and Instrument Landing System

(ILS), for operating aircraft. Criteria for Air Force airfield markings are contained in UFC 3-260-04, *Airfield And Heliport Marking.*

1-4.1 Visual air navigation facilities and systems must be standardized for operational safety. Standardization means that the configuration and color of the lights at each airfield is identical and has the same meaning. Standardization enables pilots to readily interpret the guidance information.

1-4.2 Per Public Law 85-726, the FAA regulates and promotes civil aviation to foster its development and to provide for the safe and efficient use of the airspace by both civil and military aircraft. The FAA develops, modifies, tests, and evaluates systems, procedures, facilities, and devices. It also defines the performance characteristics needed for safe and efficient navigation and traffic control of all civil and military aviation.

1-5 APPLICATION.

Use this document for all major rehabilitation (i.e., when over half of the lighting system requires replacement), or for the establishment of new visual air navigation facilities at Air Force and US Army installations.

Do not install visual air navigation facilities or equipment other than those covered in this publication except when an appropriate waiver has been obtained (refer to paragraph 1-11 for Air Force waivers, or paragraph 1-12 for US Army waivers). Exceptions are when international military standards apply, when Standards of Forces Agreements apply and *where existing facilities configured to prior standards and criteria continues to give satisfactory service*.

1-6 NAVY REQUIREMENTS.

Department of the Navy (Navy) requirements are contained in NAVAIR 51-50AAA-2. Use NAVAIR 51-50AAA-2 on all Navy airfield construction projects. NAVAIR 51-50AAA-2 takes precedence over this UFC and over FAA and International Civil Aviation Organization (ICAO) documents. This paragraph takes precedence over information presented elsewhere in this UFC regarding Navy requirements.

1-6.1 Navy airfield requirements are listed in in Table 1, “Approach Visual Aids Requirements,” in NAVAIR 51-50AAA-2.

1-6.2 LED-lighted obstruction lights are not permitted on Navy projects due to the use of Night Vision Goggles (NVG) by rotary wing aircraft operations. FAA Safety Alert for Operators (SAFO) 09007 contains additional information.

1-6.3 LED-lighted airfield lighting fixtures are permitted on Navy projects with the acknowledgement from the CO or Airfield Manager that LEDs may not be compatible with Enhanced Flight Vision System (EFVS) technology. EFVS is not known to be used on current Navy aircraft.

1-6.4 Additional Navy requirements that differ from Tri-service guidance include:

a. Install counterpoise systems using the equipotential method: above airfield lighting circuits and connected to all airfield lighting equipment, including light bases, guidance signs, and other metallic structures. Reference National Fire Protection Association (NFPA) 780, Chapter 11, "Protection for Airfield Lighting Circuits." **\1** The required use of the equipotential method of counterpoise takes precedence over NAVAIR 51-50AAA-2 counterpoise requirements.**/1/**

b. Install counterpoise ground rods at a 2,000 foot maximum spacing and at all changes in direction, terminations, crossings, and connection to existing counterpoise.

c. Ground rods are not required in cans or on cans with counterpoise systems.

d. Do not use counterpoise wire in conduit with circuit conductors.

e. An equipment ground is not required in constant current circuit conduits.

f. Encase constant current circuit ducts in concrete only when installing under new roadways.

g. For airfield constant current and low-voltage circuits, use aircraft-rated hand holes. Manholes are required for medium-voltage power systems, per UFC 3-550-01.

h. Use 2-inch (53 mm) PVC duct for airfield constant current circuits, with a maximum of two airfield cables and two constant current circuits per duct, and a maximum of two constant current circuits. This permits the interleaving of two circuits within one conduit. **/2/**

i. A drain system in light bases using a duct system or hand holes is not required.

j. Insert PVC conduit through grommets 1 inch (25 mm) (minimum) to 1.5 inches (38 mm) (maximum) into the light base.

k. Only in-pavement fixtures use L-868 cans; elevated lights and signs use L-867 cans.

l. Except for runway in-pavement lights, use anti-seize compound on all threaded connections made on-site to cans, light supports, and sign legs. For runway in-pavement lights use ceramic fluoropolymer coated steel bolts without anti-seize.

m. Photometric testing of newly installed airfield light fixtures, as specified in Unified Facilities Guide Specification (UFGS) 26 56 20 is not required.

n. Consider at taxiway or runway intersections or crossings, provide two spare 2-inch (53 mm) PVC duct bank crossings with hand holes for future use and maintenance use.

1-6.5 Airfield Lighting Control Systems (AFLCS) for Navy projects are normally provided using project funding by **\4** Naval Information Warfare Systems Command (NAVVWARSYSCOM). Coordinate with NAVWARSYSCOM during the 1391 development and during the at early stages of the project design.**/4/**

1-6.6 **\1** Precision approach path indicators (PAPI) systems for Navy projects normally require coordination with the **\4** NAVWARSYSCOM **/4/**. Coordinate with NAVWARSYSCOM during the early stages of the project design.**/1//4/**

1-6.7 **\2** NAVAIR 51-50AAA-2 can be found on the Whole Building Design Guide site at https://www.wbdg.org/ffc/dod/supplemental-technical-documents/tsewg-navair-51-50AAA-2 **/2/**

1-7 FAA STANDARDS.

\3 The Army and Air Force generally follow FAA standards that are primarily published as Advisory Circulars, Engineering Briefs, handbooks, and specifications. However, when FAA documents are in conflict with the Air Force or Army requirements, this UFC takes precedence. Outage thresholds for individual NAVAID systems are identified by FAA. **/3/** **\4** (This means, when there is an outage on the airfield at any time, FAA guidance dictates the steps to take, in priority order, to avoid an airfield shutdown. This guidance is available in the Control Tower.) When FAA documents are in conflict with Navy guidance included in this UFC or in NAVAIR 51-50AAA-2, UFC or NAVAIR 51-50AAA-2 guidance takes precedence. **/4/**

1-8 INTERNATIONAL MILITARY STANDARDS.

1-8.1 This UFC satisfies the requirements of international military standards to the greatest extent possible.

1-8.1.1 NATO Standardization Agreements (STANAGs) are promulgated by the NATO Standardization Office (NSO).
\3
1-8.1.2 AFIC Air Standards (AIR STD) are promulgated by representatives of the military air forces of Australia, Canada, New Zealand, United Kingdom, and the United States. AIR STDs governing airfield lighting and marking, obstructions, helipads, and heliports have been cancelled. **/3/**

1-8.2 Applicable international military standards take precedence over standards in this UFC as follows:

1-8.2.1 NATO.

NATO STANAGs apply at Army and Air Force facilities in NATO theater countries except the United States and Canada, or wherever NATO funding is provided for the work, regardless of location.

\3

1-8.2.2 AFIC.

At Army and Air Force facilities in New Zealand and Australia, contact:

FVEY Air Force Interoperability Council – Management Committee
5E975, Pentagon
Washington DC, 20330-1070
Email: usaf.pentagon.af-a3-5.mbx.asicad01@mail.mil
Tel: +1 7036143707 ***/3/***

1-9 CONSTRUCTION AGREEMENTS WITH OTHER NATIONS.

All construction outside of the United States is governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

\4 SOFA replaced or supplements Base Rights Agreements. Information is at https://2009-2017.state.gov/documents/organization/236456.pdf, but it is unclear whether this has been updated ***/4/***.

1-10 VISUAL AND ELECTRONIC AIDS.

Provide visual air navigation aids appropriate for operational requirements and associated electronic aids. See Table 2-1A, “Air Force Airfield Visual Facilities Requirements,” Table 2-1B, “US Army Airfield Visual Facilities Requirements” or Table 2-3 “Theater of Operations (TO) Airfield Heliport/Helipad Visual Requirements.” Except for Visual Flight Rules (VFR) operation, electronic aids are needed to provide initial positioning and direction information to approaching aircraft. Visual landing aids ensure a timely and safe transition from the instrument phase to the visual phase of an approach. Failure to provide the necessary visual aids on an instrument runway will degrade the utility of the electronic systems. Furthermore, enhancing a runway with unnecessary visual aids wastes resources, may cause confusion, and offers minimal operational advantages. Do not upgrade visual aids for a higher level of operations unless the runway, taxiway, or helipad is approved for that level, and appropriate electronic aids are programmed for installation. Waivers are required for all deviations. Also reference paragraphs 1-11, 1-12, and 2-3.

1-10.1 Electrical support equipment, including the emergency power system, for visual and air navigational aids are not airfield obstructions. If a visual or air navigation aid is classified/categorized a "permissible deviation," then the power equipment supporting that visual or air navigation aid is also classified a "permissible deviation," provided:

- The support equipment is installed behind the equipment it supports, from the perspective of a landing aircraft; and
- The horizontal footprint of the equipment, from the perspective of a landing aircraft, is minimized.

1-11 AIR FORCE WAIVERS OF REQUIREMENTS.

The major command Vice Commander may waive requirements of this UFC if compliance is not practical or feasible. In exercising this waiver authority, the Commander or Vice Commander must not adversely impact the effectiveness or safety of operations for any aircraft which may use the airfield. Under normal circumstances, funding or budgetary constraints are not adequate justification for granting a waiver.

1-11.1 Approval Authority.

Authority to approve waivers resides with the major command Commander or Vice Commander and may be delegated to the Director of Operations (DO), depending upon the waiver content, but may not be re-delegated by DO.

1-11.1.1 Installation Representative.

The installation's representative will:

a. Coordinate all waiver requests with the operations/airfield management and wing safety offices through the base level operations and safety divisions. In accordance with AFMAN 13-204V2 and Air Force Policy Directive (AFPD) 13-2, the operations/airfield management offices must coordinate as necessary with local wings and air traffic control agencies (e.g., FAA) providing terminal instrument procedures (TERPS) services for the affected locations.

b. Submit installation commander-approved waiver requests to AFIMSC/IZB for technical review; AFCEC Operations Directorate (AFCEC/CO) will provide subject matter expert (SME) support to AFIMSC.

c. Notify the FAA of waiver requests involving facilities at joint-use airfields subject to provisions of Title 14 Code of Federal Regulations (CFR) Part 77. Contact the regional FAA Airports Division having jurisdiction over the airfield for the requirements and coordination process. For contact information, consult http://www.faa.gov/about/office_org/headquarters_offices/arc/ro_center/ for National

Engagement and Regional Administration and http://www.faa.gov/airports/news_information/contact_info/regional/ (for Contact Information for FAA Regional Airports Offices (current as of October 2021). Also consult local U.S. Government telephone listings for contact numbers.

d. Maintain a complete record of all waivers requested and the disposition of each (approved or disapproved). Document all approved waivers and make these waiver packages a part of the permanent facility records, available for examination during inspections. Include a list of required waivers and those approved for a specific project in the project design analysis of future projects. **\4** Include active airfield waivers in the package of documents to be resigned by a new Commander, if applicable. ***/4/***

\2

e. Refer to paragraph 1-7. Waiver processes for fixture replacements are outlined by FAA. ***/2/***

f. Forward copies of the completed documentation for each approved waiver with detailed justification to: SMEs:

AFCEC/COSM	139 Barnes Drive, Suite 1 Tyndall AFB FL 32403-5319 afcec.cos.workflow@tyndall.af.mil
AFIMSC/IZB	3515 S. General McMullen Drive San Antonio TX 78226 afimsc.izb.workflow@us.af.mil
AF/A3X	1480 Air Force Pentagon Washington DC 20330-1480 afa3xoa.workflow@pentagon.af.mil
HQ AFSEC/SEFF	9700 G Avenue, South East Kirtland AFB NM 87117-5367 afsec.seff@kirtland.af.mil
HQ AFFSA/A3XA	6500 South MacArthur Blvd Bldg 4, Rm 240 Oklahoma City OK 73169 hqaffsa.xam@us.af.mil
ANG NGB/A7AD	3500 Fetchett Ave Joint Base Andrews MD 20762 (for Air National Guard installations only).

1-11.1.2 AFIMSC.

AFIMSC will:

a. Ensure that all required coordination has been accomplished.

b. Ensure that the type of waiver requested is clearly identified as either "Temporary" or "Permanent." Permanent waivers are required when no further mitigating actions are intended, necessary, or available. Temporary waivers are issued for a specified period during which additional actions to mitigate the situation must be initiated to fully comply with criteria or to allow the acquisition of a permanent waiver. Follow-up inspections will be necessary to ensure that mitigating actions proposed for each temporary waiver are on schedule or progressing. Re-accomplish temporary waivers at the end of the initial period or annually, whichever is earlier.

1-11.2 Existing Air Force Facilities (Grandfather Clause).

A waiver to requirements within this UFC is not required where existing facilities meet prior standards and continue to give satisfactory service.

1-12 US ARMY WAIVERS OF REQUIREMENT.

1-12.1 Waiver Procedures.

1-12.1.1 The installation's design agent, aviation representative (safety officer, operations officer, and/or Air Traffic and Airspace (AT&A) officer) and installation master planner will:

a. Jointly prepare/initiate waiver requests.

b. Submit requests through the installation to the major command (ACOM).

c. Maintain a complete record of all waivers requested and the disposition of each waiver (approved or disapproved). Include a list of required waivers and waivers approved for a specific project in the project design analysis prepared by the design agent aviation representative or installation master planner.

1-12.1.2 The ACOM will:

a. Ensure that all required coordination has been accomplished.

b. Ensure that the type of waiver requested is clearly identified as either "Temporary" or "Permanent." Permanent waivers are required when no further mitigating actions are intended or necessary. Temporary waivers are issued for a specified period during which additional actions to mitigate the situation must be initiated to fully comply with criteria or to obtain a permanent waiver. Follow-up inspections will be necessary to ensure that mitigating actions proposed for each temporary waiver granted have been accomplished.

c. Review waiver requests and forward to US Army Aeronautical Service Agency (USAASA) for action. To expedite the waiver process, ACOMs are urged to simultaneously forward copies of requests to:

Director, US Army Aeronautical Services Agency (USAASA)	ATTN: MOAS-AI 9325 Gunston Road, Suite N319 Fort Belvoir VA 22060-5582
Commander, US Army Safety Center (USASC)	ATTN: CSSC-SPC Bldg. 4905, 5th Ave. Fort Rucker AL 36362-5363
Director, US Army Aviation Center (USAAVNC)	ATTN: ATZQ-ATC-AT Fort Rucker AL 36362-5265
Director, USACE Transportation Systems Center (TSMCX)	ATTN: CENWO-ED-TX 1616 Capitol Ave. Omaha NE 68102-2403

1-12.1.3 USAASA is responsible for coordinating the following reviews for each waiver request:

- Air traffic control and safety and risk assessments by USASC.
- Technical engineering review by TSMCX.

Based upon these reviews, USAASA makes a final determination. USAASA is responsible for all waiver actions related to Army operational airfield/airspace criteria.

1-12.2 Contents of Waiver Requests.

Reference the standard/criterion to be waived, citing paragraph and page numbers.

1-12.2.1 Justification for Waivers.

Demonstrate that safety and cost factors have been considered in justification for noncompliance, and that they adequately support the Army's mission. Reference special studies which support the decision. Adequate justification for waivers of a requirement are when:

- Specific site conditions (physical and functional constraints) make compliance with existing criteria impractical and/or unsafe:
  - Recurring adverse weather conditions require hangar space to be provided for all aircraft.
  - Lack of land/space makes it necessary to expand hangar space closer to and within the runway clearances.

- Maintaining fixed-wing Class A clearance when support of Class B fixed-wing aircraft operations exceeds 10 percent of airfield operations.

- Deviation(s) from criteria fall within a reasonable margin of safety and do not impair construction of a facility long-range; for example, installing security fencing around and within established clearance areas.

- Construction that does not conform to criteria is the only alternative to meet mission requirements. Evidence of analysis and efforts taken to adhere to criteria and standards must be documented and referenced.

1-12.2.2 Operational Factors.

Include information on the following existing and/or proposed operational factors used in the assessment:

- Mission urgency.
- All aircraft by type and operational characteristics.
- Density of aircraft operations at each air operational facility.
- Facility capability Visual Flight Rules (VFR) or Instrument Flight Rules (IFR)).
- Use of self-powered parking versus manual parking.
- Safety of operations (risk management).
- Existing navigational aids (NAVAID).

1-12.2.3 Alternatives Considered.

Record all alternatives considered, their consequences, required mitigation, and evidence of coordination.

1-12.3 Existing US Army Facilities. (Grandfather Clause)

A waiver to requirements within this UFC is not required where existing facilities meet prior standards and continue to give satisfactory service.

1-13 METRICATION OF DIMENSIONS.

Use ICAO standard English or metric equivalents rounded off (e.g., 30 meters equals 100 feet), although they do not represent exact conversions. No change in standard dimensions, tolerances, or performance specifications is needed if they are applied consistently.

Note: Executive Order 12770, signed by President George H. W. Bush on July 25, 1991, citing the Metric Conversion Act of 1975 (Public Law 94-168 (15 U.S.C. 205a et seq), directs departments and agencies within the executive branch of the United States Government to "take all appropriate measures within their authority" to use metric units in federal programs - Federal Register page and date: 56 FR 35801; July 29, 1991

1-14 PHOTOMETRIC REQUIREMENTS.

Photometric requirements in this UFC are based on standards established by the ICAO and FAA**.** They have been modified as necessary to accommodate Air Force requirements.

1-15 EXISTING FACILITIES.

Do not use this document as the sole basis for advancing standards for existing facilities and equipment, except where necessary for a minimum acceptable level of safety, quality, and performance. If there is a change in mission that results in a reclassification of the facility, an upgrade to current standards is required. When existing facilities are modified, construction must conform to the criteria in this UFC unless waived per paragraphs 1-11 and 1-12. If new generation equipment must be integrated with older equipment, make certain any differences in individual performance do not degrade performance of the overall system.

1-16 DOCUMENT ORGANIZATION.

Chapters 1 through 11 provide siting criteria for the design of specific installations. They also provide application criteria to ensure that planned installations are appropriate for their intended purpose.

Chapters 12 and 13 contain information concerning design, installation and performance characteristics for each system, including an explanation of the purpose, configuration, construction, photometrics, and related equipment guidelines approved for US Army and Air Force use.

1-17 \4\ SUPPLEMENTAL CRITERIA 21 May 2018

The following documents supplement this UFC. The technical papers provide additional information for airfield lighting and NAVAIDS equipment that is suitable for use on military airfields, inspection requirements on an ongoing basis for airfield visual aid systems, and the Army's portable lighting requirements for theater of operations airfields. Air Force Expeditionary Airfield Lighting Systems guidance for contingency and expeditionary operations and temporary FOBs are provided at https://www.wbdg.org/ffc/dod/supplemental-technical-documents.

- UFC 3-535-02, *Design Drawings for visual Air Navigation Facilities*, supplements this UFC and provides drawing details for design and construction of individual components of visual navigation facilities. Note that some details apply only to a specific Service. Ensure that the appropriate Service detail is used for the specific project under design.

- TSEWG TP-20, *Air Visual Air Navigation Facilities: Qualifying Equipment*

- TSEWG TP-21, *Visual Air Navigation Facilities: Air Facility Equipment Inspection And Testing*

- Army Only: TSEWG TP-22, *Airfield/Heliport/Helipad Portable Lighting Requirements in a Theater of Operations (TO).* ***/4/***

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CHAPTER 2 APPLICATION CRITERIA

2-1 PURPOSE OF CHAPTER.

This chapter provides application criteria to ensure that the installation of visual air navigation facilities is appropriate for the purposes intended and that they are adequate to support desired levels of operation.

2-2 RELATION TO ELECTRONIC FACILITIES.

Except for Visual Flight Rules (VFR) operations, electronic facilities are required to provide initial positioning and direction information to an approaching aircraft. Visual air navigation aids are necessary to ensure a timely and safe transition from the instrument phase of an approach to its visual phase. The planned operational level for an instrument runway can be achieved only through a combination of appropriate electronic and visual guidance systems. Failure to include the required visual aids in the planning of an instrument runway will degrade the utility of the electronic systems. Conversely, enhancing a runway with inappropriate visual aids will waste resources while providing little operational advantage.

2-3 APPLICATION OF REQUIREMENTS.

Use the criteria in this chapter for planning, budgeting, and installing visual air navigation facilities. Do not upgrade or increase visual aids to a support a higher operational requirement unless the runway, taxiway, or helipad has been officially approved for the new level of operation and all appropriate electronic aids have been installed or are programmed for installation. Waivers are required for all deviations in accordance with paragraph 1-11 (Air Force) or 1-12 (US Army), as applicable.

2-4 REQUIREMENTS.

Table 2-1A contains requirements for Air Force airfields; requirements for US Army airfields are contained in Table 2-1B. Helipad/heliport requirements are listed in Table 2-2. Theater of Operations (TO) Airport Heliport/Helipad Visual Requirements are listed in Table 2-3. Each table contains application criteria for operational categories and the related visual aid requirements. A table of criteria for Navy airfields/heliports is contained in NAVAIR 51-50AAA-2.

2-4.1 Not Required (NR) designates a visual aid which is not required for a particular operation and is therefore not specifically provided to support that operation.

2-4.2 Not Applicable (NA) designates a visual aid whose operational performance is not necessary to support a particular operation or where a particular operation that could be supported is not required.

2-4.3 Optional (OPT) designates a visual aid which is not required under normal conditions, but may be installed to support or enhance operations. It may also apply to a visual aid which is required only under certain conditions, meteorological or otherwise. Design of any installed visual aid must comply with provisions of this UFC or the FAA Advisory Circular referenced, in that priority order.

2-5 LIGHT EMITTING DIODE (LED) LIGHT FIXTURES.

Increased use of airport LED light fixtures on the air operations area (AOA) has created problems when these fixtures are interspersed with their incandescent counterparts. LED light fixtures are essentially monochromatic (aviation white excepted); as such, their perceived color and/or brightness differs from equivalent incandescent fixtures. These differences may distort the visual presentation to a pilot. Therefore, LED light fixtures must not be interspersed with incandescent lights of the same type.

Example: An airport adds an extension to a runway. On the existing runway, the runway centerline light fixtures are incandescent. The airport decides to install LED runway centerline fixtures on the new section of runway and retains the incandescent fixtures on the existing section. This interspersion of dissimilar technology is not approved for installation.

In addition, defective incandescent fixtures must not be replaced with their LED counterparts. When replacing a defective light fixture, make certain that the replacement uses the same light source technology to maintain a uniform appearance.

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2-5.1 LED Placements.

2-5.1.1 Permitted Placements.

LED fixtures are permitted for the following locations:

- Runway guard lights (RGL).
- Stop bars.
- Taxiway edge lights.
- Wind cones - available only with integral LED L-810s with IR component.
- Obstruction Lights (exceptions): weather equipment and navaids under 35 feet with integral LED w/IR may be used, with the agreement of airfield management.
- Lead-on and lead-off lights.
- Airfield signage.

- PAPI installations in current projects, but PAPIs may not be upgraded to LEDs for the sole purpose of removing incandescent PAPIs.

For each of these approved systems, each circuit and paired signs/fixtures (e.g., fixtures operating as a system and located on each side of a taxiway or a runway entrance/exit) must be either LED or incandescent technology.

For Air Force: Surge protection is required. The interface circuitry (if any) and solid state devices must be designed to withstand and/or include separate surge protective devices which have been tested against defined waveforms detailed in Table 4*,* "Location Category C2" of ANSI/IEEE C62.41-1991*, Recommended Practice on Surge Voltages in Low Voltage AC Power Circuits*, *Standard 1.2/50 microsecond (µS) — 8/20 µS combination wave*. Peak voltage is 10 kilovolts; peak current is 5 kiloamps with a nominal ratio of peak open circuit voltage to peak short circuit current of 2 ohms.

When LED fixtures are installed on an airfield, FAA AC 150/5340-30J, Section 1.4 applies.

2-5.1.2 Air Force Placement Restrictions and Prohibitions.

- Runway edge lights: Lamp availability may become an issue. LEDs are prohibited as long as incandescent lamps are available. New projects may be coordinated with MAJCOM/A3 relative to LED option.

- Touchdown zone lights: MR16 quartz lamps are still readily available. When edge lights are replaced with LEDs, TDZ lights may also be replaced with LEDs in the same project.

- Approach lights and systems: PAR56 (300-500 watt) lamps and PAR38 (150 watt) lamps for elevated approach lights are becoming scarce. As long as lamps are available, continue to use existing systems. Exception (coordinated with MAJCOM/A3): replacement of the elevated approach light fixtures on bases without routine covert operations may be by LED when other lamps become unavailable, with written coordination between CE and base Operations. Notify base Operations to publish use of LEDs for the approach systems in the Flight Information Publication (FLIP). For bases with routine covert operations, these systems may be supplemented with a 4- or 6-fixture landing zone system, to identify beginning and end of runway usable area during covert operations.

- Runway centerline lights: MR16 quartz lamps are still readily available. For Air Force Category II and III airfields, runway centerline lights may be replaced with LEDs in the project that replaces edge lights and TDZ lights with LEDs.

- Obstruction lights: FAA certified LED L-810 fixtures are available with an IR component. There is currently no availability with a heat signature.

When the inventory of lamps can no longer be replenished by the manufacturer, a project to install LED edge lights with an IR emitter component may be programmed, with coordination with airfield management.

If any exception is exercised, ensure airfield management publishes a warning on the use of LEDs in the Flight Information Plan (FLIP). Rationale: Any critical piece of the lighting system attached to the runway environment needs to be published so transitory aircrew will understand their limitations on using that field for NVG operations.

Bases which are home to aircraft with head up displays in the cockpits should incorporate a modified LZ layout of five incandescent fixtures at the threshold and approach. These fixtures should be a separate circuit not tied to a circuit consisting of LED fixtures. Photometric requirements apply.

2-5.1.3 Army Placement Restrictions and Prohibitions.

Use of LED fixtures is optional for all airfield lighting systems on Army airfields.

For each of these systems, each circuit, system, or paired signs/fixtures (e.g., fixtures operating as a system and located on each side of a taxiway or a runway entrance/exit) must be either LED or incandescent technology. Intermixing of lighting technology is not allowed.

Runway edge, threshold, and end lights must all be the same lighting technology. Steady burn approach lights may be a different lighting technology from the approach lighting sequenced flashers and runway edge, threshold, and end lights.

Airfields must:

- Consider the availability of replacement lamps and fixtures.
- Determine if LED fixtures will have any potential impact on the DoD mission (USTRANSCOM, Air Mobility Command) and equipment (night vision imaging systems).
- Ensure that LEDs on Army airfields are certified as meeting FAA specifications or Host Nation agreements.
- Conduct a hazard analysis of impact to local operations and ensure risk is accepted at the appropriate level.
- Publish use of LED fixtures in the approach lighting system or runway perimeter lighting in the Flight Information Publication (FLIP). ***/4/***

2-5.2 Signage.

2-5.2.1 Sign Temperature Requirements.

Signs must withstand the following operating temperature ranges

Class 1 signs: -4 to -131 degrees F (-20 to +55 degrees C)

Class 2 signs: -40 to 131 degrees F (-40 to +55 degrees C)

Shipping and storage temperatures for Class I and 2 signs range from -67 degrees F (-55 degrees C) to 131 degrees F (55 degrees C). Sign temperature requirements are modified to accommodate LEDs. Reference AC 150-5345-44.

2-5.2.2 Sign Definitions.

See AC 150-5345-44, paragraph 1.2.6.

2-5.2.3

- Mandatory and informational signs.
- Distance remaining signs.
- Runway holding position signs.
- Separate signs in a sign array.

\2 Each signage system/array/paired array must be all LED or all incandescent technology. ***/2/***

2-5.3 LED Performance Requirements.

FAA Engineering Brief (EB) 67 provided detailed information in 2012 relative to LED concerns, but updates through Airport Improvement Program guidance indicate that, for normal operations, LEDs may be used for HIRL. At the same time, considerations for Enhanced Visual Systems must be addressed on an airfield use basis – for military, this translates to airfield mission.). AIP Program Guidance Letter 19-02 for HIRL airfields sums it up by the statement of vigilance, “EFVS users with IR-based sensors are reminded to review Safety Alert for Operator (SAFO) 09007.”

https://www.faa.gov/airports/aip/guidance_letters/media/aip-pgl-19-02-LED-HIRL.pdf

http://www.faa.gov/airports/engineering/engineering_briefs/

Table 2-1A Air Force Airfield Visual Facilities Requirements

Facility	Operational Category				
	Night VMC	Non-Precision	Precision I	Precision II	Precision III
APPROACH AIDS					
High Intensity Approach Light System (ALSF-1)	NR	NR	R[1]	NA	NA
High Intensity Approach Light System (ALSF-2)	NR	NR	NR	R	R
Short Approach Lighting (SALS)[16]	NR	OPT	NA	NA	NA
Simplified Short Approach Lighting (SSALR)[17]	NR	OPT	OPT	NA	NA
Medium Intensity Approach Light System (MALSR)	NR	NR	OPT[1]	NA	NA
Runway End Identifier Lights (REIL)	OPT	OPT	OPT	NA	NA
Precision Approach Path Indicator (PAPI)	R[2][19]	R[2][19]	R	NA	NA
RUNWAY AIDS					
High Intensity Runway Edge Lights (HIRL)	R	R	R	R	R
Medium Intensity Runway Edge Lights (MIRL)[12, 15]	OPT	OPT	OPT[1]	NA	NA
Threshold Lights[20]	R	R	R	R	R
Runway End Lights	R	R	R	R	R
Runway Distance Remaining (RDR) Signs[3]	R	R	R	R	R
Runway Centerline Lights (RCL)	NA	NA	NR	OPT	R
Touchdown Zone Lights (TDZL)[13]	NA	NA	NR	OPT	R
TAXIWAY AIDS					
Taxiway Edge Lights	R	R	R	R	R
Taxiway Centerline Lights	NA	NA	OPT	OPT	OPT[8]
Taxiway Clearance Bar (Hold Point)	NA	NA	OPT	R	R[14]
Runway Guard Lights – Elevated, FAA Type L-804[9]	NR	NR	OPT	R	R
Runway Guard Lights – In-pavement, FAA Type L-852G	NR	NR	OPT	R	R
Runway Entrance-Exit Lights	NR	NR	NR	NR	R
Guidance Signs (information and location)[11]	R	R	R	R	R
Mandatory Signs[3]	R	R	R	R	R
MISCELLANEOUS AIDS					
Airfield Beacons	R	R	R	R	R
Wind Cones[4]	R	R	R	NA	NA
Obstruction Lights	R	R	R	R	R
Emergency Power[5]	R	R	R	R	R
Apron Area Flood Lighting[7]	R	R	R	R	OPT
Apron Edge Lights[6, 10]	R	R	R	R	R

Legend:

Note: Backup power must be provided for visual landing aids listed as "R" (required).

R Required.
OPT Optional, as recommended by the wing commander and approved by the MAJCOM.
NR Not required.
NA Not applicable. Not appropriate for this application.
(1) MAJCOM approval is required to substitute MALSR for an ALSF-1 to avoid installation errors.
(2) Required only on primary runways.

(3) All new taxiway location and direction signs, RDRs, and mandatory signs are required to be internally lighted. See paragraph 9-1.4.
(4) Wind direction indicators are required to meet ICAO Annex 14 (paragraph 5.1, "Indicators and Signaling Devices"). Lighted cone is required. Integral LED obstruction light is allowed.
(5) Emergency power required for all equipment designated "R."
(6) Apron edge lighting is not required if apron flood lighting is provided. Base Ops may approve reflective markers.
(7) Apron edge lighting is required for safety concerns, even if apron flood lighting is provided. Base Ops may approve reflective markers. See UFC 3-530-01 for Apron Floodlighting.
(8) For surface movement and guidance of CAT III systems, refer to FAA AC 120-57.
(9) Runway guard lights require monitoring IAW FAA AC 150/5345-46, paragraph 3.7.3.4.
(10) Use of retroreflective markers is allowed where additional marking is required, but are not a substitute for apron edge lights.
(11) FAA requires guidance signs for the purpose of clear guidance and direction and presents signage for average airfield configuration, but simple airfields (single runway and few entering taxiways) or airfields which utilize a "follow me" vehicle, may not require complicated signage. Required with the use of REILS.
(12) Optional with the use of REILS.
(13) Required for medium intensity.
(14) Required for RVR <600 only.
(15) For RVR ≥ 2400 only.
(16) Waiver is required.
(17) Waiver is not required when used as a subsystem of ALSF-1.
\3\ (18) Outage thresholds (relating to number of missing fixtures, both total and consecutive, that invoke various stages of airfield shutdown) are identified by FAA. **/3/**
\4(19) Visual Approach Slope Indicators may be used in visual approach conditions if Airfield Operations requires.
(20) For bases home to aircraft with Head Up Displays, use a modified LZ incandescent configuration if threshold lights are LED.**/4/**

2-6 REFERENCE DOCUMENTS.

Use the most current revision or publication date for documents referenced in this UFC.

This UFC is supplemented by technical papers for various topics supporting the selection, testing and maintenance of airfield navigation aids. See Appendix A for references citations.

Table 2-1B US Army Airfield Visual Facilities Requirements

Facility	Operational Category		
	Night VMC	Non-Precision	Precision Approach (IMC)
			I
APPROACH AIDS			
High Intensity Approach Light System (ALSF-1)	NA	NA	OPT
High Intensity Approach Light System (ALSF-2)	NA	NA	NA
Short Approach Lighting (SALS)	NA	OPT	NA
Simplified Short Approach Lighting (SSALR)	NA	OPT	OPT
Medium Intensity Approach Light System (MALSR)	NA	NA	R
Runway End Identifier Lights (REIL)	OPT	OPT	OPT
Precision Approach Path Indicator (PAPI) **\4**(5)**/4/**	OPT	OPT	OPT
RUNWAY AIDS			
High Intensity Runway Edge Lights (HIRL)	NA	NA	R
Medium Intensity Runway Edge Lights (MIRL)	R(1)	R(1)	NA
High Intensity Threshold Lights	NA	NA	R
Medium Intensity Threshold Lights	R	R	NA
Runway End Lights	R	R	R
Runway Distance Remaining Signs (RDR)	R	R	R
Runway Centerline Lights (RCL)	NA	NA	NA
Touchdown Zone Lights (TDZL)	NA	NA	NA
TAXIWAY AIDS			
Taxiway Edge Lights	R	R	R
Taxiway Centerline Lights	NA	NA	NA
Taxiway Hold Lights/Stop Bar	NR	NR	NA
Runway Entrance-Exit Lights	OPT	OPT	OPT
Runway Guard Lights	OPT	OPT	OPT
Guidance Signs (Informative)(3)	R	R	R
Guidance Signs (Mandatory)(3)	R	R	R
MISCELLANEOUS AIDS			
Airfield Rotating Beacons	R	R	R
Wind Cones(2)	R	R	R
Obstruction Lights	R	R	R
Emergency Power(4)	R	R	R
Apron Area Flood Lighting **\4**(6)**/4/**	R	R	R
Apron Edge Lights(6)	R	R	R

Legend:

R Required.
OPT Option as determined by the airfield commander and approved by USAASA.
NR Not required.
NA Not applicable.
(1) Use with medium intensity threshold lights.
(2) A lighted Style 1 wind cone; aviation community to determine size.
(3) All taxiway location and direction signs, RDRs, and mandatory signs are required to be internally lighted. See paragraph 9-1.4.
(4) Emergency power required for all "R" equipment.
(5) See paragraph 3-7.1.1 for additional guidance.
(6) Apron edge lighting is not required if apron flood lighting is provided.

Table 2-2 Helipad/Heliport Visual Facilities Requirements

FACILITY	HELIPAD/HELIPORT				Helicopter Runway
	VMC	VMC	IMC		IMC
	Day Non-Instrument	Night Non-Instrument	Non-Precision Instrument	Precision Instrument Category I	Precision Instrument Category I
Perimeter Lights	NA	R	R	R	NA
Approach Direction Lights	NA	OPT	OPT	OPT	NA
Landing Direction Lights	NA	OPT	OPT	OPT	NA
Approach Lights Category I	NA	NA	NA	R	R
Floodlights	NA	OPT	OPT	OPT	OPT
Visual Glide Slope Indicator System(5)	NA	OPT	OPT	OPT	OPT
Medium Intensity Runway Edge Lights	NA	NA	NA	NA	R
Threshold Lights	NA	NA	NA	NA	R
Runway End Lights	NA	NA	NA	NA	R
Taxiway Edge Lights	NA	OPT	OPT	OPT	R
Illuminated Heliport - Guidance Signs(2)	R(1)	R	R	R	R
Obstruction Lighting	R	R	R	R	R
Hoverlane Lighting	NA	OPT	R	R	R
Rotating Beacon	R	R	R	R	R
Apron Flood Lighting	NA	OPT	OPT	OPT	OPT
Apron Edge Lighting	NA	OPT	OPT	OPT	R
Wind Direction Indicator	R(1)	R	R	R	R
Emergency Power(3, 4)	NA	R	R	R	R

Legend:
R Required
OPT Optional
NA Not applicable
(1) Not lighted for DAY VMC (VFR).
(2) See FAA AC 150/5340-18 for guidance. All guidance signs are internally lighted.
(3) Emergency power required for all “R” equipment.
(4) See paragraph 7-9.5.1, “Justification.”
(5) See paragraph 7-6.

NOTE: Refer to Chapter 7 and Chapter 8 for criteria.

Table 2-3 Theater of Operations (TO) Airfield/Heliport/Helipad Visual Requirements (For Army Only)

FACILITY	Night VMC	Non-Precision Approach Runway	Precision Approach Runway
			Category I
APPROACH AIDS			
Precision Approach Path Indicator (PAPI)	OPT	OPT	OPT
Medium Approach Lighting System w/ Runway Alignment Indicator Lights (RAIL) (MALSR)	OPT	OPT	OPT
RUNWAY AIDS			
Medium Intensity Runway Edge Lights (MIRL)	R(1)	R(1)	R(1)
Threshold Lights	R(1)	R(1)	R(1)
Runway End Lights	R(1)	R(1)	R(1)
Runway Distance Remaining (RDR) Signs	R(2)	R(2)	R(2)
TAXIWAY AIDS			
Taxiway Edge Lights	OPT(3)	OPT(3)	OPT(3)
MISCELLANEOUS AIDS			
Wind Cones	OPT	OPT	OPT
Obstruction Lights	R	R	R

Legend:

R Required

OPT Optional - highly recommended when situation and operational environment permits.

(1) The lighting system must be connected to an emergency power source such as a diesel-generator or independent utility. For US Army-only aviation operations the emergency power source need only be readily available for connection.

(2) Runway distance remaining signs are not required to be lighted, but must conform to UFC 3-535-01 RDR lighted standards. Runway distance remaining signs are optional for rotary-wing aircraft-only operations.

(3) FAA Type L-853 Retro-reflective Markers may be used when power is not available.

NOTES:

1. A TO in Joint Publication 3-0, Joint Operations, is defined as an operational area defined by the geographic combatant commander for the conduct or support of specific military operations.
2. Technical Paper 22 (TSEWG TP22) provides criteria and other essential information for this lighting.

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CHAPTER 3 STANDARDS FOR LIGHTED APPROACH AIDS

3-1 APPROACH LIGHT SYSTEM WITH SEQUENCED FLASHING LIGHTS (ALSF-1).

Approach lighting systems provide the basic means to transition from instrument flight to visual flight for landing. Descriptions of ALS types follow.

3-1.1 Purpose.

The ALSF-1 is a high intensity approach lighting system with sequenced flashing lights required for operations under Category I conditions. This system provides visual guidance to pilots aligning approaching aircraft with the runway and attempting final corrections before landing at night or during low visibility.

3-1.2 Associated Systems.

In addition to electronic aids such as an Instrument Landing System (ILS), Radar Approach Control (RAPCON)-(includes a Primary Surveillance Radar (PSR) subsystem and a Secondary Surveillance Radar (SSR), a Precision Approach Radar (PAR) Subsystem, and an Operations Subsystem), or microwave landing system (MLS), the ALSF-1 should include features described in paragraphs 3-1.2.1 through 3-1.2.3:

Note: NATO interoperability requires that we use RAPCON until at least 2040 because there is not a better system for military use.

3-1.2.1 A paved runway at least 150 feet (50 meters) wide and 6,000 feet (2,000 meters) long. Shorter runways may be approved for special operating conditions. The runway must be equipped with:

- Precision approach markings.
- High-intensity edge lights.
- High-intensity threshold lights.
- End lights.
- Runway distance remaining signs (RDR). Runway distance remaining signs are used to provide distance remaining information to pilots during takeoff and landing operations. The signs are located along the side(s) of the runway, and the inscription is a white numeral on a black background, as shown in Figure 15 to indicate the runway distance remaining in increments of 1,000 feet.

- Runway visual range (RVR) system.

3-1.2.2 An approach having a paved or stabilized end zone area extending 1,000 feet (300 meters) into the approach area and wider than the runway. The first 300 feet (100 meters) of paved or stabilized area requires the same slope as the first 1,000 feet (300 meters) of the runway. Slope of the remainder of paved or stabilized area may not exceed ±1.5 percent. These criteria and further details are provided in UFC 3-260-01.

3-1.2.3 Air traffic control support during normal operating hours.

3-1.3 Configuration.

The ALSF-1 consists of a pre-threshold light bar, a terminating bar, a 1,000 foot (300 meter) cross bar, centerline lights (barrettes), sequenced flashing lights, and threshold lights. Figure 3-1 shows a typical layout. The system centerline coincides with the extended runway centerline. The overall system length is 3,000 feet (900 meters), extending from the runway threshold into the approach zone. The generally accepted convention for locating lights along the longitudinal axis of approach light systems for the standard is that the longitudinal axis is divided in 100-foot (30 meters) stations with station 0+00 located at the threshold and higher station numbers located farther into the approach. Thus, a light a station 1+10 would be located 110 feet (33 meters) into the approach, measured from the threshold. Subsequent stations would be at 2+10, 3+10, etc. If a site condition requires a wider separation, the separation may be divided between barrettes. For example, a deviation resulting in a 34-foot increase in separation may result in 1+10, 2+20, 3+34, 4+34, etc. with a maximum deviation of 50 feet (15.2 meters) for the entire 3,000 foot approach.

Configurations of individual system elements are illustrated in Figure 3-1.

\4 For the Air Force: If terrain or other local conditions prevent a full-length installation, the system may be shortened to not less than 2,400 feet (720 meters). **/4/**

3-1.3.1 Pre-threshold Bar.

The pre-threshold bar consists of two barrettes in aviation red lights placed symmetrically about the system centerline at station 1+00. Each barrette consists of five lights on 3.5-foot (1-meter) centers, with the innermost light centers located not less than 75 feet (22.5 meters) nor more than 80 feet (24 meters) from the system centerline.

3-1.3.2 Terminating Bar.

The terminating bar consists of two barrettes in aviation red lights located symmetrically about and perpendicular to the system centerline at station 2+00. Each barrette consists of three lights on 5 foot (1.5 meter) centers, with the outermost light centers located 25 feet (7.5 meters) from the system centerline.

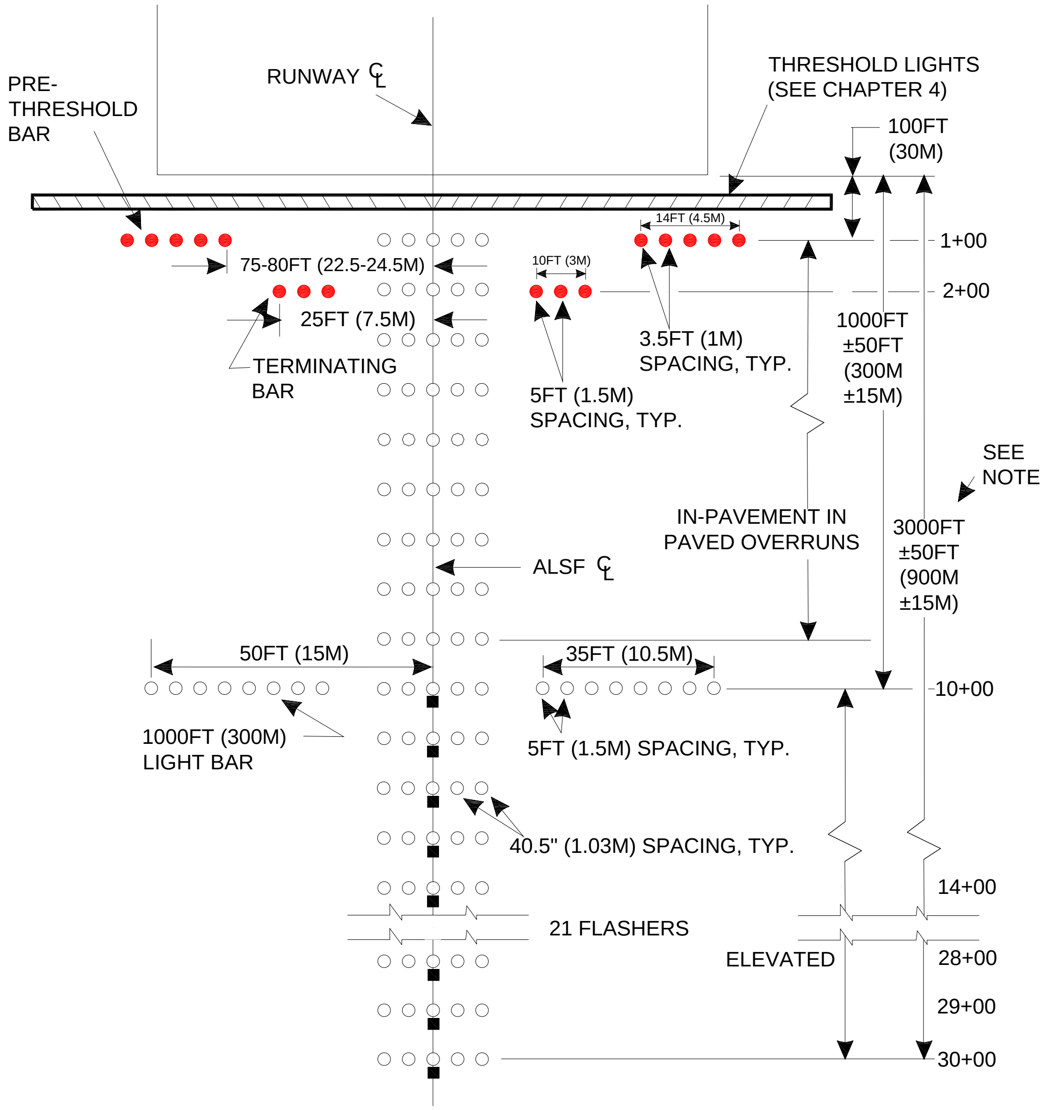
3-1.3.3 1,000-Foot (300-meter) Light Bar.

This light bar consists of two barrettes in aviation white lights located symmetrically about and perpendicular to the system centerline at station 10+00 and in line with the centerline barrette at that station. Each barrette consists of 8 lights on 5-foot (1.5-meter) centers with the outermost light center located 50 feet (15 meters) from the system centerline.

3-1.3.4 Centerline Lights.

The centerline lights consist of a series of barrettes with aviation white lights located at 100-foot (30-meter) intervals along the system centerline, from station 1+00 to station 30+00. Each barrette consists of five lights spaced at 40.5 inches (1.03 meters) on centers, centered on and perpendicular to the system centerline. Centerline lights on elevated supports may be spaced at 40.5 inches (1.03 meters) to fit standard FAA support hardware.

Figure 3-1 ALSF-1 Configuration



LEGEND:
- ○ WHITE LIGHTS
- ● RED LIGHTS
- ■ SFL (WHITE)

NOTE:
SEE TEXT FOR ADJUSTMENTS AND TOLERANCES.

NOT TO SCALE

3-1.3.5 Sequenced Flashing Lights (SFL).

The sequenced flashing lights are a series of twenty-one (21) flashing lights located on the system centerline, beginning at station 10+00, 1,000 feet (300 meters) from the threshold and ending at station 30+00. The light flashes at a rate of twice per second, in sequence from the outermost light station toward the threshold, appearing as a ball of white light traveling toward the runway. Sequenced flashing lights may be uniformly mounted a maximum of 4 feet (1.2 meters) below the steady burning lights, or when in-pavement lights are used, they may be displaced a maximum of 5 feet (1.5 meters) into the approach along the system centerline to avoid visual or physical interference between light units. (Note: SFLs are sometimes referred to in the field as “rabbits.”)

3-1.3.6 Threshold Lights.

While threshold lights are not actually a section of the approach light system, they must be present and installed according to paragraph 4-4.

3-1.4 Photometrics.

Optimum aiming of lights depends on the design and light output of the fixtures used in the system. Light fixtures may be designed to support several applications and may have fixed patterns and aiming angles which differ from the standard. Light aiming and patterns other than those prescribed in this UFC may be used, provided the resultant light pattern produces equivalent light intensities in the areas required by this UFC.

3-1.4.1 Intensity.

Luminous characteristics for the lights used in the ALSF-1 system are described below. The beam widths are measured symmetrically about the mechanical axis of the light unit, unless otherwise noted. Elevated and in-pavement SFLs must provide light intensities as specified in Tables 3-1 and 3-2. Steady burning lights used in the system must meet the intensity requirements presented in Figure 3-2.

Table 3-1 Required Intensities for Elevated SFLs

Intensity Setting	Maximum Effective Intensity (Candelas)	Minimum Effective Intensity (Candelas)
High	20,000	8,000
Medium	2,000	800
Low	450	150

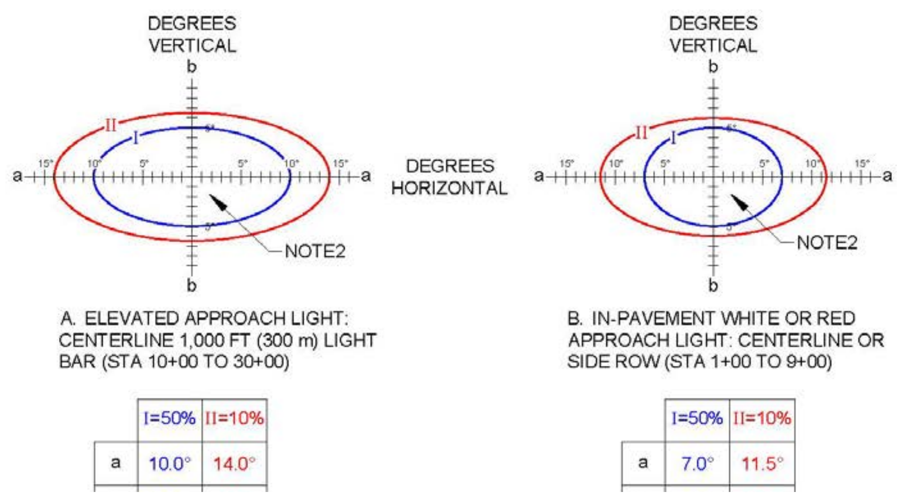
Measure effective intensity over a rectangular pattern not less than 10 degrees by 30 degrees. Corners may be rounded on a 5 degree radius to determine compliance.

Table 3-2 Required Intensities for In-Pavement SFLs

Intensity Setting	Maximum Effective Intensity (Candelas)	Minimum Effective Intensity (Candelas)
High	20,000	5,000
Medium	2,000	500
Low	600	150

Measure effective intensity over a rectangular pattern not less than 10 degrees by 30 degrees. The geometric center of this 10 degree by 30 degree pattern must be 7 degrees ± 1/3 degree above horizontal. Corners may be rounded on a 5 degree radius to determine compliance.

Figure 3-2 Approach Lighting Photometrics



NOTES:
1. ALL CONTOURS ARE ELLIPSES CALCULATED BY EQUATION: $(X/a)^2 = (Y/b)^2 = 1$.
2. THE MINIMUM AVERAGE INTENSITY OF THE MAIN BEAM (INSIDE CONTOUR i) IS 20,000 CD WHITE OR 5,000 CD RED.
3: **\2** ACTUAL AVERAGE INTENSITY MAY CHANGE OVER TIME. ***/2/***
4. CONTOURS I AND II INDICATE THE MINIMUM PERCENT VALUES OF THE MAIN BEAM INTENSITY.
5. FOR IN-PAVEMENT FIXTURES, THE PORTION OF LIGHT CUT OFF BY THE MOUNTING SURFACE MAY BE DISREGARDED.

3-1.4.2 Intensity Control.

Provide brightness control with five intensity steps for steady burning lights and three intensity steps for flashing lights. Match the intensity of the sequenced flashing lights to the intensity of the steady burning lights in accordance with Table 3-3.

Table 3-3 Steady and Flashing Light (SFL) Intensity Percentages

Intensity Step	Steady Light Intensity Percentage	Flashing Light Intensity Percentage	Intensity Step
1	0.16	2.00	1
2	0.8	2.00	1
3	4.00	10.00	2
4	20.00	100.00	3
5	100.00	100.00	3

3-1.4.3 Aiming.

Aim the beams of all approach lights into the approach zone and away from the threshold, with the beam axis parallel to the extended runway centerline. Vertically aim elevated, unidirectional, steady burning lights in accordance with Table 3-4. Aiming angles are based on a three-degree glide slope. If other glide slope angles are used, adjust the vertical aiming for the same degree of difference. Some existing SFLs may have fixed angles for the beam. Refer to paragraph 4-4.8 when threshold lights are used as part of an approach system.

Table 3-4 Elevation Setting Angles for ALSF-1

STEADY-BURNING TYPE FAA-E-982 LIGHTS					
Station	Setting Angle Above Horizontal* (Degrees)		Station	Setting Angle Above Horizontal* (Degrees)	
	Preferred	Permitted		Preferred	Permitted
30+00	8.0	8.0	14+00	7.0	7.0
29+00	7.9	8.0	13+00	6.9	7.0
28+00	7.9	8.0	12+00	6.9	7.0
27+00	7.8	8.0	11+00	6.8	7.0
26+00	7.7	7.5	10+00	6.7	6.5
25+00	7.7	7.5	9+00	6.7	6.5
24+00	7.6	7.5	8+00	6.6	6.5
23+00	7.6	7.5	7+00	6.5	6.5
22+00	7.5	7.5	6+00	6.5	6.5
21+00	7.4	7.5	5+00	6.4	6.5
20+00	7.4	7.5	4+00	6.3	6.5
19+00	7.3	7.5	3+00	6.3	6.5
18+00	7.2	7.0	2+00	6.2	6.0
17+00	7.2	7.0	1+00	6.2	6.0
16+00	7.1	7.0	0+00	6.1	6.0
15+00	7.0	7.0			

*See airfield commander for glide slope. For glide slopes other than 3 degrees, increase or decrease the setting angle by the amount of approach slope variance. For example, given a 2½ degree glide slope, the setting angle would be decreased by ½ degree.
Tolerances are ± 0.2 degrees.
Elevated SFLs are all aimed 6 degrees above horizontal.

3-1.4.4 Obstruction Clearances.

3-1.4.4.1 A light plane (or planes) in which the lights of the system are located is used for determining obstruction clearances of the approach lights.

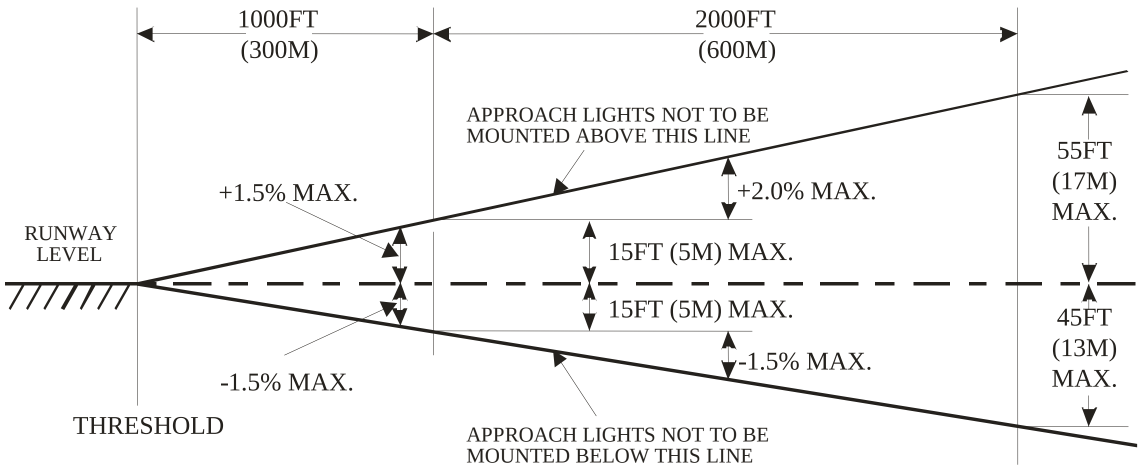
3-1.4.4.2 Side boundaries of the light plane are 200 feet (60 meters) on each side of the extended runway centerline (except SFL).

3-1.4.4.3 End boundaries are at the runway threshold and at 200 feet (60 meters) before the start of the approach light system.

3-1.4.4.4 All lines in the plane perpendicular to the centerline are level.

3-1.4.4.5 The ideal light plane (Figure 3-3) is a single horizontal plane through the runway threshold. If the 1,000 feet (300 meters) of the runway at the threshold end is sloped, the first 300 feet (100 meters) of the paved or stabilized area of the approach zone and the light plane for this area must continue with the same slope.

Figure 3-3 Ideal Light Plane Elevation Limits



NOTE: THE BOUNDARIES OF THE LIGHT PLANES ARE THE RUNWAY THRESHOLD, 200FT (60M) AHEAD OF THE END LIGHT STATION, AND 200FT (60M) EACH SIDE OF CENTERLINE.

3-1.4.4.6 The final 700 feet (210 meters) of the paved or stabilized area may have a slope of not more than 1.5 percent up or down. From the 1,000-foot (300-meter) light bar to the beginning of the approach light system, the preferred light plane is horizontal and includes the 1,000-foot (300-meter) light bar lights.

3-1.4.4.7 If the clearance of obstructions or terrain prohibits using a horizontal light plane, this plane may be sloped. The slope of this plane must not exceed 2 percent up or 1.5 percent down. The preferred light plane in the area beyond the 1,000-foot (300-meter) light bar is a single plane, but changes in the slope of the plane are permitted. All light planes start and end at a light station and contain not less than three light stations.

3-1.4.5 Light Plane Obstructions.

3-1.4.5.1 No objects may penetrate the light plane except for ILS components and components of airfield lighting systems that are fixed by function. These components must not interfere with the pilot's view of the approach lights when on a normal approach and must be obstruction lighted. For clearance purposes, all roads, vehicle parking areas, and railroads are considered vertical solid objects.

3-1.4.5.2 To avoid roads, buildings, railroads, or other obstacles, it may be necessary to move a light station away from its nominal location. Where this is so, see paragraph 3-1.3.

3-1.4.5.3 Obtaining needed clearance above a road is preferred over controlling traffic. Obstructions beyond the approach light system must comply with UFC 3-260-01.

3-1.4.6 Configuration Adjustments.

Siting considerations may require adjustment of the approach light system configuration. Adjustments described in paragraphs 3-1.4.6.1 and 3-1.4.6.2 are permitted without a waiver.

3-1.4.6.1 System Centerline.

The system centerline may be offset laterally not more than 2 feet (0.6 meters) to maintain alignment with runway centerline lights or to avoid installation problems.

3-1.4.6.2 Light Station Adjustments.

To avoid roads, buildings, railroads, or other obstacles, it may be necessary to move a light station longitudinally away from its nominal location. In such instances, change the light bar spacing to distribute the difference uniformly so the spacing between adjacent light stations is kept at 100 feet ± 10 feet (30 meters ± 3 meters) and the system length is maintained.

3-1.4.7 Construction Tolerances.

Tolerances for positioning ALSF-1 and ALSF-2 lights are as follows:

- Light stations must be installed longitudinally within ± 6 inches (150 millimeters) of the designated location.
- The lateral tolerance for installation of a light bar is ± 3 inches (± 75 millimeters).
- The tolerance for distance between individual lights is ± 1 inch (± 25 millimeters).
- Mounting height tolerances are:

Support Height	Mounting Tolerance
0-6 ft (0-1.8 m)	1 in. (25 mm)
6–40 ft (1.8-12 m)	2 in. (50 mm)
40+ ft (12+ m)	3 in. (75 mm)

- Deviation from a line perpendicular to the ALS centerline is ± 1 inch (± 25 millimeters) maximum.
- Vertical angular alignment of a light must be within 1 degree.
- Horizontal angular alignment of a light must be within 5 degrees.

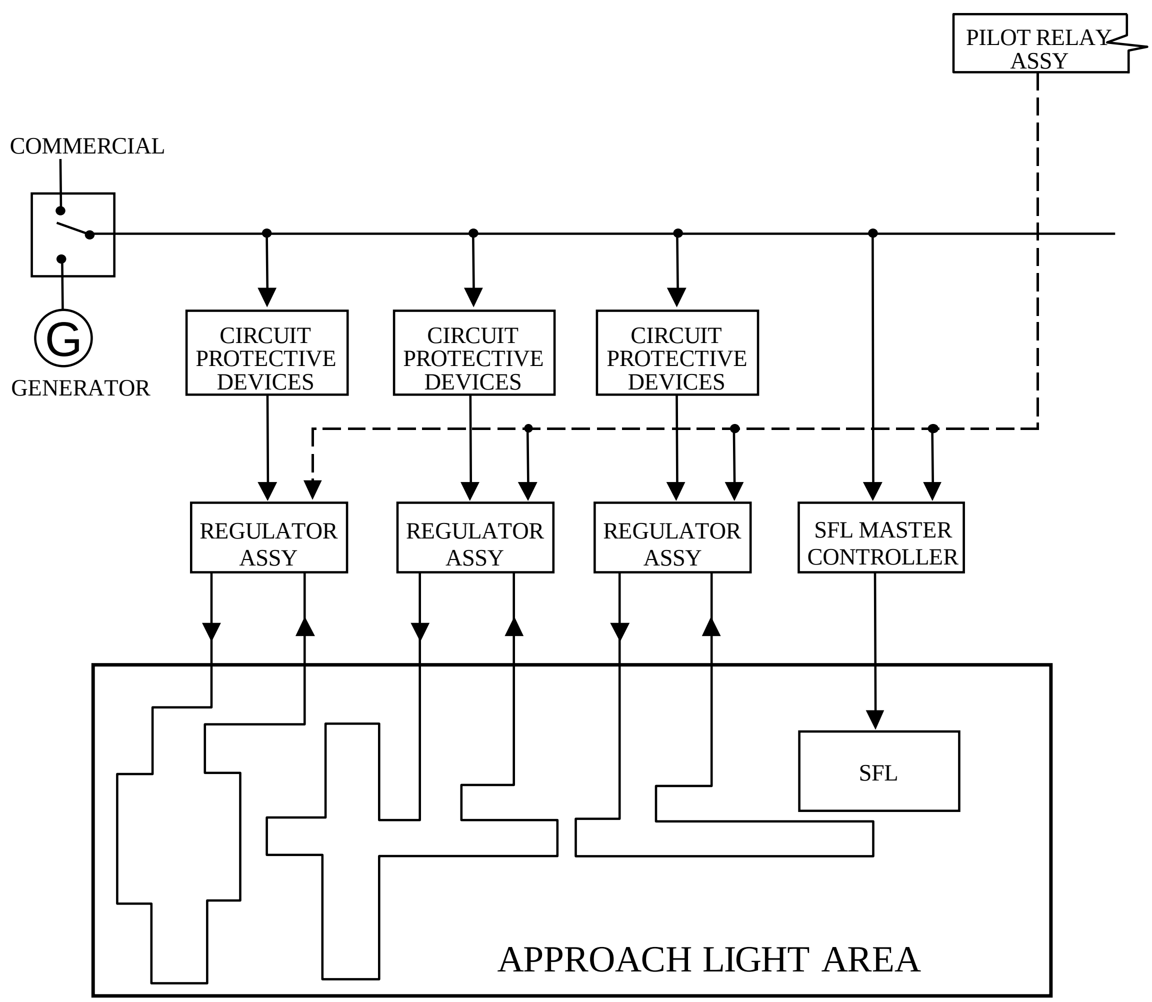
3-1.5 Power Requirements.

Provide a standby power system with automatic transfer in accordance with UFC 3-540-01, *Engine-Driven Generator Systems for Backup Power Applications*. Do not locate the power and control substation or the standby power equipment within the approach light area, shown in Figure 3-4. For Air Force, voltage driven navaids may be supported by larger conductors and other design elements such as step up/down transformers, to assist with voltage drop. Any transformers located near the navaid served must be either installed outside the mandatory zone of frangibility or low profile or both.

Figure 3-4 Block Diagram-Approach Lighting, ALSF-1

FAA L-854 Radio Controller

Assembly (Pilot Controlled Lights)



3-1.6 Control Requirements.

Provide remote on-and-off and five-step intensity control for the steady burning lights. Provide remote on-and-off for SFL with automatic three-step intensity matched with steady burning lights (reference paragraph 3-1.4.2). Provide new systems or systems receiving major upgrades with the capability of being electrically switched from the ALSF-1 configuration to the simplified short approach lighting system with runway alignment indicator lights (SSALR) configuration described in paragraph 3-4. No waiver is required for this configuration capability. Provide a selector switch in the control tower to switch from ALSF-1 to SSALR. SFLs must not be operated without steady burning lights.

3-1.7 Monitoring Requirements.

Monitoring is required if the runway will be used when the RVR is below 2,400 feet (720 meters). Provide monitoring when required, which, at a minimum, gives a positive indication at the control facility that power is provided to the system. Refer to FAA AC 150/5345-10 for additional information about monitoring and AC 150/5345-56, *Specification for L-890 Airport Lighting Control and Monitoring System (ALCMS).*

3-1.8 Equipment.

3-1.8.1 Fixtures.

Use in-pavement fixtures in paved overruns and in displaced thresholds and other locations where fixtures are subject to damage by jet blast. They must be mounted on corrosion-resistant anodized aluminum light bases set in a concrete foundation. No part of the unit must extend more than 1 inch (25 millimeters) above surrounding pavement. All other fixtures must be elevated and capable of being aimed as required by this UFC.

3-1.8.2 Fixture Support.

Support elevated fixtures on frangible, low-impact resistant, or semi-frangible supports depending on the required mounting height:

Mounting Height	Support Type
0-6 ft (0-1.8 meters)	Frangible
6-40 ft (1.8-12 meters)	Low impact resistant
40+ ft (12+ meters)	Semi-frangible

See FAA AC 150/5345-45 for more information about the available classifications (types and styles) of support structures. See also FAA AC 150/5220-23 for additional information about the selection and installation of frangible fittings.

3-1.9 Compliance with International Military Standards.

3-1.9.1 AFIC.

AFIC AIR STD 90/27 has been cancelled.

3-1.9.2 NATO.

This standard meets requirements for a Type II approach lighting system as described in NATO STANAG 3316 (Edition 11). except for the vertical aiming of the lights.

3-2 ALSF-2.

3-2.1 Purpose.

The ALSF-2 is a high intensity approach light system for operations under Category II or Category III conditions.

3-2.2 Configuration.

The ALSF-2 (reference Figure 3-5) is configured as an ALSF-1 system modified as described in paragraphs 3-2.2.1 through 3-2.2.4.

3-2.2.1 Pre-threshold Bar.

The red lights at the pre-threshold bar are removed.

3-2.2.2 Terminating Bar.

The red lights are re-designated to nine stations of side row lights.

3-2.2.3 500 Foot (150 Meter) Light Bar.

A 500 foot (150 meter) light bar is added. It consists of two barrettes of aviation white lights, located symmetrically about and perpendicular to the runway centerline, in line with the centerline barrette at that station. Each barrette consists of four aviation white lights on 5 foot (1.5 meter) centers, centered in the space between the centerline lights and the side row lights.

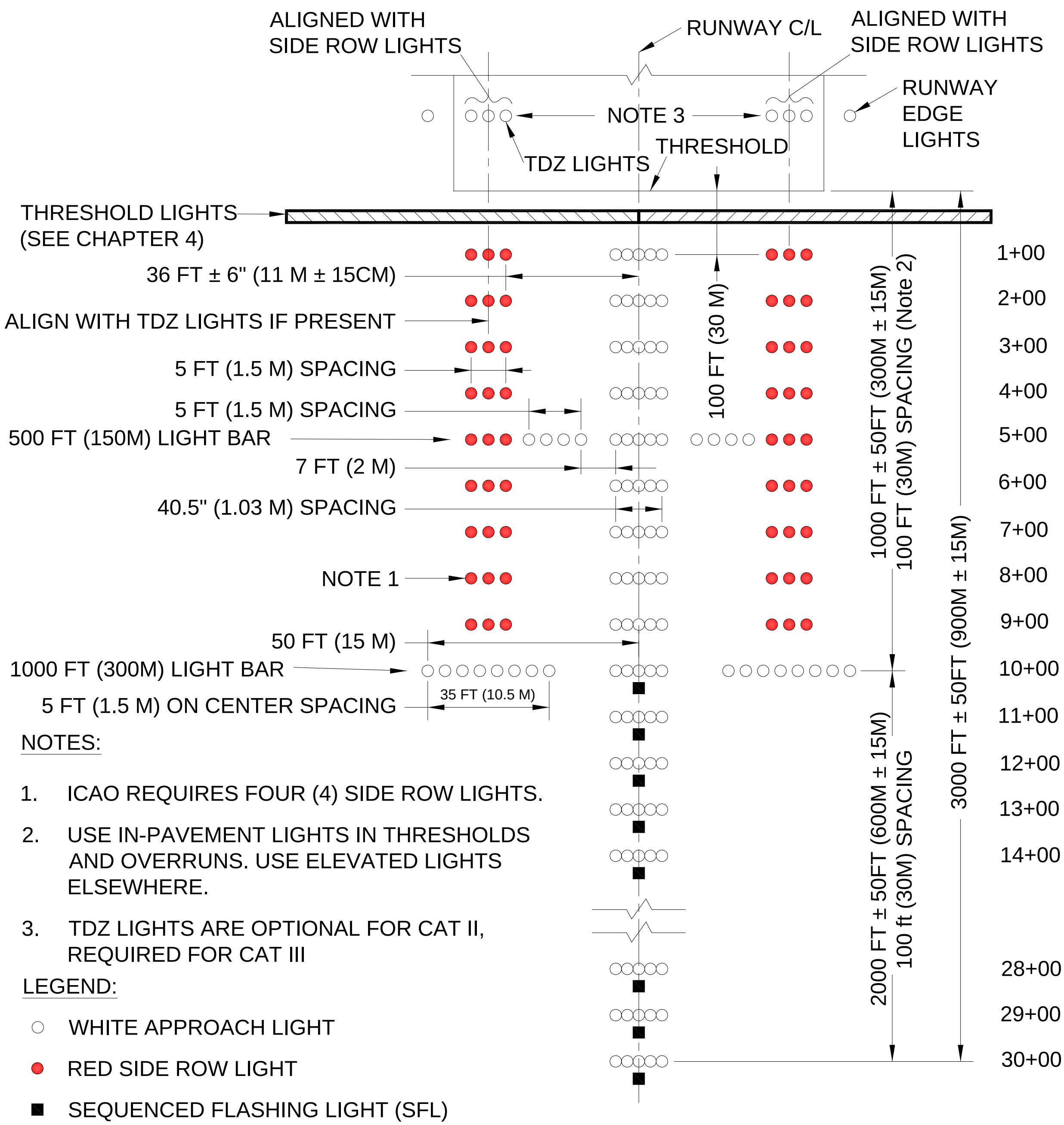
3-2.2.4 Side Row Lights.

Side row lights are added to the inner nine lights' stations at stations 1+00 through 9+00. They consist of barrettes containing three aviation red lights, located symmetrically about and perpendicular to the extended runway centerline at each of the light stations 1+00 through 9+00. The lights in each barrette are on 5 foot (1.5 meter) centers, with the innermost light spaced 36 feet (11 meters) from the extended runway centerline.

3-2.3 Photometrics.

The requirements in paragraphs 3-1.4 and 3-1.4.1 for ALSF-1 apply.

Figure 3-5 ALSF-2 Configuration



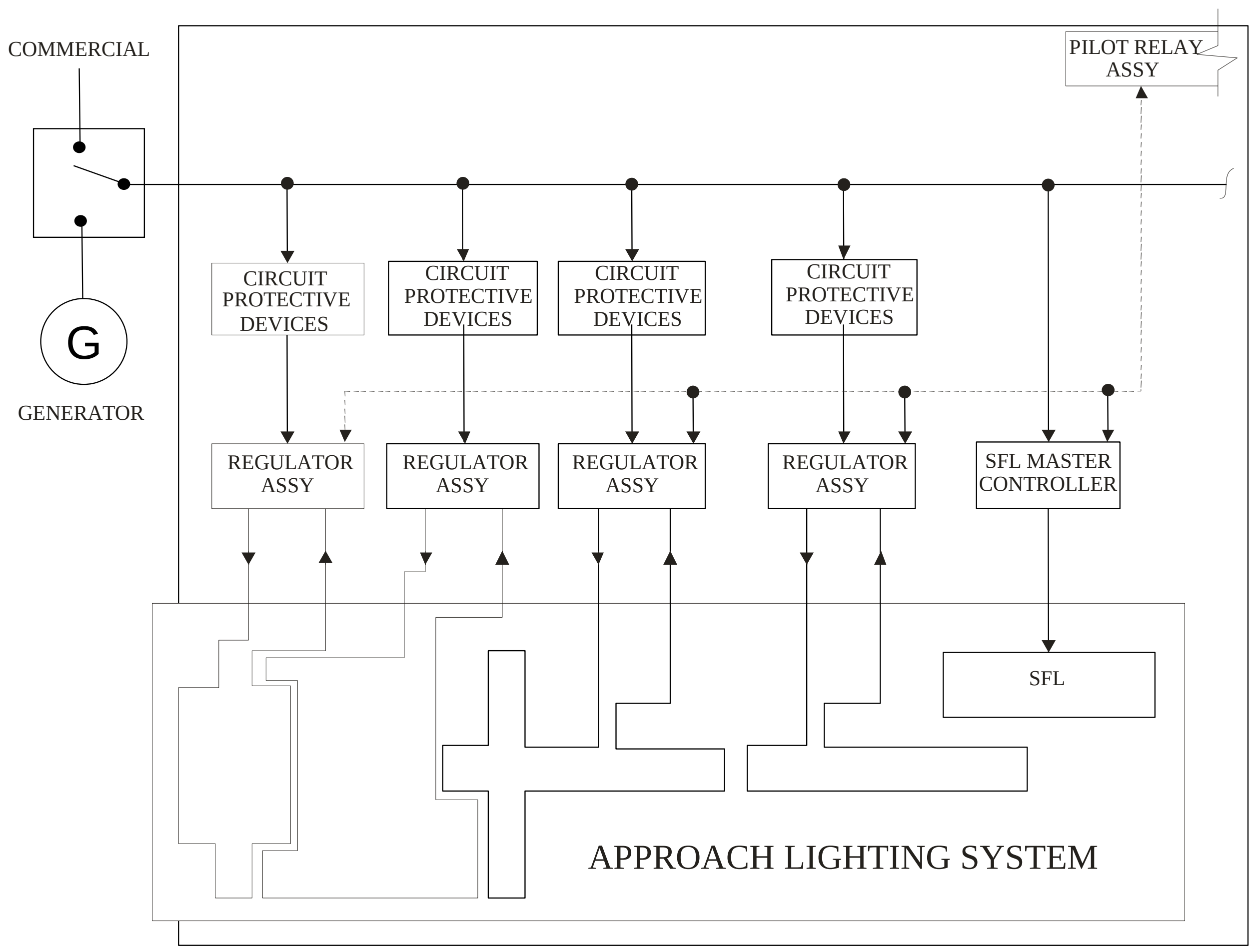
3-2.4 Aiming Criteria.

The aiming criteria as specified in paragraphs 3-1.4.2 through 3-1.4.5 for ALSF-1 apply, except that the red side row lights must be aligned with any existing touchdown zone lights.

3-2.5 Power Requirements.

Provide a standby power system with an automatic transfer switch. Switch should be complete with 30 seconds of power loss. Consider manual transfer, prior to a predicted severe thunderstorm, for a CAT II or CAT III operational runway. Allow the generator to run prior to the storm and until 30 minutes past the end of the storm. Operating parameters should be recorded prior to switching back to commercial power. This operation may be used as the generator test for the month. ***/2/***

Figure 3-6 Block Diagram-Approach Lighting, ALSF-2



3-2.6 Control Requirements.

The control requirements in paragraph 3-1.6 for ALSF-1 systems apply. Provide a selector switch in the control tower to switch from ALSF-2 to SSALR.

3-2.7 Monitoring Requirements.

Provide monitoring that, at a minimum, gives a positive indication at a control facility that power is being provided to the system. Refer to FAA AC 150/5345-10 for additional information about monitoring.

3-2.8 Equipment.

See paragraph 13-9.1; fixtures and supports for ALSF-1 apply.

3-2.9 Compliance with International Military Standards.

3-2.9.1 AFIC.

AFIC AIR STD 90/27 has been cancelled.

3-2.9.2 NATO.

This standard meets the requirements for a Type II system as described in NATO STANAG 3316 (Edition 11). except for the vertical aiming of the lights.

3-3 SHORT APPROACH LIGHTING SYSTEM (SALS).

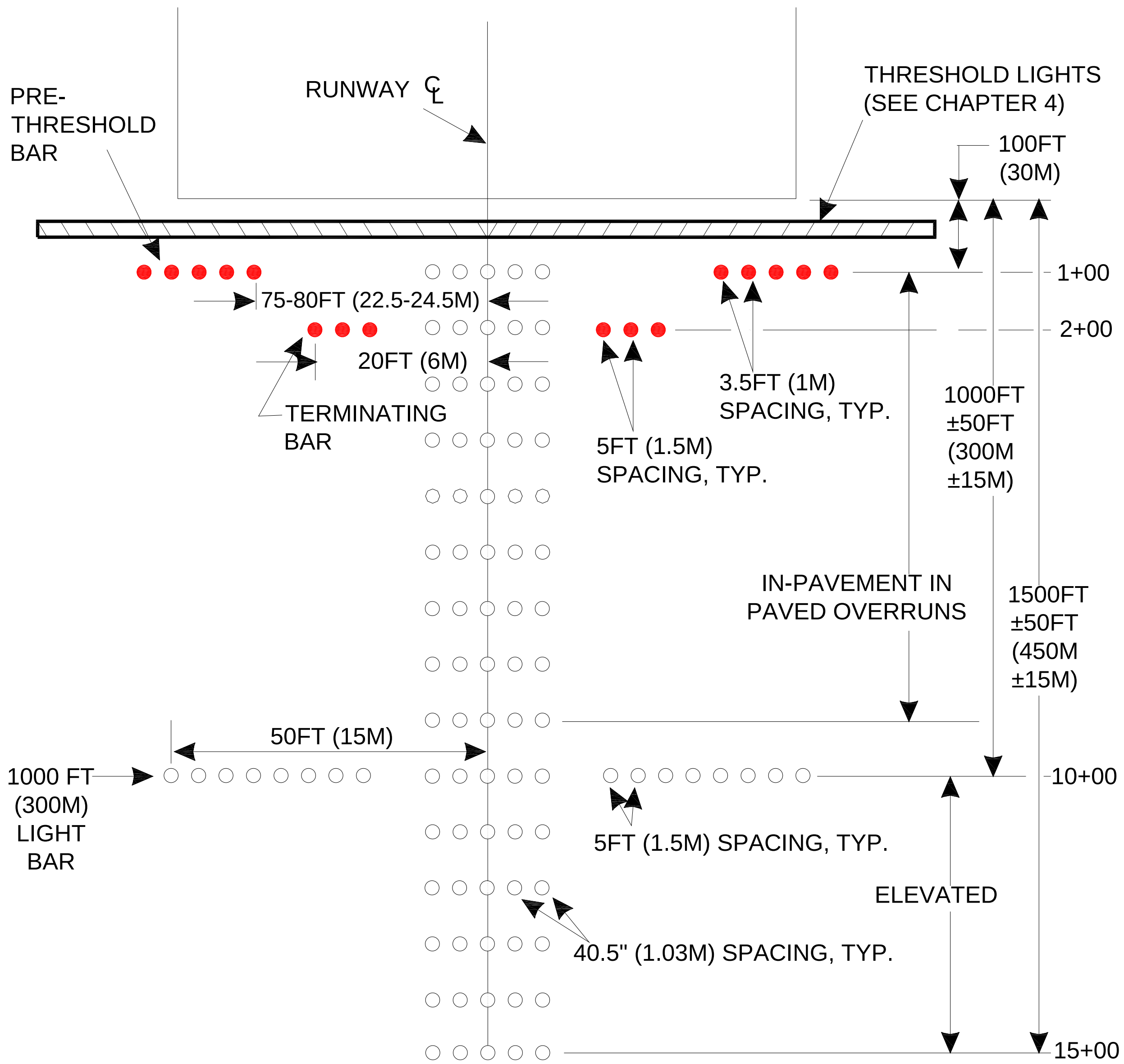
3-3.1 Purpose.

The SALS is a high intensity approach lighting system used at locations where installation space is limited and non-precision approaches are conducted. This configuration requires a waiver. See paragraphs 1-11 or 1-12 for Air Force and Army waiver processes, respectively.

3-3.2 Configuration.

The SALS, as shown in Figure 3-7, is configured as an ALSF-1, except the system is 1,500 feet (450 meters) long and does not have sequenced flashing lights.

Figure 3-7 SALS Configuration



LEGEND:

○ WHITE LIGHTS

● RED LIGHTS

NOTE: Requires a waiver for Air Force use.

3-3.3 Photometrics.

The requirements in paragraph 3-1.4 for ALSF-1 apply.

3-3.4 Power, Control and Monitoring.

The requirements in paragraphs 3-1.5, 3-1.6 and 3-1.7 for the ALSF-1 system apply. See Figure 3-4 for the system block diagram.

3-3.5 Equipment Used.

See paragraph 13-9.1 for applicable components.

3-3.6 Compliance with International Standards.

There are no equivalent systems in the previous AFIC AIR STDs or current NATO STANAGs.

3-4 SIMPLIFIED SHORT APPROACH LIGHTING SYSTEM WITH RUNWAY ALIGNMENT INDICATOR LIGHTS (SSALR).

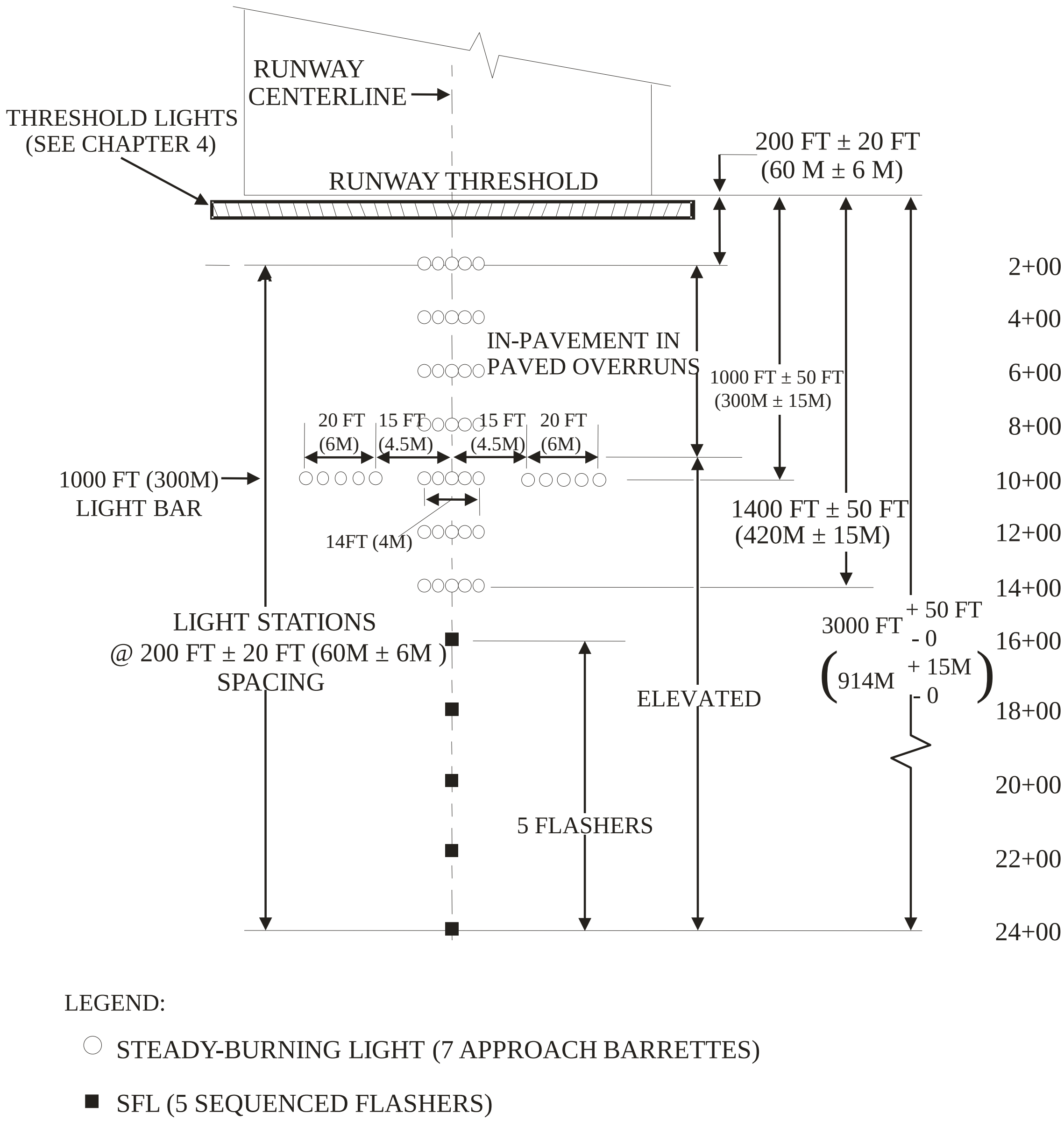
3-4.1 Purpose.

The SSALR is a simplified version of the ALSF-1 or ALSF-2. This system configuration is achieved by electrically switching off elements of an ALSF-1 or ALSF-2 for energy conservation purposes, when weather conditions permit.

3-4.2 Configuration.

The SSALR, shown in Figure 3-8, is configured as an ALSF-1, except that the outer 16 light stations of the steady burning lights are inoperative, as are the odd numbered light stations on the inner 1,400 feet (420 meters), the outer three lights at each end of the 1,000-foot (300 meter) light bar, and the red lights in the terminating and pre-threshold bars. Also, the sequenced flashing lights are inoperative at stations 10+00 through 15+00 and at the odd numbered stations thereafter.

Figure 3-8 SSALR Configuration



3-4.3 Other Requirements.

All other requirements in paragraph 3-1 for ALSF-1 apply.

3-4.4 Compliance with International Standards.

There are no equivalent systems in the previous AFIC AIR STDs or NATO STANAGs.

3-5 MEDIUM INTENSITY APPROACH LIGHT SYSTEM WITH RUNWAY ALIGNMENT INDICATOR LIGHTS (MALSR).

3-5.1 Purpose.

The MALSR is an economy medium intensity approach light system (MALS) with SFLs used as the FAA standard system for Category I runways. This system provides visual approach area identification, centerline alignment, and roll reference for aircraft making approaches for landings during day or night operations. Although the MALSR system is FAA-approved for Category I approaches, a waiver is required for the system to be installed at an Air Force base. See paragraph 1-11.

3-5.2 Associated Systems.

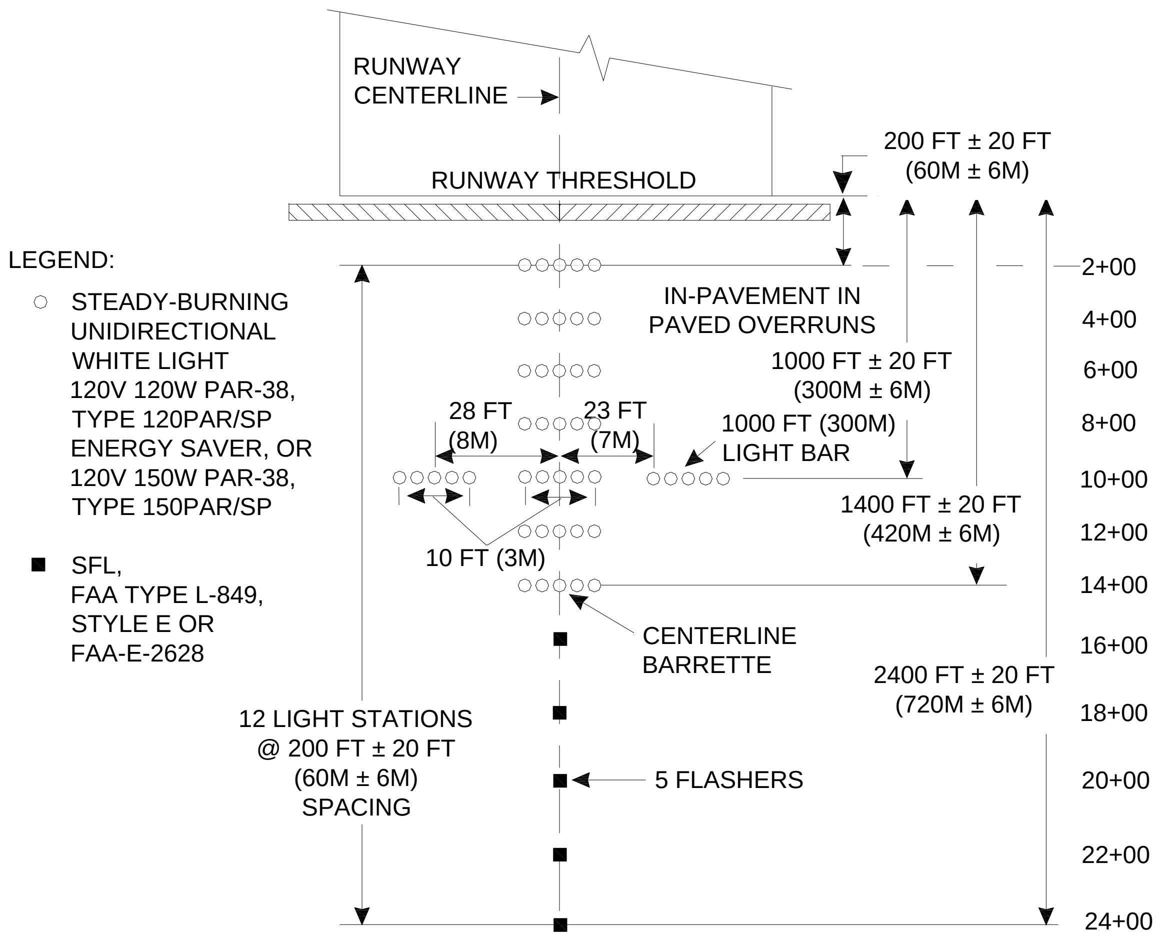
In addition to electronic aids such as ILS, which provide electronic guidance down to a minimum of not less than 200 feet (60 meters) minimum decision height Category I condition, the MALSR includes the following:

- Non-precision or precision approach instrument runway markings.
- Runway threshold lights or displaced threshold lights.
- PAPI.

3-5.3 Configuration.

The MALSR is a system of light bars, barrettes, and SFLs in the approach zone immediately ahead of the runway threshold. The MALSR is configured the same as a SSALR, except the SSALR is a subsystem of an ALSF-1, while the MALSR is a complete system. The MALSR consists of 12 light stations made up of seven approach barrettes and five SFLs located at even numbered-stations. The 1,000-foot (300-meter) bar consists of five lights either side of the approach barrette.

Figure 3-9 MALSR Configuration



3-5.4 Photometrics.

See FAA-E-2980 for information about MALSR photometric requirements. The color of the steady-burning lights must be aviation white for the centerline and 1,000 foot (300 meter) light bar lights. The color of the SFL may be aviation white or bluish-white (xenon flash tube). The intensity steps based on rated intensity must be 100 percent for high setting, 20 percent for medium setting, and 4 percent for low setting for the steady burning centerline and 100 foot (30 meter) light bar lights; and 100 percent for high setting, 10 percent for medium setting, and 2 percent for low setting for the SFL. The SFL must flash in sequence from the outer end toward the runway threshold at a steady rate between 60 and 120 times per minute. The interval between flashes of adjacent lights must nominally be 1/30 seconds.

3-5.5 Aiming Criteria.

See FAA-E-2980 for information about MALSR light aiming settings. Aim the beams of all approach lights into the approach zone and away from the threshold with the axis of the beams parallel in azimuth to the extended runway centerline. Aim the elevated lights vertically in accordance with Table 3-5. The in-pavement lights have fixed elevation angles for the beams, and only require that the light base flange be level.

Table 3-5 Elevation Setting Angles for MALSR

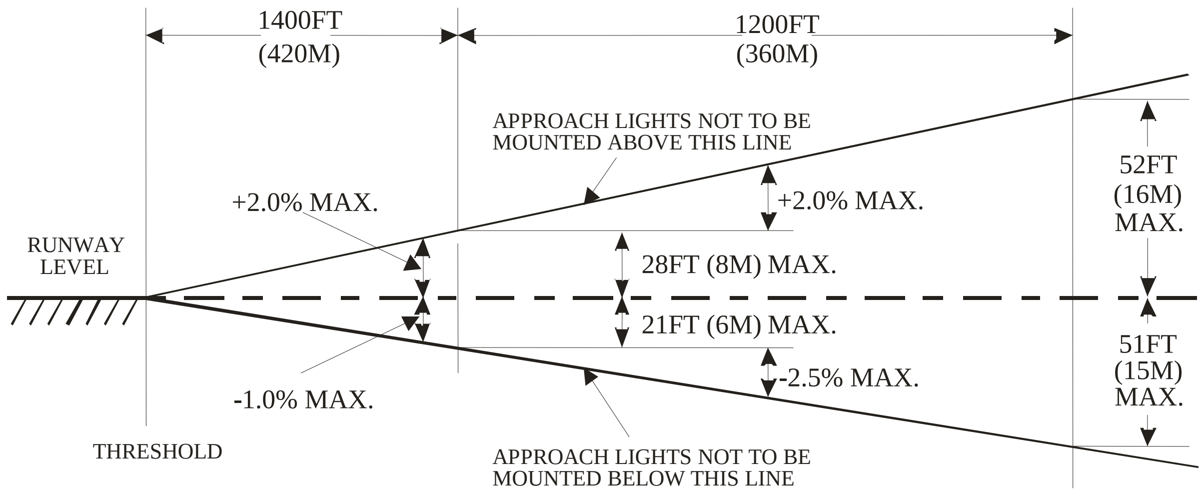
ELEVATED UNIDIRECTIONAL LIGHTS Steady-Burning Lights					
Station	Setting Angle above Horizontal (Degrees)		Station	Setting Angle above Horizontal (Degrees)	
	Preferred	Permitted		Preferred	Permitted
14+00	3.7	3.5	6+00	3.4	3.5
12+00	3.6	3.5	4+00	3.3	3.5
10+00	3.5	3.5	2+00	3.2	3.0
8+00	3.4	3.5			
All elevated SFL are aimed 6 degrees above horizontal.					

3-5.6 Approach Light Planes.

See FAA-E-2980 and FAA JO 6850.2B for information about MALSR approach light planes. Restrictions described in paragraphs 3-5.6.1 and 3-5.6.2 apply for a MALSR installation.

3-5.6.1 The approach light plane (Figure 3-10) is an area 400 feet (120 meters) wide centered on the extended runway centerline which begins at the runway threshold and extends 200 feet (60 meters) beyond the outermost light in which the approach light centers are located. All lines in the planes perpendicular to the runway centerline are horizontal. Ideally, all the lights will be installed in a single horizontal plane at the same elevation as the runway threshold without any penetrations by fixed solid objects. Where deviations are necessary for terrain or objects which cannot be removed, the sections starting from the first approach light station from the threshold must have a slope not exceeding +2.0 percent upward or -1.0 percent downward for the steady-burning barrette lights. For the SFL section, the slope of the light planes must not exceed +2.0 percent or -2.5 percent. Any sloping or horizontal plane must contain not less than three light stations.

Figure 3-10 Light Plane Elevation Limits



NOTE: THE BOUNDARIES OF THE LIGHT PLANES ARE THE RUNWAY THRESHOLD, 200FT (60M) AHEAD OF THE END LIGHT STATION, AND 200FT (60M) EACH SIDE OF CENTERLINE.

3-5.6.2 No object may penetrate the light plane except for ILS components and components of airfield lighting systems which are fixed by their function. These components must not interfere with the pilot’s view of the approach lights when on a normal approach and must be obstruction lighted. For clearance purposes, all roads, vehicle parking areas and railroads are considered as vertical solid objects. The required clearance above railroads is 23 feet (6.9 meters) and above interstate highways is17 feet (5.1 meters). The clearance required above other public roads and parking lots is 15 feet (4.5 meters). The clearance above private and military roads is 10 feet (3 meters). Airfield service roads, where traffic is controlled, are not considered as obstructions. Control of the service road traffic must be accomplished by appropriate signs or directly by the control tower; parking or stopping is prohibited between the signs. The airfield commander must approve the means of control and the wording of signs. It is preferred to get the needed clearance above a road, rather than controlling the traffic so the clearance is not necessary. Obstructions beyond the approach light system must be in accordance with UFC 3-260-01/TM 5-803-7.

3-5.6.2.1 Every effort must be made to remove or relocate objects which penetrate the light plane. For objects which cannot be moved, the height must be the minimum possible and located as far from the runway threshold as possible.

3-5.6.2.2 The major command has waiver authority to adjust the slope of the light plane beyond the allowances in this UFC to avoid interference from obstacles that cannot be removed or lowered.

3-5.7 Tolerance.

The tolerances for positioning steady burning MALSR lights are as follows:

- Lateral tolerance of a light bar is 6 inches (150 mm).
- Distance between individual light centers in a barrette is 2 inches (50 mm).
- Height for light centers up to 6 feet (1.8 meters) is 2 inches (50 mm).
- Height for light centers over 40 feet (12 meters) is 6 inches (150 mm).
- Tolerance for vertical aiming of light units is 1.0 degree.
- Tolerance for horizontal aiming of light unit is 5 degrees.

Longitudinal deviation for light bars or single SFL from a designated station is 20 feet (6 meters), except light stations may be displaced 100 feet (30 meters) to avoid omitting a light station where obstructions cannot be removed or cleared by acceptable clearance planes. Where a light station must be located more than 20 feet (6 meters) from the usual station, position the nearby light stations to provide more uniform spacing between lights.

3-5.8 Power Requirements.

Electrical power for the MALSR approach lights must be supplied as described in paragraphs 3-5.8.1 and 3-5.8.2.

3-5.8.1 For the centerline and 1,000 foot (300 meter) light bar steady-burning lights, a special power unit must furnish power to these lights from a multiple circuit rated at 120 volts or 120/240 volts 3-wire. This power unit must energize the lights at any of the three intensity settings selected.

3-5.8.2 For the SFL, the power to operate these lights is furnished by the master control unit at 120 volts. These lights have individual power supply units which may be combined with or separated from the flasher head. Allow an additional 5 KVA of transformer capacity for the SFL.

Note: Emergency power is not essential for the MALSR system, but if emergency power is available, it requires automatic emergency power transfer – an automatic transfer switch with isolation bypass.

3-5.9 Control Requirements.

The MALSR must be remotely controlled from the airfield lighting control panel in the control tower. Alternate control from the airfield lighting vault is desirable. A separate control must provide for switching ON and OFF and for selecting the intensity setting of the centerline lights, the 1,000 foot (300 meter) light bar lights, and the SFL.

3-5.10 Monitoring Requirements.

Automatic monitoring is not required, but must be operational if installed.

3-5.11 Equipment.

See paragraphs 13-9.5 through 13-9.5.3 for typical MALSR components.

3-5.11.1 Light Supports.

The type of supports used for MALSR lights depends on the height the light or barrette is above the surface, as described in paragraphs 3-5.11.2.1 through 3-5.11.2.3.

3-5.11.1.1 Mount light supports on corrosion resistant aluminum light bases, set in a concrete foundation. In-pavement lights may not project more than 0.75 inch (19 millimeters) above the paved surface.

Use frangible supports for elevated lights 6 feet (1.8 meters) or less.. The support consists of a frangible coupling and sections of 2-inch -(53-millimeter-) diameter conduit elbows set in concrete foundation.

3-5.11.1.2 Use low-impact-resistant supports (LIR) for lights greater than 6 feet (1.8 meters) and 40 feet (12 meters)or less. The individual SFL or five-light barrettes must be installed on low-impact-resistant supports of the correct height. These supports may be non-metallic or of the triangular antenna type; see FAA AC 150/5345-45 or FAA-E-2702.

3-5.11.1.3 For lights more than 40 feet (12 meters) in height, use semi-frangible supports; see descriptions in FAA AC 150/5345-45. The top 20 feet (6 meters) of supports for individual SFL or five-light barrettes must be low-impact resistant and installed on a rigid support of the correct height.

3-5.12 Compliance with International Standards.

There are no equivalents for the MALSR systems in previous AFIC AIR STDs or current NATO STANAGs; however, MALSR systems satisfy requirements for a Category I approach approved by the FAA.

3-6 RUNWAY END IDENTIFIER LIGHTS (REIL).

3-6.1 Purpose.

The REIL system is used to identify the threshold (approach end) of a visual or instrument non-precision runway and provides guidance to pilots during approach for landing. They are effective for identification of a runway surrounded by a preponderance of other lighting, identification of a runway which lacks contrast with surrounding terrain, and identification of a runway during reduced visibility.

The REIL consists of two uni-directional or omni-directional simultaneous discharge-type flashing lights. A light is located at each side of the runway threshold.

The Omni-Directional Approach Light System (ODALS) system uses seven omni-directional discharge-type flashing lights, five of which are installed on an extended runway centerline. The lights flash in sequence and appear as a ball of light traveling toward the runway threshold. This aids the pilot in determining which runway is in use. In addition to the five centerline lights, two lights are installed in a REIL configuration. The two REIL system lights flash simultaneously after the last flash of the centerline lights.

3-6.2 Associated Systems.

Several visual aids must be used when REILs are installed: high intensity runway edge lights, runway threshold lights or displaced threshold lights, and runway markings. The PAPI system may also be an associated visual aid.

3-6.3 Description.

A REIL system consists of two synchronized flashing lights placed symmetrically about the runway centerline in the vicinity of the runway threshold, and are only allowed for use with a PAPI system.

3-6.4 Configuration/Location/Aiming.

See FAA AC 150/5340-30 for REIL installation details.

3-6.5 Photometric Requirements.

3-6.5.1 Unidirectional Fixtures.

See FAA AC 150/5345-51 for equipment-specific details and photometric data.

3-6.5.2 Omnidirectional Fixtures.

Omnidirectional fixtures must flash once per second, producing a white light through 360 degrees horizontally and vertically from +2 degrees to +10 degrees above the horizontal. Light units must be capable of being shielded when required by local conditions. Mount all REIL fixtures on frangible supports. See FAA AC 150/5345-51 for equipment-specific details and photometric data.

3-6.6 Power Requirements.

The system may be powered separately or by use of a power adapter unit connected to the runway light circuit. There is no requirement for standby power.

3-6.7 Control Requirements.

REIL systems may be controlled separately or matched to the associated runway edge light circuit through current sensing relays or other devices. When coupled to the runway edge lights, joint operation with edge lights is as follows:

Edge Light Intensity	REIL Intensity
Off	Off
Step 1 or 2	Low
Step 3	Medium
Step 4 or 5	High

3-6.8 Monitoring Requirements.

There are no monitoring requirements for the REIL system.

3-6.9 Compliance with International Standards.

3-6.9.1 NATO.

The unidirectional flashing lights meet the requirements of NATO STANAG 3316 (Edition 11). except for the displacement distance from the runway edge and the aiming angle.

3-6.9.2 AFIC.

AFIC AIR STD 90/27 has been cancelled.

3-7 PRECISION APPROACH PATH INDICATOR (PAPI) SYSTEM.

3-7.1 Purpose.

The PAPI is an unattended system that provides visual glide path guidance for landing an aircraft. See paragraph 12-3 for PAPI siting.

3-7.1.1 Justification.

For the US Army, a PAPI will be provided where one or more of the following conditions exists:

- The runway is used by turbojet or other aircraft with similar approach guidance requirements.

- The pilot of any type of aircraft may have difficulty judging the approach due to inadequate visual guidance that may be experienced during an approach over water or featureless terrain by day, or in the absence of sufficient extraneous lights in the approach area by night.

- If judging the approach is difficult due to misleading information, such as produced by deceptive surrounding terrain or runway slopes. Objects in the approach area may present a serious hazard if an aircraft descends below the normal approach path, especially if there are no navigation aids to give warning of these objects.

- Physical conditions at either end of the runway present a serious hazard in the event of an aircraft undershooting or overrunning the runway.

- Terrain or prevalent meteorological conditions are such that the aircraft may be subjected to unusual turbulence during approach.

3-7.2 Configuration.

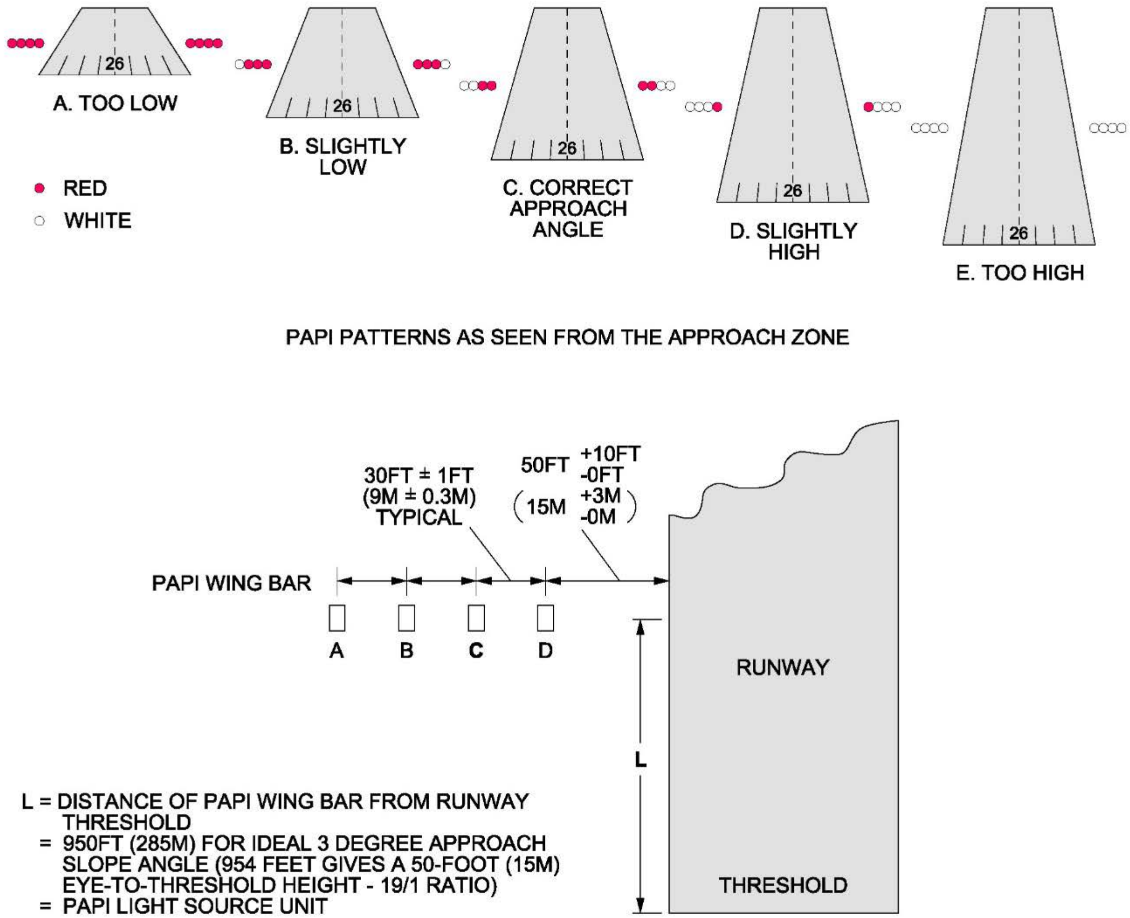
For airfields serving fixed wing aircraft, the PAPI system consists of a light bar with four light units (FAA L-880, per FAA AC 150/5345-28) placed on the left side of the runway in the vicinity of the touchdown point. (See Figure 3-11.)

3-7.2.1 Each light unit must be mounted on frangible fittings. Each unit must contain a minimum of two lamps (three lamps are preferred) and an optical system that produces a horizontally split, two-color (white over red) light beam.

3-7.2.2 Beginning at the out-board-most units, each unit in a light bar is aimed into the approach at a successively higher angle above the horizontal. When on a proper approach path, the pilot sees the two inboard lights in both light bars as red and the two outboard lights as white. As the approaching aircraft settles below the proper path, the pilot sees an increasing number of red lights in each light bar. As the aircraft rises above the path, the pilot sees an increasing number of white lights. (See Figure 3-11.)

3-7.2.3 See FAA AC 150/5340-30 for PAPI installation requirements.

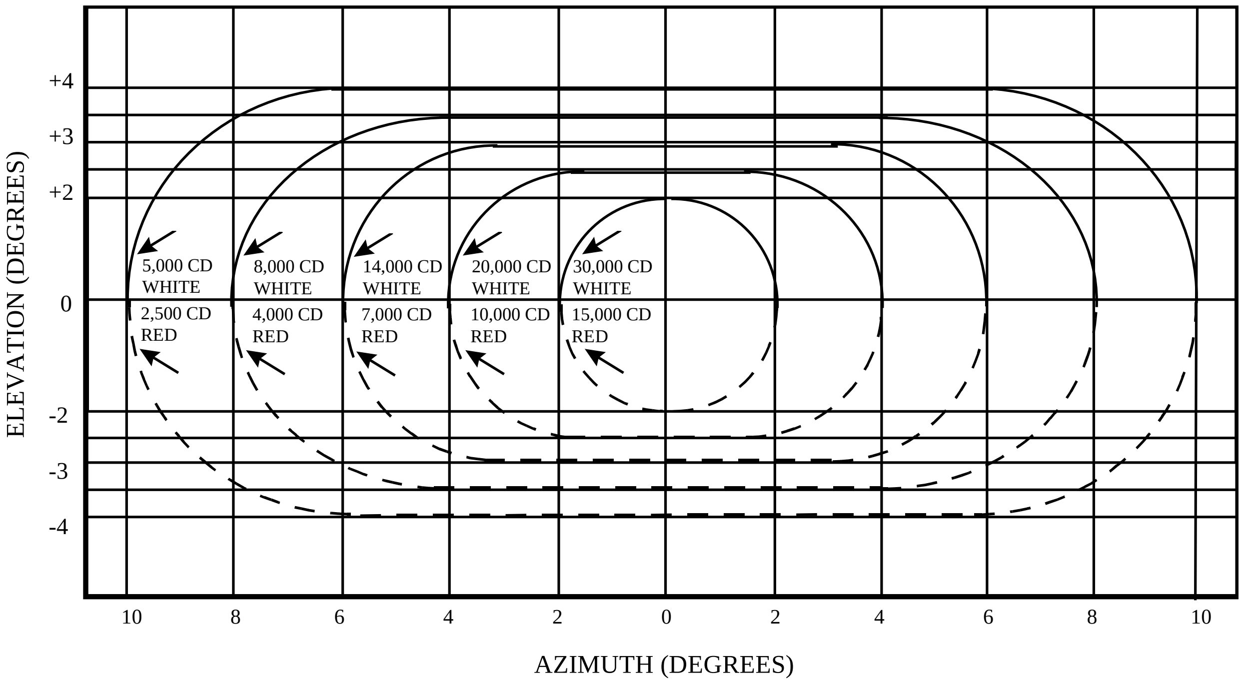
Figure 3-11 PAPI Configuration



3-7.3 Photometric Requirements.

See Figure 3-12 and FAA AC 150/5345-28 for detailed PAPI photometric requirements.

Figure 3-12 PAPI Photometric Requirements



3-7.3.1 Aim PAPI units in accordance with FAA AC 150/5340-30, parallel with the approach within 0.5 degrees. Aim successive light units in a light bar vertically, beginning with the out-board-most unit, and incrementally at increasingly higher angles. The glide path angle is the mean of the highest and lowest angle setting. (See Figure 3-13.) Set the angular difference between successive light units as follows:

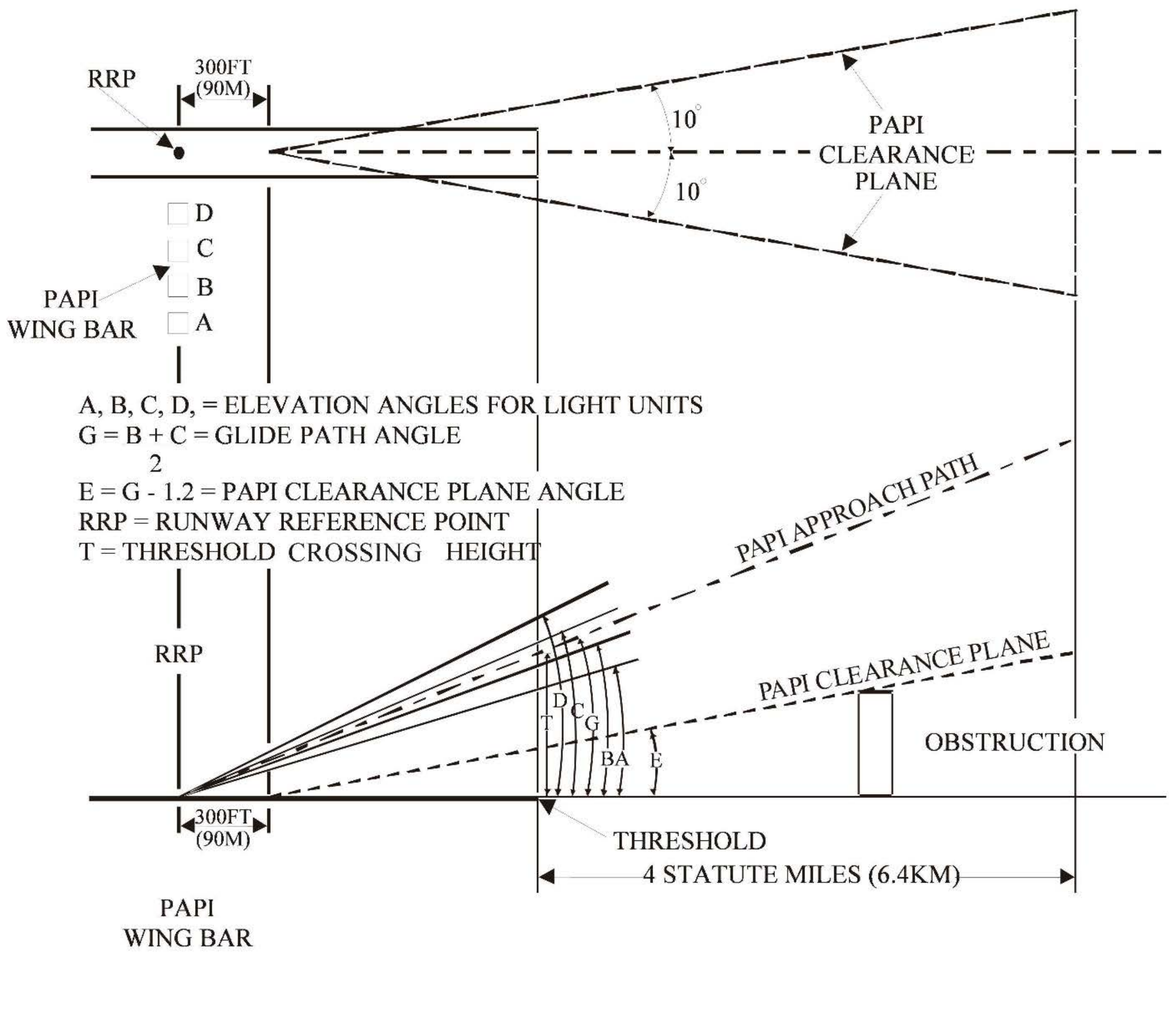
Approach Angle	Angular Difference
2 to 4 degrees	20 minutes
over 4 to 7 degrees	30 minutes
over 7 degrees	1 degree

3-7.3.2 The location and alignment of the PAPI may be varied to meet local conditions if the effective glide path is not less than 2.5 degrees or more than 4.0 degrees above the horizontal. Unless otherwise directed or where conditions dictate otherwise, use 3.0 degrees for the design glide path angle. For design purposes, the visual glide path begins at the PAPI runway reference point (RRP), which is a point on the runway centerline at the PAPI light bar (through lens center of light units) coinciding with the elevation of the lens center of the light units, and which projects into the approach at the glide path angle. (See Figure 3-13.) On a precision instrument runway, aim the PAPI at the same angle as the electronic glide path.

a. For the Army only, this procedure must be modified for runways that serve aircraft in height group 4 (Table 3-6); for these runways, the distance of the PAPI from the threshold must equal the distance to the electronic glide slope source plus an additional 300 feet (90 meters).

b. For the Air Force only, PAPI locating procedures will ensure a minimum safe wheel height above the threshold for all height groups using the runway.

Figure 3-13 PAPI Aiming Criteria



3-7.4 Considerations.

At a minimum, the following factors must be considered when siting a PAPI: existing or planned ILS glide slope; the established glide path (aiming angle, typically 3 degrees);

the threshold crossing height (TCH) for the selected aircraft height group; and the runway gradient (longitudinal slope) from the threshold to the PAPI location.

3-7.4.1 When used on a runway with ILS, the PAPI must be located the same distance from the runway threshold as the virtual source of the ILS glide slope, in accordance with FAA AC 150/5340-30. For Army airfield only, this is modified for aircraft in the height group #4 (Table 3-6), in which case the PAPI is sited at the runway point of intercept (RPI), plus an additional 300 feet (90 meters), +50 feet, -0 feet (+15 meters – 0 meters) from threshold. (See paragraph 12-3 to site PAPI.)

Table 3-6 Visual Threshold Crossing Height Groups

Height Group	Approximate Cockpit-to-Wheel Height	Visual Threshold Crossing Height
#1. General Aviation, Small Commuters, Corporate Turbojets, T-37, T-38, C-21, T-1, C-12, C-20 Fighter Jets	10 ft (3 m) or less	40 ft (+5, -20) (12 m (+1.5, -6))
#2. F-28, CV-340/440/580, B-737, DC-9, DC-8,	15 ft (4.5 m)	45 ft (+5, -20) (13.5 m (+1.5, -6))
#3. B-727/707/720/757, C-130, C-17	20 ft (6 m)	50 ft (+5,-15) (15 m (+1.5, -4.5))
#4. B747/767, L-1011, DC-10, A300, KC-46, C-5	over 25 ft (7.6 m)	75 ft (+5, -15) (22.5 m (+1.5, -4.5))
Refer to FAA AC 150/5340-30 for Group 4, ILS Glide Slope-PAPI coordination and other additional information.		

3-7.4.2 Without an ILS, determine the position and aiming for the PAPI that will yield the required TCH and clearance over obstacles in the approach area, per procedures in FAA AC 150/5340-30.

3-7.4.3 No light unit can be closer than 50 feet (15 meters) to any other runway, taxiway, or apron. Avoid locations where the system could be obscured by other installations. Do not place other lights so close to the PAPI as to cause pilot confusion. Where these conditions cannot readily be satisfied with the system located on the left side of the runway, the system, with waiver approval (paragraph 1-11 or paragraph 1-12), may be sited on the right side of the runway.

3-7.4.4 Establish a PAPI obstruction clearance plane per procedures in FAA AC-150/5340-30.

3-7.4.5 Per Air Force Flight Standards Agency: Any PAPI calibrated to a height group other than #3 will be annotated in the appropriate aircrew flight publications." Rationale: This sets a standard an give clarity to aircrews on what TCH the PAPIs are set to and if it different those aircrew can then adjust their landing profile to touch down at the appropriate point vs touching down too long or too short.

3-7.5 Power Requirements.

Provide the electrical power for the PAPI system from a separate 120/240 volt circuit or a 6.6A series circuit. The 120/240 volt circuit is for parallel operation with control by photocell and selector switch at the unit. Energize the 6.6A series circuit by a constant-current regulator. A 4 kW constant current regulator, five intensity steps, is used to energize the PAPI on a series circuit. When the PAPI is required to be on a series circuit, the lights must be connected to the series circuit by series isolation transformers of suitable capacity for each lamp housing assembly. For emergency power requirements, see Chapter 2. Monitoring of the PAPI is not required, except for daily visual checks of operations and periodic checks for proper aiming. See FAA AC 150/5340-30 for additional information about PAPI power requirements.

3-7.6 Control Requirements.

Control the PAPI on/off manually from the air traffic control tower and from the airfield lighting vault. Brightness control will be manual; however, the PAPI may also be controlled by photocell or pilot radio control at airfields without air traffic controllers, or where the air traffic control tower is not manned full time. At these locations, provide an electrical interlock between the PAPI and the runway edge lights. This interlock may be an electrical contractor or radio interface unit to ensure that, during the hours of darkness the PAPI is on only when the runway edge lights are on. During daylight hours, the PAPI will be capable of operating independently of the runway edge lights. PAPI on/off and intensity controls must be included on the airfield lighting control panel.

3-7.6.1 Provide radio control when required by using an FAA L-854 radio controller (see FAA AC 150/5345-49), which allows the PAPI to be turned on by a pilot on approach or by a ground control station. Note: For radio controller, the low end of environmental temperature range is changed to -40 degrees F (-40 degrees C) for better parts availability (per 150/5245-49D).

3-7.6.2 The photocell must operate per requirements in FAA AC 150/5345-28. The photoelectric control requires a time delay of at least 30 seconds to prevent false switching caused by stray light or temporary shadows. Install the photocell at an unobstructed location and aim it towards the northern horizon.

3-7.7 Foundations.

Foundations for mounting light boxes and a power control unit (PCU) will be made of concrete and designed for the region, to prevent frost heave or other displacement. Extend the foundation at least 12 inches (300 millimeters) below the frost line. To minimize damage from mowers, extend the foundation at least 12 inches (300 millimeters) beyond the light boxes and do not install the foundation more than 1 inch (25 millimeters) above grade. All light boxes will be frangible-mounted to the foundation.

3-7.8 Equipment.

See FAA AC 150/5345-28 for additional information.

3-7.9 Flight Inspections.

Refer to AFJMAN 11-225(I) for flight inspection requirements (commissioning flight) prior to use.

3-7.10 PAPI Siting.

Refer to paragraph 12-3.

3-7.11 Compliance with International Standards.

3-7.11.1 NATO.

These PAPI criteria satisfy requirements of NATO STANAG 3316 (Edition 11) with the exception that the Air Force system is located on only one runway side.

3-7.11.2 AFIC.

AFIC AIR STD 90/27 has been cancelled.

CHAPTER 4 STANDARDS FOR RUNWAY LIGHTING SYSTEMS

4-1 MIXING OF LIGHT SOURCE TECHNOLOGIES.

LED light fixtures must not be interspersed with incandescent light fixtures of the same type.

> *Example:* An airport adds an extension to a runway. On the existing runway, the runway centerline light fixtures are incandescent. The airport decides to install LED runway centerline fixtures on the new section of runway and retains the incandescent fixtures on the existing section. This interspersion of dissimilar technology is not approved for installation. See FAA Engineering Brief 67D for mixed light source uses.

When replacing a defective light fixture, ensure the replacement is of the same light source technology, to maintain a uniform appearance. For Air Force and Army airfields, Paragraph 2-5 lists LED light fixtures that are prohibited and allowed.

4-1.1 Runway Perimeter Lighting.

Runway edge lights, threshold lights, and runway end lights are used to outline the lateral and longitudinal limits of the usable surface of the runway. They are required for VFR night operation and for all categories of instrument operations.

For new construction, medium intensity is standard for Army airfields; high intensity is standard for Air Force airfields.

4-1.2 Runway Surface Lighting.

When Category III instrument operations are necessary, the runway perimeter lighting is augmented with touchdown zone and centerline lighting in-pavement light fixtures. For Category II instrument operations, touchdown zone and centerline lighting are optional.

4-1.3 Runway Visual Aid Requirements.

Table 2-1A and Table 2-1B show the visual landing aids required under various conditions.

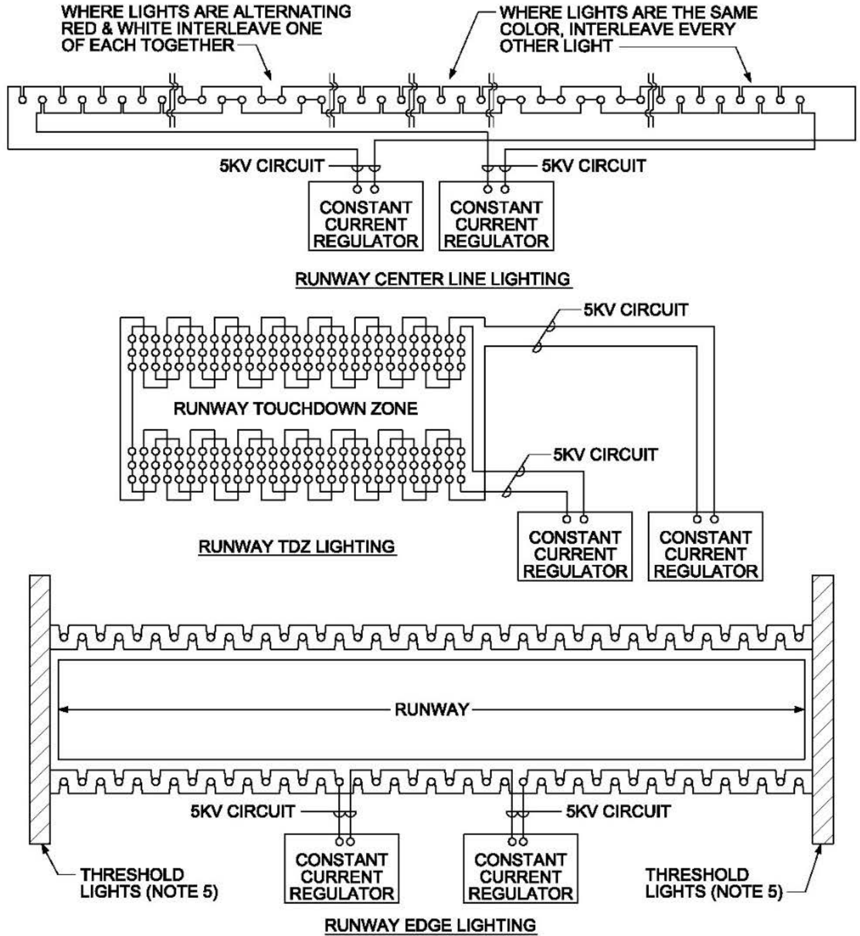
4-1.4 Runway Circuiting Requirements.

Each runway lighting system (edge, center line and touchdown zone) must be served with two separate regulators. Light fixtures may be connected in an interleaved manner as shown in Figure 4-1, but interleaving is not recommended for Air Force.

4-1.5 Photometric Testing.

Photometric testing is recommended to be performed on all newly installed runway edge, centerline, touchdown cone, threshold and end lights on site. The purpose of these tests is to verify the installed fixtures meet or exceed the minimum photometric requirements.

Figure 4-1 Optional Interleaved Runway Lighting Circuits (not recommended for Air Force airfields)



NOTES:

1. EXAMPLES ABOVE ARE ILLUSTRATIONS OF INTERLEAVED RUNWAY LIGHTING CIRCUITS.
2. INBOARD IN-PAVEMENT THRESHOLD LIGHTS SHOULD ALTERNATE BETWEEN APPROACH LIGHT CIRCUIT AND RUNWAY EDGE LIGHT CIRCUIT(S).
3. THE ONLY TYPE OF GUIDANCE SIGNS THAT SHOULD BE CONNECTED TO THE RUNWAY EDGE LIGHT CIRCUIT ARE MANDATORY HOLD SIGNS AND ARRESTING GEAR MARKERS. RUNWAY EXIT SIGNS SHOULD BE CONNECTED TO RESPECTIVE TAXIWAY EDGE LIGHT CIRCUITS. IF RUNWAY DISTANCE REMAINING SIGNS ARE CONNECTED TO RUNWAY EDGE LIGHTS THEY SHOULD ALL BE ON ONE OF THE INTERLEAVED CIRCUITS. IT IS PREFERRED THAT RUNWAY DISTANCE REMAINING SIGNS ARE ON A SEPARATE CIRCUIT.
4. EACH RUNWAY EDGE, TDZ AND CENTER LINE CIRCUIT SHOULD BE INSTALLED IN A DEDICATED 2" (53MM) CONDUIT.
5. FOR INTERLEAVING OF THRESHOLD LIGHTS REFER TO FIGURE 4-5A AND 4-5B (AIR FORCE) OR FIGURES 4-5C AND 4-5D (ARMY).

4-2 HIGH INTENSITY RUNWAY LIGHTS (HIRL) – RUNWAY EDGE LIGHTS.

4-2.1 Purpose.

A runway edge lighting system is a configuration of lights that defines the lateral and longitudinal limits of the usable landing area of the runway. Two straight lines of lights installed parallel to and at equal distances from the runway centerline define the lateral limits. Longitudinal limits of the usable landing area are defined at each end of the area by straight lines of lights called threshold/runway end lights, which are installed perpendicular to the lines of runway edge lights. HIRLs provide visual guidance during takeoff and landing operations at night and under low visibility conditions. High intensity runway edge lights are required for Air Force Night VMC, Non-Precision, and Category I, II, and III instrument operations. High intensity runway edge lights are required for Army for Category I operations.

4-2.2 Configuration.

See FAA AC 150/5340-30 for additional runway edge light configuration and installation information. Locate runway edge lights along the full length of the runway in two parallel rows equidistant from the centerline. Place along the edge of the area declared for use as the runway or outside the edge of the area not more than 10 feet (3 meters). (See Figure 4-2.) It is recommended that lights be placed at a distance of 7 to 8 feet (2.1 to 2.4 meters) unless otherwise justified.

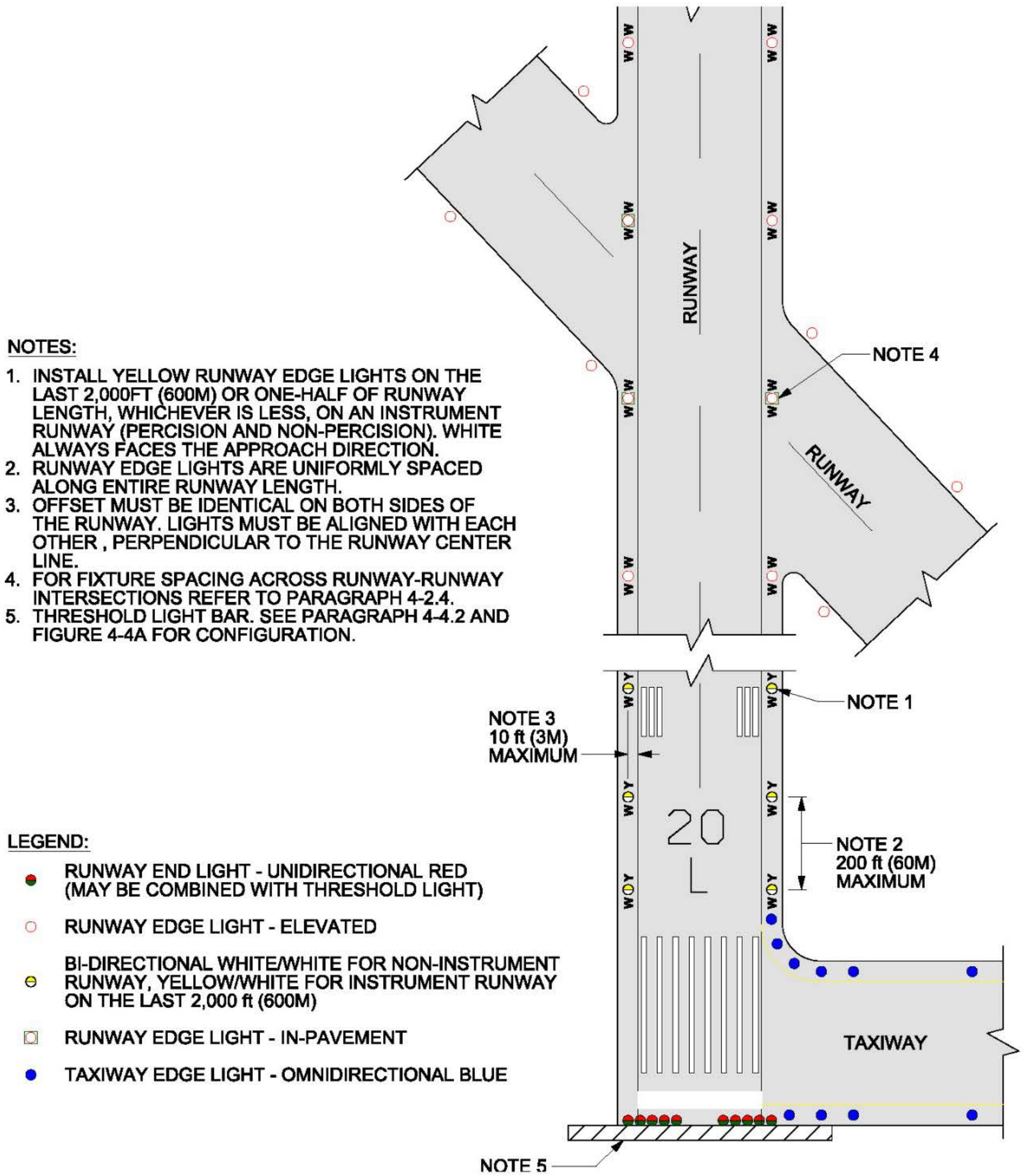
4-2.2.1 Light Spacing (HIRL).

Longitudinally, space the lights along the runway light lines at equal distances not exceeding 200 feet (60 meters). Determine the distance between lights by dividing the length of the runway light line between the threshold light lines into equal spaces approaching but not exceeding 200 feet (60 meters).

4-2.2.2 Elevated Lights.

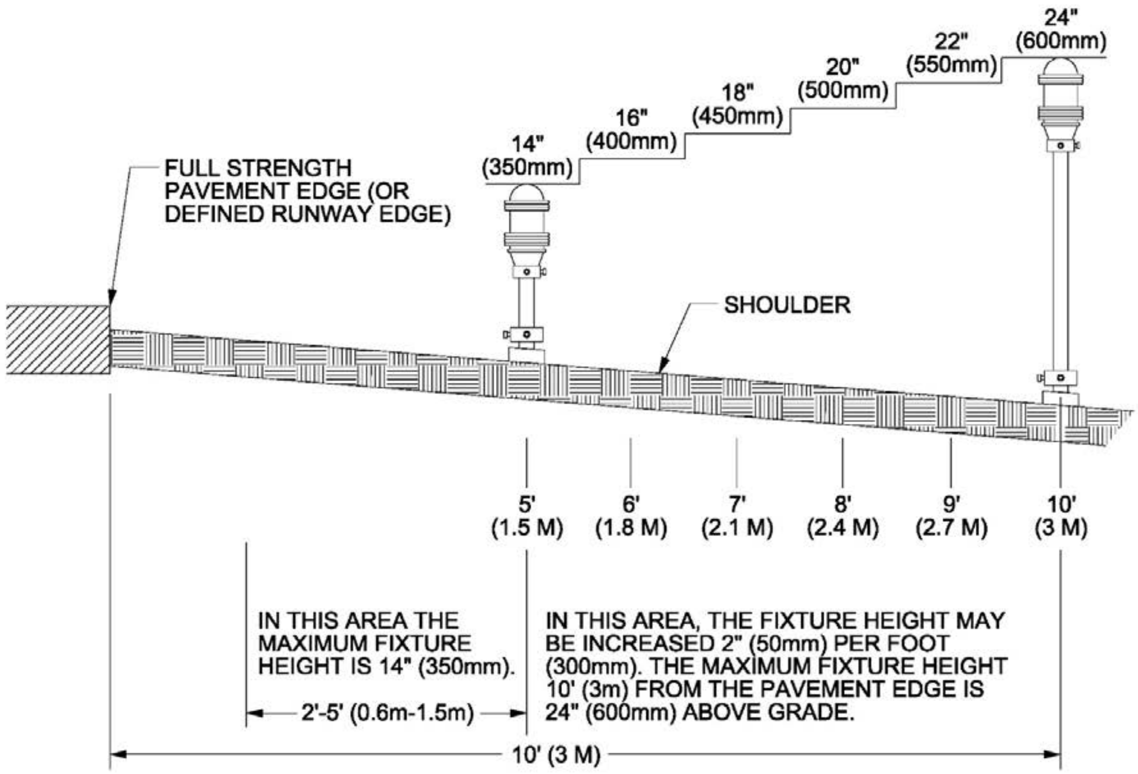
Use elevated lights in all instances except as noted in paragraph 4-2.2.3. If it is known that some fixtures will be changed to in-pavement fixtures in the near future, size the fixtures, light bases, and transformer housings to accept in-pavement fixtures.

Figure 4-2 Runway Edge Light Configuration



Note: This configuration for runway aligned taxiways will not be approved for new construction.

Figure 4-3 Elevated Fixture Height



NOTES:

1. WHEN LIGHTS ARE ELEVATED ABOVE 14" (350mm) (STANDARD), A MINIMUM CLEARANCE OF 6" (150MM) MUST BE MAINTAINED BETWEEN THE FIXTURE AND ANY OVERHANGING PART OF AN AIRCRAFT.
2. FOR OTHER HEIGHT VARIANCES, SEE FAA AC150-5340-30.

3\4

4-2.2.3 In-Pavement Fixtures.

Use in-pavement units in areas where elevated lights are subject to damage from jet blast, operation of an arresting system, or interference with aircraft operation. See paragraph 3-1. All bolts, studs, nuts, lock washers, and other similar fasteners used for the light fixture assemblies must be fabricated from 316L (equivalent to EN 1.4404), 18-8, 410, or 416 stainless steel. If 18-8, 410, or 416 stainless steel is utilized it shall be passivated and be free from any discoloration. All screw threads must be Class 2 or Class 3 per ANSI B1.1. This paragraph does not apply to current carrying components. Note: Paragraph 3.10.1.1 does not apply to fasteners that are used to attach the light fixture to the light base; see AC 150/5345-42, Specification for Airport Light Bases, Transformer Housings, Junction Boxes, and Accessories, for additional information. In addition, refer to the light fixture manufacturer's installation instructions about recommended bolt torque, locking washers, and the use of anti-seize and thread-locking compounds. **/4/**

4-2.3 Photometric Requirements.

See FAA AC 150/5345-46 for detailed photometric requirements of runway edge light fixtures. See FAA AC 150/5340-26 for additional information about the toe-in of runway edge light fixtures. Follow the manufacturer's instructions for proper fixture toe-in alignment. Use bidirectional high intensity runway edge lights. The lights must be white, except that the last 2,000 feet (600 meters) on an instrument runway must be yellow (caution zone indication to the pilot). The runway edge lights may be capable of providing small amounts of omnidirectional light to provide circling guidance to the runway. Ensure the omnidirectional component is capable of being shielded during times of emergency. The main beams must be toed-in 3.5 degrees and elevated 4 degrees above the horizontal. Edge lights are operated at five intensity steps:

Intensity Step	Minimum Light Intensity Percentage
1 (2.8 A)	0.15 %
2 (3.4 A)	1.0 %
3 (4.1 A)	3.9 %
4 (5.2 A)	16.9 %
5 (6.6 A)	100.00 %

4-2.4 Runway/Runway Intersections.

For runways that are approved for CAT III operations, maintain uniform spacing across intersections by installing in-pavement edge lights on the intersecting runway.

For other operations on runways with HIRL, the installation of an in-pavement edge light is based on the following:

- The availability of other visual cues at the intersection, such as guidance signs or runway centerline lighting.
- The geometric complexity of the intersection, such as crossing runways. When the gap exceeds 400 feet (120 meters install an in-pavement light fixture to maintain uniform spacing.
- Whether the addition or not the addition of an in-pavement edge light could cause confusion with ground operations.

4-2.4.1 In-Pavement Fixtures in Sweep Area of Arresting Gear Marker Tape

The runway edge lights in the immediate area of the arresting gear markers are vulnerable to being swept by the tape when an aircraft engages the arresting gear. The lights in the sweep area must be in-pavement fixtures. The length of the sweep area (B) along the row of edge lights on each side of the runway is calculated by: $B = A \times C / ((R / 2) + A – D)$, where:

A = the displacement of the arresting gear sheave from the runway edge.

C = the cable runout, normally 1,333 feet (400 meters).

R = the runway width.

D = the distance from the runway centerline to the point of engagement on the pendant wire. The maximum expected distance is 40 feet (12 meters).

The sweep area is in the direction of engagement of the arresting gear and can be in either runway direction, if the arresting gear can be engaged in either direction.

4-2.5 Equipment.

Elevated fixtures must be mounted on a frangible fitting at a maximum height of 14 inches (350 millimeters) at 2 to 5 feet (0.6 to 1.5 meters) from the defined pavement edge. At locations with frequent snow accumulations of 12 inches (300 millimeters) or more, the mounting height may be increased to not more than 24 inches (600 millimeters) in height at 10 feet (3 meters) from the defined pavement edge. No part of in-pavement fixtures must extend more than 1 inch (25 millimeters) above the surrounding surface. See Figure 4-3 for heights.

4-2.6 Power Requirements.

Provide a main and a standby power system with automatic transfer. Where used in support of Category II or III instrument operations, the transfer must occur within 1 second of a failure of the system. For other operations, transfer must occur within 15 seconds of the power failure.

4-2.7 Control Requirements.

When used in support of instrument operations below 2,400 feet (720 meters) RVR, provide system monitoring which, at a minimum, gives positive indication at the control facility that power is being delivered to the system. For interleaved edge lights, do not place adjacent edge lights on the same side of the runway on the same circuit. Lights on direct opposite sides of the runway must be on the same circuit.

4-2.8 Compliance with International Military Standards.

4-2.8.1 NATO.

These standards meet NATO STANAG 3316 (Edition 11) – Airfield Lighting.

4-2.8.2 AFIC.

AFIC AIR STD 90/27 is cancelled.

4-3 MEDIUM INTENSITY RUNWAY LIGHTS (MIRL).

4-3.1 Purpose.

MIRL edge lights are used on VFR runways, or on non-precision Instrument Flight Rule runways, for either circling or straight-in approaches. MIRL edge lights are not installed on runways intended for precision approaches.

4-3.2 Configuration.

The configuration must be per paragraph 4-2.2 for high intensity runway edge lighting.

4-3.3 Photometric Requirements.

See FAA AC 150/5345-46 for detailed photometric requirements of runway edge light fixtures. See FAA AC 150/5340-26 for additional information about the toe-in of runway edge light fixtures. Follow the manufacturer's instructions for proper fixture toe-in alignment.

Optimum aiming of lights depends on the design and output of the fixtures used in the system. Light fixtures may be designed to cover several applications and may have fixed patterns and aiming angles that differ from this document. Light aiming and patterns other than those given in this document may be used if the resultant light pattern produces equivalent light intensities in the required areas. Medium intensity runway edge lights must be omnidirectional and white. Where in-pavement lights are required, they may be bidirectional. The edge lights must be operated at three intensities as follows:

Intensity Step	Percent of Full Intensity
1	10%
2	30%
3	100%

4-3.4 Runway/Runway Intersections

For runways using MIRL, where the configuration across the intersection does not allow the matching of edge lights on the opposite side of the runway to be maintained, the distance must not exceed 400 feet (120 meters). If the distance between the runway edge lights is greater than 400 feet (120 meters), install an FAA Type L-852D taxiway centerline light fixture. Modify the light fixture to produce white light (remove the filters) and maintain the designed spacing.

4-3.5 Equipment.

Elevated fixtures must be mounted on a frangible fitting at a maximum height of 14 inches (350 millimeters) at 2 to 5 feet (0.6 to 1.5 meters) from the defined pavement edge. At locations with frequent snow accumulations of 12 inches (300 millimeters) or more, the mounting height may be increased to not more than 24 inches (600 millimeters) in height at 10 feet (3 meters) from the defined pavement edge. See FAA AC 150/5340-30 and Figure 4-3 for additional information about light fixture height versus distance from the defined pavement edge.

4-3.6 Power Requirements.

Standby power is not required for medium intensity runway lights, except where they are installed on the primary runway. When installed on the primary runway, provide a main and a standby power system with automatic transfer within 15 seconds of failure of the system in use.

4-3.7 Control Requirements.

Provide remote on, off, and brightness control.

4-3.8 Compliance with International Military Standards.

4-3.8.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

4-3.8.2 NATO.

This system does not meet NATO STANAG 3316 (Edition 11) – Airfield Lighting for lighting of subsidiary runways.

4-4 THRESHOLD LIGHTS.

4-4.1 Purpose.

Threshold lights provide positive identification of the beginning of the operational runway surface for approaching aircraft at night or under instrument weather conditions.

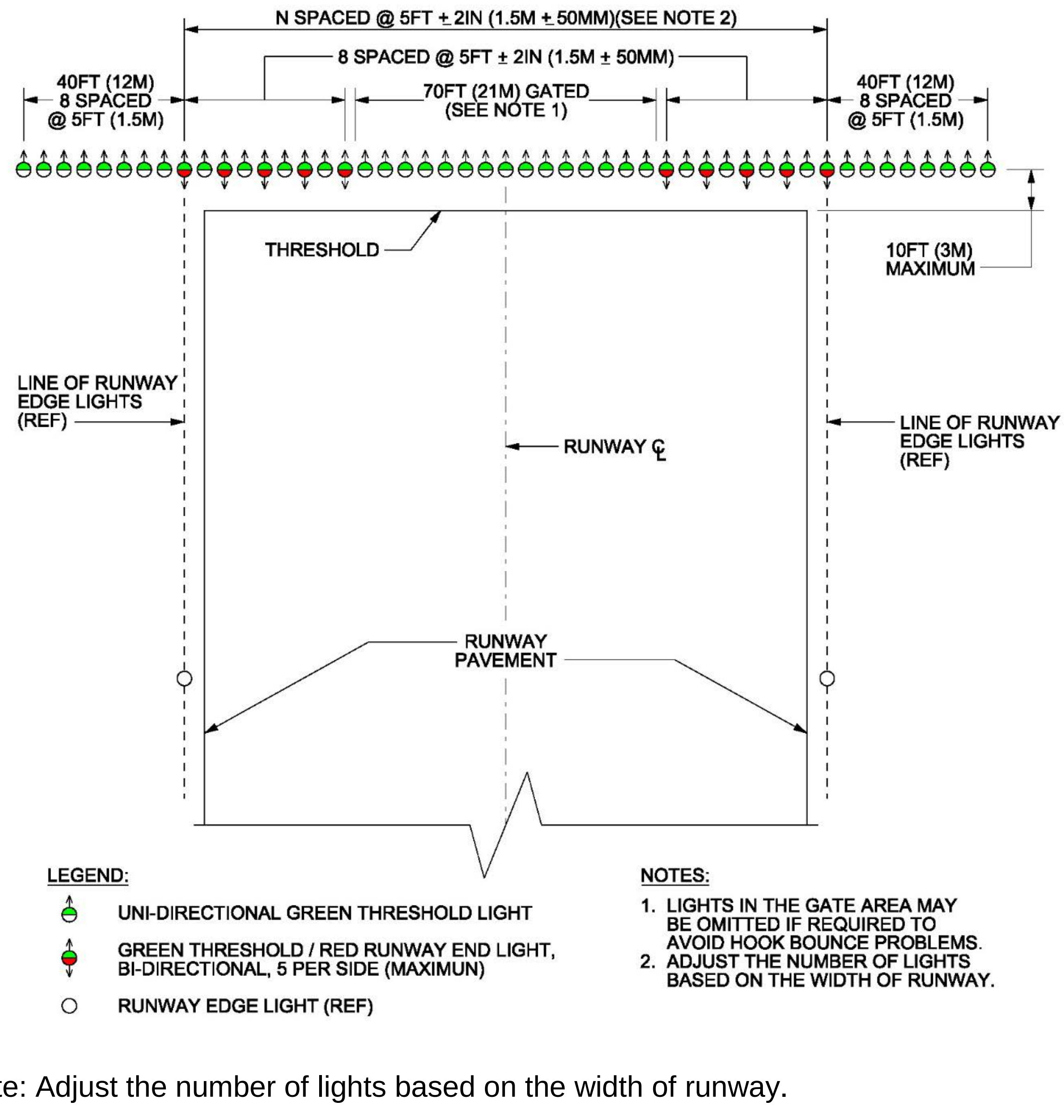
4-4.2 High Intensity Threshold Light Configuration.

Install threshold lights in a line perpendicular to the extended runway centerline outside the usable landing area a distance of not more than 10 feet (3 meters). The line of lights is symmetrical about the runway centerline and extends 40 feet (12 meters) outboard of the lines of runway edge lights. (See Figure 4-4A for the Air Force configuration, and Figure 4-4B for the Army configuration). Determine the position of the lights as follows:

4-4.2.1 Place a light where the line of threshold lights intersects the line of runway edge lights. Then place lights at 5 feet (1.5 meters) for a distance of 40 feet (12 meters) outboard of the runway edge light lines.

4-4.2.2 Place lights at uniform intervals between the lines of runway edge lights and along the line of the threshold lights. Space as near to 5 feet (1.5 meters) as possible and do not exceed 5 feet 2 inches (1.55 meters). The line of threshold lights may be gated to lessen the problem of tail hook bounce by eliminating those lights in the center 70-foot (21-meter) portion of the threshold. For new installations, it is recommended that where fixtures are not installed, bases be installed with blank covers that are flush with the runway surface and are suitable for future in-pavement fixtures. This is intended to accommodate future mission requirements where tail hook equipped aircraft are no longer using the runway.

Figure 4-4A1 Threshold Light Configuration for Air Force



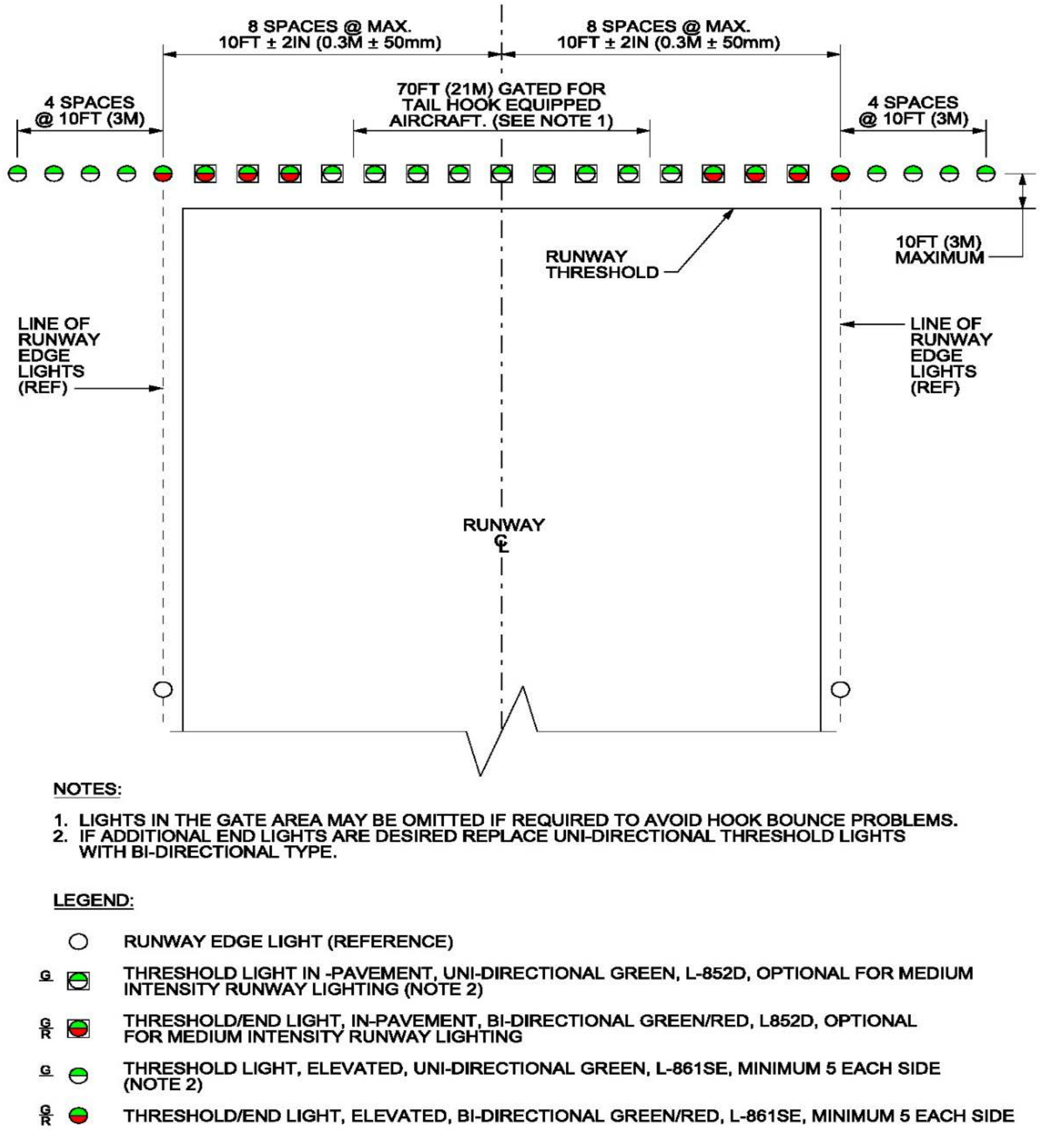
Note: Adjust the number of lights based on the width of runway.

Figure 4-4A2 Modified Threshold Light Configuration for Introduction of FLIR Component Used by Aircraft with Head Up Displays

\4 TBD – Next Full Revision ***/4/***

Note: Aircraft with Head Up Display systems require a wavelength consistent with Forward Looking InfraRed systems which are based on a Heat Signature. When the Threshold consists of LED fixtures, a modified LZ configuration of five fixtures (four threshold and one approach) should be used so that the runway end is clearly indicated on the HOD of the aircraft. These five incandescent fixtures should not be on the same circuit as the LEDs, but should be controlled from the same regulator so that light output is consistent between the two circuits.

Figure 4-4B Threshold Light Configuration for Army



4-4.3 Medium Intensity Threshold Lights.

Install threshold lights in a line perpendicular to the extended runway centerline outside the usable landing area a distance of not more than 10 feet (3 meters). The line of lights is symmetrical about the runway centerline and extends 40 feet (12 meters) outboard of the lines of runway edge lights. (See Figure 4-5C and Figure 4-5D.) Determine the position of the lights as follows:

- Place a light where the line of threshold lights intersects the line of runway edge lights. Next, place lights at 10 feet (3 meters) for a distance of 40 feet (12 meters) outboard of the runway edge light lines.

- If inboard lights are used, place lights at uniform intervals between the lines of runway edge lights and along the line of the threshold lights. The interval must be a maximum of 10 feet (3 meters).

4-4.4 Photometric Requirements.

See Figure 4-6 for detailed photometric information for high intensity runway threshold lights. See FAA AC 150/5345-46 for detailed photometric information for medium intensity runway threshold lights.

4-4.4.1 High Intensity Threshold Lights.

The runway threshold lights must be unidirectional green aimed into the runway approach with intensities per Figure 4-6 when used with high intensity runway edge lights or approach lights. The light beams are aimed parallel with the runway centerline and angled upward at an angle of 4.5 degrees. High intensity threshold lights must operate at five intensity levels, together with the associated runway edge lights. High intensity runway edge lights will be used with high intensity threshold lights.

4-4.4.2 Medium Intensity Threshold Lights.

The lights must be bidirectional red/green, with green aimed towards the approach. Outboard threshold elevated lights must be FAA L-861SE, and inboard threshold in-pavement lights must be FAA L-852D. See FAA AC 150/5345-46 for additional requirements.

Figure 4-5A Threshold Light Circuiting for Air Force (Interleaved)

Note: Interleaving is allowed, but not recommended.

Figure 4-5B Air Force (Non-interleaved)

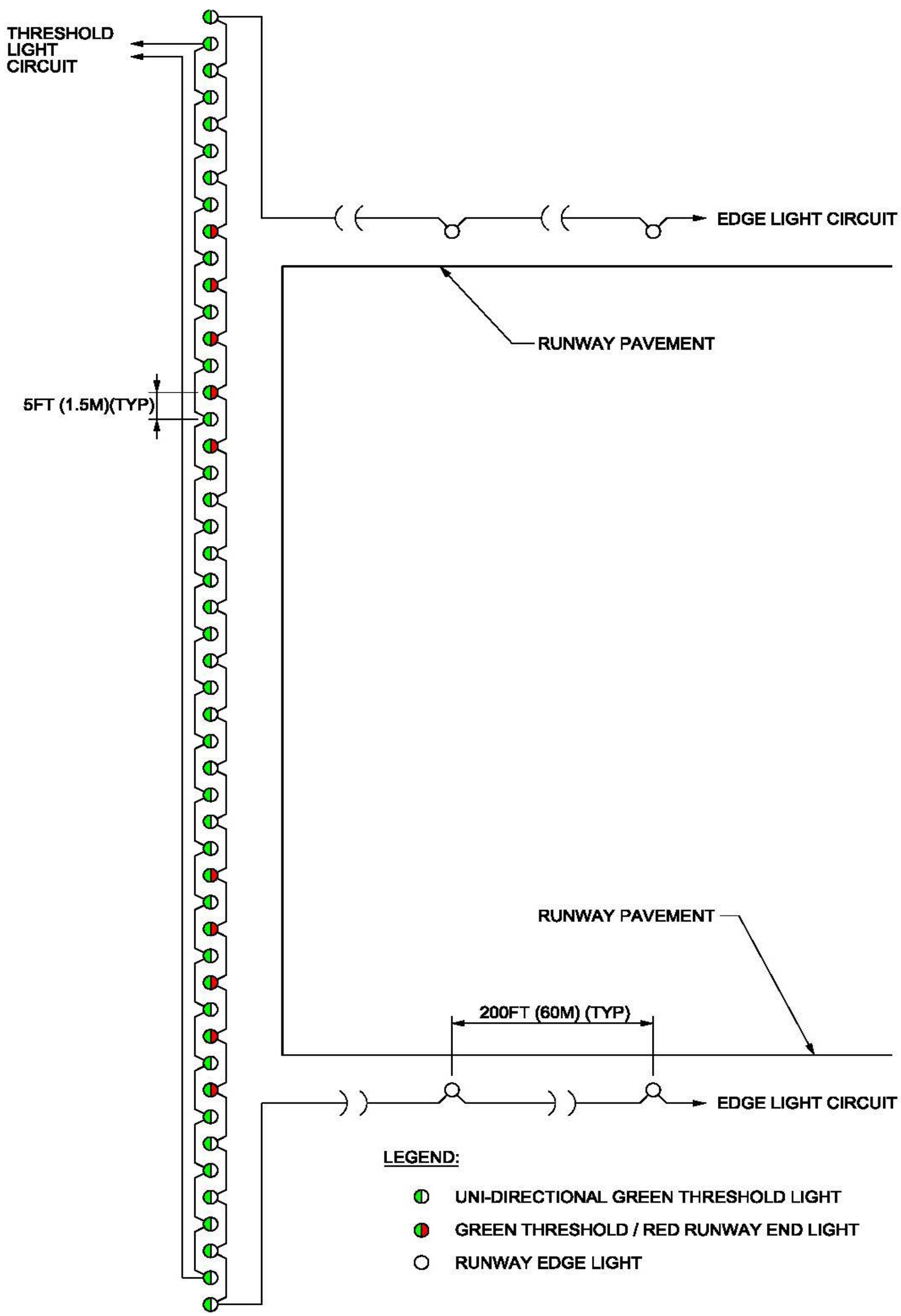


Figure 4-5C Threshold Light Circuiting for Army (Interleaved)

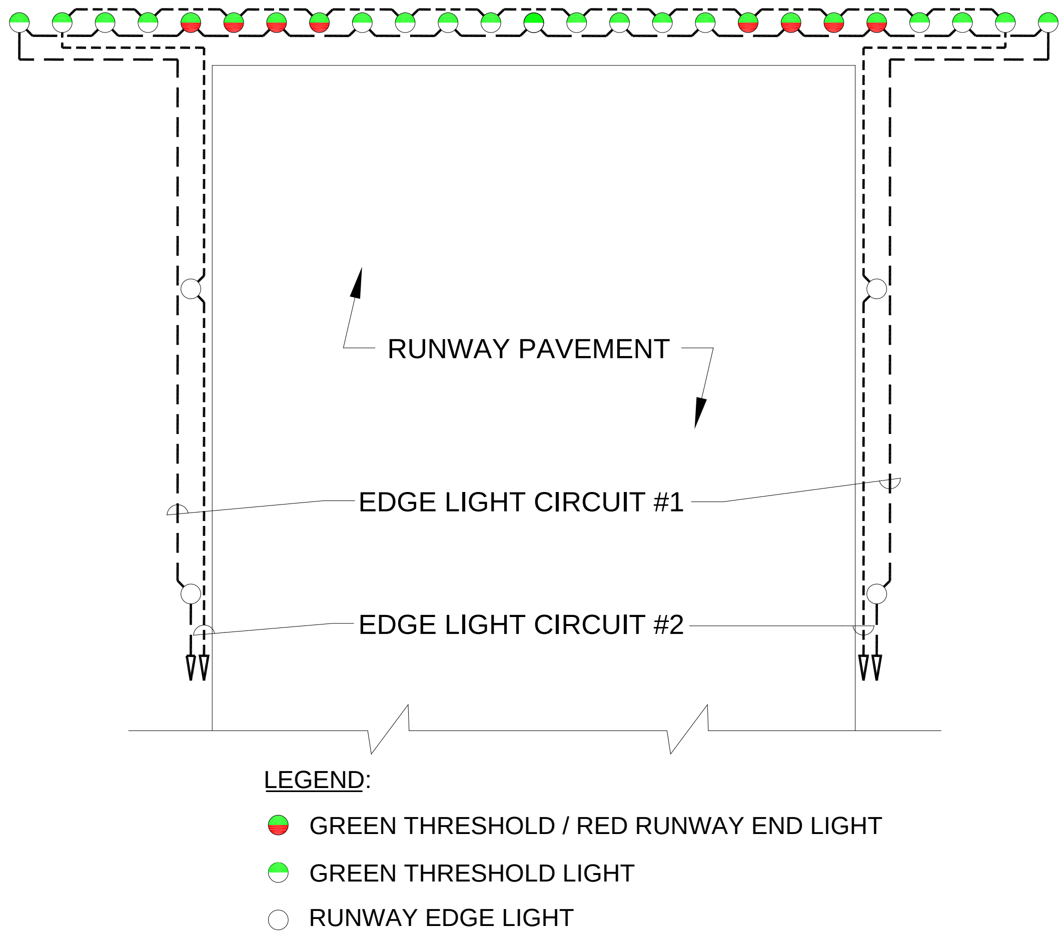


Figure 4-5D Army (Non-interleaved)

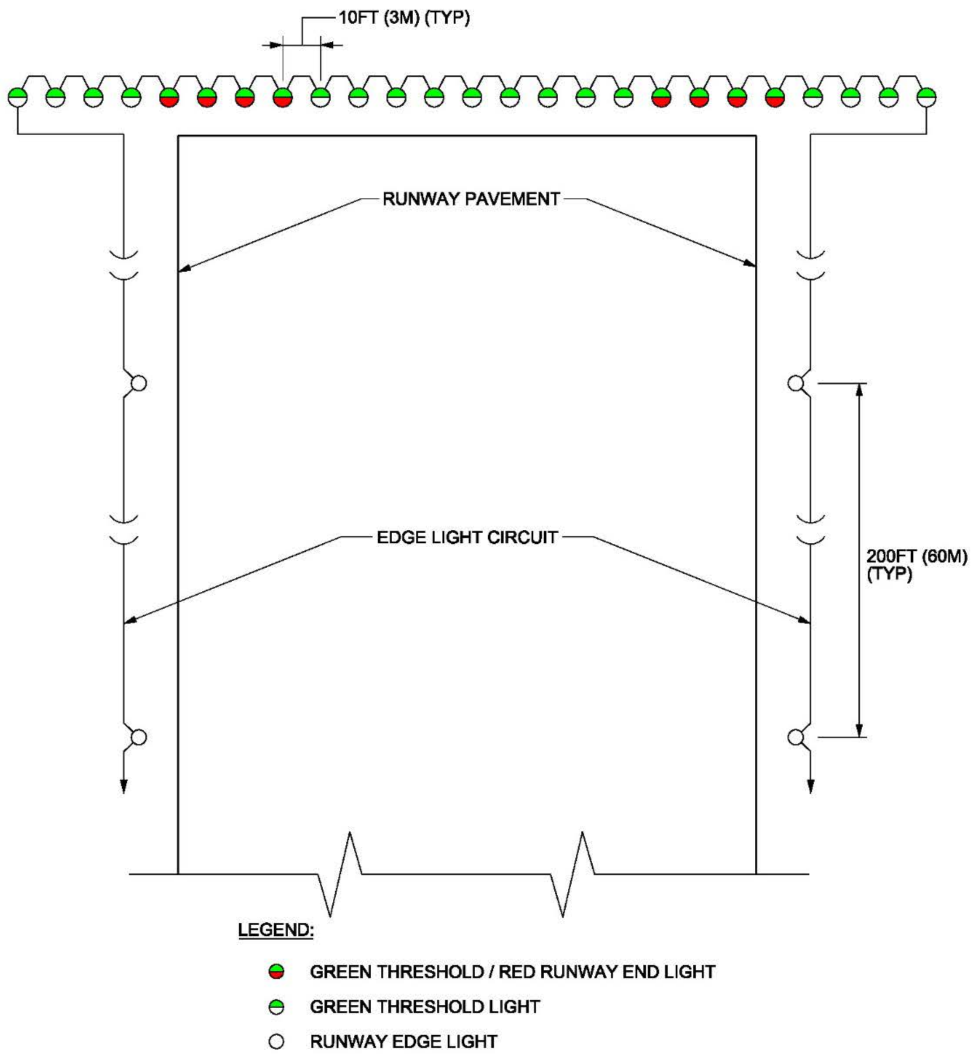
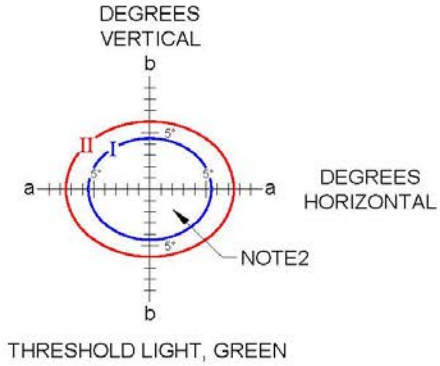


Figure 4-6 Threshold Light Photometric Requirements



	I=50%	II=10%
a	5.5°	7.5°
b	4.5°	6.0°

NOTES:
1. ALL CONTOURS ARE ELLIPSES CALCULATED BY EQUATION: $(X/a)^2 + (Y/b)^2 = 1$
2. THE MINIMUM AVERAGE CANDELA IN GREEN LIGHT OF THE MAIN BEAM (INSIDE CONTOUR I) IS 10,000 CD FOR HIGH INTENSITY SYSTEMS AND 100 CD FOR MEDIUM INTENSITY SYSTEMS.
3. MAXIMUM INTENSITY MUST NOT EXCEED 3 TIMES AVERAGE CANDELA SPECIFIED AND THE AVERAGE INTENSITY MUST NOT EXCEED 1.5 TIMES MINIMUM AVERAGE INTENSITY SPECIFIED.
4. PORTIONS OF THE LIGHT BEAM CUT OFF BY THE MOUNTING SURFACE MAY BE DISREGARDED.
5. CONTOURS I AND II INDICATE THE MINIMUM PERCENT VALUES OF THE MAIN BEAM INTENSITY.

4-4.5 Equipment.

Inboard threshold lights use in-pavement fixtures with no part of the fixture protruding more than 1 inch (25 millimeters) above the surrounding surface. Outboard threshold lights use elevated fixtures, frangible mounted. Where the opposite direction runway end is collocated with the threshold, runway end lights may be incorporated into threshold light fixtures. The number of bidirectional fixtures must be the minimum required to satisfy the requirement for end light fixtures. Where traffic patterns or arresting gear equipment interfere with the use of elevated fixtures, in-pavement fixtures must be used. (See paragraphs 13-12.3. and 13-12.3.1)

4-4.6 Power Requirements.

4-4.6.1 For Air Force airfields, connect the threshold lights with the interleaved runway edge light circuits as in Figure 4-5A. If the runway edge lights are not interleaved, connect the threshold lights as in Figure 4-5B.

4-4.6.2 For Army airfields, connect the threshold lights with the interleaved runway edge light circuits as in Figure 4-5C. If the runway edge lights are not interleaved, connect the threshold lights as in Figure 4-5D.

4-4.7 Control Requirements.

4-4.7.1 Where there is no approach light system, provide remote on and off and intensity levels to correspond to the runway edge light controls. The intensity levels must be the same as the runway edge lights.

4-4.7.2 When installing approach lights, the threshold lights may be circuited so approximately half of them are controlled by the approach light system. Interleave the threshold lights selected for operation with the approach lights, with the threshold lights to be operated with the runway lights so they present a uniform pattern symmetrical about the runway centerline when operated without runway lights. This may require that the two innermost lights be operated off the same circuit. Bidirectional fixtures are not allowed for operation with approach lights when runway end lights are installed. Interleaving of runway edge lights are allowed, but are not encouraged. When runway edge lights are interleaved with two circuits, connect the runway threshold lights so that a uniform symmetrical pattern will remain if either of the runway edge light circuits fails.

4-4.8 Aiming Threshold/Approach.

When used as part of an approach light system, bidirectional threshold lights, both in-pavement and elevated, have fixed aiming angles (with 3.5 to 4.0 degree toe-in on the red side only) for the beams and cannot be adjusted.

4-4.9 Monitoring Requirements.

Threshold lights have the same monitoring requirements as the edge lights.

4-4.10 Compliance with International Military Standards.

4-4.10.1 NATO.

The standard meets NATO STANAG 3316 (Edition 11) – Airfield Lighting,, for high intensity threshold lights.

4-4.10.2 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

4-5 LIGHTING WITH DISPLACED THRESHOLDS.

4-5.1 General.

The runway threshold is the beginning of the landing area, and may not be located at the physical beginning or end of the full strength runway. It may be used for takeoff, but not for landing. After landing at the other end, the landing aircraft may use the displaced portion of the runway for roll out. Displacements may be permanent or temporary. Reasons for permanent displacement may be to give arriving aircraft clearance over an obstruction while still allowing departing aircraft the maximum amount of runway available, because of operational problems, or as noise mitigation measures. Reasons for temporary displacement may be for ongoing construction, for repairs after accidents or to displace landing position to a stronger part of full strength pavement if the keel is unreliable. Displaced runways require waivers. The area of full strength pavement in front of the threshold may be required for takeoff or for rollout on landings from the opposite direction. Where this occurs, changes to the standards for runway lighting are required.

4-5.2 Configuration for Permanent Displacement.

See Figure 4-7 and Figure 4-8 for typical layouts of permanent displaced thresholds.

4-5.2.1 Install threshold lights, as specified in paragraph 4-4, with dimensions referenced to the theoretical beginning of the usable landing area.

4-5.2.2 Install runway end lights, as specified in paragraph 4-6 with measurements referenced from the end of the usable takeoff and rollout area.

4-5.2.3 When the displaced runway area is used for specific operations (takeoff, rollout, taxiing) appropriate edge lights for the function are installed to delineate the outline.

4-5.2.4 The runway centerline lights facing the approach direction in the displaced area must be blanked out if the length of the displacement is less than 700 feet (210 meters). If the displacement is 700 feet (210 meters) or greater, circuit the centerline lights in the area separately. Provide the capability to turn runway centerline lights off during landing operations. If a high intensity approach light system is installed, this switching capability is not required.

4-5.2.5 Install approach lights and visual approach slope indicators, such as PAPI, as specified in this standard using the theoretical beginning of the usable landing area (threshold) as the reference. Ensure coordination has been performed for relocation of any instrument approach aids.

4-5.2.6 Where the abandoned runway surface is not used for aircraft movement, the threshold lighting is relocated to the new threshold location. Lights in or along the abandoned surface are not required.

4-5.3 Configuration for Temporary Displacement.

See Figure 4-9 for a typical layout of temporary displaced threshold with construction or obstructions on the approach end. See Figure 4-10 for layout when threshold/end of runway lights are co-located.

Where the threshold is temporarily displaced and the duration of the displacement is insufficient to warrant the relocation of all facilities (normally 6 months or less), the following applies:

Figure 4-7 Displaced Threshold Light Configuration (Permanent) Where Runway Surface is Used as a Taxiway with Taxiway End Lights

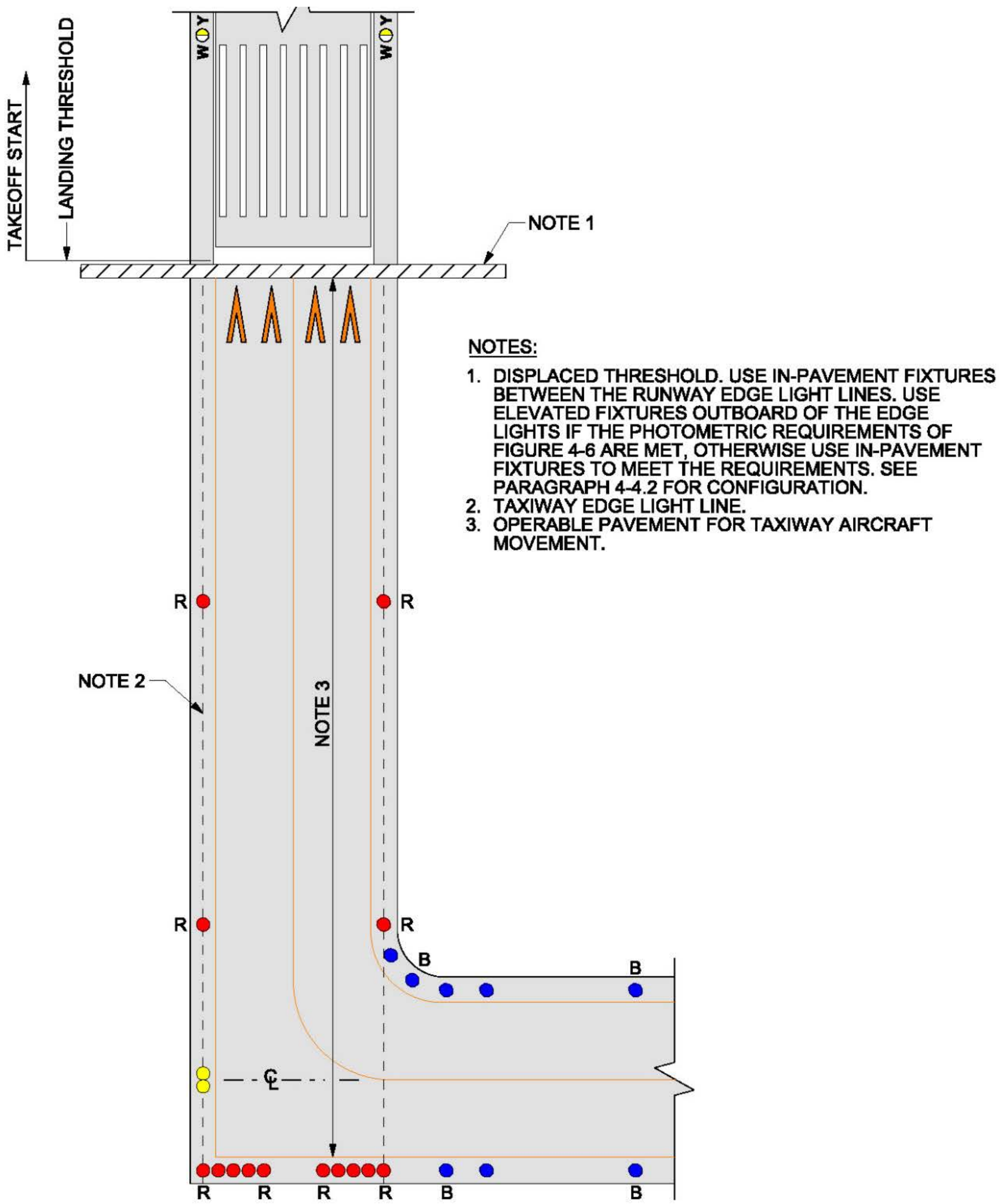


Figure 4-8 Displaced Threshold Light Configuration (Permanent) Where Runway Surface is Used for Takeoff and Landing Rollout

Note: Not supported for new construction.

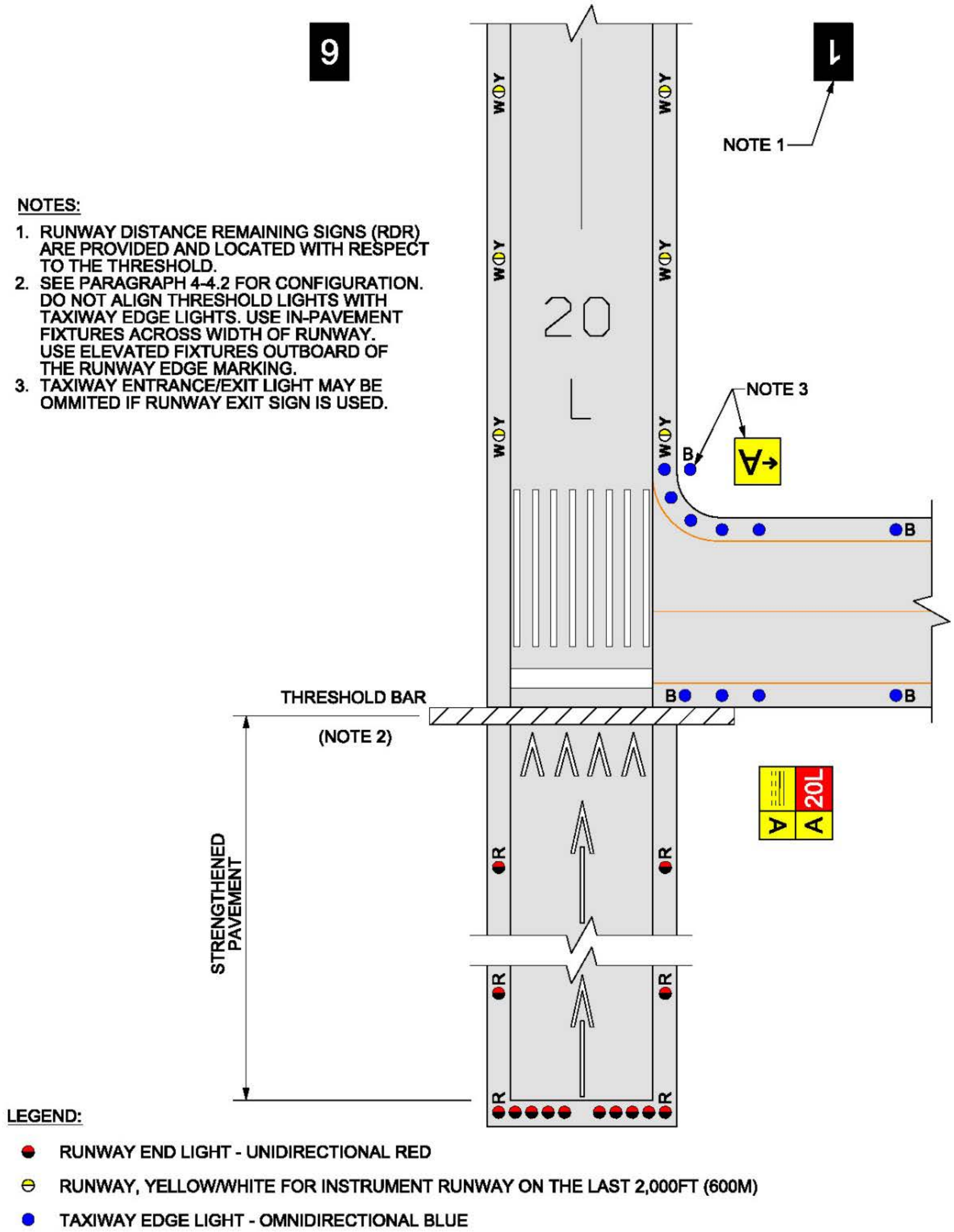
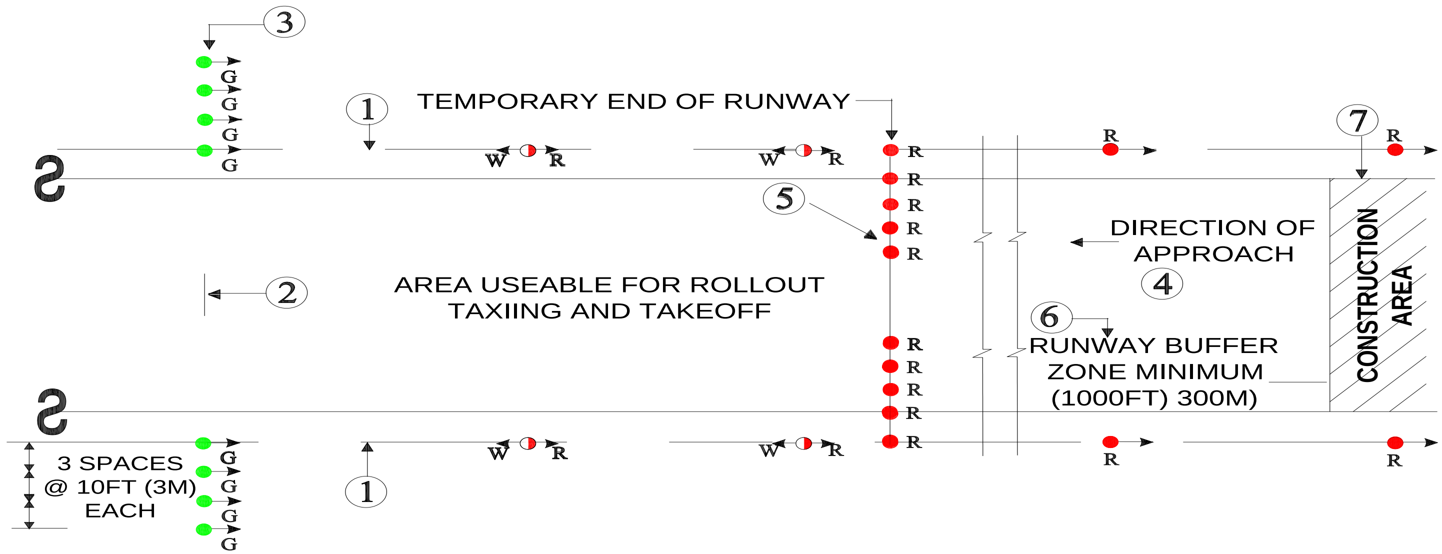


Figure 4-9 Displaced Threshold Lighting Configuration (Temporary)

Precautionary Note: Means must be provided to secure the plank and fixtures to prevent any movement arising from jet blast. Where spikes (asphalt) or concrete anchors (PCC) are used to secure the plank to the pavement, the holes left in the pavement after removal must be repaired.



LEGEND:

- G — GREEN THRESHOLD LIGHT, PLANK MOUNTED
- W / R — RED TOWARD APPROACH (WHITE TOWARD RUNWAY IF USEABLE FOR ROLL-OUT, STOPWAY OR TAXIWAY)
- R — PLANK MOUNTED 360° RED
- R — UNI-DIRECTIONAL RED

NOTES:

1. RUNWAY EDGE LIGHT LINE.
2. INDICATES LOCATION OF THRESHOLD OF USABLE LANDING AREA.
3. LINE OF THRESHOLD LIGHTS MARKING LOCATION OF THRESHOLD OF USABLE LANDING AREA.
4. EXISTING APPROACH/THRESHOLD LIGHTS DISCONNECTED.
5. TEMPORARY RUNWAY END LIGHTS, FIVE ON EACH SIDE.

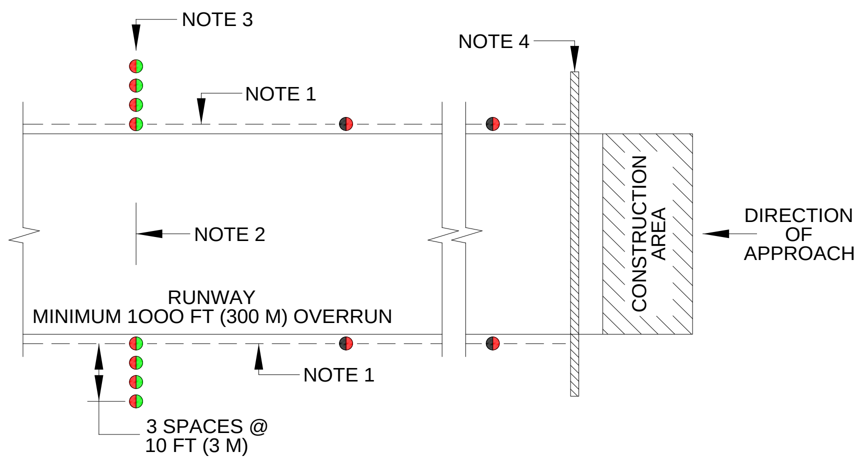
   PLANK-MOUNTED 360° RED, SPACED AT 10FT (3M) APART.
6. REQUIRED WHEN TEMPORARY DISPLACEMENT IS FOR CONSTRUCTION WORK.
7. CONSTRUCTION AREA.

Figure 4-10 Displaced Threshold Lighting Configuration With Co-Located Threshold/End of Runway Lights (Temporary)

LEGEND:

THRESHOLD/RUNWAY END LIGHT - BI-DIRECTIONAL RED/GREEN

EXISTING RUNWAY EDGE LIGHTS. CHANGE TO RED TOWARD APPROACH AND BLANK TOWARD TEMPORARY THRESHOLD (MAY BE WHITE TOWARD TEMPORARY THRESHOLD IF USED FOR ROLL-OUT).



NOTES:

1. RUNWAY EDGE LIGHT LINE.
2. LOCATION OF THRESHOLD OF USEABLE LANDING AREA.
3. LINE OF THRESHOLD LIGHTS MARKING LOCATION OF THRESHOLD OF USEABLE LANDING AREA. (L-862 FOR HIRL, L-861 FOR MIRL) LIGHTS MAY BE STAKE OR PLANK MOUNTED.
4. EXISTING APPROACH THRESHOLD LIGHTS DISCONNECTED. RUNWAY END LIGHTS (UNI-DIRECTIONAL RED TOWARD RUNWAY) SHALL REMAIN ACTIVE IF AREA BEWTEEN TEMPORARY AND EXISTING THRESHOLDS IS USED ROLL-OUT.

4-5.3.1 Coordinate with TERPS specialist or FAA equivalent, airfield manager, CE Community planner, safety, and standardization and evaluation office to determine placement of the threshold.

Include temporary displaced threshold layout and configuration, along with temporary PAPIs as required, in the construction phasing plan and submit temporary displaced threshold requirement/configuration as a part of the temporary waiver request to the installation commander for a construction project within the airfield environment.

4-5.3.2 Disable the permanent runway threshold lights, runway end lights, approach lighting system, visual glide slope indicating systems such as PAPI or VASI, and any touchdown zone lights serving that end of the runway and runway edge lights along the section of runway not used for aircraft traffic.

4-5.3.3. Install temporary runway threshold lights, per Figure 4-9 or Figure 4-10, with dimensions referenced to the theoretical beginning of the usable landing area. Additional lights maybe added for a 300 foot (90 meter) wide runway. Reference UFC 3-260-01, Table 3-2, Runways.

4-5.3.4 Install temporary runway end lights, as specified in paragraph 4-6, with dimensions referenced from the end of the usable takeoff and rollout area.

Note: When temporary displacement is due to construction work, place the runway end lights to allow an additional 1,000 feet (300 meters) for emergency roll-out or to protect the Approach-Departure Clearance Surface from the tallest equipment that will be erected in the approach-departure zone. See UFC 3-260-01 for geometric requirements of the Approach-Departure Clearance Surface.

4-5.3.5 All fixtures are elevated and may be stake mounted or mounted on planks fastened to the runway surface.

4-5.3.6 Cables and transformers may be laid on the surface but must be protected from damage.

4-5.3.7 Modify runway edge lights in the temporary displaced area to show red light toward the approach direction (see Figure 4-9 and Figure 4-10). (When the displaced area is intended to be used for rollout or taxiing operations, the color of the edge lights must be modified with red toward approach and white toward the runway.) See paragraph 4-2.3 for photometric requirements on instrument runways.

4-5.3.8 Runway centerline lights in the displaced area will be blanked toward the approach direction and red toward the runway opposite the approach.

4-5.3.9 Runway Distance Remaining Signs (RDR) number panels facing toward the opposite end approach must be blanked or temporarily replaced with the new number panels reflecting the shorter distance to go. Renumbering is done so that at least 1,000 feet (300 meters) remain between the last number (#1) and the displaced runway end.

4-5.4 Equipment.

See paragraphs 13-12.3. and 13-12.3.1

4-5.5 Power, Control and Monitoring.

See paragraphs 4-4.6 and 4-4.7.

4-5.6 Compliance with International Standards.

4-5.6.1 NATO.

Same as paragraph 4-4.10.

4-5.6.2 AFIC.

Same as paragraph 4-4.10.

4-5.7 Additional Information.

See FAA AC 150/5345-46 for more information.

4-6 RUNWAY END LIGHTS.

4-6.1 Purpose.

Runway end lights define the end of the operational runway surface for aircraft for landing, rollout or takeoff. They are required on all lighted operational runways.

4-6.2 Configuration.

Runway end lights consist of 10 red lights in two groups of 5 lights for Air Force and 8 red lights in two groups of 4 lights for Army. Place the groups symmetrically and on a line perpendicular to, the runway centerline within 10 feet (3 meters) of the end of the usable runway surface. The lights in each group must have a uniform spacing of 5 feet ± 2 inch (1.5 meters ±50 mm) for Air Force and 10 feet ±2 inch (3 meters ±50 mm) for Army. The outboard-most light in each group must be in line with the line of the runway edge lights on that side of the runway. Runway end lights are usually co-located with the opposite end threshold lights. Where they are co-located, runway end lights may be incorporated into the opposite end threshold fixtures provided the photometric requirements are met. (See Figure 4-4A for the Air Force configuration, and Figure 4-4B for the Army configuration). When runway width exceeds 150 feet (45 meters) additional runway end lights may be added.

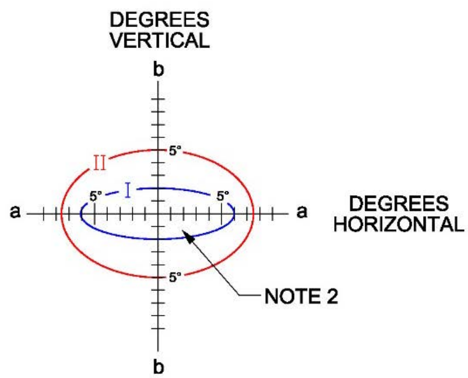
4-6.3 Photometric Requirements.

Optimum aiming of lights depends on the design and output of the fixtures used in the system. Light fixtures may be designed to cover several applications and may have fixed patterns and aiming angles that differ from this document. Light aiming and patterns other than those in the standard may be used if the resultant light pattern produces equivalent light intensities in the areas required by this standard. Use unidirectional red runway end lights facing toward the runway. Aim the lights parallel with the runway centerline and upward at 3 degrees above the horizontal. They must operate at five intensities as specified in paragraph 4-2.3 for HIRL.
Note: This configuration for runway aligned taxiways will not be approved for new construction.

Runway end lights used with MIRL must have reduced intensities compatible with the edge lights and operate at three intensity steps. (See Figure 4-11.)

For detailed photometric requirements for runway end lights, see FAA AC 150/5345-46.

Figure 4-11 Runway End Light Photometrics



	I=50%	II=10%
a	6.0°	7.5°
b	2.25°	5.0°

RUNWAY END LIGHT, RED

NOTES:

1. ALL CONTOURS ARE ELLIPSES CALCULATED BY EQUATION: $(X/a)^2 + (Y/b)^2 = 1$.
2. THE MINIMUM AVERAGE INTENSITY OF THE MAIN BEAM (INSIDE CONTOUR I) IS 2,500 CD AVIATION RED, MAXIMUM INTENSITY SHOULD NOT EXCEED 1.5 TIMES ACTUAL AVERAGE INTENSITY.
3. CONTOURS I AND II INDICATE THE MINIMUM PERCENT VALUES OF THE MAIN BEAM INTENSITY.

4-6.4 Equipment.

Unless the lights are to be located in an area not paved, use in-pavement fixtures with no part protruding more than 0.75 inch (19 millimeters) above the surrounding surface. Where the runway end is co-located with the opposite direction threshold, the threshold and runway end lights may not be incorporated into the same fixture unless the photometrics meet the requirements for both the red and green colors. For Army only, fixtures meeting FAA AC 150/5345-46 Type L-862 may be used. (See paragraph 13-12.4.)

4-6.5 Compliance with International Military Standards.

4-6.5.1 NATO.

These standards meet NATO STANAG 3316 (Edition 11) – Airfield Lighting.

4-6.5.2 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

4-6.6 Additional Information.

See FAA AC 150/5345-46 for more information.

4-7 RUNWAY CENTERLINE LIGHTS (RCL).

4-7.1 Purpose.

The runway centerline lights provide lateral guidance during landing, rollout and takeoff roll under low visibility conditions. They are optional for Category II and are required for Category III instrument operations.

4-7.2 Configuration.

The runway centerline lighting system is a straight line of lights which runs parallel with and within 2 feet (0.6 meters) of the runway centerline. Configure the system as shown in Figure 4-12. The lighting system extends from 75 feet (22.5 meters) of the upwind end of the runway. It is desirable to offset centerline light fixtures on runways equipped with aircraft arresting systems to avoid hook-skip problems and damage to the centerline light fixtures. Up to five fixtures may be omitted in the vicinity of the arresting gear pendant cables to avoid hook bounce and minimize light damage. Remove existing centerline light fixtures within this area and replace with blank cover plates.

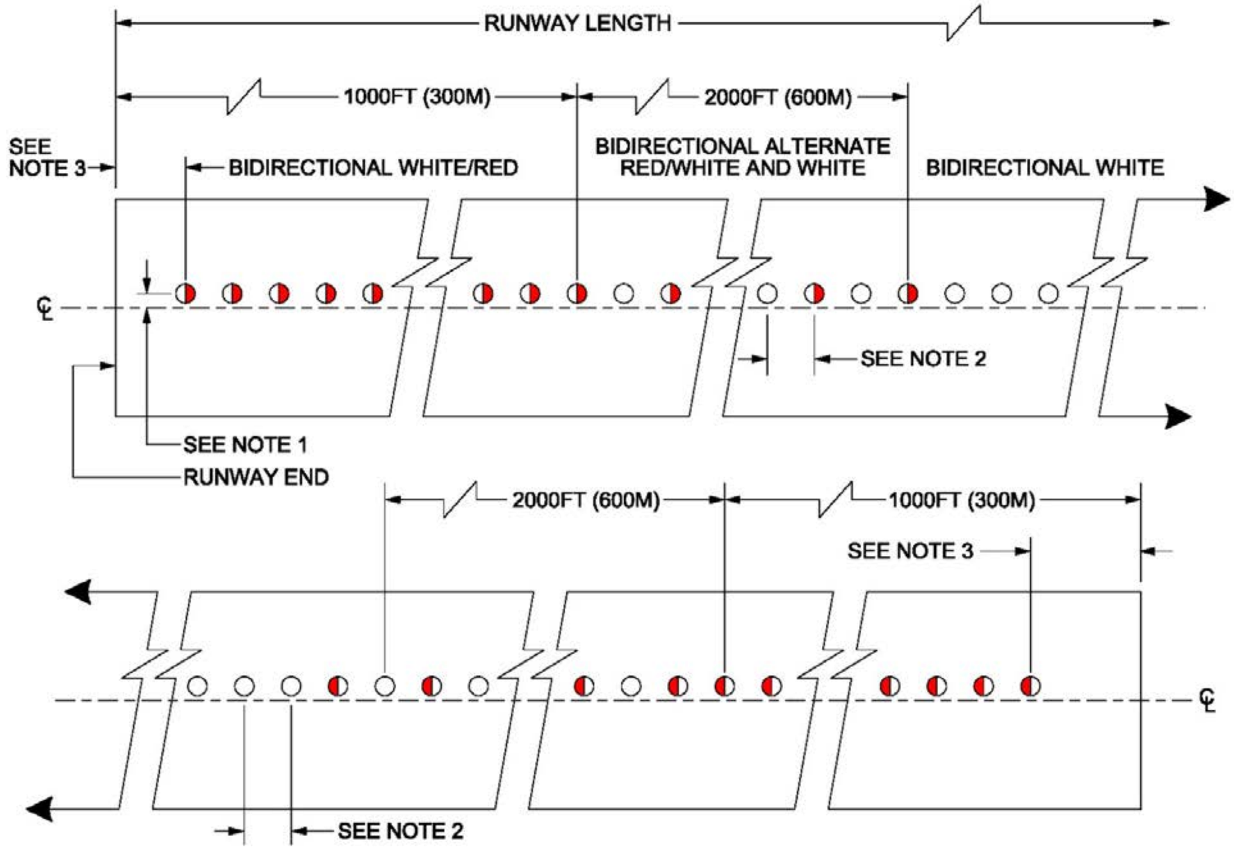
4-7.3 Photometric Requirements.

See FAA AC 150/5345-46 for photometric requirements for runway centerline light fixtures. The lights must meet the intensity requirements shown in Figure 4-13. They must be aimed parallel with the runway centerline ±1/2 degree and upward at 4.5 degrees. They must operate at 5 intensity steps as specified in paragraph 4-2.3 for runway edge lights.

4-7.3.1 Color Coding.

The last 3,000-foot (900 meters) portion of the runway centerline lighting system is color coded to warn pilots of the impending runway end. Alternating red and white lights are installed, starting with red, as seen from 3,000 feet (900 meters) to 1,000 feet (300 meters) from the runway end, and red lights are installed in the last 1,000 foot (300 meters) portion.

Figure 4-12 Runway Centerline Light Configuration



NOTES:

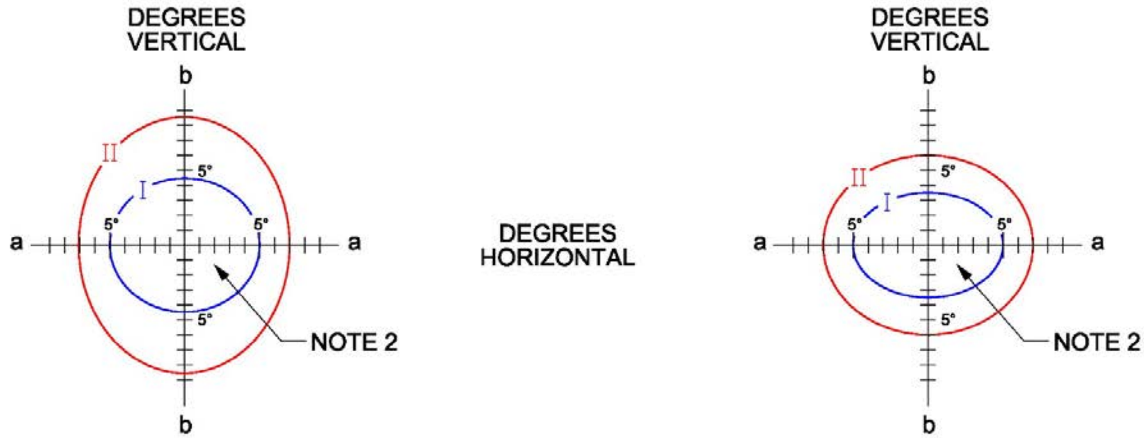
1. THE RCL LINE MAY BE OFFSET NOT MORE THAN 2FT (0.6M) RIGHT OR LEFT OF THE RUNWAY CENTERLINE. THE LATERAL TOLERANCE FROM THE LINE OF LIGHTS ± 1IN (25MM).
2. THE RCL MUST BE EQUALLY SPACED AT 50FT (15M) FOR FAA TYPE L-850A LIGHTS. THE LONGITUDINAL TOLERANCES IS ± 2FT (0.6M).
3. THE FIRST LIGHT FROM EITHER END OF THE RUNWAY MUST BE FOR FAA TYPE L-850A LIGHTS NOT LESS THAN 50FT (15M) AND NOT MORE THAN 87.5FT (26.25M).

LEGEND:

○ BIDIRECTIONAL RCL - WHITE BOTH DIRECTIONS

◐ BIDIRECTIONAL RCL - RED IN DIRECTION OF SHADED SIDE, WHITE IN DIRECTION OF WHITE SIDE.

Figure 4-13 Runway Centerline Light Photometric Configuration



A. CENTERLINE LIGHTS, HOOK-RESISTANT, 25 FT (7.5M) SPACING

B. CENTERLINE LIGHTS, HIGH INTENSITY, 50 FT (15M) SPACING

A.

	I=50%	II=10%
a	5.0°	7.0°
b	4.5°	8.5°

B.

	I=50%	II=10%
a	5.0°	7.0°
b	3.5°	6.0°

NOTES:

1. ALL CONTOURS ARE ELLIPSES CALCULATED BY EQUATION: $(X/a)^2 + (Y/b)^2 = 1$.
2. THE MINIMUM AVERAGE INTENSITY OF THE MAIN BEAM (INSIDE CONTOUR I) IS 250 CD WHITE OR 150CD RED FOR 25 FT (7.5M) SPACING; 5,000 CD WHITE AND 750 CD RED FOR 50 FT (15M) SPACING. MAXIMUM INTENSITY SHOULD NOT EXCEED 1.5 TIMES ACTUAL AVERAGE INTENSITY.
3. CONTOURS I AND II INDICATE THE MINIMUM PERCENT VALUES OF THE MAIN BEAM INTENSITY.

4-7.4 Adjustment and Tolerances.

The line of runway centerline lights may be uniformly offset laterally to the same side of the physical runway centerline a maximum of 2.5 feet (0.75 meters) (tolerance ±1 inch (25millimeters) measured from the physical runway centerline to the fixture centerline. For any new runway, the light base installation must be no closer than 2 feet (0.6 meters) (measured to the edge of the fixture base) to any pavement joints. The mounting surface of the fixture must be level within 1 degree in any direction and the horizontal must be within 1 degree of that specified.

4-7.5 Equipment.

Use in-pavement fixtures with no part protruding more than 0.5 inch (13 mm) above the surrounding surface.

4-7.6 Power Requirements.

For Categories II and III operations, provide a main and standby power system with automatic transfer within one second of a failure of the system. For Category I operation, a 15 second transfer is adequate.

4-7.7 Control Requirements.

Provide remote on-off and intensity control.

4-7.8 Monitoring Requirements.

When supporting of operations below 2,400 feet (720 meters) RVR, provide system monitoring which, at a minimum, gives positive indication at the control facility that power is being delivered to the lights.

4-7.9 Compliance with International Military Standards.

4-7.9.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

4-7.9.2 NATO.

These standards meet the NATO STANAG 3316 (Edition 11) – Airfield Lighting.

4-7.9.3 Additional Information.

See FAA AC 150/5340-30 for more information.

4-8 TOUCHDOWN ZONE LIGHTS (TDZL).

4-8.1 Purpose.

Touchdown zone lights provide continuity when crossing the threshold into the touchdown area and provide visual cues during the flare out and touchdown phases of the landing. They are required for Category II or III operations. The Touchdown zone (sometimes called the Landing Zone) is the portion of a runway, beyond the threshold, intended as the first point of contact between landing aircraft and the runway. For rotary-wing and vectored-thrust aircraft, it is the portion of the helipad or runway used for landing.

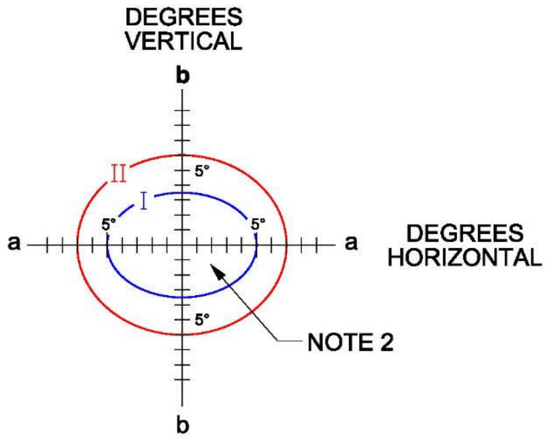
4-8.2 Configuration.

Touchdown zone lights consist of 2 rows of transverse light bars located symmetrically about the runway centerline per FAA AC 150/5340-30J, **\4** Figure A-35 **/4/**. Each light bar consists of 3 unidirectional lights facing the landing threshold. The rows of light bars extend to 3,000 feet (900 meters), or one-half the runway length for runways less than 6,000 feet (1,800 meters), from the threshold with the first light bars located 100 feet (30 meters) from the threshold. See FAA AC 150/5340-30J for additional information about TDZ lights and installation adjustments (light optical assembly toe-in). (See Figure 4-14.)

4-8.3 Photometric Requirements.

Optimum aiming of the lights depends on the design and layout of the fixtures used in the system. The light fixtures may be designed to cover several applications and may have fixed patterns and aiming angles which differ from this document. The light aiming and patterns other than those cited in this standard may be used if the resultant light pattern produces equivalent light intensities in the areas regulated by the standard. TDZ lights must emit unidirectional aviation white light as shown FAA AC 150/5340-30. They must be toed in 4 degrees toward the centerline and aimed upward 5.5 degrees. This is achieved by either installing light fixtures that have had their optical assembly toed 4 degrees, in accordance with FAA AC 150/5340-30, or by angling the light base 4 degrees and installing the light fixture. The lights must operate at five intensity steps per paragraph 4-2.3 for HIRL.

Figure 4-14 Touchdown Zone Light Photometric Requirements



	I=50%	II=10%
a	5.0°	7.0°
b	3.5°	6.0°

TOUCHDOWN ZONE LIGHT, WHITE

NOTES:

1. ALL CONTOURS ARE ELLIPSES CALCULATED BY EQUATION: $(X/a)^2 + (Y/b)^2 = 1$.
2. THE MINIMUM AVERAGE INTENSITY OF THE MAIN BEAM (INSIDE CONTOUR I) IS 5,000 CD WHITE, MAXIMUM INTENSITY SHOULD NOT EXCEED 1.5 TIMES ACTUAL AVERAGE INTENSITY.
3. CONTOURS I AND II INDICATE THE MINIMUM PERCENT VALUES OF THE MAIN BEAM INTENSITY.
4. THE INTENSITY REQUIREMENTS FOR ANGLES BELOW THE SURFACE OF THE PAVEMENT MAY BE DISREGARDED.

4-8.4 Adjustment and Tolerances.

Refer to notes in Figure 4-15 for installation tolerances. All light bars must be located at the same distance from the runway centerline. The mounting surface of the fixture must be level within 1 degree in any direction and the horizontal aiming must be within 1 degree.

4-8.5 Equipment.

Use in-pavement fixtures with no part protruding more than 0.5 inches (13 mm) above the surrounding surface.

4-8.6 Power, Control and Monitoring.

The requirements in paragraphs 4-7.6 through 4-7.8 for runway centerline lights apply.

4-8.7 Compliance with International Standards.

4-8.7.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

4-8.7.2 NATO.

These standards meet the requirement of STANAG 3316 (Edition 11) – Airfield Lighting.

4-8.8 Additional Information.

See FAA AC 150/5340-30 for more information.

CHAPTER 5 STANDARDS FOR TAXIWAY LIGHTING

5-1 TAXIWAY EDGE LIGHTING.

5-1.1 Purpose.

Taxiway edge lights define the lateral limits and direction of a taxiing route. Taxiway edge lighting must be installed for night VMC operations and for day and night instrument operations.

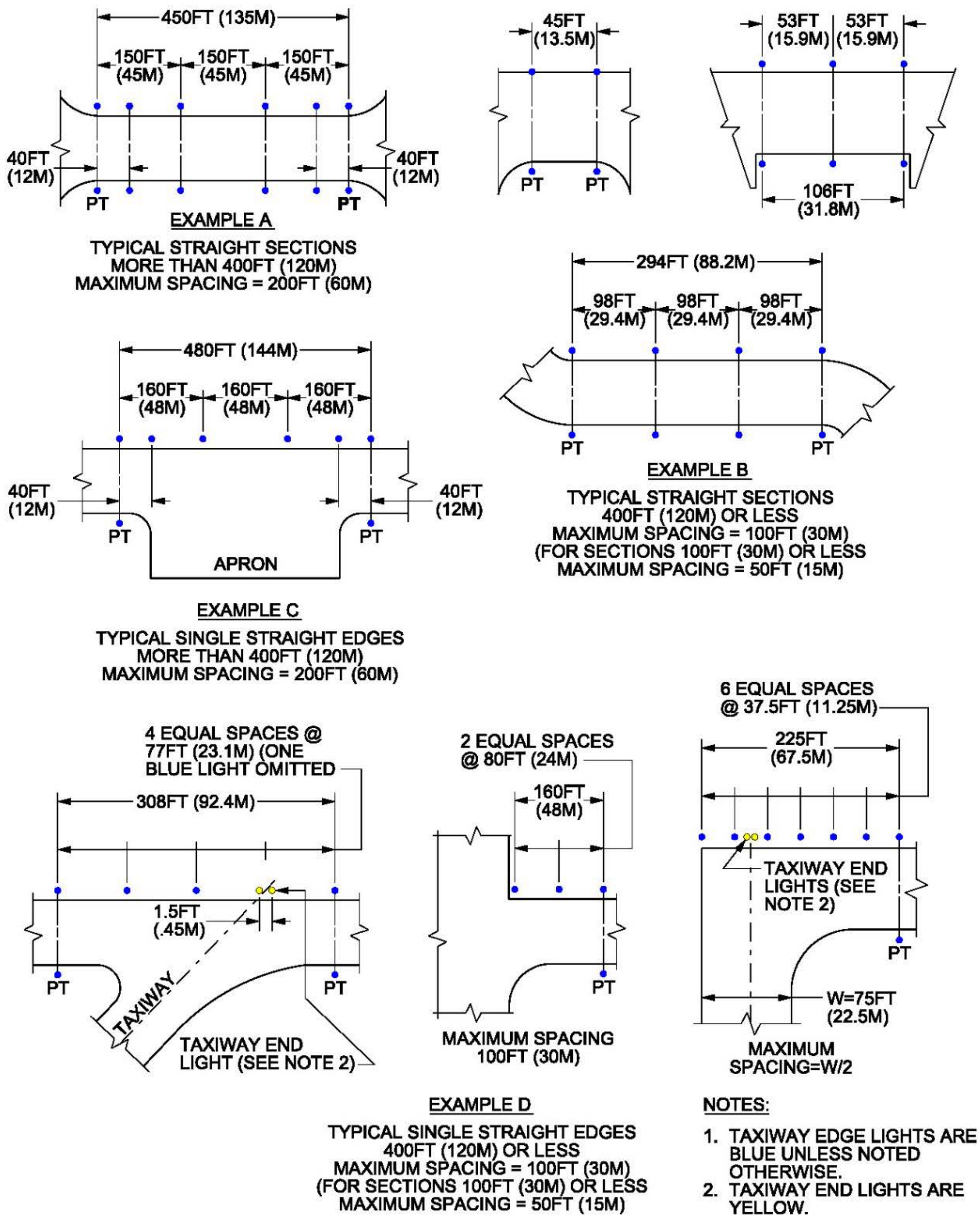
5-1.2 Configuration.

Locate the center line of taxiway edge lights on each side of the taxiway no more than 10 feet (3 meters) from the edge of the full-strength paving, and no closer than the edge of the full-strength paving. The line of lights on both sides of a taxiway must be the same distance from their respective taxiway sides. Runway aligned taxiways are not approved for new construction. For existing installations, it is strongly recommended that runway aligned lights ahead of the runway threshold be changed to red. To determine the spacing of lights along the taxiway length, such as intersections with runways and other taxiways or changes in alignment or width, a discontinuity on one side of a taxiway applies to the other side as well; Figure 5-1 illustrates most situations. Place an edge light at each discontinuity. For intersecting pavements, place them at the point of tangency (PT) of each fillet. Place a companion light on the side opposite the discontinuity as well.

5-1.2.1 Straight Sections.

Place edge lights along all straight taxiway edges at uniform intervals between the lights, as in paragraph 5-1.2. Where the length of the section is greater than 400 feet (120 meters), the spacing must not exceed 200 feet (60 meters) (see Figure 5-1, examples A and C). Where the light spacing exceeds 100 feet (30 meters), place one additional light 40 feet (12 meters) from each end of the section (See Figure 5-1, examples A and C). If the section under consideration is opposite an intersecting taxiway, the uniform spacing must not exceed 1/2 the width of the intersecting taxiway. Where the length of the section is equal to or less than 400 feet (120 meters) the spacing must not exceed 100 feet (30 meters) (see Figure 5-1, examples B and D). Where the section is opposite an ending taxiway, the uniform spacing must not exceed 1/2 the width of the ending taxiway (see Figure 5-1, example D). Place companion lights along the opposite edge where there is no intersecting pavement. Place all companion lights on lines perpendicular to the taxiway centerline (see Figure 5-1, examples A and B).

Figure 5-1 Taxiway Edge Lighting Configuration (Straight)



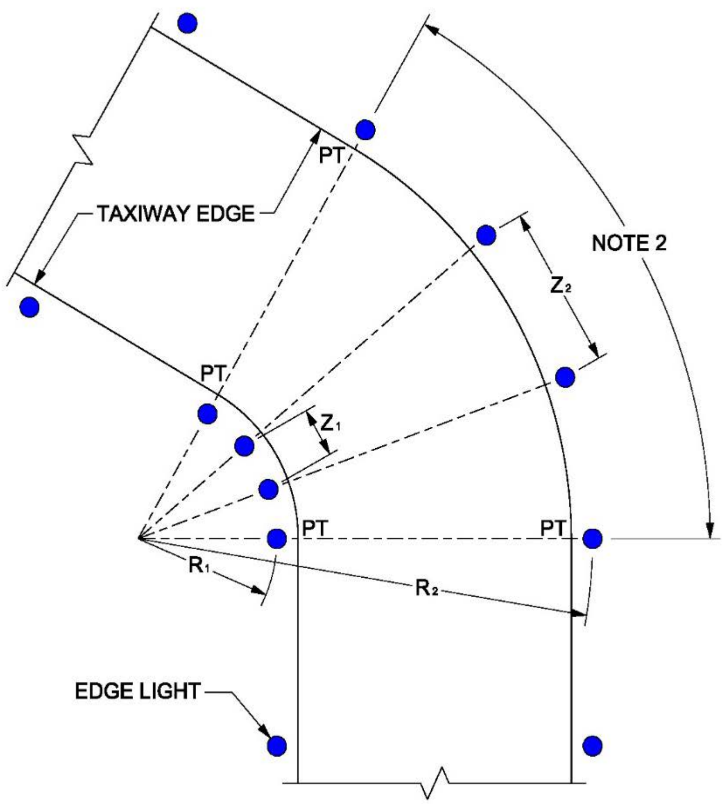
Note: See paragraph 5-1.2.3 for taxiway end lights.

\4\
5-1.2.2 Curved Sections.

Place edge lights along all curved taxiway sections. Uniformly space the lights on the outer line at a distance, not to exceed the value obtained from the formula given in Figure 5-2. Place the lights on the inner line on radials from the outer line of lights, except where the resultant spacing would be less than 20 feet (6 meters). In this case, select spacing not less than 20 feet (6 meters) for the inner line of lights and place the outer line of lights on radials from the inner line.

Place uniformly spaced edge lights at all fillets as shown in Figure 5-3. The spacing must not exceed one half the width of the straight taxiway section.

Figure 5-2 Taxiway Edge Lighting Configuration (Curves)



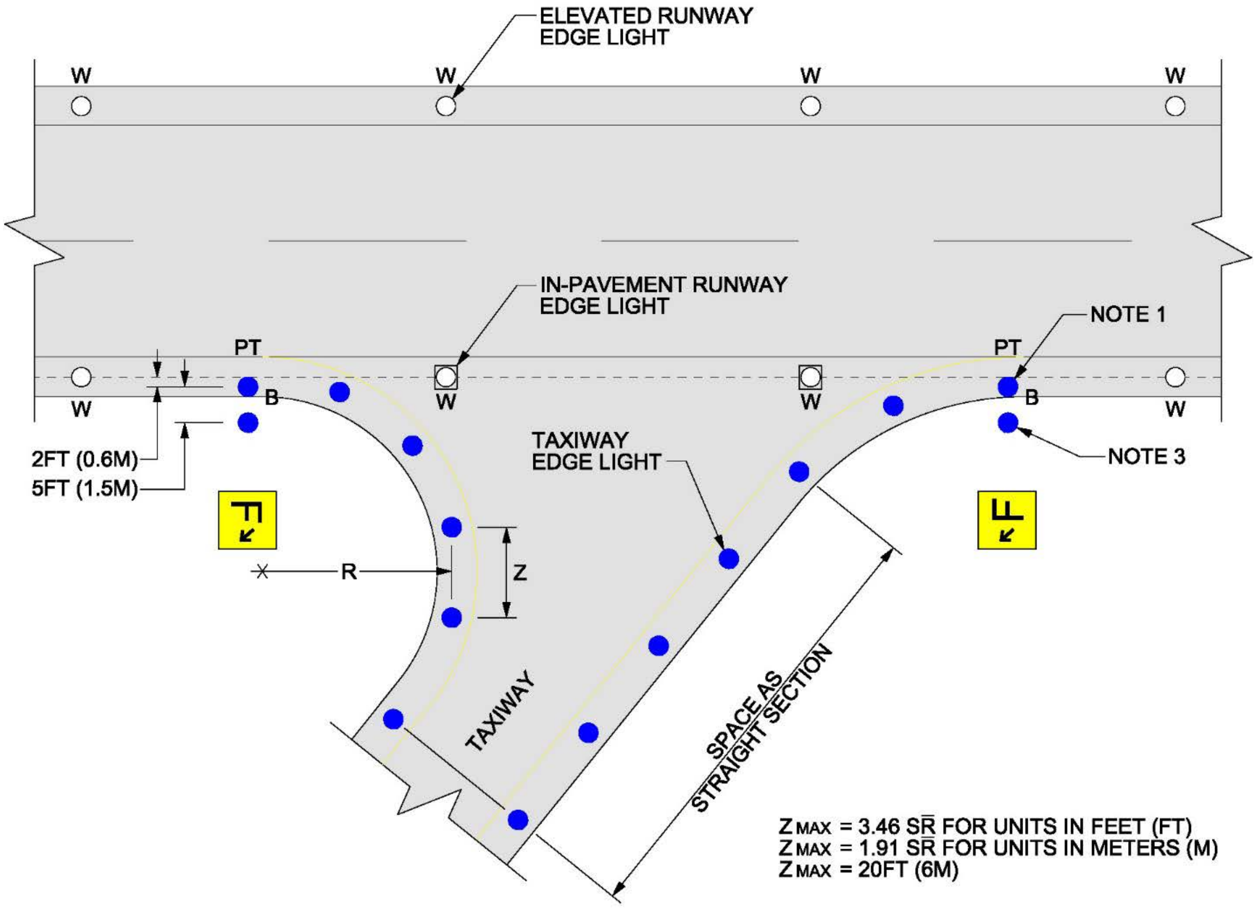
Z_{MAX} = 3.46 x R FOR UNITS IN FEET (FT)
Z_{MAX} = 1.91 x R FOR UNITS IN METERS (M)

NOTES:

1. SPACE LIGHTS UNIFORMILY ON BOTH SIDES OF THE TAXIWAY BETWEEN POINTS OF TANGENCY (PT). DETERMINE SPACING BY DIVIDING TOTAL ARC INTO INCREMENTS (Z).
2. ON ALL CURVES IN EXCESS OF 30° OF ARC, USE A MINIMUM OF THREE EDGE LIGHTS, INCLUDING THOSE AT THE PTs FOR A CURVE OF 30° OR LESS PROVIDE LIGHTS ONLY AT THE PTs.
3. ALIGN LIGHTS ON THE INSIDE RADIUS (R_1) WITH THOSE ON THE OUTSIDE RADIUS (R_2). IF $Z_1 < 20$FT (6M) DECREASE THE NUMBER OF LIGHTS ON R_1 UNTIL $Z_1 \geq 20$FT (6M) AND SPACE EVENLY ALONG RADIUS R_1.

/4/

Figure 5-3 Taxiway Edge Lighting Configuration Entrance/Exit



NOTES:
1. TAXIWAY LIGHTS MUST NOT BE IN LINE WITH RUNWAY LIGHTS.
2. PT = POINT OF TANGENCY.
3. TAXIWAY ENTRANCE/EXIT LIGHT MAY BE OMITTED IF RUNWAY EXIT SIGN IS USED.

5-1.2.3 Taxiway End Lights.

Where a taxiway ends at a crossing taxiway, place two yellow lights spaced 1.5 feet (0.45 meters) apart and in the line of the edge lights of the crossing taxiway. Center them on the point where the extended centerline of the ending taxiway intersects. If a yellow light falls within 5 feet (1.5 meters) of a blue edge light, the blue light may be eliminated (see Figure 5-1, examples C and D). Not supported for new construction.

5-1.2.4 Entrance/Exit Lights.

On intersections of taxiways with runways or aprons, place entrance/exit lights at the point of tangency of the taxiway fillet with the runway or apron. Do not place them at an intersection of taxiways. An entrance/exit light consists of 2 taxiway edge lights spaced 5 feet (1.5 meters) apart. One is located 5 feet (1.5 meters) out, on a line extending through the first light and perpendicular to the side of the runway or apron. The entrance/exit light may be omitted if a taxiway exit direction sign is used on the runway. See Figure 5-3.

FAA taxiway fillet geometry changed in 2018, AC 150/5354-30J, Design and Installation Details for Airport visual Aids, but application of this geometry does not apply to Army and Air Force airfields. Current fillet geometry is acceptable.

5-1.2.5 Apron Taxiways.

For a taxiway that is adjacent to, or on the edge of, an apron, the taxiway edge lights are usually placed only on the side of the taxiway farthest from the apron. (“Taxiing” routes through an apron will not have these lights.)

5-1.2.6 Apron Perimeter Lights Without a Taxiway

Aircraft parking aprons are arranged in many ways, with perimeters defined by open spaces or hangars or other facilities. Generally, the edge lighting of the perimeter defined by an open space can have taxiway edge lights that are placed according to the spacing examples for straight and curved taxiway edge lighting.

5-1.3 Tolerances.

Adjust the longitudinal location of any light a maximum of 5 feet (1.5 meters) to avoid installation problems. Move the companion light the same amount, if practical, to maintain the relationship between the two lights. Install taxiway edge lights within 6 inches (150 mm) laterally or longitudinally of the design location.

5-1.4 Photometric Requirements.

Optimum aiming of lights depends on the design and output of the fixtures used in the system. See FAA AC 150/5345-46 for additional detailed photometric information about taxiway edge lights.

5-1.5 Equipment.

Use frangible mounted elevated fixtures in all areas, including Category II and Category III operations, as described. Mount elevated fixtures a maximum of 14 inches (350 millimeters) above grade. Where there are frequent snow accumulations of 12 inches (300 millimeters) or more, the mounting height may be increased as shown in Figure 4-3.

5-1.5.1 Provide a fixture base that houses the isolation transformer; fixture base and can should be a standard size that will fit both elevated and in-pavement fixture types. This facilitates future runway and taxiway configuration changes or modifications should an elevated fixture no longer be suitable. The light base and can installation must be no closer than 2 ft (0.6 m) (measured to the edge of the fixture base) from any pavement joint.

5-1.5.2 To reduce the "sea of blue lights" effect at an airfield with many taxi routes, hoods may be used on elevated fixtures. Do not use hoods on taxiway entrance/exit light fixtures.

5-1.5.3 Where elevated lights may be damaged by jet blast or operation of an arresting gear, or where they interfere with aircraft operation such as B-52 outrigger gears, use in-pavement fixtures.

5-1.6 Power Requirements.

Provide a main power system and circuits which permit independent control of the taxiways. Provide standby power only for those taxiways supporting precision instrument approaches. Transfer time from the failed power system must not exceed 15 seconds.

5-1.7 Control Requirements.

Taxiway lighting circuits must be segmented and controlled to provide the degree of flexibility required for airfield operations. (See Figure 5-4.) Provide remote on/off control for all taxiway segments, and provide a three step intensity control.

5-1.8 Monitoring Requirements.

There is no requirement for monitoring taxiway circuits.

5-1.9 Compliance with International Standards.

5-1.9.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

5-1.9.2 NATO.

These standards meet the requirements of STANAG 3316 (Edition 11) – Airfield Lighting, except for the light spacing on curves.

5-2 TAXIWAY CENTERLINE LIGHTS.

5-2.1 Purpose.

Taxiway centerline lights are a system of aviation green in-pavement lights installed along the taxiway centerlines to provide alignment and course guidance information in specific instances of visibility, established by FAA AC 120-57A, *Surface Movement Guidance and Control System.* They may be installed where it is impractical to install taxiway edge lights. On taxiways which support Category II and Category III operations, the particular use of taxiway centerline lights depends upon the runway visual range (RVR) and allowable landing conditions.

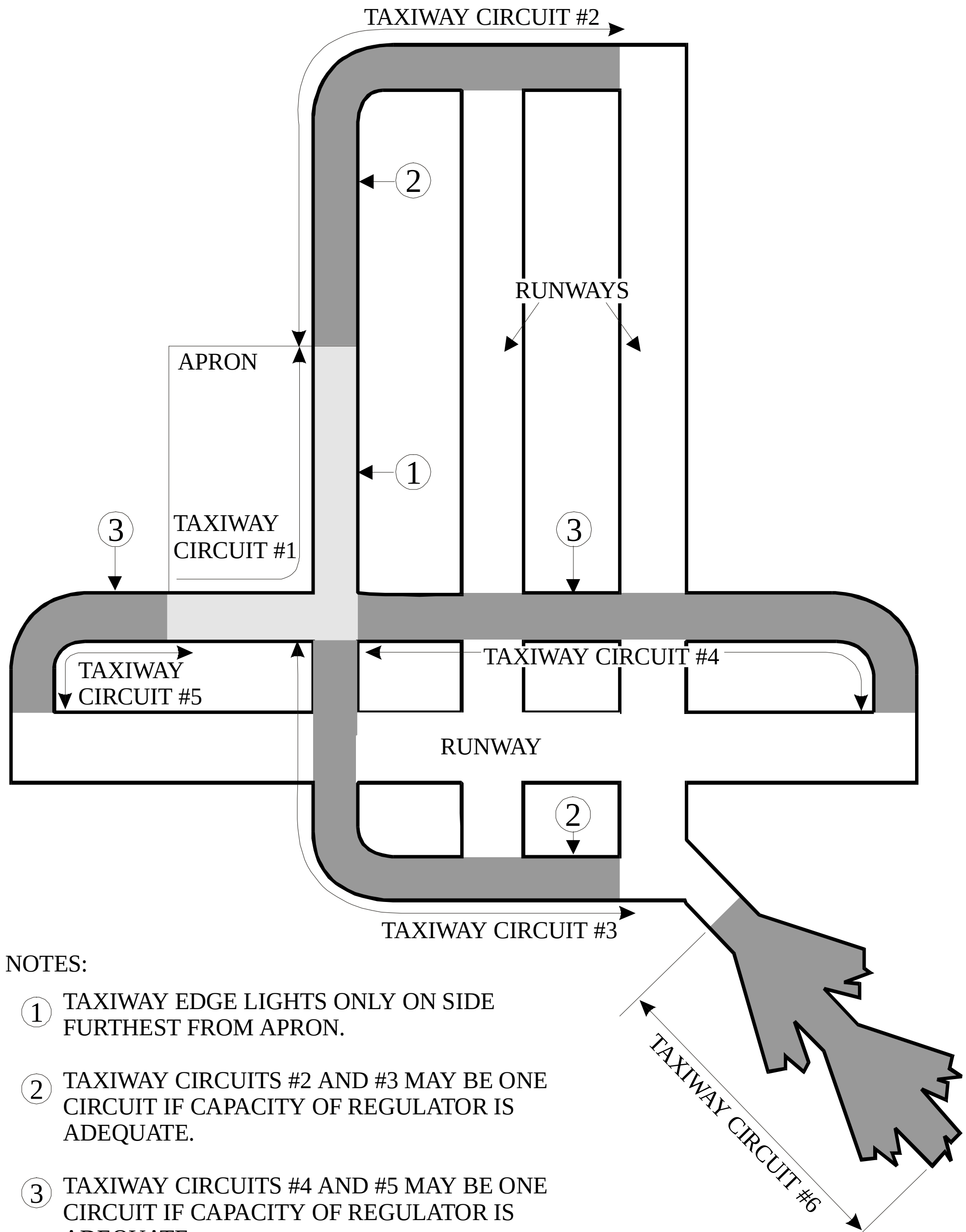
Taxiway centerline light requirements are determined within FAA AC 120-57A, paragraph 8, "Visual Aid Requirements." When required, they are installed in accordance with FAA AC 150-5340-30, *Design and Installation Details for Airport Visual Aids*, Chapter 4, "Taxiway Lighting Systems."

5-2.2 Configuration.

Install taxiway centerline lights in smooth lines along the taxiway centerline. To avoid construction joints or markings, the line of lights may be offset uniformly a maximum of 2 feet (0.6 meters) from the centerline. Actual configuration and spacing must conform with FAA AC 150-5340-30.

5-2.2.1 Place a light at each holding position, at each PT of a curved section, at each taxiway end, at each intersection with a runway edge or apron, and at the PTs of all fillets. Where taxiways cross, place a light at the intersection of the centerlines.

Figure 5-4 Taxiway Circuit Layout



NOTES:

1. TAXIWAY EDGE LIGHTS ONLY ON SIDE FURTHEST FROM APRON.
2. TAXIWAY CIRCUITS #2 AND #3 MAY BE ONE CIRCUIT IF CAPACITY OF REGULATOR IS ADEQUATE.
3. TAXIWAY CIRCUITS #4 AND #5 MAY BE ONE CIRCUIT IF CAPACITY OF REGULATOR IS ADEQUATE.

LEGEND:

LIGHTED TAXIING ROUTE

LIGHTED TAXIING ROUTE ALONG EDGE OF APRON

5-2.2.2 Place uniformly spaced lights between the points defined above, along all straight and curved sections of the taxiway. The uniform spacing will approach, but not exceed, the criteria given in Figure 5-5. The location of individual lights may be adjusted along the line of lights a maximum of 2 feet (0.6 meters) to avoid construction problems. Note: See AC 120-57A, Chapter 8, for taxiway lighting requirements in the movement area.

5-2.2.3 At taxiway intersections, place lights along an arc drawn tangent to the centerlines of the taxiways (or lines of lights) in the direction of all aircraft turns. To reduce confusion where aircraft turns are not anticipated, the arc of lights may be omitted. The minimum clearance to the inner edge of either taxiway must be equal to one half the width of the narrower taxiway. Select the largest radius that will provide the clearance for the arc of lights. Do not install taxiway centerline lights on runway surfaces, except as specified for runway exit lights.

5-2.3 Tolerances.

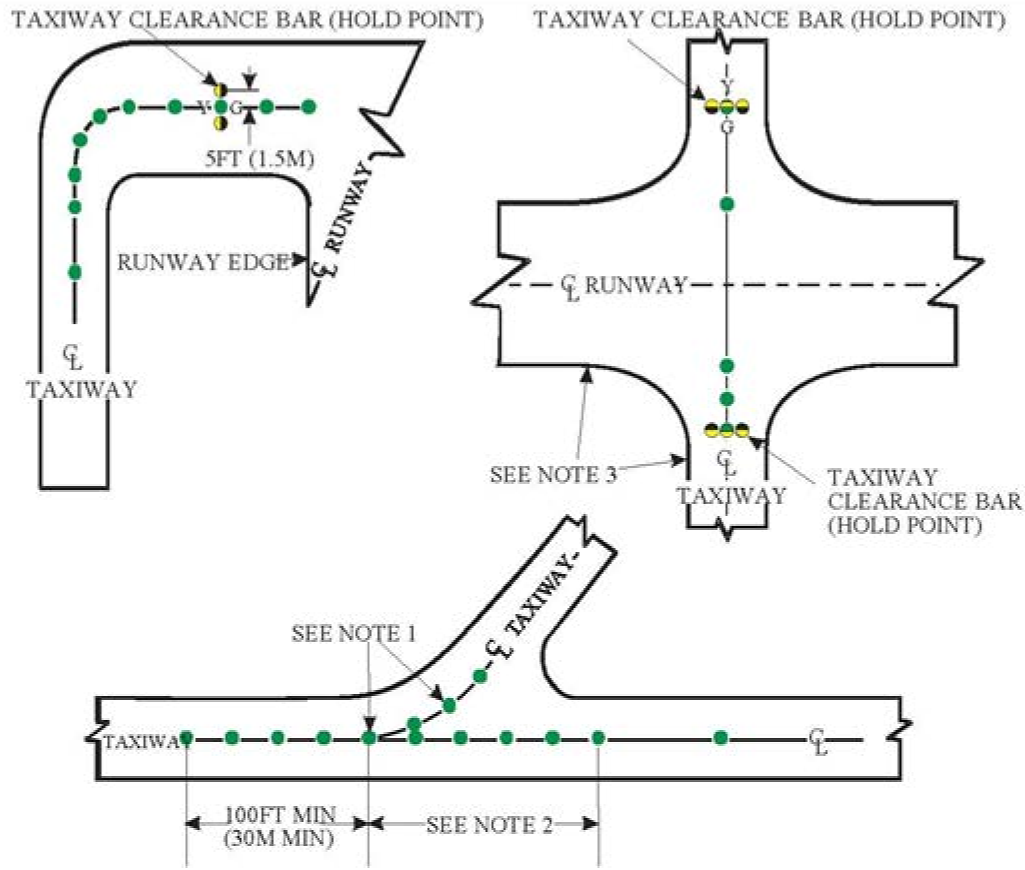
Taxiway centerline lights must not be more than 3 inches (75 millimeters) off of the designated line of lights and not more than 6 inches (150 millimeters) from the designated locations along the line of lights.

5-2.4 Equipment.

Use in-pavement fixtures which do not protrude more than 0.50 inch (13 millimeters) above the pavement. They must be bidirectional aviation green except as follows:

- At crossing taxiways, the light at the intersection must be omnidirectional aviation yellow.
- On taxiways where the aircraft movement is in one direction only, the lights may be unidirectional and facing the oncoming aircraft.
- Where hold lights are installed, the centerline light must be aviation yellow facing the holding aircraft.

Figure 5-5 Taxiway Centerline Lighting Configuration (See FAA AC 120-57A)



LONGITUDINAL SPACING CRITERIA

		CAT II/III IFR	ALL OTHER
NOMINAL		50FT (15M)	100FT (30M)
AT INTERSECTIONS (SEE NOTE 2)		50FT (15M)	50FT (15M)
CURVES	RADIUS LESS THAN 400FT (120M)	12.5FT (3.75M)	25FT (7.5M)
(SEE	RADIUS 400FT (122M) TO 1200FT (360M)	25FT (7.5M)	50FT (15M)
NOTE 1)	RADIUS GREATER THAN 1200FT (360M)	50FT (15M)	100FT (30M)

NOTES:

1. LOCATE LIGHTS AT PT1 AND PT2, AND SPACE INTERMEDIATE LIGHTS EQUALLY ALONG SELECTED CURVE IN COMPLIANCE WITH SPACING CRITERIA.
2. SPACE LIGHTS EQUALLY BETWEEN PT1 AND CLEARANCE BAR (HOLD POINT) LIGHTS.
3. RUNWAY AND TAXIWAY EDGE LIGHTS NOT SHOWN.

LEGEND:

Y/G ● BIDIRECTIONAL, GREEN AND YELLOW

● BIDIRECTIONAL, GREEN

● UNIDIRECTIONAL, YELLOW

5-2.5 Photometric Requirements.

See FAA AC 150/5345-46 for taxiway centerline light fixture photometric requirements. Taxiway centerline lights must be bidirectional and emit aviation green light at three intensity steps: 100 percent, 30 percent, or 10 percent of full brightness. The minimum intensities and beam widths are shown in Table 5-1.

Table 5-1 Taxiway Centerline Light Intensity and Beam Widths

Application	Average Intensity of Main Beam	---------------- BEAM WIDTH ----------------			
		50% Of Main Beam Average		10% Of Main Beam Average	
		Hor.	Vert.	Hor.	Vert.
Category II					
Straight (L-852A)	20 cd	±10	1 to 4	±16	0.5 to 10
Curved (L-852B)	20 cd	±30	1 to 4	±30	0.5 to 10
Category III					
Straight (L-852C)	200 cd	±3.5	1 t 8	±4.5	0 to 13
Curved (L-852D)	100 cd	±30	1 to 10	±30	0 to 15

5-2.5.1 Horizontal Aiming.

Aim lights on straight sections parallel with the taxiway centerline. Aim lights on curved sections along the tangent at the light location. See FAA AC 150/5340-30 for additional detailed information about light fixture aiming.

5-2.6 Power Requirements.

Provide a main power system and circuits which permit independent control of the taxiways. Provide standby power only for those taxiways essential for precision instrument approaches. Transfer time from the failed system to standby system must not exceed 15 seconds for CAT I runways and 1 second for CAT II and CAT III runways.

5-2.7 Control Requirements.

For new installations, provide remote ON, OFF and stepped intensity control. Provide 3 step intensity control for taxiway edge lights. Provide 5 step (preferred) or 3 step intensity control for taxiway centerline lights. The system may be segmented to provide flexibility in choosing taxiway routing.

5-2.8 Monitoring Requirements.

There is no monitoring requirement for taxiways.

5-2.9 Compliance with International Standards.

5-2.9.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

5-2.9.2 NATO.

These standards meet the requirements of STANAG 3316 (Edition 11) – Airfield Lighting, except for the light spacing on curves.

5-3 RUNWAY LEAD-OFF LIGHTS.

5-3.1 Purpose.

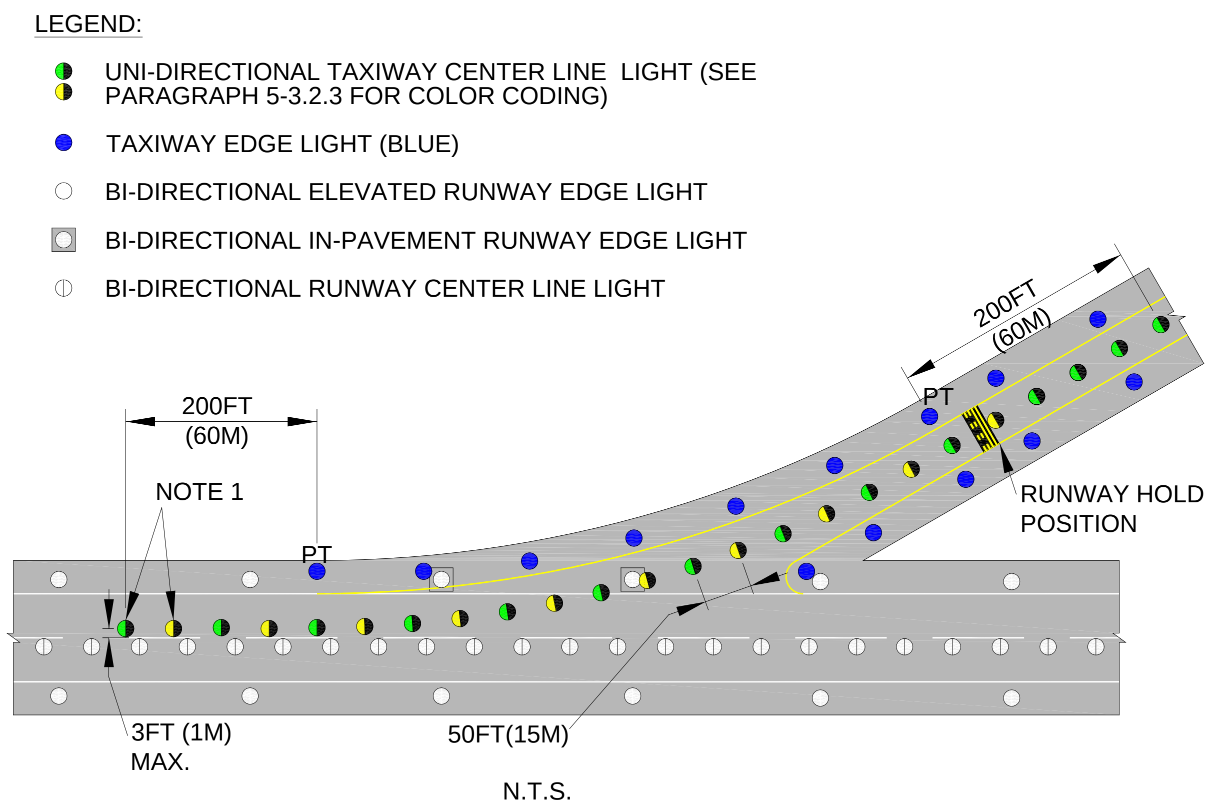
Runway lead-off lights are taxiway centerline lights that provide visual guidance to aircraft exiting the runway. They are color-coded green/yellow to warn pilots and vehicle drivers that they are within the runway environment or instrument landing system/microwave landing system (ILS/MLS) critical area. See FAA AC 150/5340-30 for detailed information about lead-off light installation.

5-3.2 Configuration.

5-3.2.1 Long Radius Exits.

Long radius exit lights are installed on exits with radii exceeding 1,200 feet (360 meters). They consist of a line of unidirectional taxiway centerline lights. The line begins at a point which is a maximum of 3 feet (1 meter) off the runway centerline and 200 feet (60 meters) before the beginning of the taxiway centerline curve. The line of lights runs parallel to the runway to the beginning of the taxiway centerline curve. It then follows the taxiway centerline curve to a point which is a minimum of 200 feet (60 meters) beyond the beginning of the straight portion of the taxiway. The lights are uniformly spaced at a distance of not more than 50 feet (15 meters). (See Figure 5-6.)

Figure 5-6 Taxiway Long Radius High Speed Exit Lights, Radius > 1,200 FT (360 M) (See FAA AC 120-57A)



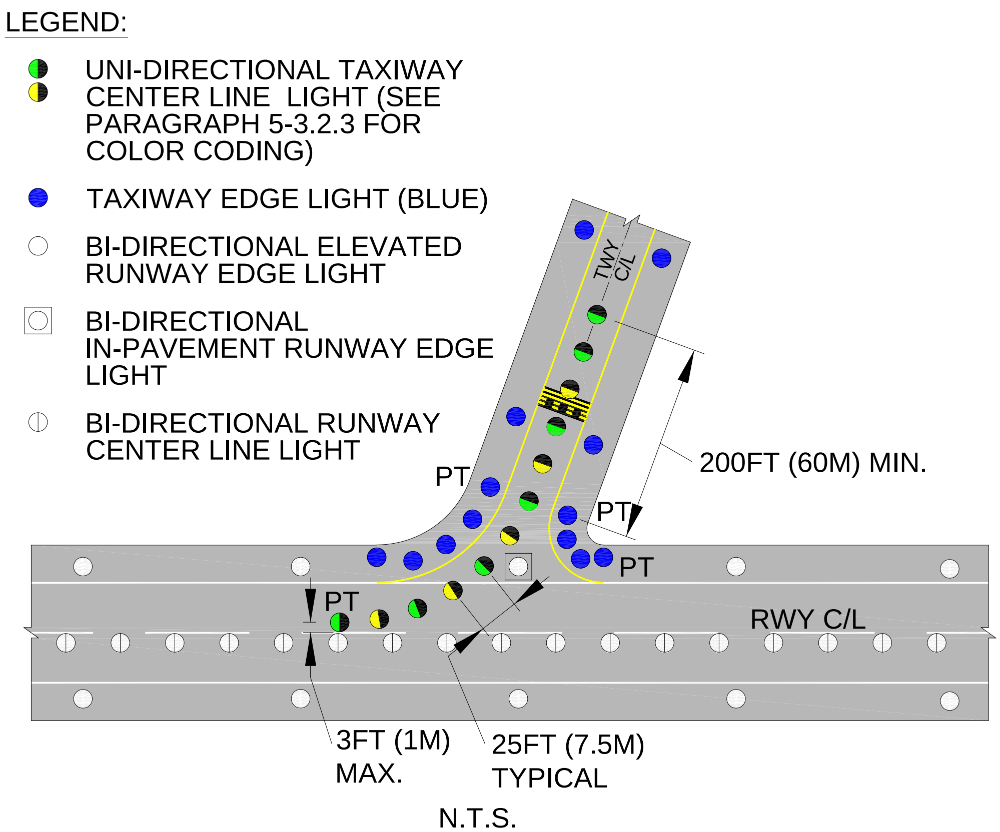
NOTES:

1. THE FIRST LIGHT ON THE RUNWAY IS GREEN. IF THERE IS AN ODD NUMBER OF COLOR-CODED LIGHTS, THE FIRST TWO LIGHTS SHOULD BE GREEN.
2. IF THERE IS AN ILS/MLS CRITICAL AREA PRESENT BEYOND THE RUNWAY HOLDING POSITION, THE COLOR-CODED LIGHTS CONTINUE TO THE ILS/MLS CRITICAL AREA HOLDING POSITION WITH THE LAST YELLOW LIGHT SIMILARLY LOCATED BEYOND THE CRITICAL AREA HOLDING POSITION.

5.3.2.2 Short Radius Exits.

Short radius exit lights consist of a line of taxiway centerline lights. The line of lights begins at a point that is not more than 3 feet (0.9 meter) off the runway centerline on the near side and is the PT of the exit curve. Ensure the radius of the curve is the largest that will provide a minimum clearance to the pavement edge equal to one half the width of the taxiway. The line of lights runs along the arc to the PT with the taxiway centerline. It then follows the taxiway centerline for a minimum of 200 feet (60 meters). The spacing between the lights is not greater than 25 feet (7.5 meters). (See Figure 5-7.)

Figure 5-7 Taxiway Short Radius High Speed Exit Lights Radius ≤ 1,200 FT (360 M) (See FAA AC 120-57A)



NOTES:

1. THE FIRST LIGHT ON THE RUNWAY IS GREEN. IF THERE IS AN ODD NUMBER OF COLOR-CODED LIGHTS, THE FIRST TWO LIGHTS SHOULD BE GREEN.
2. IF THERE IS AN ILS/MLS CRITICAL AREA PRESENT BEYOND THE RUNWAY HOLDING POSITION, THE COLOR-CODED LIGHTS CONTINUE TO THE ILS/MLS CRITICAL AREA HOLDING POSITION WITH THE LAST YELLOW LIGHT SIMILARLY LOCATED BEYOND THE CRITICAL AREA HOLDING POSITION.
3. TAXIWAY CENTERLINE LIGHTS MAY BE BI-DIRECTIONAL (GREEN-GREEN OR YELLOW-YELLOW) IF USED FOR BI-DIRECTIONAL TRAFFIC.

5-3.2.3 Color Coding.

Color-code taxiway exit lights within the runway safety area FAA aviation green or yellow. The first light on the runway must be green. Fixtures between the runway centerline and the runway hold position must alternate green and yellow. The first fixture past the runway hold position must be yellow. If there are an odd number of color-coded lights, the first two lights must be green. Taxiway centerline lights beyond the first fixture past the runway hold position on the runway must be green. Where fixtures are used for bidirectional traffic, fixtures must be color coded in both directions.

5-3.3 Adjustments and Tolerances.

The requirements in paragraph 5-2.3 for taxiway centerline lights apply.

5-3.4 Photometric Requirements and Horizontal Aiming.

The requirements in paragraph 5-2.5 for taxiway centerline lights apply.

5-3.5 Equipment.

Use unidirectional, in-pavement fixtures with no part extending more than 0.5 inch (13 mm) above the surrounding pavement. (See paragraph 13-13.2.)

5-3.6 Power Requirements.

Provide a main power supply and circuits that permit independent control except on a taxiway with centerline lighting. In this case, they may be connected to and controlled with the taxiway centerline lights.

5-3.7 Control Requirements.

Provide remote on/off and intensity control. Runway exit lights shall be controlled with associated taxiway centerline lights.

5-3.8 Monitoring Requirements.

There are no monitoring requirements.

5-3.9 Compliance with International Military Standards.

5-3.9.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

5-3.9.2 NATO.

These standards meet NATO STANAG 3316 (Edition 11) – Airfield Lighting.

5-4 TAXIWAY CLEARANCE BARS.

5-4.1 Purpose.

For Category III airfield operation (below 600 RVR), clearance bars serve two purposes:

5-4.1.1 In low visibility, clearance bars warn pilots and vehicle drivers that they are approaching a hold point (other than a runway holding position). They are installed at designated hold points on the taxiway for operations below 600 feet (180 meters) RVR.

5-4.1.2 At night and in inclement weather, clearance bars warn pilots and vehicle drivers that they are approaching an intersecting taxiway. They are generally installed at taxiway intersections where the taxiway centerline lights do not follow the taxiway curve and taxiway edge lights are not installed.

5-4.2 Configuration.

See FAA AC 150/5340-30 for information about taxiway clearance bar configuration.

A clearance bar consists of a row of three in-pavement yellow lights to indicate a low visibility hold point (see Figure 5-5). The fixtures are normally unidirectional but may be bidirectional depending upon whether the hold point is intended to be used in one or two directions. In addition, with the below exceptions, clearance bars are installed (without regard to visibility) at a taxiway intersection with non-standard fillets or where the taxiway centerline lights do not follow curves at intersections. Clearance bars installed for this purpose consist of unidirectional fixtures.

5-4.2.1 Clearance bars may be omitted if taxiway edge lights are installed at the intersection.

5-4.2.2 If the angle between the centerlines of any two adjacent segments of the pavement is 90 degrees ±10 degrees, clearance bars at a “T” or “+” shaped taxiway/taxiway intersection may be substituted by or supplemented with an omnidirectional yellow taxiway intersection light (L-852E or F, as appropriate) installed near the intersection of the centerline markings.

5-4.2.3 The clearance bar located on an exit taxiway may be omitted if it would be located before, or within 200 feet (60 meters) beyond, a runway holding position (as viewed while exiting the runway).

5-4.3 Location of a Clearance Bar Installed at a Low Visibility Hold Point.

A low visibility hold point consists of a taxiway/taxiway holding position marking, a geographic position marking, and a clearance bar. However, hold points are not necessarily located at taxiway/taxiway intersections. In-pavement clearance bar lights are centered on an imaginary line that is parallel to, and 2 feet (600 millimeters) from, the holding side of the taxiway/taxiway holding position marking. The lights may vary from this imaginary line up to ±2 inches (±50 millimeters) (perpendicular to the holding position marking). If a conflict occurs with rigid pavement joints or other undesirable spots, the taxiway/taxiway holding position marking, geographic position marking, and the clearance bar may all be moved longitudinally any amount necessary to resolve the conflict. However, if the hold point is located at a taxiway/taxiway intersection, move the aforementioned items away from the intersecting taxiway by the minimum necessary to resolve the conflict. If a conflict occurs between the center fixture in the clearance bar and a centerline light, the center fixture may take the place of an existing centerline light.

5-4.4 Location of a Clearance Bar Installed at a Taxiway Intersection.

A clearance bar installed at a taxiway intersection is located in accordance with the criteria of paragraph 5-4.3 if that location is established as a hold point and taxiway/taxiway holding position markings are present. Otherwise, locate the clearance bar in the same manner as if the holding position marking were present. This allows room for the possible future installation of the marking.

5-4.4.1 Lateral Spacing.

The center light of the clearance bar is installed in line with existing or planned taxiway centerline lights. The two remaining lights are installed outboard of the center fixture on 5 foot (1.5 meter) intervals, center-to-center. The outboard fixtures may be moved laterally a maximum of ±1 foot (±300 millimeters) to avoid an undesirable spot (e.g., conduit).

5-4.5 Light Beam Orientation for Clearance Bars.

The axis of the light beam for each fixture is parallel to the centerline of the designated taxiway path with a tolerance of ±1 degree.

5-4.6 Equipment.

Use in-pavement fixtures with no part extending more than 0.50 inches (13 millimeters) above the surrounding pavement. Hold lights must emit unidirectional aviation yellow light toward the holding aircraft. When installed with taxiway centerline lights, the center light must be bidirectional aviation yellow/green with the yellow light toward the holding aircraft.

5-4.7 Photometric Requirements.

See FAA AC 150/5345-46 for taxiway clearance bar light fixture photometric requirements. All other photometric requirements in paragraph 5-2.5 for straight section taxiway centerline lights apply.

5-4.8 Fixtures.

Power and Control Requirements. The requirements for taxiway centerline lights apply. Power and control the fixtures with the associated taxiway lighting system.

5-4.9 Monitoring.

There is no requirement for monitoring.

5-4.10 Compliance with International Military Standards.

Previous AFIC AIR STDs and current NATO STANAGs contain no comparable systems.

5-5 RUNWAY GUARD LIGHTS (RGL).

5-5.1 Purpose.

RGLs provide a distinctive warning to anyone approaching the runway holding position that they are about to enter an active runway.

5-5.2 Configuration.

See FAA AC 50/5340-30 for detailed information about both elevated and in-pavement runway guard light installation and configuration.

Elevated and in-pavement RGLs serve the same purpose and are not generally both installed at the same runway holding position. However, if snow could obscure in-pavement RGLs or there is an acute angle between the holding position and the direction of approach to the holding position, it may be advantageous to supplement in-pavement RGLs with elevated RGLs. Each elevated RGL fixture consists of two alternately illuminated unidirectional yellow lights. In-pavement RGLs consist of a row or alternately illuminated unidirectional yellow lights.

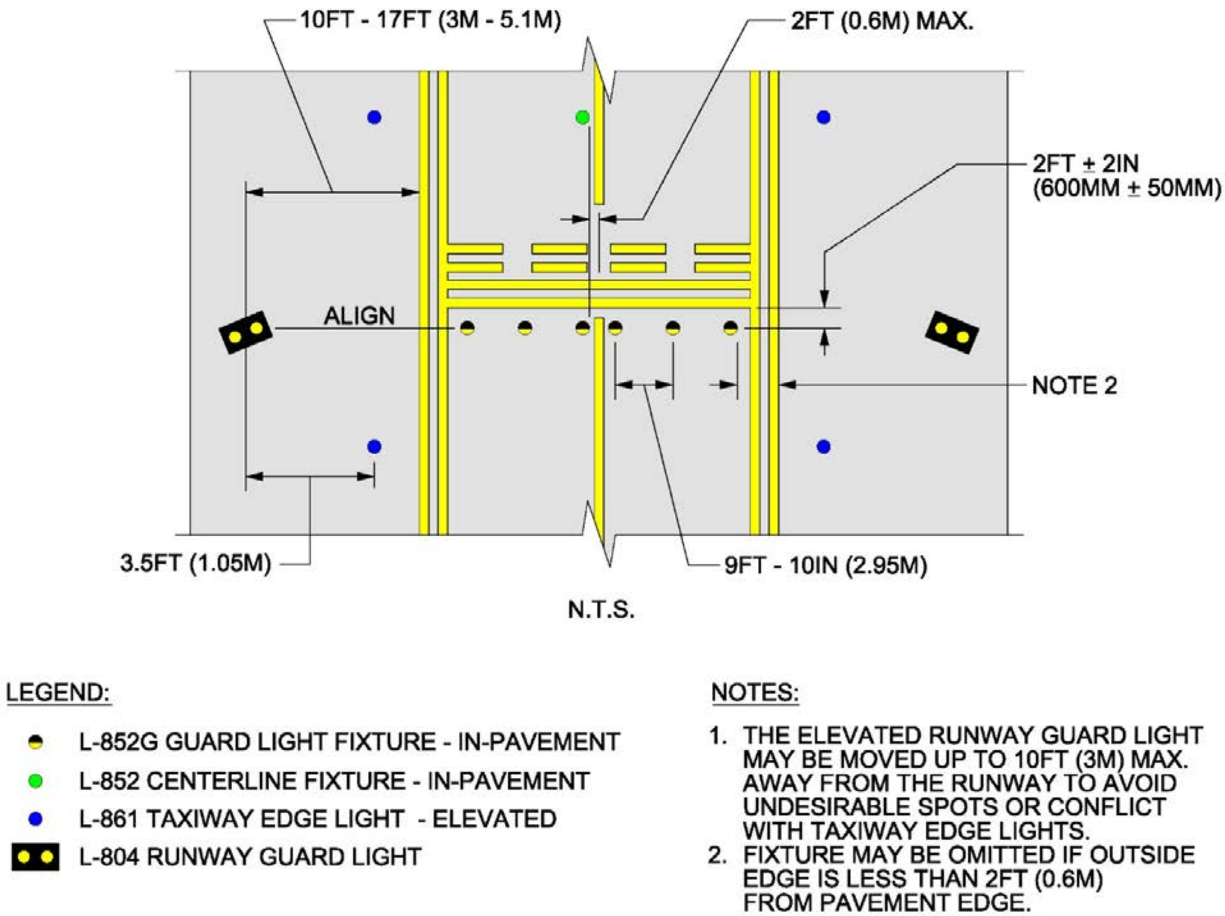
5-5.3 Location of In-pavement Runway Guard Lights.

In-pavement RGLs are centered on an imaginary line that is parallel to, and 2 feet (600 millimeters) from, the holding side of the runway holding position marking (see Figure 5-8). The lights may vary from this imaginary line up to ±2 inches (±50 millimeters) in a direction perpendicular to the holding position marking. If a conflict with rigid pavement joints occurs, the RGLs may be moved away from the runway the minimum distance required to resolve the conflict.

5-5.3.1 Lateral Spacing – Preferred Method.

The lights are spaced across the entire taxiway, including fillets and holding bays, at intervals of 9 feet 10 inches (3 meters), ±2 inches (±50 millimeters), on-center. The lights are spaced in relation to a reference fixture that is installed in-line (longitudinally) with existing or planned taxiway centerline lights. However, it is not intended that the reference fixture replace a taxiway centerline light. If a conflict between the reference fixture and a centerline light occurs, the reference fixture may take the place of an existing centerline light and a new centerline light should be installed in accordance with the criteria in FAA AC 150/5340-30, paragraph 4.3c. If the holding position marking is intersected by multiple taxiway centerline markings, set the reference fixture at the centerline. A fixture whose outboard edge falls at a point less than 2 feet (0.6 meters) from the defined edge of the taxiway (outboard edge of the taxiway marking) may be omitted. Individual fixtures may be moved laterally maximum of ±1 foot (±0.3meters) to avoid undesirable spots (e.g., conduit). Note: Generally, undesirable spots must be avoided by a total of 2 feet (0.6 meters). If this cannot be met by applying the aforementioned ±1 foot (±0.3meters) tolerance, then use the following alternate method.

Figure 5-8 Runway Guard Light Configuration



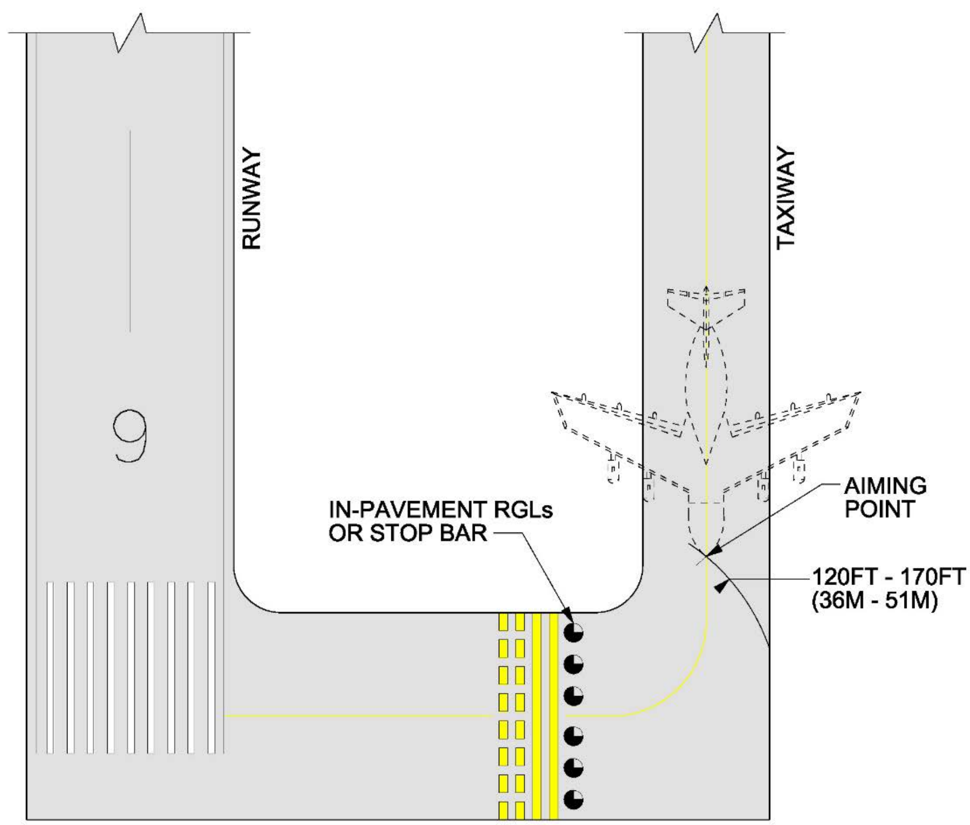
5-5.3.2 Lateral Spacing – Alternate Method.

Use the following alternate method of spacing the lights if it is not possible to meet the preferred method specified in paragraph 4.4b(1), Lateral Spacing – Preferred Method, of FAA AC 150/5340-30. The lights are spaced across the entire taxiway, including fillets and holding bays. If allowing the reference fixture to be moved any amount laterally makes it possible to meet paragraph 4.4b(1) requirements, then use that method. Otherwise, space the lights as uniformly as possible with a minimum spacing of 8 feet (2.4 meters) and a maximum of 13 feet (3.9 meters).

5-5.3.3 Light Beam Orientation for In-pavement RGLs.

Install L-868 bases for in-pavement RGLs such that a line through one pair of bolt holes on opposite sides of the base is parallel to the runway holding position marking. Each fixture is installed so that the light beam faces away from the runway and is perpendicular to the runway holding position marking within a tolerance of ±1 degree. For some pavement configurations, it may be necessary to orient the lights at some angle to the marking. To accomplish this, install a 12 bolt-hole base using the above procedure. This allows the light fixtures to be adjusted 30 degrees left or right, as required. See Figure 5-9 for typical examples.

Figure 5-9 Light Beam Aiming Point for In-Pavement RGLs and Stop Bars



5-5.4 Location of Elevated RGLs.

Elevated RGLs are collocated with the runway holding position marking and are normally installed on each side of the taxiway (see Figure 5-8). Generally, elevated RGLs should be located as close as practical to the taxiway edge to maximize their conspicuity. The distance from the defined taxiway edge to the near side of an installed light fixture should be 10 to 17 feet (3 to 5.1 meters). To avoid undesirable spots, the RGL may be moved up to 10 feet (3 meters) farther from the runway, but may not be moved toward the runway. If a stop bar is installed at the runway holding position, the elevated RGL should be located at least 3 feet, 6 inches (1.05 meter) outboard of the elevated stop bar light. The RGL should not be located where it will interfere with the readability of the runway holding position sign.

5-5.4.1 Light Beam Orientation for Elevated RGLs.

RGLs should be oriented to maximize the visibility of the light by pilots of aircraft approaching the runway holding position. In general, the orientation should be specified by the design engineer to aim the center of the light beam toward the aircraft cockpit, when the aircraft is between 150 feet (45 meters) and 200 feet (60 meters) from the holding position, along the predominant taxi path to the holding position. The vertical aiming angle should be set between 5 degrees and 10 degrees above the horizontal. The designer should specify aiming of the lights such that the steady burning intensity at all viewing positions between 150 feet (45 meters) and 200 feet (60 meters) from the holding position is at least 300 cd when operated at the highest intensity step. (Refer to FAA AC 150/5345-46 for specifications for the light intensity and beam spread of the L-804 RGL fixture.) If these criteria cannot be met for all taxi paths to the holding position, consider the following: use of multiple fixtures aimed to adequately cover the different taxi paths, use of in-pavement fixtures to increase the viewing coverage, or aiming the single fixtures on each side of the holding position to optimize the illumination of the predominant taxi path.

5-5.5 Equipment.

Install the elevated RGLs on light bases, or on conduit set in concrete foundations, using frangible supports. The transformers, or power supply unit may be placed in the same light fixture base. The light emitted must be aviation yellow, and alternately flash 50 to 60 times per minute. The illumination period of each flash must not be less than 1/2 or more than 2/3 of the total cycle.

5-5.6 Power, Control and Monitoring.

Provide the electrical power for the guard lights with a dedicated 3-step regulator for each runway where they are installed. The regulator must be configured to operate only at steps two and three. There is no monitoring requirement.

5-5.7 Compliance with International Standards.

Previous AFIC AIR STDs and current NATO STANAGs contain no comparable systems.

5-6 RUNWAY STOP BAR.

5-6.1 Purpose.

Stop bars provide a distinctive "stop" signal to anyone approaching a runway.

5-6.1.1 Low Visibility.

In low visibility conditions, controlled stop bars are used to permit access to the active runway. Uncontrolled stop bars protect the active runway at taxiway/runway intersections that are not part of the low visibility taxi route. Stop bars are required for operations below 600 feet (180 meters) RVR on illuminated taxiways that provide access to the active runway.

5-6.1.2 Runway Incursion.

Stop bars may also be used as a means of preventing runway incursions regardless of visibility conditions. For example, stop bars could be illuminated in certain airfield configurations that would prevent aircraft access from particular taxiways to active, as well as closed runways.

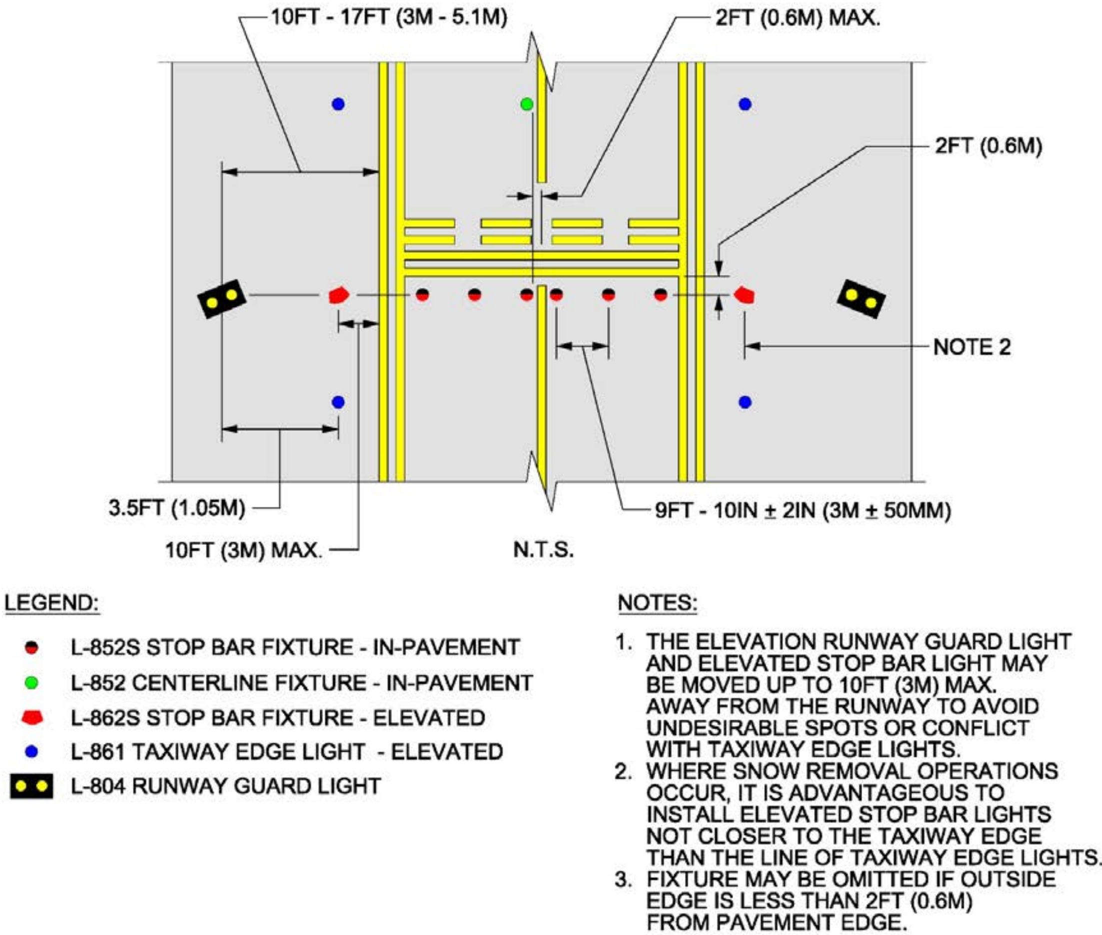
5-6.2 Configuration.

A stop bar consists of a row of unidirectional in-pavement red lights and an elevated red light on each side of the taxiway.

5-6.3 Location of In-Pavement Stop Bar Lights.

In-pavement stop bar lights are centered on an imaginary line which is parallel to, and 2 feet (0.6 meters) from, the center of the fixture and the holding side of the runway holding position marking, as shown in Figure 5-10. The lights may vary from this imaginary line up to ±2 in (±50 mm) in a direction perpendicular to the holding position marking. Holding position marking locations are described in FAA AC 150/5340-1. If a conflict with rigid pavement joints occurs, move both the runway holding position marking and the stop bar lights away from the runway the minimum distance required to resolve the conflict.

Figure 5-10 Runway Stop Bar Configuration



5-6.3.1 Lateral Spacing – Preferred Method.

The lights are spaced across the entire taxiway, including fillets, holding bays, etc., at intervals of 9 feet 10 inches ±2 inches (3 meters ±50 millimeters), center-to-center, as shown in Figure 5-10. The lights are spaced in relation to a reference fixture which is installed inline (longitudinally) with existing or planned taxiway centerline lights. However, it is not intended that the reference fixture replace a taxiway centerline light. If a conflict between the reference fixture and a centerline light occurs, the reference fixture takes the place of an existing centerline light and a new centerline light must be installed per the criteria in paragraph 5-2.2. If the holding position marking is intersected by multiple taxiway centerline markings, the reference fixture must be set at the centerline that is used most. If a fixture's outboard edge falls at a point less than 2 feet (0.6 meters) from the defined edge of the taxiway marking, the outboard edge of the taxiway marking may be omitted. Individual fixtures may be moved laterally ± a maximum of 1 foot (0.3 meters) to avoid undesirable spots (e.g., conduit). If undesirable spots cannot be avoided in this way, fixtures may be moved no more than 2 feet (0.6 meters) using the following alternate method.

5-6.3.2 Lateral Spacing – Alternate Method.

This alternate method of spacing the lights should be followed if it is not possible to meet the preferred method per paragraph 5-6.3.1. The lights are spaced across the entire taxiway, including fillets, holding bays, etc. If it is possible to meet paragraph 5-6.3.1 by allowing the reference fixture to be moved any amount laterally, then that method should be used. Otherwise, the lights should be spaced as uniformly as possible with a minimum spacing of 8 feet (2.4 meters) and a maximum spacing of 13 feet (4 meters).

5-6.3.3 Light Beam Orientation for Elevated Stop Bar Lights.

Elevated stop bar lights should be oriented to enhance conspicuity of the light by pilots of aircraft approaching the runway holding position. In general, the orientation must be specified by the design engineer to aim the axis of the light beam toward the aircraft cockpit when the aircraft is between 120 feet (36 meters) and 170 feet (51 meters) from the holding position, along the predominant taxi path to the holding position. The vertical aiming angle must be set between 5 degrees and 10 degrees above the horizontal. The designer must specify aiming of the lights such that the axis of the light beams intersects the primary taxiway centerline between 120 feet (36 meters) and 170 feet (51 meters) from the holding position (see Figure 5-9).

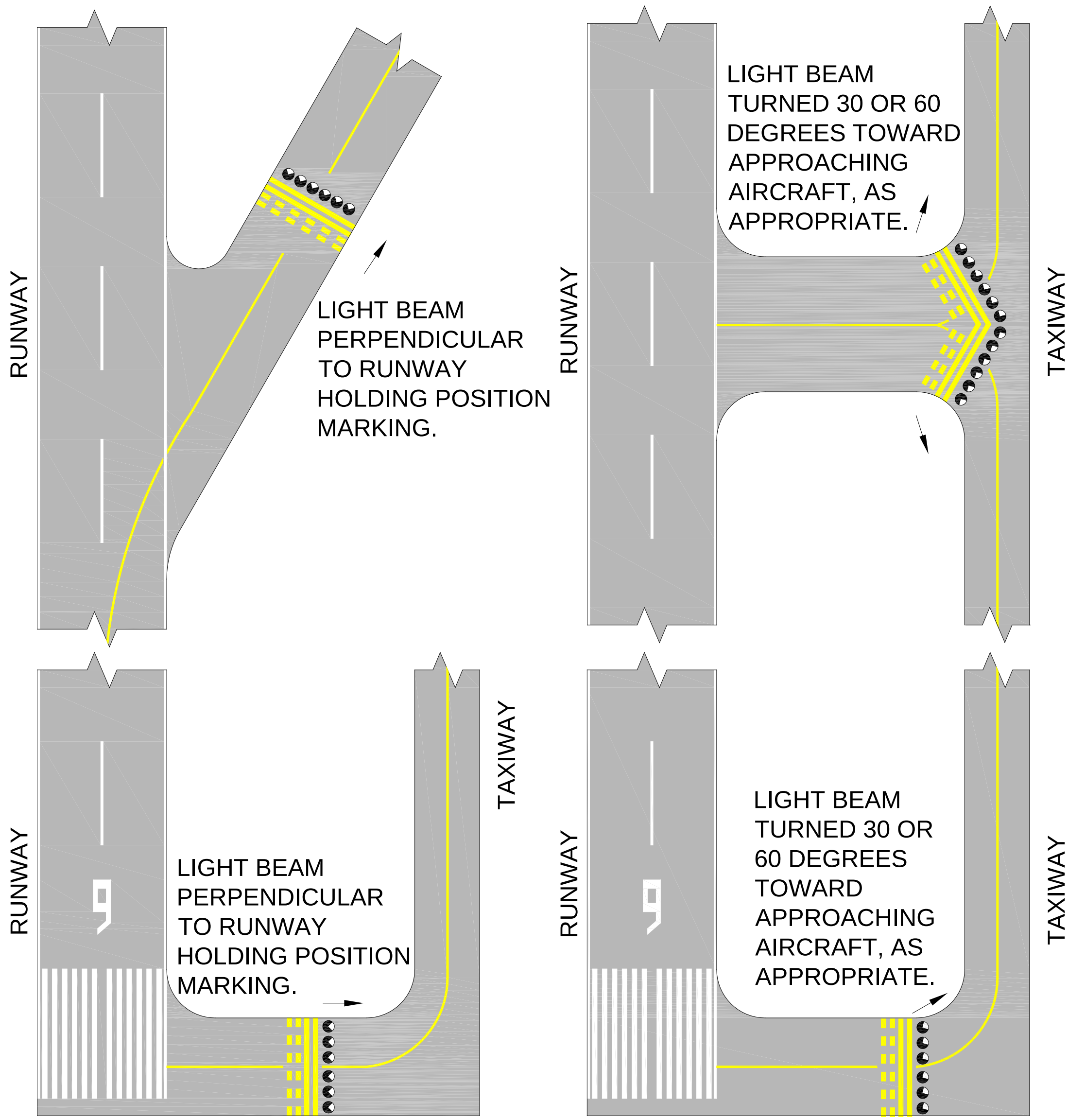
5-6.4 Location of Elevated Stop Bar Lights.

Elevated stop bar lights are installed in line with the in-pavement stop bar lights on each side of the taxiway. They are located not more than 10 feet (3 meters) from the defined edge of the taxiway. For airports that perform any snow removal operations, if taxiway edge lights are present, the elevated stop bar light should not be installed closer to the taxiway edge than the line of taxiway edge lights. This is to help prevent the elevated stop bar light from being struck by snow removal equipment. To avoid conflicts with taxiway edge lights or undesirable spots, the elevated stop bar lights may be moved up to 10 feet (3 meters) farther from the runway, but may not be moved toward the runway. See Figure 5-10.

5-6.4.1 Light Beam Orientation for In-Pavement Stop Bar Lights.

L-868 bases for in-pavement stop bar lights must be installed such that a line through one pair of bolt holes on opposite sides of the base is parallel to the runway holding position marking. Each fixture is installed so that the axis of the light beam faces away from the runway and is perpendicular to the marking with a tolerance of ±1 degree. In some instances, it may be necessary to aim the lights at some angle to the marking. To accomplish this, install a 12 bolt-hole base using the above procedure. This allows the light fixtures to be adjusted 30 degrees left or right, as required. See Figure 5-11 for typical examples.

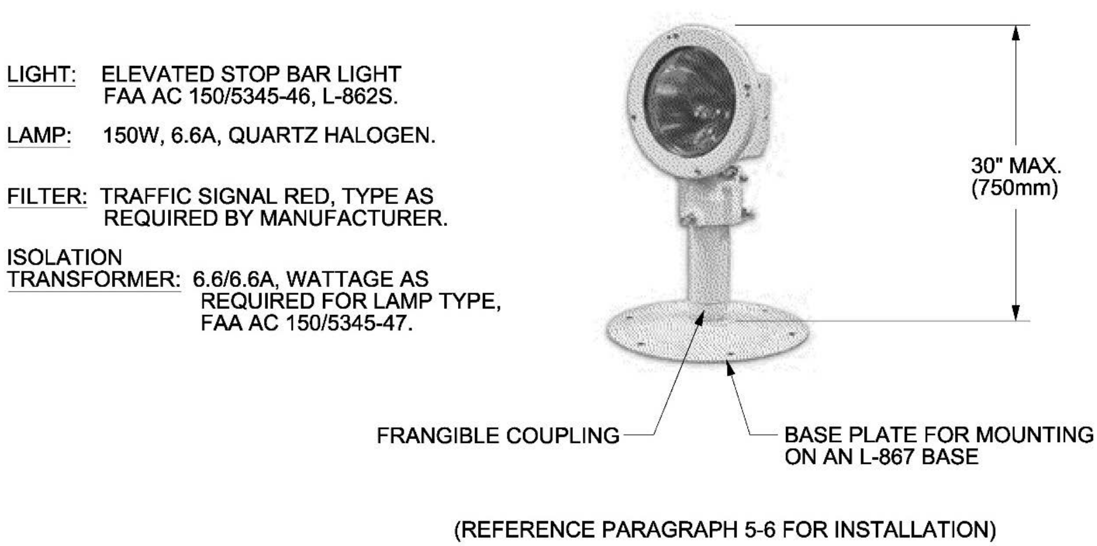
Figure 5-11 Typical Light Beam Orientation for In-Pavement RGLs and Stop Bars



5-6.5 Equipment.

Install the elevated stop bar fixture on an FAA L-867 light base, using frangible supports. Install the in-pavement stop bar fixture on and FAA L-868 base. The current transformer may be placed in the same light fixture base. The light emitted must be traffic signal red. See Figure 5-12 for a typical elevated fixture.

Figure 5-12 FAA L-862S, Elevated Stop Bar Light



5.6.6 Power and Control.

You must power elevated and in-pavement stop bar light circuits from an appropriately sized L-828, Class 1, Style 1 (3-step) CCR. Brightness control is achieved by varying the output current of the CCR. You must install elevated stop bar fixtures on the same circuit as the associated in-pavement stop bar fixtures. There are two types of stop bars: controlled and uncontrolled. Controlled stop bars are controlled individually via FAA L-821 stop bar control panel(s) or via buttons on a touch screen display panel in the Air Traffic Control Tower (ATCT). Uncontrolled stop bars are generally "on" for the duration of operations below 1,200 feet (360 meters) RVR. If the need arises for an uncontrolled stop bar to be turned off, all stop bars for a given low visibility runway may be temporarily turned off via a master stop bar button for each low visibility runway.

5-6.6 Monitoring Requirements for Controlled Stop Bars.

Controlled stop bars and associated lead-on lights must be electronically monitored. Within 5 seconds of pressing the stop bar button, the actual status of the lights must be displayed on the stop bar control panel in the ATCT. This response time reflects the state-of-the-art for local control devices. Ideally, the lights would be switched and their status returned to the ATCT within 2 seconds of pressing the stop bar button. A standard L-827 monitor or L-829 CCR with integral monitor may be used if it is accurately calibrated to indicate a fault indication with approximately 2 stop bar or lead-on lights not functioning. In locations where the circuit resistance to ground varies widely from day to day, it may not be possible to use the L-827 monitor for this level of precision. Because this monitoring system is not capable of determining adjacency, a visual inspection would have to be made to determine whether or not the failed lights are adjacent. There is individual lamp monitoring technology currently available; the system manufacturer must be consulted for the application of this technology.

5-6.7 Compliance with International Standards.

Previous AFIC AIR STDs and current NATO STANAGs contain no comparable systems.

CHAPTER 6 STANDARDS FOR OBSTRUCTION LIGHTING

6-1 PURPOSE.

Obstruction lighting defines the vertical and horizontal limits of natural or manmade objects which are considered a hazard to air navigation. Typical examples of various obstruction lighting arrangements are shown in Figure 6-1, Figure 6-2, Figure 6-3 and Figure 6-4.

6-2 OBJECTS TO BE LIGHTED.

6.2.1 Permanent Structures.

Objects that penetrate the planes and surfaces defined in UFC 3-260-01 are hazards to air navigation and must have obstruction lights installed. Other objects, which are hazards due to their nature or location even though they do not penetrate the planes and surfaces, as defined above, must also be lighted. This includes obstructions that affect TERPS criteria. Construction or objects which may impact navigable airspace under the provisions of FAR Part 77 are also subject to the administrative procedures in FAA AC 70/7460-1 for determining obstruction marking and lighting requirements. Also, obstruction lighting is required on the facilities and other obstructions along the periphery of the Building Restriction Line defined in UFC 3-260-01.

6.2.2 Temporary Structures.

For marking and lighting of *temporary structures*, See AC 70/7460-1, added Chapter 14, *Marking and Lighting Temporary Structures*, and associated figures in the FAA Appendix, Figures A-31 through A-33.

6-3 LIGHTING CONFIGURATION.

The number and arrangement of obstruction lights must ensure unobstructed visibility of one or more lights from an aircraft at any normal angle of approach. Arrange obstruction lights per FAA AC 70/7460-1.

Figure 6-1 Obstruction Light Configuration, Height up to 350 Feet (105 Meters)

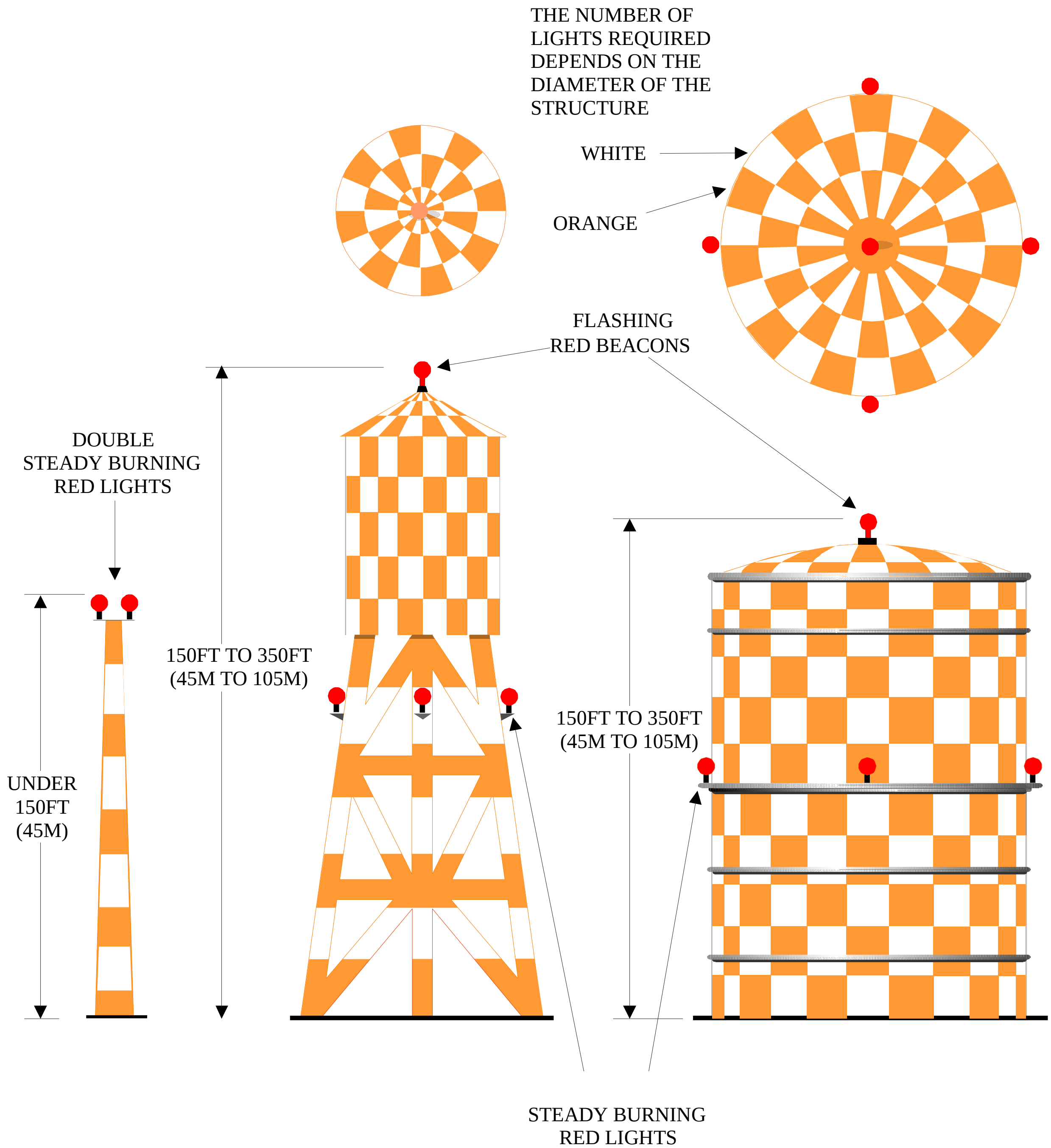


Figure 6-2 Obstruction Light Configuration Height 150 to 350 Feet (45 to 105 Meters)

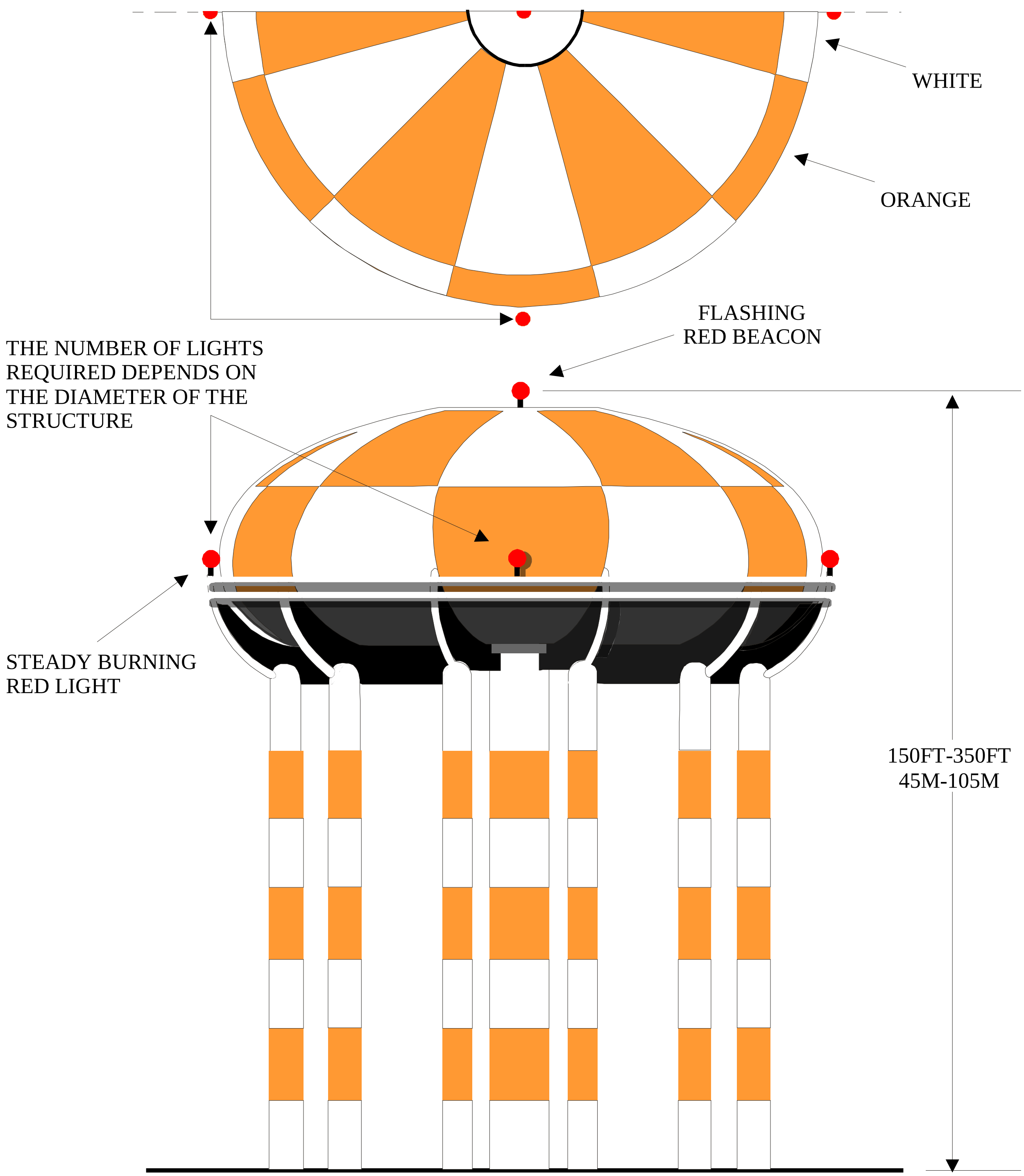


Figure 6-3 Obstruction Light Configuration Height 350 to 700 Feet (105 to 210 Meters)

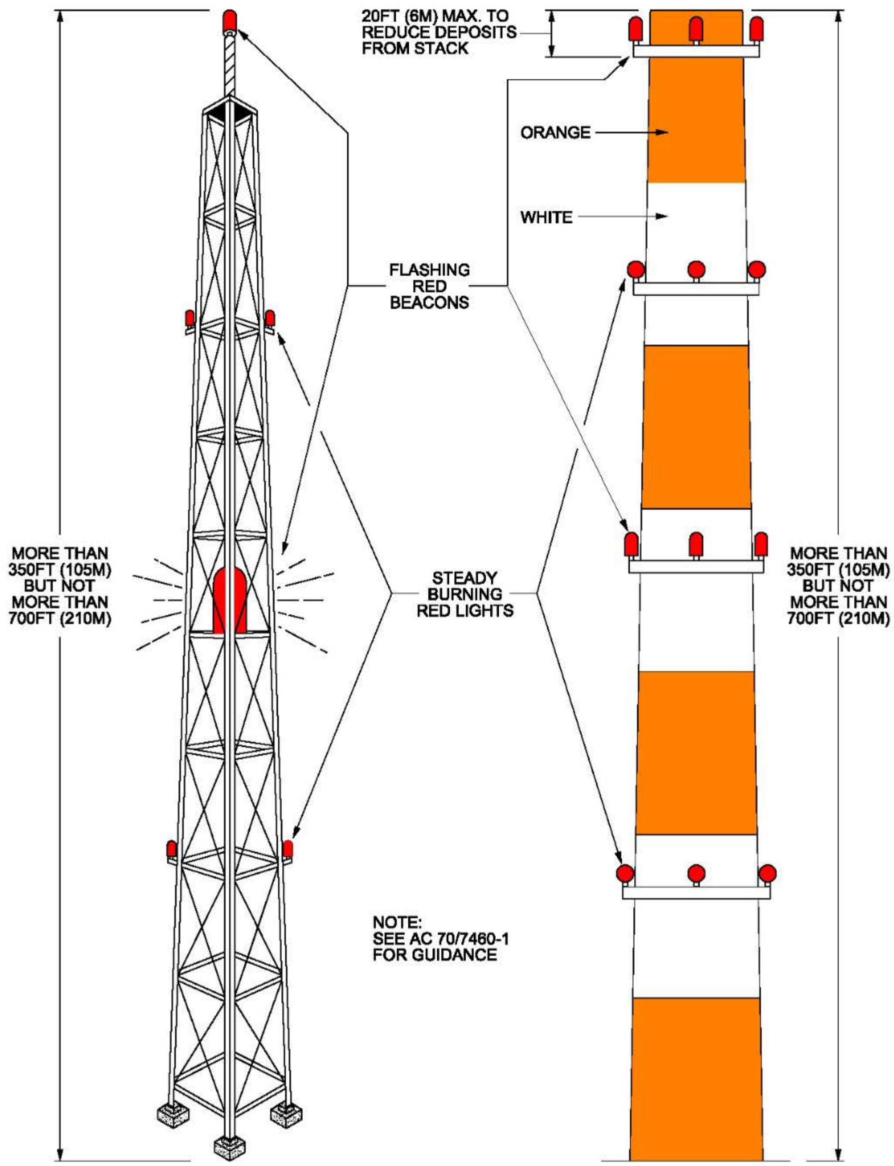
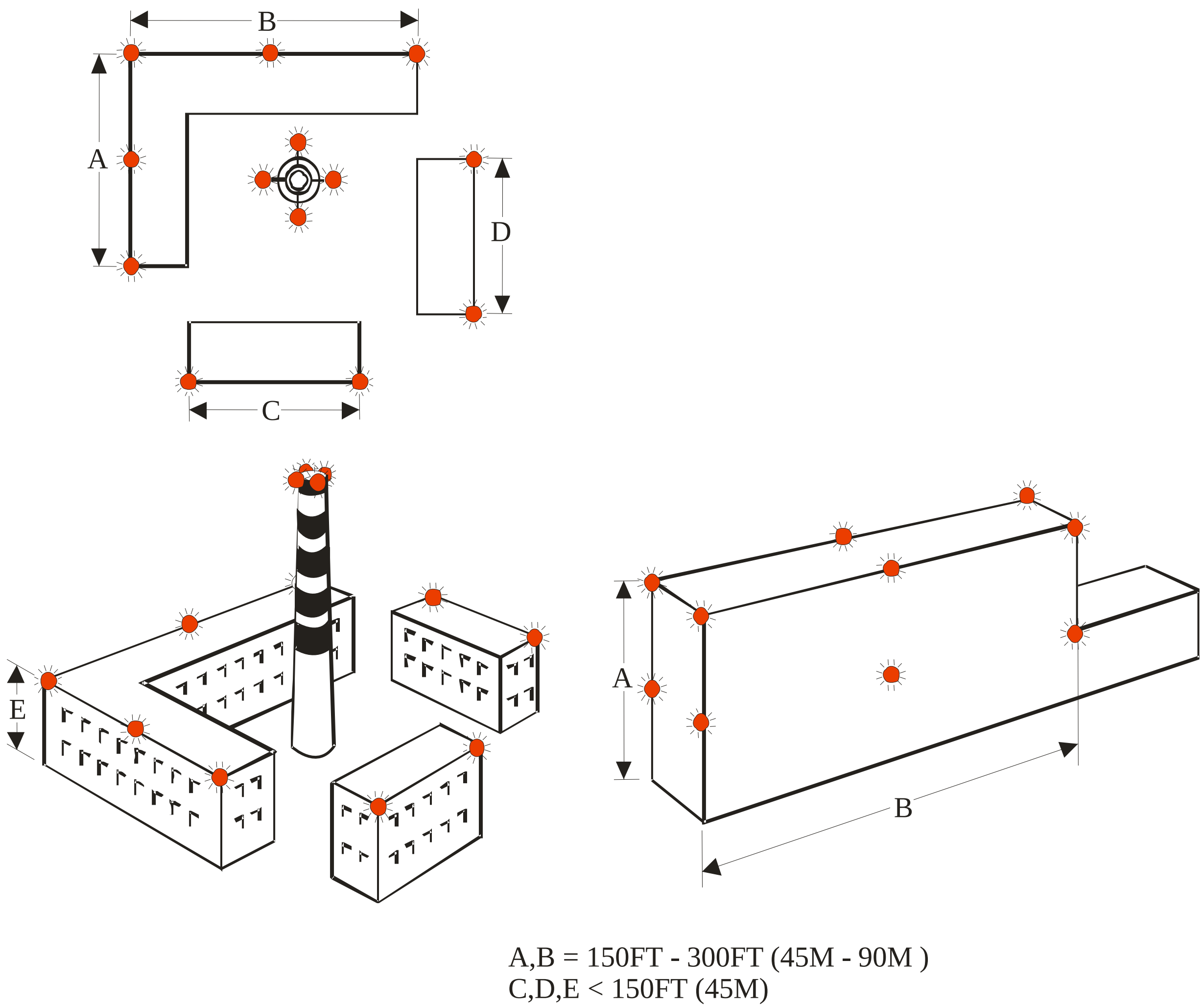


Figure 6-4 Obstruction Lights on Buildings



6-4 LIGHTING VERSUS DAY MARKING.

Flashing white obstruction lighting may be used instead of obstruction marking on structures less than 200 feet (60 meters) tall with major command approval. Do not install these lights in clear zones or on objects in the immediate vicinity of runways where approaching pilots may mistake them for other flashing white lights.

6-5 WAIVERS.

The military component decision to waive obstruction lighting requirements must be coordinated with appropriate civil aviation authorities to ensure there is no negative impact to civil aviation. (See paragraph 1-11 for Air Force waivers and paragraph 1-12 for US Army waivers.)

6-6 EQUIPMENT.

The equipment shown meets the requirements of the FAA.

6-6.1 LED-Based Obstruction Lights.

\4 On Air Force bases, LED-based obstruction lights with integral IR emitters are allowed on weather equipment and NAVAIDs under 35 feet with agreement from Airfield Management.

On Army airfields and posts, obstruction lights may be incandescent or LED. If LED obstruction lights are used, they must have an integral IR emitter. **/4/**

6-7 POWER REQUIREMENTS.

Depending on the equipment installed, the power is usually 120/240 volts AC. Emergency power is not a requirement but is desirable if readily available.

6-7.1 Intensity Requirements.

See FAA AC 150/5345-43 for required obstruction light photometric characteristics.

6-8 CONTROL REQUIREMENTS.

6-8.1 Obstruction Lights

Obstruction lights intended for day marking must remain on at all times and have automatically selected reduced intensity levels for night operations. Other obstruction lights must be on when the northern sky illumination falls on a vertical surface to a level of not less than 35 footcandles (350 lux), or during daytime, when visibility is restricted. The lights may be turned off when the northern sky illuminance rises to a level of 58 footcandles (580 lux) or more. If practicable, obstruction lights should be controlled from the airfield lighting control panel. Otherwise use automatic controls and provide an auxiliary manual control (that can be locked) at ground level on the exterior of the object to be lighted.

For Flashing White Obstruction Lighting Systems, comply with paragraph 3.3.5 of AC 150/5345-43.

Equipment with solid state devices must be designed to withstand and/or include separate surge protective devices that are tested against defined waveforms per IEEE C62.41-1991, Table 4, Location Category C1 for single phase modes (line to ground, line to neutral, line, and neutral to ground). Note: Does not apply to DC powered systems.

6-8.2 Dual Lighting.

See FAA AC 70/7460-1 for information and requirements about dual lighting systems that use red lights for night operation and white medium or high intensity lights for day operation.

6-9 MONITORING REQUIREMENTS.

Obstruction lights should be visually observed for proper operation at least once each 24 hours. If the lighting cannot be readily observed, provide a remote monitoring system to indicate the malfunction of all the top lights and any flashing or rotating beacons regardless of their position.

6-10 COMPLIANCE WITH INTERNATIONAL STANDARDS.

6-10.1 NATO.

These standards meet the requirements of STANAG 3346 (Edition 7) – Marking and Lighting of Airfield Obstructions, 26 November 2012, except for the use of high intensity white lights.

6-10.2 AFIC.

AFIC AIR STD 90/19 is cancelled.

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CHAPTER 7 STANDARDS FOR LIGHTING HELIPADS

7-1 GENERAL DESCRIPTION.

Helipad lighting defines the helicopter landing pad during operations at night and during periods of poor visibility. It is used for single helicopter landing pads. For heliport and helicopter landing lanes lighting system criteria, refer to Chapter 8.

7-2 HELIPAD PERIMETER LIGHTS.

7-2.1 Purpose.

Perimeter lights provide visual cues to pilots for identifying the safe operational limits of the helipad during takeoff, landing or hover operations.

7-2.2 Standard Perimeter Light Configuration.

Place aviation yellow, omnidirectional lights at each corner of the helipad, with three more lights spaced equally along each side between the corner lights. Lights on opposite sides of the helipad must be opposite each other. They must be equidistant and parallel to the extended centerlines of the helipad. They are usually located on the perimeter of the helipad, but may be placed not more than 7.5 feet (2.25 meters) away from the edge of the pad. In-pavement (FAA L-852E) fixtures must be used where taxiing of wheeled helicopters, skid mounted helicopters or other vehicular traffic is required. Elevated light fixtures (FAA L-861) should preferably be 14 inches (350 millimeters) maximum. Elevated light fixtures may be used where only approach and departure procedures are conducted. (See Figure 7-1.)

7-2.3 Hospital Pad Perimeter Light Configuration.

The lighting of a hospital helipad is the same as the standard helipad perimeter lights in paragraph 7-2.2, except there are additional wing lights located on the geometric centerlines of the helipad at a distance of 25 feet (7.5 meters), as shown in Figure 7-2, outboard of the existing perimeter light fittings.

7-3 HELIPAD VFR LANDING DIRECTION AND APPROACH LIGHTS.

These lights are installed to indicate a specific landing direction, in the procedure for touchdown or hover at the helipad.

Figure 7-1 Helipad Perimeter Lights, Standard Configuration

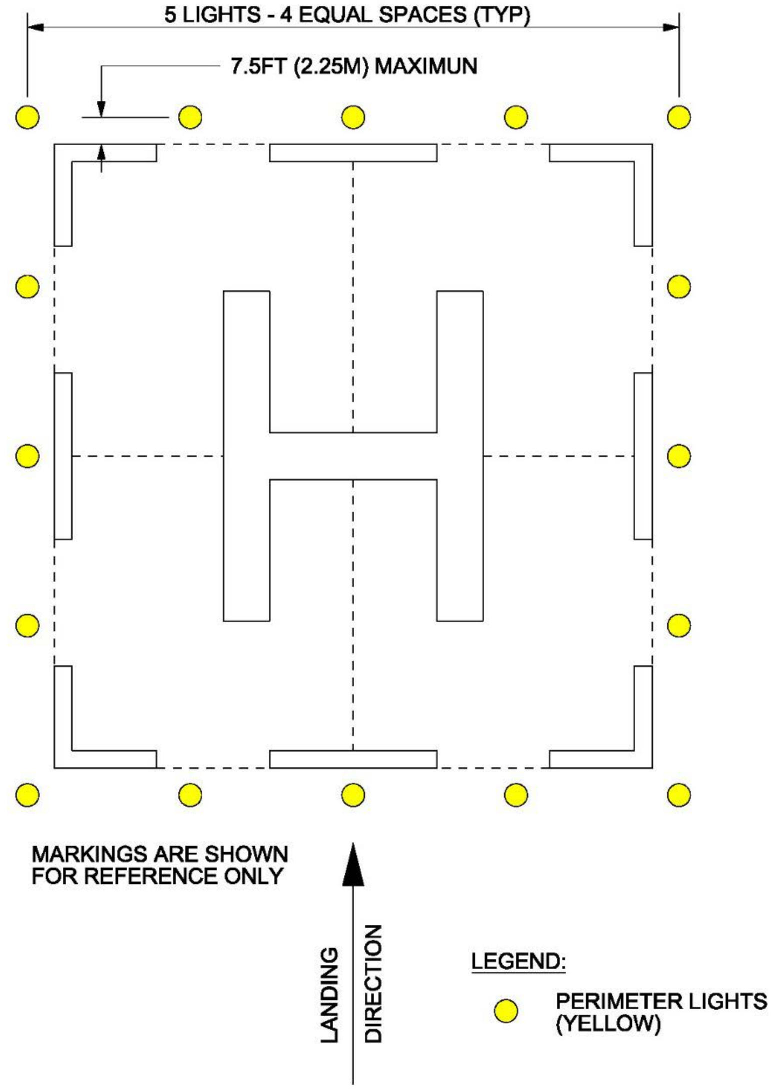
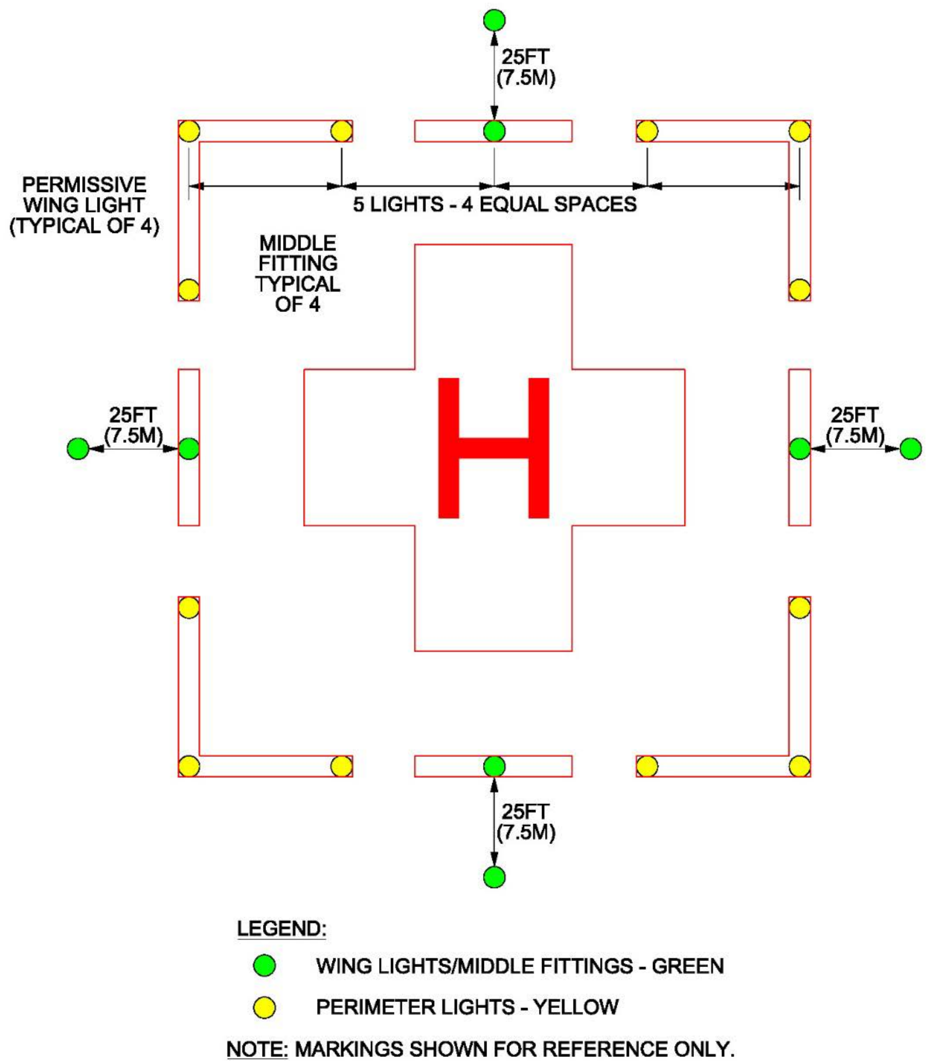


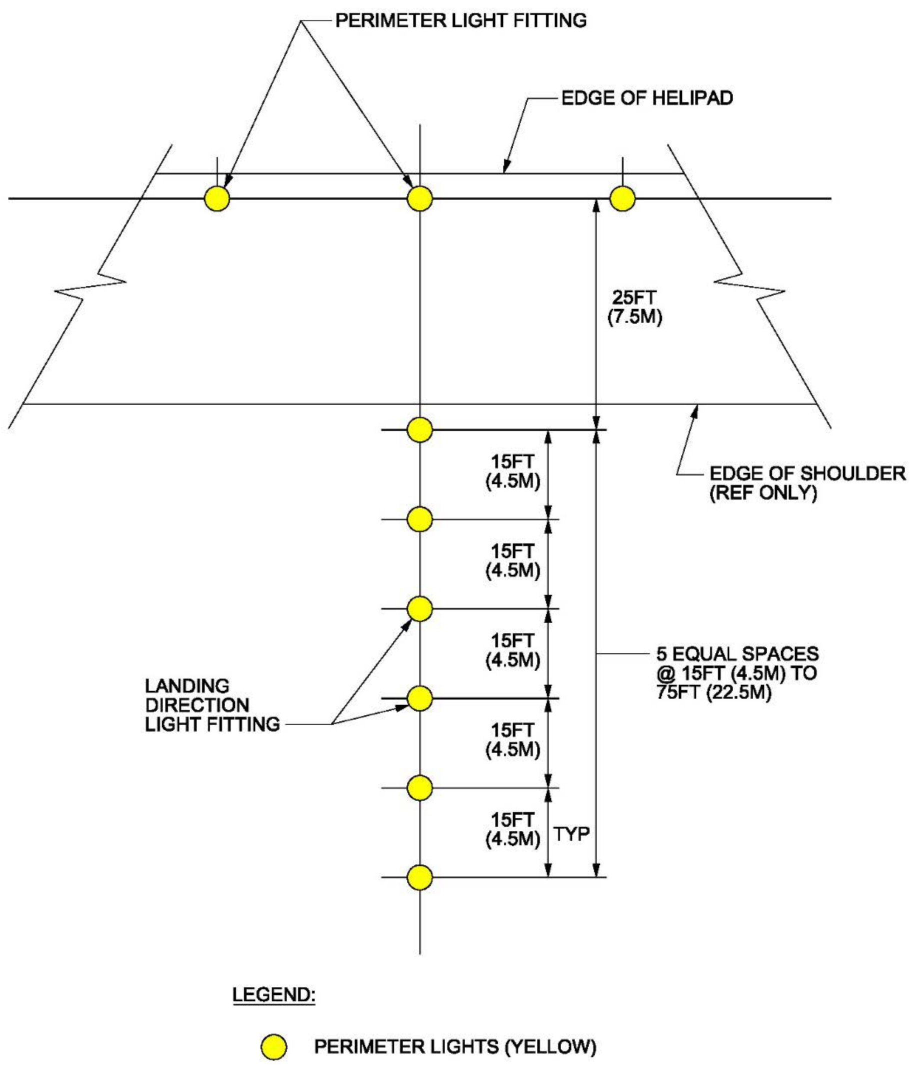
Figure 7-2 Helipad Perimeter Lights, Hospital Configuration



7-3.1 Configuration of Landing Direction Lights.

Provide aviation yellow omnidirectional lights (FAA L-861) in a straight line along one or more of the centerlines of the helipad, extended, and perpendicular to the perimeter lights. They must consist of six lights spaced 15 feet (4.5 meters) apart and starting 25 feet (7.5 meters) from the middle perimeter light. Locate the lights in a horizontal plane. (If a deviation is necessary, a tolerance of plus 2 percent or minus 1 percent in the longitudinal slope is permitted.) Use elevated fixtures on frangible supports, except use in-pavement fixtures when taxiing is a requirement. (See Figure 7-3.)

Figure 7-3 VFR Helipad Landing Direction Lights



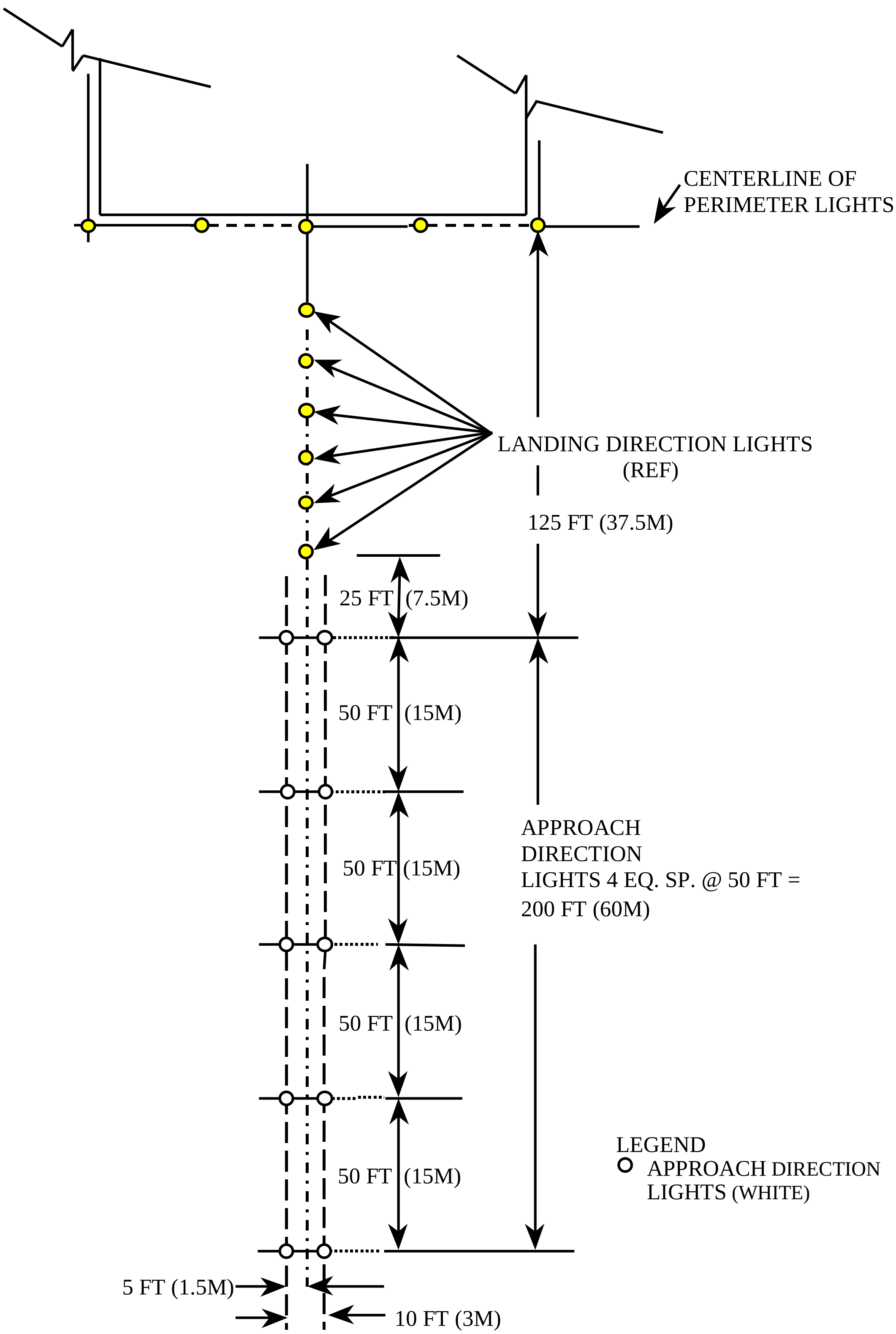
7-3.2 Purpose of Approach Direction Lights.

These lights are installed to provide approach guidance in order to restrict the path of approach to the helipad or when additional guidance is needed by the pilots.

7-3.2.1 Configuration of Approach Direction Lights.

Provide aviation white, unidirectional lights in two parallel rows extending out from the landing direction lights. Each row must consist of five lights spaced 50 feet (15 meters) apart, starting 125 feet (37.5 meters) from the perimeter lights and offset 5 feet (1.5 meters) either side of the extended centerline of the landing direction lights. The slope of the approach direction lights must be the same as that used for the landing direction lights. (See Figure 7-4.)

Figure 7-4 Helipad VFR Approach Direction Lights



7-3.3 Helipad IMC Approach Lights Category I.

7-3.3.1 Purpose.

These lights provide additional approach guidance for instrument meteorological conditions, with a decision height of 200 feet (60 meters) and an RVR of 2,400 feet (720 meters).

7-3.3.2 Configuration of IMC Approach Lights.

The approach lighting system will be symmetrical about, and extend for the entire length of, the centerline of the helipad direction lights. This additional light system starts at the position of the approach direction lights, shown in Figure 7-3, at 125 feet (37.5 meters) from the helipad and extending out to 1,025 feet (307.5 meters), shown in Figure 7-5.

7-4 REFUELING AREA LIGHTS.

Refueling areas are class 1, division 1, group D hazardous locations as defined in NFPA 70 National Electrical Code. See paragraphs 8-4 and 8-6.5 for more information.

7-5 HELIPAD FLOODLIGHTS.

7-5.1 Purpose.

Helipad floodlights illuminate the helipad surface at night to provide visual cues to the pilot for determining his height above the surface during the touchdown phase of his approach. To prevent interference with or damage to an aircraft, the helipad floodlights must be as close to grade as practical and have frangible couplings. The floodlights must provide a uniform illumination of the helipad surface. When installed, the fixtures must not permit any direct light to be visible above the horizontal. The fixtures emit a narrow fan-shaped illuminating beam for which the axis of the beam must be adjustable in elevation between 1 degree up and 5 degrees from horizontal. Another purpose is for ground operations on a helipad where access to a lighted apron is not available for loading or unloading of equipment or personnel. A typical application would be a helipad located near a hospital or headquarters building.

7-5.2 Configuration.

Locate these lights a minimum of 16 feet (4.8 meters) beyond the edges of the helipad on two opposite sides, parallel to the normal approach to the helipad. Mount the floodlights not over 16 inches (400 millimeters) above the grade of the helipad with a small obstruction light at each floodlight visible from any direction. The number of floodlights installed depends on the size of the helipad and the light output of the fixtures used. (See Figure 7-6.)

Figure 7-5 Approach Lights Category I

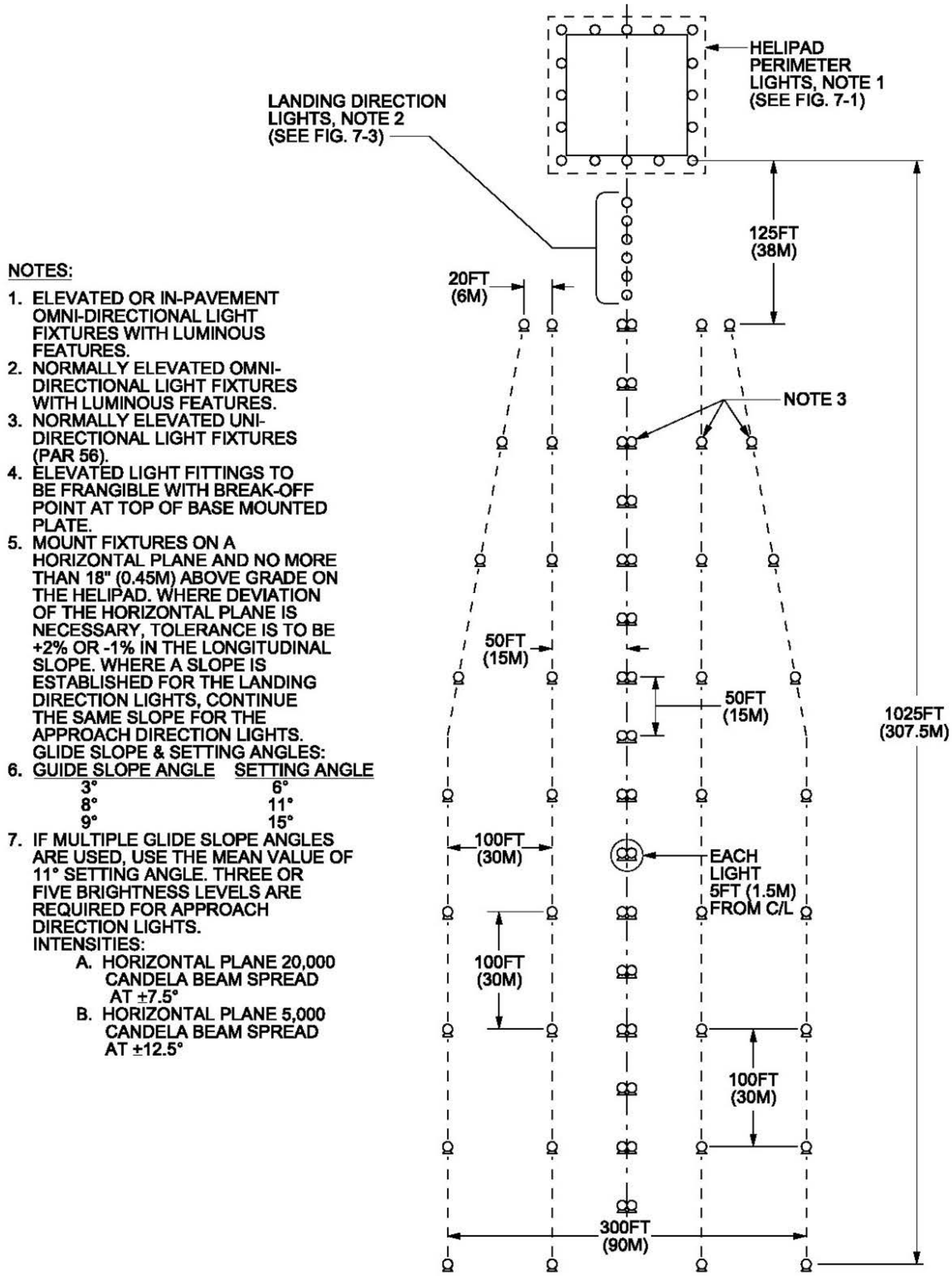
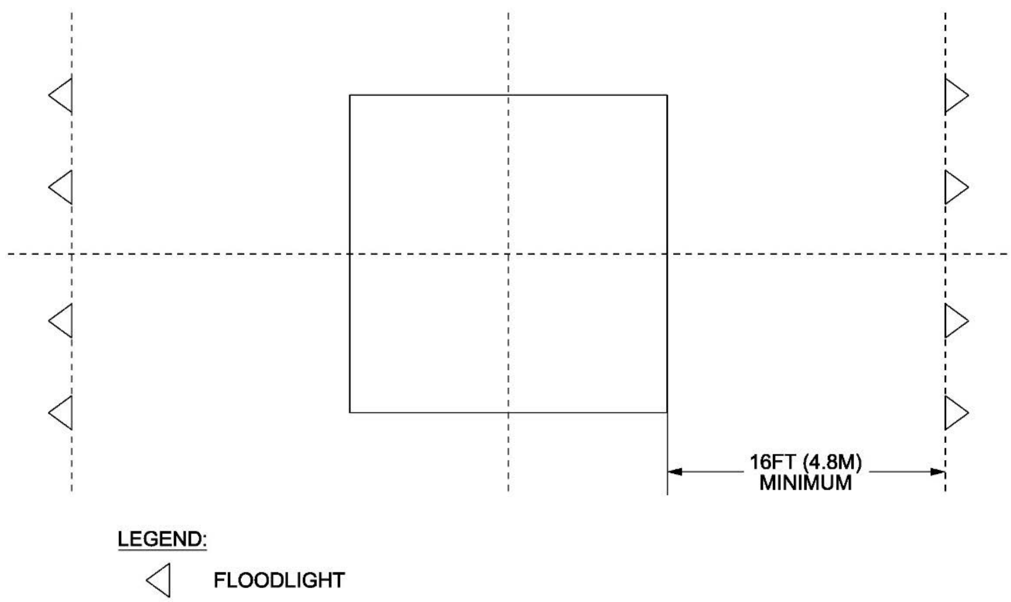


Figure 7-6 Helipad Floodlight Typical Configuration



7-5.3 Helipad Refueling Floodlights.

Helipad refueling floodlights are class 1, division 1, group D hazardous locations, as defined in NFPA 70 National Electrical Code. See paragraphs 8-4 and 8-6.5 for more information.

7-6 HELIPAD APPROACH SLOPE INDICATOR.

7-6.1 Purpose.

A visual glide slope indicator should be provided for a helipad when obstacle clearance, noise abatement or traffic control procedures require a particular approach slope angle be flown, when the environment of a helipad provides few visual cues, or when the characteristics of a particular helicopter requires a stabilized approach path. The preferred system is CHAPI. An FAA L-881 2-light housing assembly PAPI system is optional.

\4

7-6.2 Justification.

A Visual Glide Slope Indicator System shall be provided to serve the approach whether or not there are other visual approach aids or by non-visual aids where one or more of the following conditions exist, especially at night:

7-6.2.1 Obstacle clearance, noise abatement or traffic control procedures require a particular slope to be flown.

7-6.2.2 The characteristics of the helicopter required a stabilized approach.

7-6.2.3 The pilot of any type of aircraft may have difficulty judging the approach due to inadequate visual guidance that may be experienced during an approach over water or featureless terrain by day, or in the absence of sufficient extraneous lights in the approach area by night.

7-6.2.5 If judging the approach is difficult due to misleading information produced by deceptive surrounding terrain or runway slopes. The presence of objects in the approach area may present a serious hazard if an aircraft descends below the normal approach path, especially if there are no navigation aids to give warning of these objects.

7-6.2.6 Physical conditions at either end of the runway present a serious hazard in the event of an aircraft undershooting or overrunning the runway.

7-6.2.7 Terrain or prevalent meteorological conditions are such that the aircraft may be subjected to unusual turbulence during approach.

7-6.2.8 If a stabilized approach is required due to the possible medical condition of patients that will be transported to a hospital.

7-6.3 Configuration.

The CHAPI system consists of two transition light units projecting red/green/white lights. They are located forward of the helipad on the extended centerline at a distance determined in order to project an on glide path angle (usually 6 degrees) at the helipad hover point prior to touchdown. The glide slope must be determined based on the site conditions. The glide slope angle must provide a minimum of 1 degree above obstructions from the lowest on-course visual signal. For precision approaches, the glide slope of the CHAPI must be must be consistent with the approach lighting system, instrument landing system (ILS), or other electronic NAVAID. The units are positioned at approximately 20 feet (6 meters) apart lateral (horizontal). The CHAPI system must be constructed and mounted as low as possible and be sufficiently lightweight and frangible so as not to constitute a hazard to helicopter operations. **/4/**

7-7 HELIPAD BEACON.

7-7.1 Purpose.

A helipad beacon provides long-range guidance and helipad identification.

7-7.2 Configuration.

The beacon must contain a sequence of three lights. For Army or Air Force medical facilities – double-peaked white, a single green, and a single red. For all other facilities – double-peaked white, a single green, and a single yellow. For Navy medical facilities – double-peaked white, green, yellow as per NAVAIR 51-50AAA-2. The flash must be 10 to 15 sequences of flashes per minute. The time between each color should be one-third of the total sequence time. The beacon should not be installed within 1 mile (1.6 km) of any existing airport beacon or other helipad area.

7-7.3 Construction.

The beacon should be visible for a distance of 1 mile (1.6 kilometers) in 1 mile (1.6 kilometer) VMC visibility daylight, and 3 miles (4.8 kilometers) in 3 mile (4.8 kilometer) VMC at night, both from an altitude of 3,000 feet (900 meters) above ground level. The beacon should be mounted a minimum of 50 feet (15 meters) above the helipad surface. Where a control tower or control area is utilized the beacon should be no closer than 400 feet (120 meters), nor further than 3,500 feet (1,050 meters), from that area, and not located between the control tower and the helipad. The beacon will be installed so that the base is not less than 15 feet (5 meters) above the floor of the control tower or operations room.

7-7.4 Luminous Features.

The main beam of the light should be aimed a minimum of 5 degrees above the horizontal and should not produce light below the horizontal in excess of 1,000 candelas. Light shields may be used to reduce the intensity below the horizontal.

7-8 HELIPAD WIND DIRECTION INDICATORS.

7-8.1 Purpose.

Helipad wind direction indicators enhance operational capabilities, increase safety and reduce pilot workload during approach, hover and takeoff operations.

7-8.2 Configuration.

A helipad should be equipped with at least one wind direction indicator located in a position to indicate the wind conditions over the final approach and take-off area. The wind indicator must be free from the effects of air flow disturbances caused by nearby objects or rotor wash. It must be visible from a helicopter in flight, in a hover, or on the movement area. Where a helipad may be subject to a disturbed air flow, additional indicators located close to the area should be provided to indicate surface winds.

7-8.3 Construction.

A wind direction indicator must be constructed to give a clear indication of the wind direction and a general indication of the wind speed. An indicator should be a truncated cone made of light weight fabric. The approximate minimum dimensions are 8 feet (2.4 meters) long, 18 inches (450 millimeters) diameter (large end), and 12 inches (300 millimeters) diameter (small end). The color selected must make it clearly visible and understandable from a height of at least 650 feet (195 meters) above the helipad. When practical the preferred colors should be white or orange. Where it is necessary to provide adequate conspicuity against varied backgrounds, combined colors are permitted such as orange and white, red and white, or black and white.

7-8.4 Illumination.

A wind direction indicator intended for use at night must be illuminated, and have a red obstruction light mounted on the mast.

7-9 PHOTOMETRIC REQUIREMENTS.

7-9.1 Perimeter and Landing Direction Lights.

These lights must emit omnidirectional aviation yellow light with intensities as follows:

2 to 10 degrees vertical	37 cd min.	67 cd average
10 to 15 degrees vertical	20 cd min.	

7-9.1.1 A 25 percent reduction in light output is permitted at structural ribs on in-pavement lights.

7-9.2 Approach Direction Lights.

These lights must emit directional aviation white light with intensities as follows:

2 to 10 degrees vertical	5 cd min.	125 cd average
10 to 15 degrees vertical	40 cd min.	

7-9.2.1 A 25 percent reduction in light output is permitted at structural ribs of in-pavement lights.

7-9.3 Helipad Floodlights.

These fixtures must direct the entire output of the fixture below the horizontal. The minimum average luminance in the horizontal helipad surface must be 2 footcandles (20 lux) with a uniformity ratio (average to minimum) that should be not more than 4 to 1.

7-9.4 Helipad Beacons.

These lights are rotating or flashing lights. They must appear to an observer at any azimuth as a series of flashing lights coded white-green-yellow or white-green-red as applicable. The flash duration must be 75 to 300 milliseconds. The effective intensities of white light for vertical angles above the horizontal must be:

1 to 2 degrees	12,500 cd
2 to 8 degrees	25,000 cd
8 to 10 degrees	12,500 cd

The minimum intensities of the green must be 15 percent of those given for the white light, and the minimum effective intensities of the yellow flashes must be 40 percent of that given for the white light.

\4
7-9.5 CHAPI Systems.

The CHAPI light units are similar to a PAPI system (see paragraph 3-7.1), with the addition of a 2.0 degree wide green sector command path. The vertical color sectors for the CHAPI system are:

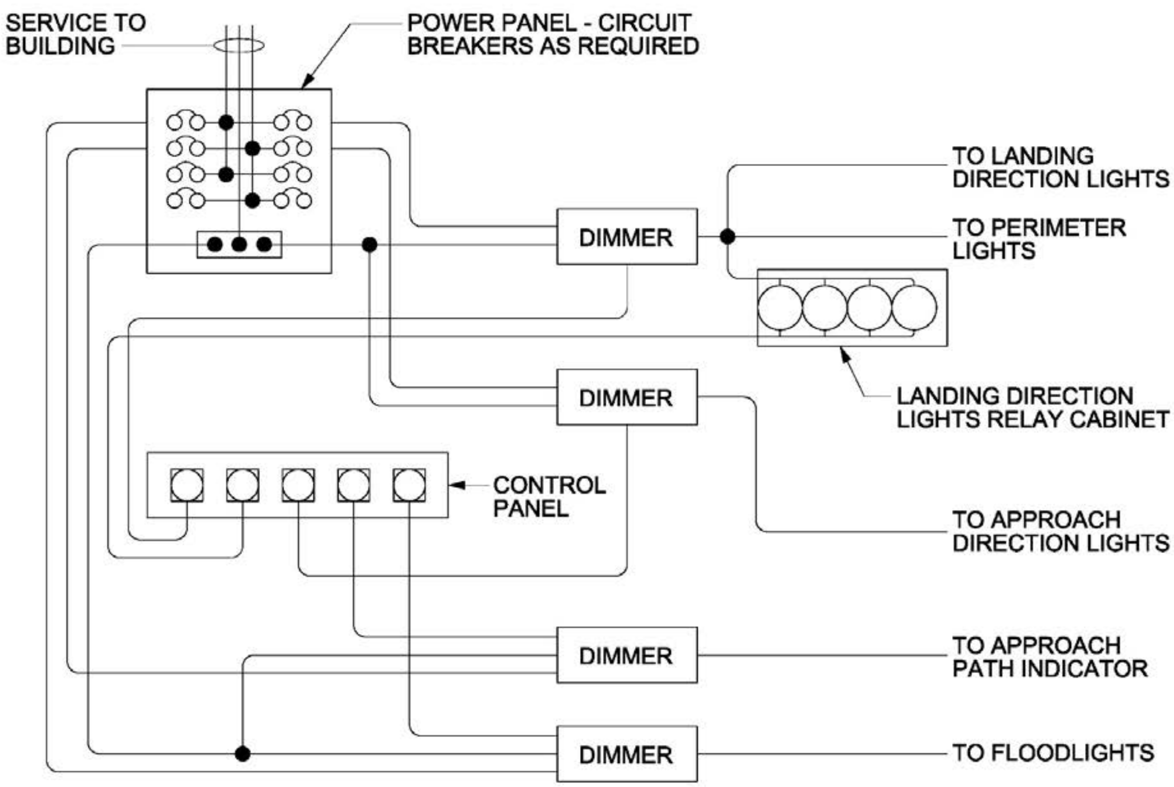
above course	7.5 degrees or more	W	W
slightly high	6.5 to 7.5 degrees	W	G
on course	6.0 degrees	G	G
slightly low	4.5 to 5.5 degrees	G	R
below course	4.5 degrees or less	R	R

Adjust the CHAPI to accommodate the required glide slope angle to provide 1.0 degrees between the approach departure clearance surface and the ‘below course’ signal. ***/4/***

7-10 POWER REQUIREMENTS.

Provide a main and an alternate power system with the capability to automatically transfer within 15 seconds from the system in use if a system fails. Typical lighting control diagrams for helipad lighting systems are shown in Figure 7-7 for systems without a control tower, and in Figure 7-8 with systems with a control tower.

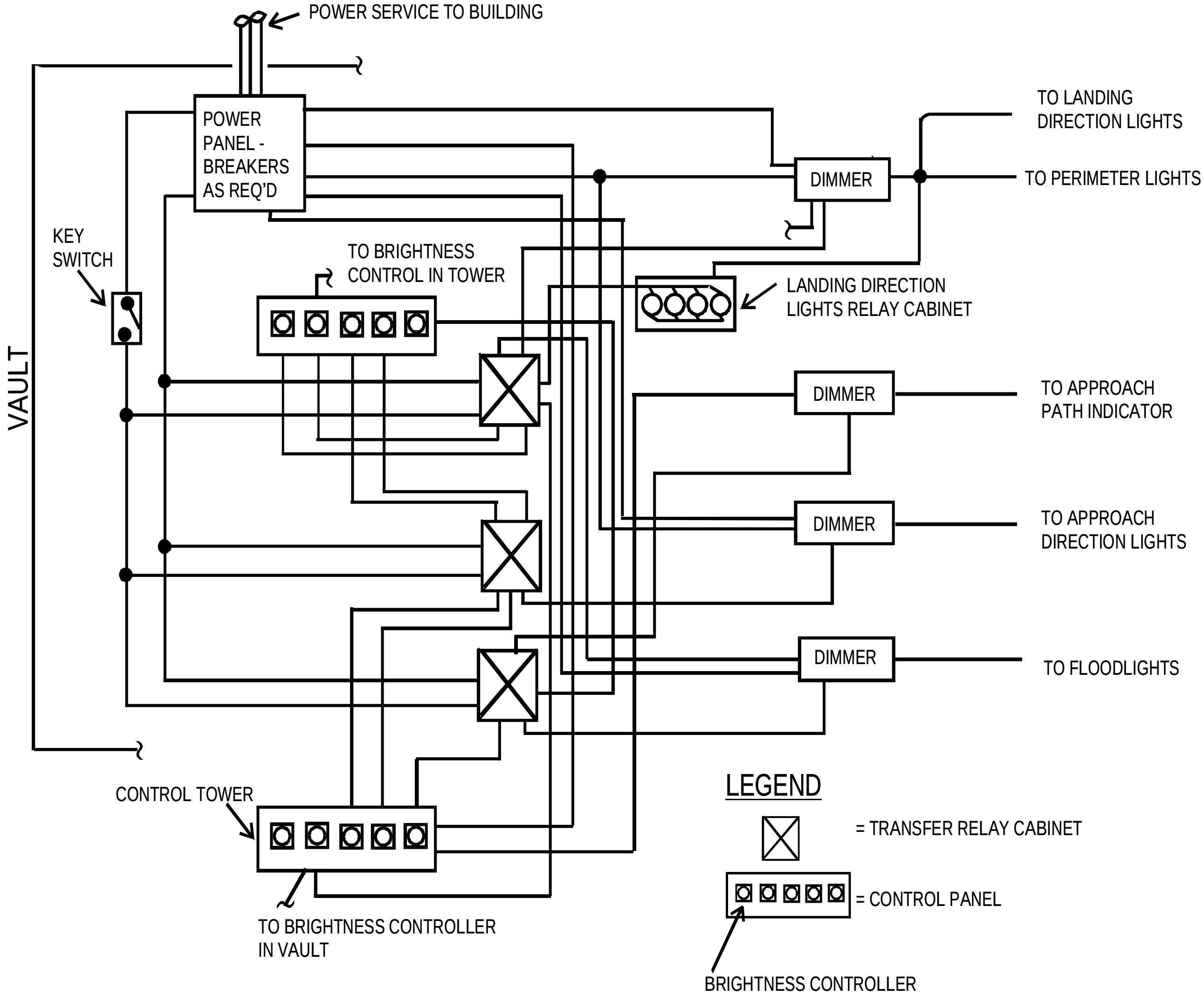
Figure 7-7 Block Diagram Without Tower



NOTE:

DELETE UNNEEDED COMPONENTS WHEN NOT USED IN THE HELIPAD LIGHTING SYSTEM.

Figure 7-8 Block Diagram with Tower



7-11 CONTROL REQUIREMENTS.

7-11.1 Perimeter Lights.

Provide on and off control and a three-step intensity control.

7-11.2 Landing Direction Lights.

Provide on and off control and a three-step intensity control. Interconnect the controls with the perimeter light controls to prevent operation without the perimeter lights being activated; however, they must have the capability of being independently turned off.

7-11.3 Approach Direction Lights.

Provide on and off control and a three-step intensity control. Interconnect the controls to the landing direction light circuit in order to prevent their operation unless the landing direction lights are activated; however, they must also be capable of being turned off independently. The intensity controls may be connected to the same regulator as the landing direction lights.

7-11.4 Helipad Floodlights.

\4 Helipad floodlights require on and off control. ***/4/***

7-11.5 Helipad Beacons.

Provide on and off control only.

7-11.6 CHAPI.

Provide on and off control and a minimum of three-step intensity control, similar to the PAPI system.

7-12 MONITORING REQUIREMENTS.

There are no requirements for monitoring helipad lighting systems.

7-13 COMPLIANCE WITH INTERNATIONAL STANDARDS.

7-13.1 AFIC.

Previous AFIC AIR STD 90/34 cancelled.

7-13.2 NATO.

These standards meet the requirements of STANAG 3619 (Edition 5) – Helipad Marking and Lighting, 6 June 2013.

7-14 EQUIPMENT.

See paragraph 13-14 for appropriate Helipad lighting equipment.

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CHAPTER 8 STANDARDS FOR LIGHTING HELIPORTS

8-1 GENERAL DESCRIPTION.

8-1.1 Helicopter Runway

A helicopter runway is a prepared surface used for the approach and departure of rotary wing aircraft. It is not intended for use of fixed wing aircraft.

8-1.2 Design Criteria.

The design criteria set forth herein are intended to guide in designing and installing a permanent heliport lighting system utilizing elevated and in-pavement lights. Figure 8-1 illustrates a typical heliport having two 75 foot (22.5 meter) wide by 1,600 foot (480 meter) long intersecting runways with 40 foot (12 meter) wide connecting taxiways and 25 foot (7.5 meter) wide adjacent surface treated shoulders. Changes in the layout or design may be necessary to fit the requirements of a particular heliport runway installation, including a basic one runway configuration.

Figure 8-1 Layout Heliport Lighting

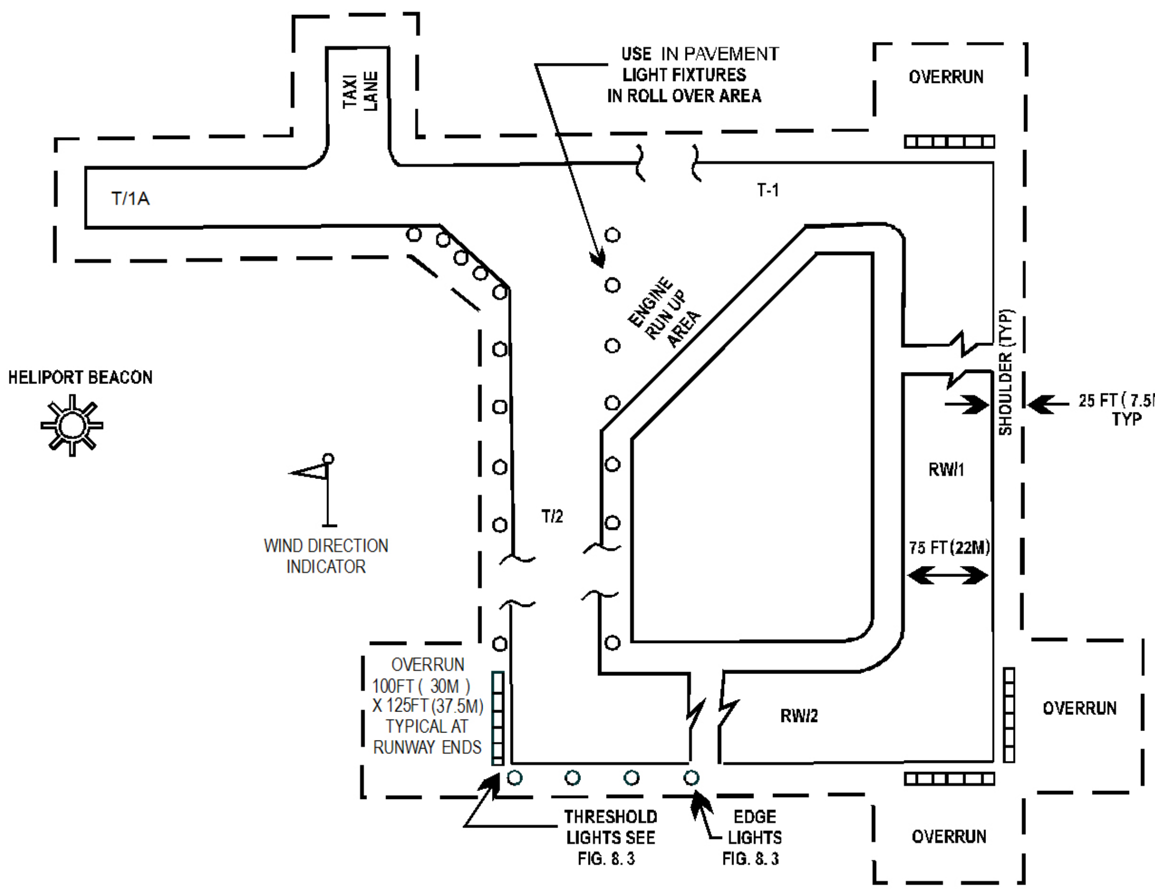
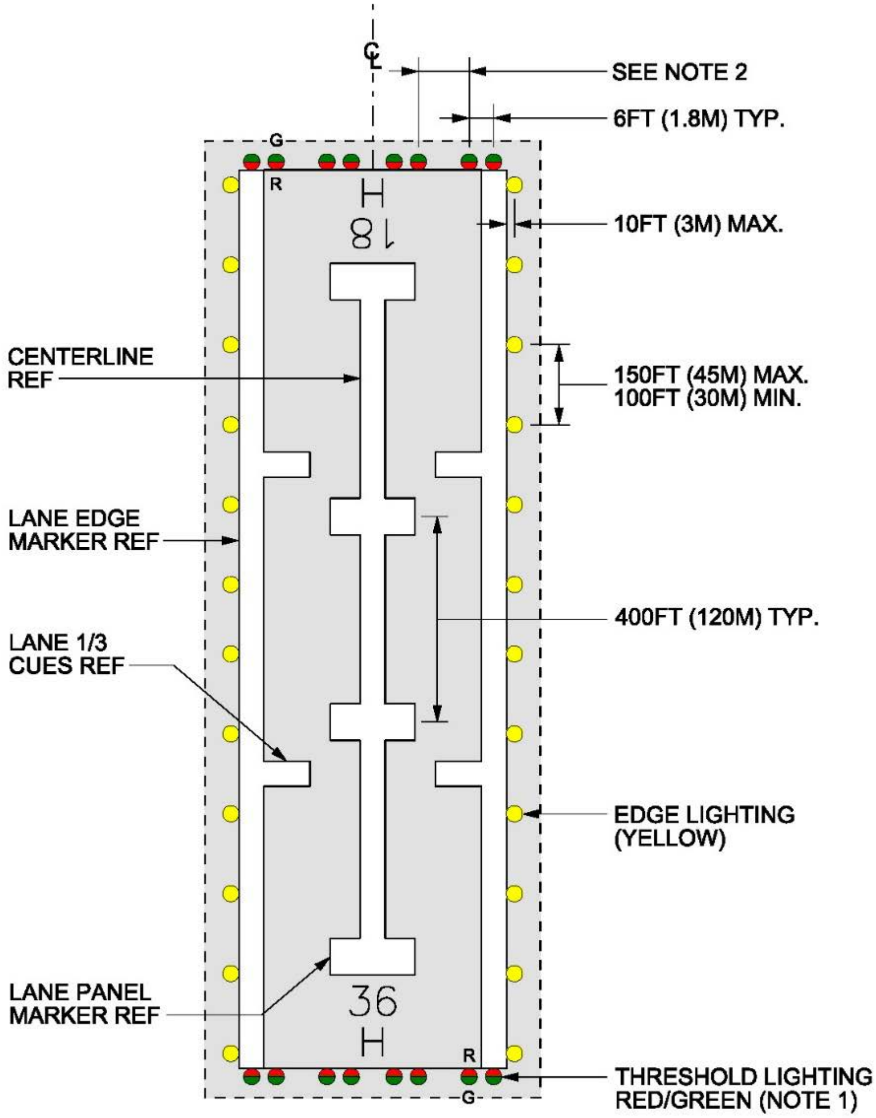


Figure 8-2 Rotary Wing Landing Lane



NOTES:

1. THRESHOLD LIGHTING MAY BE PLACED ON OR OFF THE PAVEMENT.
2. THE DISTANCE BETWEEN THE LIGHT GROUPS WILL VARY DEPENDING ON LANDING WIDTH. FOR EXAMPLE, 75FT (22.5M) = 17FT (5.1M) SPACING.

8-2 HELIPORT LIGHTS.

8-2.1 Runway Edge Lights (White).

The line of edge lights, aviation white, must be located on each side of a heliport runway, and not less than 5 feet (1.5 meters), nor more than 10 feet (3 meters) from the paved edge of the runway. The lights will be of the elevated type and will be uniformly spaced at 100 feet (30 meters).

8-2.2 Taxiway Edge Lights (Blue).

When a runway is also used as a taxiway, such as two runways at 90 degree intersections, where one of the runways leads to a taxiway opposite of the approach end, aviation blue taxiway lights will be installed in addition to the white lights. The line of blue lights will be spaced at 100 feet (30 meter) maximum intervals, between the white lights (Figure 8-3). Connect these blue lights to the appropriate intersecting taxiway circuit. The blue edge lights must not be ON when the white edge lights are ON (runway is active). Where only one runway is constructed, blue lights will not be installed. All lights, both white and blue, located in runway or taxiway intersections where subjected to rollover traffic will be the in-pavement type.

Figure 8-3 Heliport Threshold and Edge Light Details

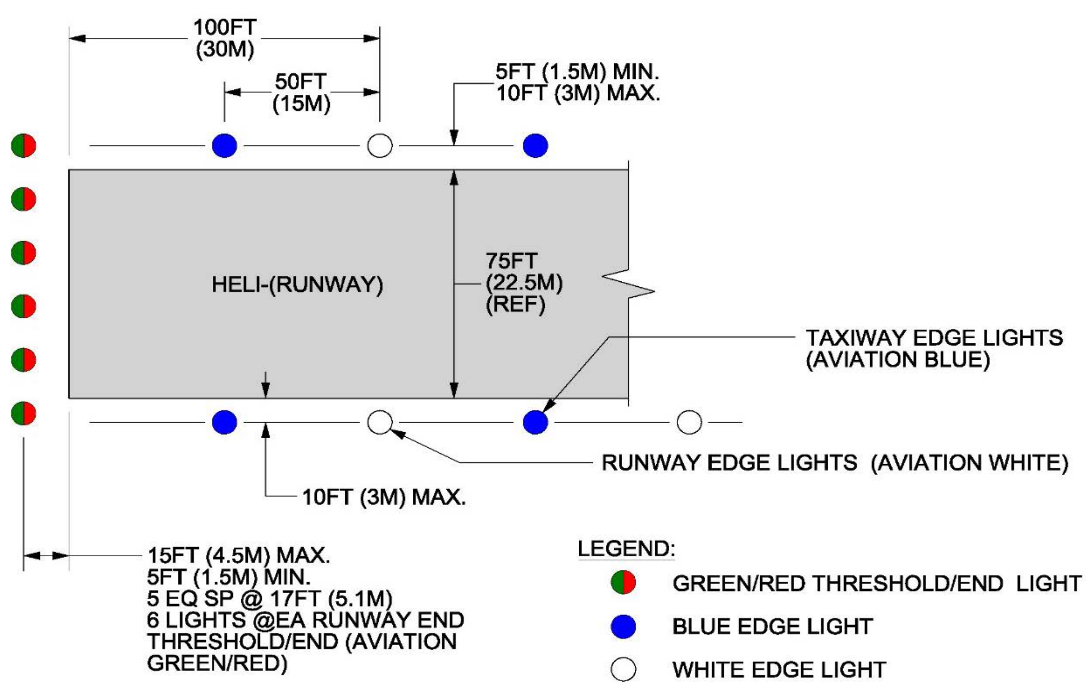


Figure 8-4 Runway/Runway L Intersection

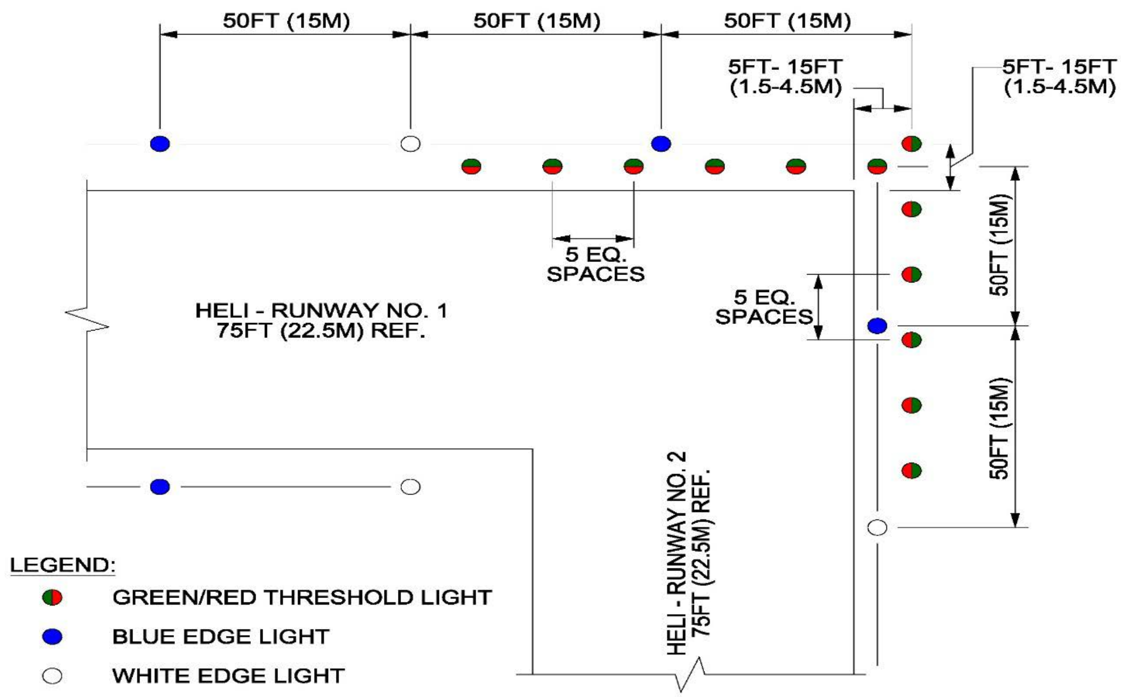
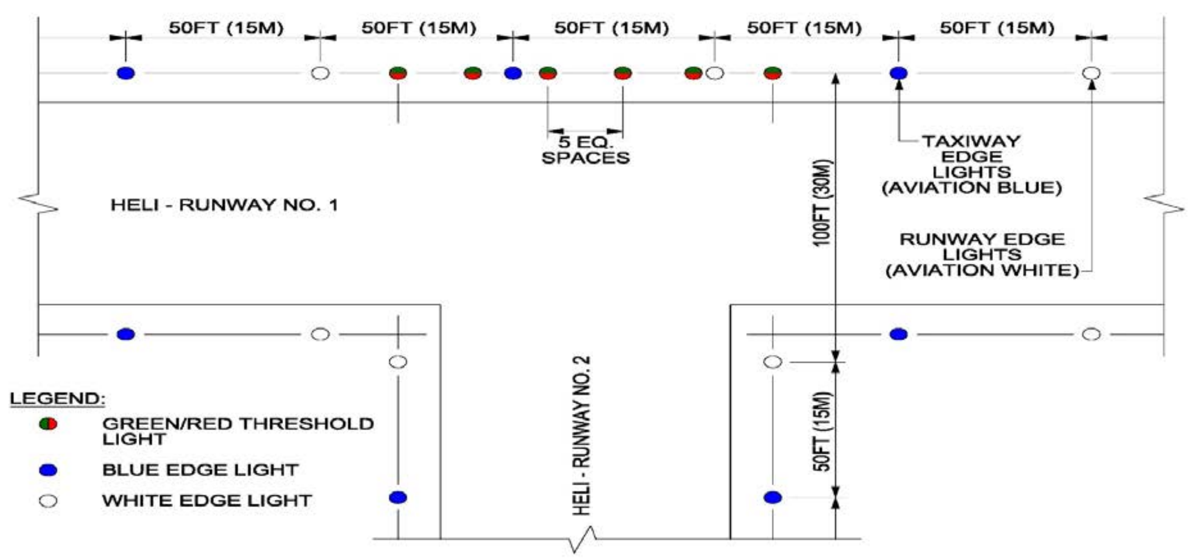


Figure 8-5 Runway/Runway T Intersection



8-2.3 Runway Threshold Lights.

The line of in-pavement threshold lights must be bidirectional, 180 degrees aviation green and 180 degrees aviation red, located not less than 5 feet (1.5 meters) or more than 15 feet (4.5 meters) from the runway ends, with the lights spaced approximately 17 feet (5.1 meters) on centers. The outermost light of each group will be located in line with the corresponding row of runway edge lights. Each group of threshold lights will contain a minimum of six lights. When the line of runway edge lights are located at the maximum distance of 10 feet (3 meters) from the pavement edge of the runway, an additional in-pavement light will be installed in each group for a total of seven lights in each group. The threshold lights should be controlled with the runway edge light circuit.

8-2.4 Taxiway Lights and Signs.

Taxiway lighting (per Chapter 5) and associated taxiway guidance signs will be in accordance with the criteria stated in Chapter 9.

8-2.5 Approach Lights.

Approach light systems, when considered necessary, should be installed in accordance with the criteria cited in Chapter 7 for VFR or IFR conditions as appropriate.

8-2.6 Heliport/Helipad Identification Beacon.

8-2.6.1 Purpose.

A heliport beacon provides long-range guidance and helipad identification.

8-2.6.2 Configuration.

The beacon must contain a colored sequence of lights, double peak white flash, and a single peak green and yellow. The flash must be 10 to 15 sequences of flashes per minute. The time between each color should be one-third of the total sequence time. The beacon should not be installed within 1 mile (1.6 kilometers) of any existing airport beacon or other helipad area.

8-2.6.3 Construction.

The beacon should be visible for a distance of 1 mile (1.6 kilometers) in 1 mile (1.6 kilometer) VMC visibility daylight, and 3 miles (4.8 kilometers) in 3 miles (4.8 kilometer) VMC at night, both from an altitude of 3,000 feet (900 meters) above ground level. The beacon should be mounted a minimum of 50 feet (15 meters) above the helipad surface. Where a control tower or control area is utilized the beacon should be no closer than 400 feet (120 meters) nor further than 3,500 feet (1,050 meters) from that area, and not located between the control tower and the helipad. The beacon will be installed so that the base is not less than 15 feet (4.5 meters) above the floor of the control tower or operations room.

8-2.6.4 Luminous Features.

The main beam of the light should be aimed a minimum of 5 degrees above the horizontal and should not produce light below the horizontal in excess of 1,000 candelas. Light shields may be used to reduce the intensity below the horizontal.

8-3 ROTARY WING LANDING LANES.

8-3.1 Rotary Wing Landing Lanes (formerly Stagefields).

Figure 8-2 and the associated design criteria contained herein are intended to guide in designing and installing a permanent Army rotary wing landing lane, which is normally 1,600 feet (480 meters) long and 75 feet (22.5 meters) wide, utilizing elevated or in-pavement light fixtures.

8-3.2 Rotary wing landing lanes permit efficient simultaneous operations by a number of helicopters (in most cases, up to four at one time) while additional helicopters are in a designated traffic pattern.

8-3.3 Edge Lights.

The edge lights on landing lanes must be aviation white in color, located on a line 3 feet (0.9 meter) maximum from the edge of the full strength pavement that is designated for lane use, as illustrated in Figure 8-2.

8-3.4 Other Requirements.

The longitudinal spacing must be uniform and not greater than 150 feet (45 meters) and not less than 100 feet (30 meters) on each side of the landing lane. The height of the light fixture will not exceed 14 inches (350 millimeters) above grade except, when snow accumulations of 12 inches (300 millimeters) will be frequent, the edge light height may be increased to 24 inches (600 millimeters) above grade. The light fixtures will be mounted on frangible posts of not more than 2 inches (50 millimeters) in diameter. Each landing lane edge light system will be equipped with a 5-step constant current regulator which permits control from blackout to full intensity. For additional information see Chapter 13, or refer to FAA AC 150/5340-30.

8-3.5 Threshold/End Lights.

Combination threshold and lane end light fixtures must be located on a line perpendicular to the extended centerline of the landing lanes. The line of lights must not be less than 2 feet (0.6 meters) nor more than 10 feet (3 meters) outboard from the designated threshold of the landing lane. The lights must consist of four groups of two lights, symmetrically located perpendicular to the extended centerline of the landing lanes (see Figure 8-2).

8-4 REFUELING AREA LIGHTS.

A hazardous location exists within 50 feet (15 meters) of an aircraft fuel inlet or fuel system vent and within 63 feet (18.9 meters) of an aircraft direct fuel outlet/fuel-dispensing nozzle. Refueling areas are Class 1, Division 1, Group D hazardous locations as defined in National Fire Protection Association NFPA 70 National Electrical Code. The light fixture assemblies and associated wiring must be suitable for installation in the hazardous location. Refer to FAA AC 150/5345-39 for the use of retro-reflective markers.

8-5 HOVERLANE LIGHTING SYSTEMS.

8-5.1 A hoverlane is a designated aerial traffic lane (air taxi) for the directed movement of helicopters between a helipad or hover point and the servicing and parking area of a heliport or airfield.

8-5.2 Hoverlane lighting systems will consist of a single row of alternating aviation green and yellow taxiway light fixtures located along the centerline of the hoverlane (see Figure 8-4). Elevated fixtures (FAA L-861T light fixture modified with lens color as indicated) will be installed and will be spaced nominally 50 feet (15 meters) on center for long straight sections, and mounted on metal light base fittings. For curves, fixtures will be spaced nominally 25 feet (7.5 meters) on centers.

8-5.2.1 When hoverlanes terminate adjacent to hanger access aprons or boundaries of other areas not intended for own-power operation, the desirable limit of helicopter travel along hoverlanes toward such areas will be indicated by three lighting fixtures emitting aviation red light. Two red hoverlane limit lights will each be installed on opposite sides of, and approximately 15 feet (4.5 meters) from, the hoverlane centerline. The third light, forming a line of three such lights perpendicular to the alternating aviation green and yellow hoverlane lights, will be located in line with the alternating aviation green and yellow hoverlane lights.

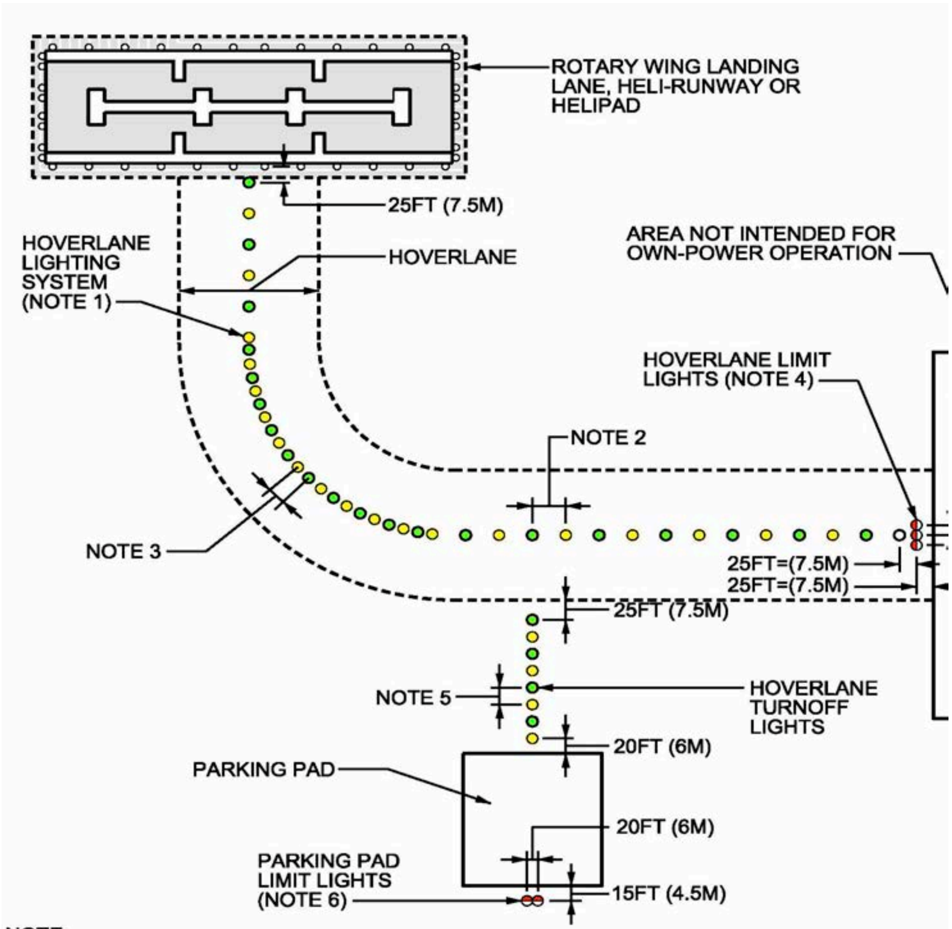
8-5.2.2 Red hoverlane limit lights will provide unidirectional guidance by use of a combat-type hood attached to a taxiway light fitting. The row of alternating aviation green and yellow hoverlane lights described above will terminate approximately 25 feet (7.5 meters) from the red limit lights, outward from the apron or boundary.

8-5.2.3 Hoverlane limit light mountings and types will be as for the alternating aviation green and yellow hoverlane lights described above. Hoverlane turnoffs to individual parking pads will be indicated by aviation green and yellow hoverlane lights beginning approximately 25 feet (7.5 meters) from and perpendicular to the hoverlane, installed on nominal 25 foot (7.5 meter) centers. The line of hoverlane turnoff lights will terminate approximately 25 feet (7.5 meters) from the edge of the parking pad nearest the hoverlane.

8-5.2.4 The limit of helicopter travel from the hoverlane toward the pad, along the turnoff, will be indicated by two parking pad limit lights, which will be located approximately 20 feet (6 meters) beyond the pad, 15 feet (4.5 meters) apart, and perpendicular to the turnoff light line.

8-5.2.5 Parking pad limit lights will emit aviation red light, and will provide unidirectional guidance with a combat-type hood, attached to a taxiway light fitting with red lens. All hoverlane limit and parking pad limit lights will be provided with brightness control and circuited separately, as a group, from other lights. Hoverlane lighting will not be installed in the rigid pavement area of mass parking aprons.

Figure 8-6 Hoverlane Lighting System



NOTE:

1. HOVERLANE LIGHTING SYSTEMS CONSIST OF ELEVATED ALTERNATING AVIATION GREEN YELLOW TAXIWAY LIGHT FIXTURES LOCATED ALONG THE CENTERLINE OF THE HOVERLA (REFERENCE PARAGRAPH 8-5.2.)
2. FIXTURES SPACED NOMINALLY 50FT (15M) ON CENTER FOR LONG STRAIGHT SECTIONS.
3. FOR CURVES, FIXTURES ARE SPACED NOMINALLY 25FT (7.5M) ON CENTERS.
4. UNI-DIRECTIONAL RED LIMIT LIGHTS INDICATE HOVERLANE TERMINATION ADJACENT TO HANGER ACCESS APRONS OR BOUNDARIES OF OTHER AREAS NOT INTENDED FOR OWN-POWER OPERATION.
5. HOVERLANE TURNOFF LIGHTS ARE ALTERNATING AVIATION GREEN AND YELLOW FIXTUR SPACED NOMINALLY 25FT (7.5M) ON CENTER.
6. UNI-DIRECTIONAL RED LIMIT LIGHTS INDICATE THE END OF TRAVEL FROM HOVERLANE T PARKING PAD.

8-6 LIGHTING EQUIPMENT.

8-6.1 Elevated Runway and Landing Lane Edge Lights.

Elevated runway edge lights will be omnidirectional, medium intensity, FAA type L-861. The lamp for this light will be approximately 30 watts, 6.6 amperes, as recommended by the manufacturer (Figure 13-11).

8-6.2 In-pavement Runway Lights.

In-pavement runway lights will be medium intensity, FAA type L-852 E (FAA Type L-852D with colored lenses removed). Where rollover is anticipated on a runway or taxiway, use in-pavement light fixtures of the appropriate color.

8-6.3 Threshold Lights.

8-6.3.1 **\4** In-pavement threshold lights will be FAA type L-852D with red and green light filters. No toe-in is required for this fixture. **/4/**

8-6.3.2 Elevated threshold lights must be FAA Type L-861SE. A 180 degree aviation red filter will be supplied with the light fixture.

8-6.4 Runway Blue Lights.

Elevated and in-pavement lights will be aviation blue, FAA type L-861T or L-852T.

8-6.5 Refueling Area Lights.

Fixture assembly must meet the requirements Underwriters Laboratories (UL) test and approval requirements as stated in UL 844 for class 1, division 1, group D hazardous locations as defined in NFPA 70. The fixture assembly will include a light fixture, frangible coupling, power disconnect switch that will kill power if the frangible mount is broken, and a junction box. As an alternative, use the light fixture assemblies and associated wiring that are intrinsically safe and meet Underwriters Laboratories (UL) test and approval requirements as stated in UL 913 for class 1, division 1, group D hazardous locations as defined in NFPA 70.

8-6.6 Runway and Taxiway Signs.

When operational requirements consider it necessary to install informational mandatory guidance signs, see Chapter 5 for guidance. Runway and taxiway signs are designated in two groups: mandatory signs are white letters on a red background, and information signs are black letters on a yellow background.

8-6.7 Auxiliary Lighting.

For auxiliary lighting such as floodlights, protective lighting and intensities, see paragraph 10-4.

8-7 POWER REQUIREMENTS.

Runway lighting systems will be supplied through interleaved or non-interleaved series circuits served by constant current regulators. The regulators are available in various load capacities and output current values, and have brightness controls so that the light output can be adjusted to suit the visibility conditions.

8-7.1 Circuit Criteria.

The number and type of regulators required will be determined by the circuit length. Address power losses from cable lengths to and from the lighting vault to the lights and the isolation transformer loss when designing the lighting system.

8-7.2 Cable Connectors, Plugs and Receptacles.

See Chapter 13.

8-7.3 Cables.

Cables used for series circuit. Will be No.8 or No. 6 1/C stranded copper, 5,000 volt, cross-linked polyethylene (XLP). See paragraph 13-8.7 and FAA AC 150/5345-7. Use No. 6 cable on all 20 ampere circuits.

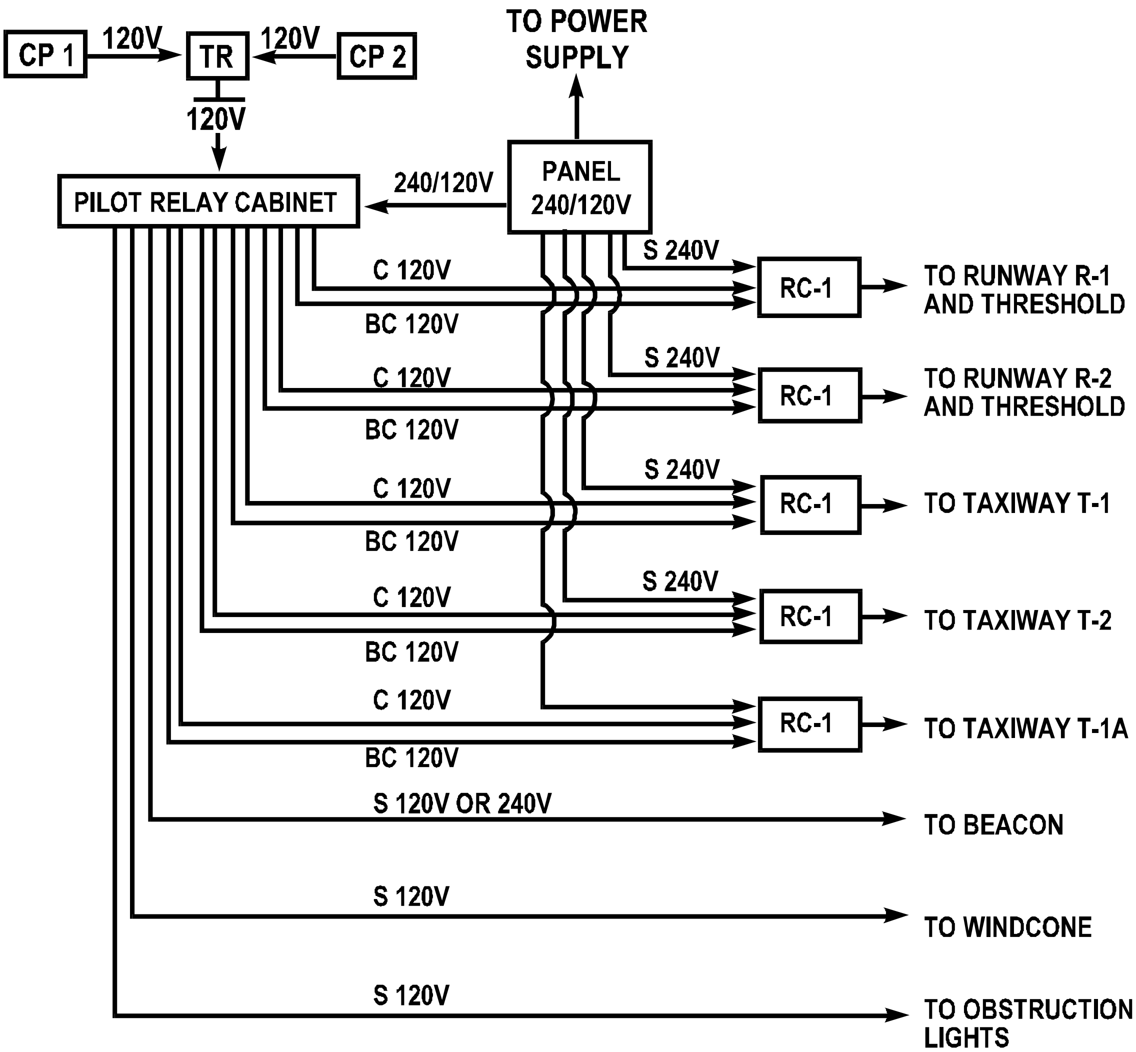
8-7.4 Isolation Transformers.

See paragraph 13-8.9.

8-8 CONTROL REQUIREMENTS.

The heliport lighting control system is an integral part of the control system for all heliport lighting facilities. The function of this portion of the control system is to energize and de-energize the selected runway lighting systems, and to control the brightness of the lights. All lights will be controlled from the control tower and from the lighting equipment vault. The circuits will be provided and connected as indicated in Figure 8-5, with the runway/taxiway combination control panels and associated equipment connected to permit separate control of each heliport lighting system, independent of each other, and permit simultaneous control of the taxiway circuits in combination. Coordinate the need to interlock the lighting on intersecting runways so that both runway lighting systems cannot be energized simultaneously. Taxiway circuit T-1A will be connected with separate individual control to permit flexibility in the operation of the runway and taxiway lights either singly, in combination, or simultaneously, as required for the heliport operations by the control tower operator. The layout will also allow for future changes, and expansion in the methods of operation with a minimum of expense and interruption of service.

Figure 8-7 Block Diagram Typical System



LEGEND

- CP-1 - Control Point Primary (Control Tower)
- CP-2 - Control Point Alternate (Vault)
- RC-1 - Regulator
- TR - Transfer Relay
- BC - Brightness Control
- C - Control
- S - Supply

NOTE: Electric power source, main service switch, emergency generator and transfer switch and main distribution panel not shown. Installation of theses items will be designed to meet local conditions.

8-8.1 Provide edge lights and threshold lights with 3 intensities as follows:

Intensity Step	Percent of Full Intensity
1	10%
2	20%
3	100%

If required by the operations community, for compatibility with night vision goggles, the edge lights and threshold lights may be provided with 5 intensities as follows:

Intensity Step	Percent of Full Intensity
1	0.16%
2	0.8%
3	4.0%
4	20%
5	100%

8-8.2 The initial sequence of operations of the heliport lighting circuits anticipated is such that when helicopters are utilizing the night landing facilities of the heliport: the blue taxiway lights (circuits T-1 and T-2) will be turned on, but only the white edge lights and green/red threshold lights (circuits R-1 or R-2) of the runway in use will be turned on. Use Figure 8-1 as a reference.

Example: White edge lights, R-1, ON
Threshold lights, R-1, ON
Blue edge lights, R-2, ON
Blue edge lights, T-2, ON
Blue edge lights, T-1A, ON
All other taxiway/runway lights, OFF

The above example will allow a helicopter to land on R-1, taxi on R-2, taxi on T-2, and proceed to a designated area via T-1A.

8-9 MONITORING REQUIREMENTS.

There are no requirements for monitoring the lighting systems on heliports or rotary landing lanes.

8-10 COMPLIANCE WITH INTERNATIONAL STANDARDS.

8-10.1 AFIC.

There are no AIR STDs for heliports or landing lanes.

8-10.2 NATO.

There are no standards for heliports or landing lanes; however, STANAG 3619 (Edition 5) – Helipad Marking and Lighting, 6 June 2013, makes reference to the US Army criteria for IFR approach lighting.

8-11 EQUIPMENT.

See Chapter 13 for lighting equipment.

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CHAPTER 9 STANDARDS FOR AIRFIELD SIGNS AND MARKERS

9-1 GENERAL.

9-1.1 Purpose.

Signs and markers provide important guidance and control for the safe and efficient surface movement of aircraft on an airfield. Proper signing provides information on location, direction, destination, mandatory holding positions, important boundaries, and other information. Additionally, runway distance remaining markers provide to the pilot the remaining distance on a runway for landing and take-off operations. See AC 150/5340-18, paragraph 1.13

\4 This UFC provides signing standards consistent with current FAA and ICAO requirements and standards, including: FAA AC 150/5340-18, FAA AC 150/5345-44 and ICAO Annex 14, Chapter 5, Visual Aids for Navigation. The signing criteria in this chapter and in the references above should be applied at all airfields to the extent that they do not conflict with any special local requirements. All signs must be internally lighted and meet the luminance values indicated.

9-1.2 General Signing Conventions.

9-1.2.1 If signs are installed on both sides of the taxiway at the same location, the sign faces are identical, except for holding position signs, where the taxiway location signs are located outboard of the runway holding position sign. There is also an exception for runway exits, where an RSA/OFZ boundary sign is installed on the right side of the exit taxiway and if a taxiway direction sign is needed, then a taxiway direction sign maybe installed on the left side. Signs are not installed between the taxiway location/runway holding position sign and the runway.

9-1.2.2 Signs may be located on the right side of the taxiway when necessary to meet clearance requirements or where it is impractical to install them on the left side because of terrain or conflicts with other objects.

9-1.2.3 Signs that may be installed in this manner include: RSA/OFZ boundary signs which may be installed on the back of taxiway/runway intersection holding position sign. ILS critical area boundary signs, which may be installed on the back of ILS critical area holding position signs. Taxiway location signs, which may be installed on the back of direction signs when they are installed on the far side of an intersection. Note: Location signs installed in this manner do not negate the need for location signs installed on the left of the runway holding position sign prior to the intersection. Taxiway location signs, which may be installed on the back of holding position signs. Destination signs, which may be installed on the back of direction signs on the far side of intersections when the destination referred to is straight ahead.

9-1.2.4 Taxiway location signs installed in conjunction with holding position signs for taxiway/runway intersections are installed outboard of the holding position sign.

9-1.2.5 Location signs are normally included as part of a direction sign array, which is located prior to the taxiway intersection. Except for intersections of only two taxiways (see 5/10/2019 AC 150/5340-18G 1-16 paragraph 1.13.8), the location sign is placed in the array so the designations for all turns to the left are located to the left of the location sign; the designations for all turns to the right or straight ahead, when required, are located to the right of the location sign.

9-1.2.6 When more than one taxiway direction sign is installed at the same location, the designations of the intersecting taxiways and their respective arrows are arranged left to right in a clockwise manner, starting from the taxiway or runway on which the aircraft is located.

9-1.2.7 All direction signs have arrows. Arrows on signs are oriented to the approximate direction of the turn. Each designation appearing in an array of direction signs is accompanied by only one arrow. A direction sign with an arrow indicating that a taxiway continues straight ahead (25 degrees or less change in alignment at the intersection) is not normally needed. Where the intersection alignment changes more than 25 degrees, a sign with an arrow approximating the direction of the taxiway is used. If the taxiway continues straight ahead (25 degrees or less change in alignment) and the designation of the taxiway changes at the intersection, then a direction sign with an arrow is used.

9-1.2.8 When a taxiway intersection comprises only two crossing taxiways, it is permissible to use a double arrow direction sign in place of separate direction sign panels. In this case, the location sign panel is on the left side of the sign array. For this type of installation, the taxiway that the pilot is on may not change designation or alignment (more than 25 degrees) on the other side of the intersection.

9-1.2.9 In some cases, location signs may not be needed in conjunction with direction signs. Consider all information concerning the intersection when analyzing the need for a location sign. This would include but is not limited to: • Complexity of the intersection layout. • Distance from the last location sign. • Complexity of prior intersections. Traffic flow patterns through the intersection. • Visibility conditions under which the intersection is used.

9-1.2.10 Destination signs are usually installed in advance of intersections prior to turns. However, they may also be installed on the far side of an intersection when the taxiway route continues ahead and the destination sign is installed on the back of another sign. Destination signs usually are not collocated with other signs because it could result in abnormally long signs.

9-1.2.11 Information signs are not collocated with mandatory instruction, location, direction, or destination signs.

9-1.2.12 Each designation and its associated arrow included in an array of direction signs or destination signs are delineated from the other designations in the array by a black vertical border. When it is appropriate, a location sign may be used to provide this delineation.

9-1.2.13 On a sign face, a dot means “and.” It is used on signs where one arrow is common to two designations. For example, if the routes to two different runway ends involve the same taxiways, the runway numbers appearing on an outbound destination sign would be separated by a dot; the directional arrow on the sign face would be applicable to both runway ends.

9-1.2.14 A dash is used only with mandatory instruction signs. On these signs, a dash is used to separate the designations for opposite ends of the same runway (for example: 18-36) or to separate the runway designation from the abbreviation "APCH" or "DEP" on holding position signs for runway approach/departure areas.

9-1.2.15 When replacing sign panels due to damage or changing message elements, the entire message element should be replaced. This will avoid panel-to-panel color changes that may be distracting to pilots. See AC 150/5345-44 for additional information about replacement sign panels.

9-1.2.16 A sign may be "canted" or angled towards the pilot's line of vision when necessary to improve its visibility. This situation is illustrated where a pilot would have difficulty seeing the sign on the left due to its proximity to the edge of the parallel taxiway. The back of a canted sign is not available for use because it may not be visible to pilots.

9-1.2.17 When using two separate signs in an array, do not separate message elements between the two signs. For example, do not locate the arrow for a sign panel on a separate sign in the array. Extension of an existing sign (i.e., physically increase its length by adding modules to it) requires all of the following criteria be met: The existing sign meets the applicable standards in AC 150/5345-44. The length of the sign (existing plus extension) cannot exceed the maximum overall length limitations per AC 150/5345-44. Unless the extension involves the addition of only a location sign, the sign face (existing plus extension) meets the standards for legend, borders, arrows, spacing, and color per AC 150/5345-44. • The extension meets the electrical and frangibility standards of AC 150/5345-44. 12/23/2020 AC 150/5340-18G Change 1 1-18 The separation between individual sign housings meets the requirements in AC 150/5345-44. **/4/**

9-1.3 Components of a Sign System.

The following types and styles of signs, discussed more below, are basic components of a sign system for an airfield:

9-1.3.1 Mandatory Instruction Signs.

Type L-858R, white legend on a red background (see FAA AC 150/4345-44, Appendix C, Figure 12, for examples of typical lighted signs). Note: the black outline is considered as background and does not add to the spacing to the next character or border (FAA AC 150/4345-44, Appendix I, Figure 18. Current requirement for new signage contains a 0.75 inch black outline around all characters.

9-1.3.2 Direction, Destination, and Boundary signs.

Use Type L-858Y, black legend on a yellow background (see FAA AC 150/4345-44, Appendix C, Figures 11 and 12, for examples of typical signs).

9-1.3.3 Taxiway Location Signs.

Use Type L-858L, yellow legend and border on a black background indicating the surface on which the aircraft is operating. The yellow border is inset from the inner edge of the sign to provide a continuous black margin (see FAA AC 150/4345-44, Appendix C, Figures 11 and 12, for an example of a typical sign). While primarily indicating taxiway location, these also may be used to indicate runway location at potentially confusing areas.

9-1.3.3 Sign Arrays.

Signs are often established as a sign array with several messages. For example, a location sign may be grouped with a mandatory holding position sign or with one or several direction sign messages as a sign array. However, not all types of signs may be grouped together; for example, guidance and information signs may not be co-located with mandatory signs.

9-1.3.4 Runway Distance Remaining Signs.

Use Type L-858B, white legend on a black background, with a single number indicating in multiples of 1,000 feet (300 meters) the remaining runway distance for pilots during takeoff and landing operations. Metric measure is not used for this sign. (See FAA AC 150/4345-44, Appendix F, Figure 14.)

9-1.3.5 Arresting Gear Markers.

Use a yellow circle on black background, identifying the location of arresting system cables on the runway (similar to FAA Type L-858B).

9-1.3.6 Other Signs.

Other signs serving special situations may be used, provided they do not conflict with the sign standards, or have the potential for confusing ground traffic with respect to standard signing. Vehicle control signs conforming to the Manual of Uniform Traffic Control Devices (MUTCD) (Air Force use UFC 3-120-01), such as the standard octagonal stop sign, may be used at locations that would apply only to vehicles.

9-1.4 Sign Styles.

Lighted signs can be powered from a 3-step 6.6 ampere series circuit (FAA Style 2), a 5-step 6.6 or 20 ampere series circuit (FAA Style 3) or a dedicated 5.5 ampere series circuit (FAA Style 5). Unlighted signs are FAA Style 4.

For new installations, mandatory signs, runway exit signs, RDR and AGM must be FAA Style 5 and connected to a dedicated 5.5 ampere, 1-step regulator. The intent is to have a more reliable sign system for these signs by eliminating the electronics required to maintain uniform brightness over the range of a 3 or 5 step regulator. Taxiway guidance and information signs and location signs may be either FAA Style 2 or FAA Style 3 depending on the series circuit intensity steps the signs are connected to. See FAA AC 150/5345-44 for more information about sign power and electrical requirements.

9-1.5 Failure of Lighted Signs.

The failure of any light source within a sign must not result in a potential miscommunication of the intended message to a pilot. If the failure of an internal lamp(s) in a sign causes a panel or any section of a panel to be dark, or have an average luminance less than the minimum required in FAA A/C 150-5345-44, paragraph 3.2.5.6, sign operation must be automatically discontinued.

9-2 MANDATORY SIGNS.

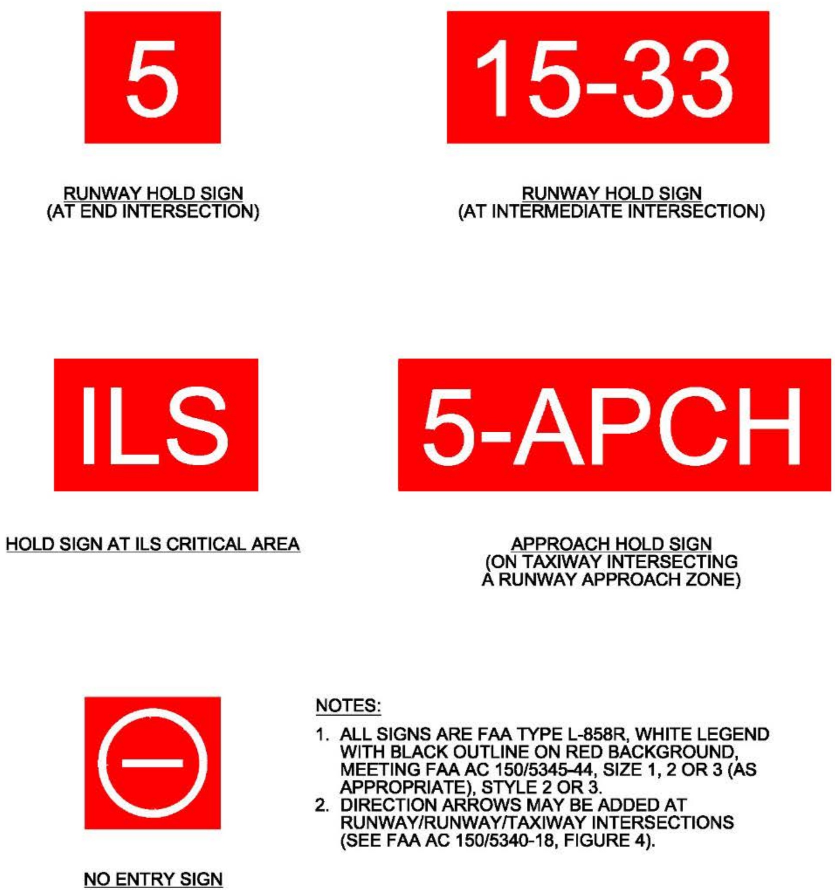
9-2.1 Purpose.

Mandatory signs provide an instruction that must be followed. They denote an entrance to a runway or critical area, or other situation such as a no-entry location. At controlled airfields (with active tower), aircraft and vehicles are required to hold at the holding position unless cleared by air traffic control. At uncontrolled airfields, the intent is that traffic may only proceed beyond the sign after appropriate precautions are taken by the pilot. Examples of mandatory sign messages are in FAA AC 150/5340-18 and 150/5345-44.

Note: All mandatory instruction sign white legends are now outlined in black (see Figure 9-1). See FAA AC 150/5345-44 for additional information about the black outline. Signs with white legends may be used until stock is exhausted.

Figure 9-1 Typical Mandatory Signs

Note**:** These signs represent the bulk of existing signs and comply with previous edition of FAA AC 150/5345-44. These signs do not require replacement until the end of their economic lives or with a major renovation to the airfield. See current edition of FAA AC for new sign message elements. Current edition of AC 150/5345-44



9-2.2 Installation.

Mandatory signs are installed on the left-hand side at taxiway/runway intersections, runway/runway intersections, ILS critical areas, runway approach zones, no entry areas.

9-2.2.1 At some locations, signs should be installed on both sides of runways and taxiways. This includes: runways more than 150 feet (45 meters) in width; runways of any width which are used for “land and hold short” operations; or taxiways that are 150 feet (45 meters) or greater in width.

9-2.2.2 Holding position signs should be collocated with holding position markings and located at a distance from the intersecting runway to meet the clearance requirements of the intersecting runway or ILS critical area. Coordinate this distance with Airfield Management and Flight Safety Offices. On taxiways in approach areas, the sign is installed where an aircraft would cross the runway safety area or penetrate the required airspace for approaches and departures.

9-2.2.3 Mandatory signs may be FAA Size 1, 2 or 3. Size 3 signs are recommended for Category I facilities and higher. From the defined edge of runway or taxiway, locate a Size 3 sign 35-60 feet (10.5-18 meters), a Size 2 sign 20-35 feet (6-10.5 meters), and a Size 1 sign 10-20 feet (3-6 meters). The distance indicated is the perpendicular distance from defined pavement edge to near side of sign. Signs are oriented perpendicular to the runway or taxiway centerline, but may be canted up to 15 degrees to increase visibility if the sign is not a double-face sign. At locations where large wingspan aircraft operations are common, place signs far enough from taxiway edges to allow required wingtip clearance. Signs must provide 12 inches (300 millimeters) of clearance between the top of any sign in an array and any part of the most critical aircraft using, or expected to use, the airfield when the aircraft's wheels are at the defined pavement edge.

9-2.2.4 Mandatory signs may be grouped in an array with a location sign, or may have a location sign or a Safety Area/Obstacle Free Zone (OFZ) or ILS Critical Area boundary sign on the back face. Direction or destination signs may not be grouped with a mandatory sign. In an array, the location sign is always positioned outboard of the mandatory sign. See FAA AC 150/5340-18 for further guidance on grouping several sign messages in an array. The Air Force will use “INST” instead of “ILS” for the instrument holding position/critical area boundary when more than just the ILS is available, such as PAR, MLS, or GPS.

9-2.3 Characteristics.

See Chapter 13 and FAA AC 150/5345-44 for additional sign characteristics information.

9-2.3.1 Message.

See FAA AC 150/5345-44 for technical information concerning sign legend sizes, fonts, spacing, border requirements, power requirements, sign sizes, and mounting methods.

9-2.3.2 Dimensions.

See FAA AC 150/5345-44 Tables 1 and 2 for sign and legend height dimensions. As an example, an FAA Size 3 sign has a legend height of 18 inches (457 millimeters), legend panel height of 30 inches (762 millimeters), overall sign mounting height of 3 to 3.5 feet (0.9-1.05 meters), maximum overall sign length of 170 inches (4.318 meters), and minimum sign length of 42 inches (1.07 meters).

9-2.3.3 Electrical.

For new installations, it is preferred that mandatory signs be FAA Style 5 and connected to the 5.5 amp, 1-step RDR circuit. The intent is to have a more reliable sign system by eliminating the electronics required to maintain uniform brightness over the range or a 3 or 5-step regulator. The mandatory sign 5.5 amp circuit can also be used for RDR signs and AGM signs.

9-2.3.4 Photometrics.

See FAA AC 150/5345-44 for detailed information about sign luminance and methods of measurement. It is recommended that photometric testing be performed on all newly installed mandatory signs on site. The purpose of these tests is to verify the installed fixtures meet or exceed the minimum photometric requirements.

9-2.4 Power and Control.

For new installations, mandatory signs will be powered from a dedicated 1-step (5.5 ampere) circuit. Control of the circuit will be interlocked with the corresponding runway edge lighting circuit so as to turn on and off with its runway edge lighting.

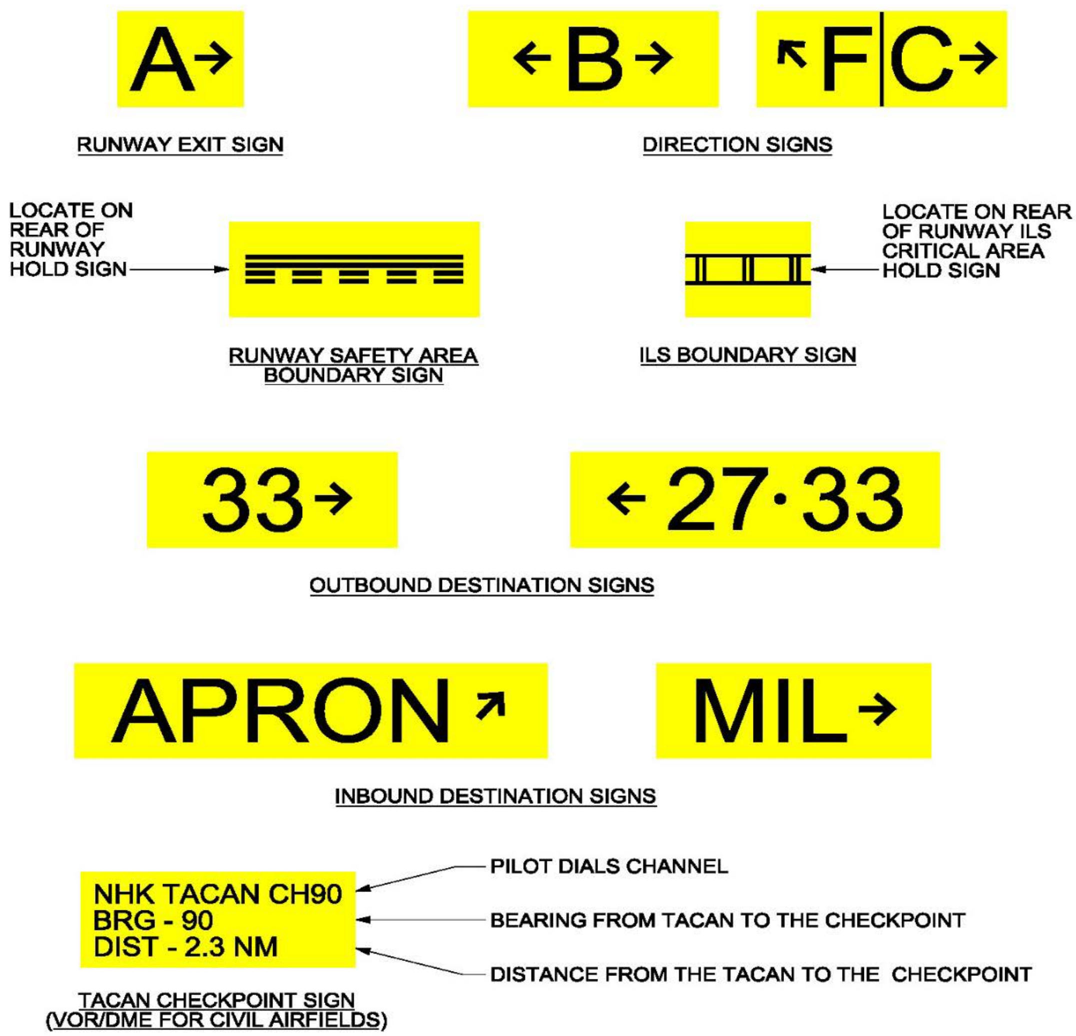
9-3 TAXIWAY GUIDANCE AND INFORMATION SIGNS.

9-3.1 Purpose.

See FAA AC 150/5340-18 for detailed information about taxiway guidance and information sign function, location, and rules for location. Taxiway guidance signs include direction signs, destination signs, other informational signs, and boundary signs. Direction signs indicate the direction of taxiways leading out of an intersection, and are installed at runway exits, taxiway intersections, and other locations. Destination signs indicate the general direction to a remote location. For example, outbound destination signs are used to identify the direction to takeoff runways, while inbound destination signs are used to indicate direction to major areas such as aprons, fueling points, and other locations. Both direction and destination sign messages include an arrow. Boundary signs indicate important boundaries such as ILS critical areas and runway approach areas. Other signs are used to provide specific information such as noise abatement procedures, check points, and others. Examples of guidance sign messages are shown in Figure 9-2.

Figure 9-2 Typical Taxiway Guidance and Information Signs

Note: These signs represent the bulk of existing signs and comply with previous edition of FAA AC 150/5345-44. These signs do not require replacement until the end of their economic lives or with a major renovation to the airfield. See current edition of FAA AC for new sign message elements.



NOTE:

1. ALL SIGNS, EXCEPT TACAN CHECKPOINT SIGNS, ARE FAA TYPE L-858Y, WITH BLACK LEGEND ON YELLOW BACKGROUND, MEETING FAA AC 150/5345, SIZE 3, STYLE 2 OR 3.

9-3.2 Installation.

Signs are installed on the left side of the taxiway unless aircraft operations require otherwise.

9-3.2.1 Runway exits signs are located prior to the runway/taxiway intersection on the side and in the direction from which the aircraft is expected to exit. If a taxiway crosses a runway and an aircraft can be expected to exit on either side, then exit signs are located on both sides of the runway. For taxiways that are intended only to be used as exits from the runway in one direction, such as taxiways located near the end of the runway or intersecting the runway at an acute angle, the signs should be installed only for the runway direction in which they are intended to be used. When two acute-angle taxiways (e.g., high speed exits) are intended to be used in opposite directions and intersect the runway at a common point, the exit signs are located prior to the common point intersection rather than in the area between the two exits (see FAA AC 150/5340-18, Figure 18). “Bracketing” a runway exit sign (where a sign is placed before and after the exit) is not permitted. A runway exit sign should never have more than one arrow for each taxiway designation shown on the sign.

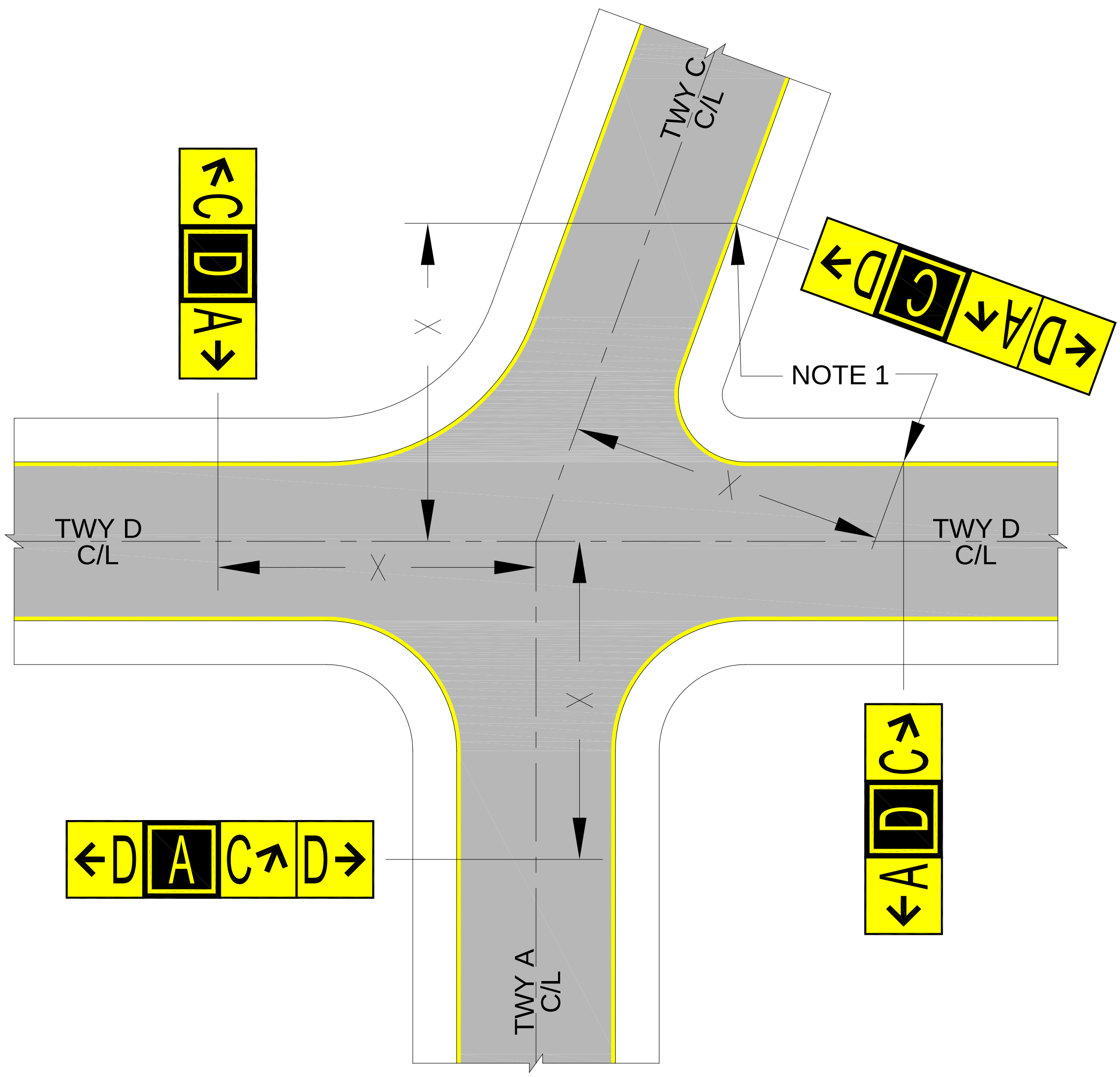
9-3.2.2 A direction sign is installed prior to an intersection. If there is no surface painted hold position marking at a taxiway intersection then the location of the direction sign can be used by the control tower to direct an aircraft to hold for crossing traffic. Typically they are installed at the point of tangency of the taxiway intersection, but not closer than the minimum distance from the intersecting taxiway centerline indicated in Table 9-1 (see Figure 9-3). The distance used for a given airfield should be applied uniformly and should be based on the predominant operating aircraft.

Table 9-1 Perpendicular Distances for Taxiway Signage from Centerline of Crossing Taxiway

AIRCRAFT DESIGN GROUP (ADG) (FAA AC 150/5300-13)	I	II	III	IV	V	VI
WING SPAN	<49ft (<15m)	49ft- <79ft (15m- <24m)	79ft- <118ft (24m- <36m)	118ft- <171ft (36m- <52m)	171ft- <214ft (52m- <65m)	214ft- <262ft (65m- <85m)
AIRCRAFT TYPE	T-1, T-37, T-38, C-21	C-12, C-20, F28 (1000/2000)	T-43, C-9, F28 (3000/4000) CV-340/440/580, B-727, B-737, DC-9	C-17, C-130, C-141, B-1B, KC-10, KC-135 B-707/720, B-757/767, L-1011, A-300, DC-8, DC-10	B-2, B-52, B-747, VC-25	C-5
PERPENDICULAR DISTANCE FROM CENTERLINE OF CROSSING TAXIWAY (1)	44.5ft (13.5m)	65.5ft (20m)	93ft (28.5m)	129.5ft (39m)	160ft (48.5m)	193ft (59m)

(1) DISTANCE IS DERIVED USING THE FORMULA: 0.7 X MAX. WINGSPAN IN ADG + 10ft (3m). REFERENCE FAA AC 150/5300-13.

Figure 9-3 Example of Taxiway-Taxiway Intersection Sign Location



X = THE PERPENDICULAR DISTANCE FROM CENTERLINE OF THE CROSSING TAXIWAY (SEE TABLE 9-1).

NOTES:

1. SIGNS SHOULD BE LOCATED PERPENDICULAR TO THE POINT AT WHICH THE DISTANCE "X" INTERSECTS THE EDGE OF PAVEMENT THAT IS FARTHEST FROM THE INTERSECTION OF THE TAXIWAY CENTERLINES. THIS ASSURES THAT THE ENTIRETY OF AN AIRCRAFT AT THAT LOCATION IS BEHIND THE CLEAR DISTANCE "X".

9-3.2.3 Destination signs are not always needed where direction signs are used, but are helpful where direction signs alone do not adequately guide a pilot to the desired destination. They may be particularly helpful at uncontrolled airfields. Destination signs should be located where they will not cause confusion with direction signs, and are subject to the same minimum distances from intersecting taxiways. See FAA AC 150/5340-18 for additional guidance.

9-3.2.4 An ILS Critical Area boundary sign is installed at the boundary limit to indicate where it is clear of the ILS Critical Area.

9-3.2.5 TACAN checkpoint signs are provided when an airfield has a TACAN system and provides information for the pilot who verifies the operation of the navigational aid in the aircraft before takeoff. The sign includes information on the type of navigational aid, identification code, radio channel, magnetic bearing, and the distance in nautical miles to the transmitting antenna from the checkpoint marking. The sign is positioned so it will be visible to the pilot of the aircraft properly positioned on the checkpoint marking. See Figure 9-7.

9-3.2.6 When runway end elevations differ by 25 feet (7.5 meters) from the published field elevations, an “Altimeter Check Point Sign” is required. Coordinate with TERPS to verify runway and field elevations. This sign should be combined and/or collocated with the TACAN checkpoint sign when available, as the same height and lettering requirements apply. Lettering may be abbreviated as follows: “ALT CHK PT - ELEV: XXXX,” where “XXXX” is the elevation in feet above mean sea level.

9-3.2.7 Other informational signs have messages and are located as determined by operations.

9-3.2.8 Guidance and information signs may be FAA Size 1, 2 or 3. Size 3 signs are recommended for Category I facilities and higher. Locate a Size 3 sign 35-60 feet (10.5-18 meters), a Size 2 sign 20-35 feet (6-10.5 meters), and a Size 1 sign 10-20 feet (3-6 meters) from the defined edge of runway or taxiway. The distance indicated is to the perpendicular distance from defined pavement edge to near side of the sign. Signs are oriented perpendicular to the runway or taxiway centerline, but may be canted up to 15 degrees to increase visibility if the sign is not a double-face sign.

9-3.2.9 Direction signs other than runway exit signs may be grouped in an array with a location sign. Destination signs may not be grouped with other signs, but may be on the back of another sign in which case it would be on the right-hand side for traffic. See guidance in paragraph 9-5 for conventions on sign arrays. See FAA AC 150/5340-18 for further guidance on grouping several sign messages in an array.

9-3.3 Characteristics.

See Chapter 13 and FAA AC 150/5345-44 for additional sign characteristic information.

9-3.3.1 Dimensions.

See paragraph 9-2.3.2. For TACAN checkpoint signs, the character height must not be less than 6 inches (152 millimeters) or more than 9 inches (229 millimeters), and the stroke width not less than 1 inch (25 millimeters). The height of a TACAN checkpoint sign must not be more than 32 inches (0.8 meters) with the maximum sign elevation above the taxiway edge not more than 40 inches (1 meter). The TACAN checkpoint sign should not be located less than 50 feet (15 meters) from the taxiway edge.

9-3.3.2 Electrical.

See paragraph 9-1.4.

9-3.3.3 Photometrics.

See FAA AC 150/5345-44 for detailed information about sign luminance and measurement methods.

9-3.3.3.1 Photometric Testing.

Photometric testing must be performed on all newly installed runway exit signs on site. The purpose of these tests is to verify the installed fixtures meet or exceed the minimum photometric requirements.

9-3.4 Power and Control.

For new installations, runway exit signs will be powered from a dedicated 1-step (5.5 ampere) circuit. Control of the circuit will be interlocked with the corresponding runway edge lighting circuit so as to turn on and off with its runway edge lighting. Other lighted guidance signs as well as information signs are typically connected to taxiway edge lighting circuits. This configuration permits the signs to be turned on and off with the respective runway or taxiway lighting.

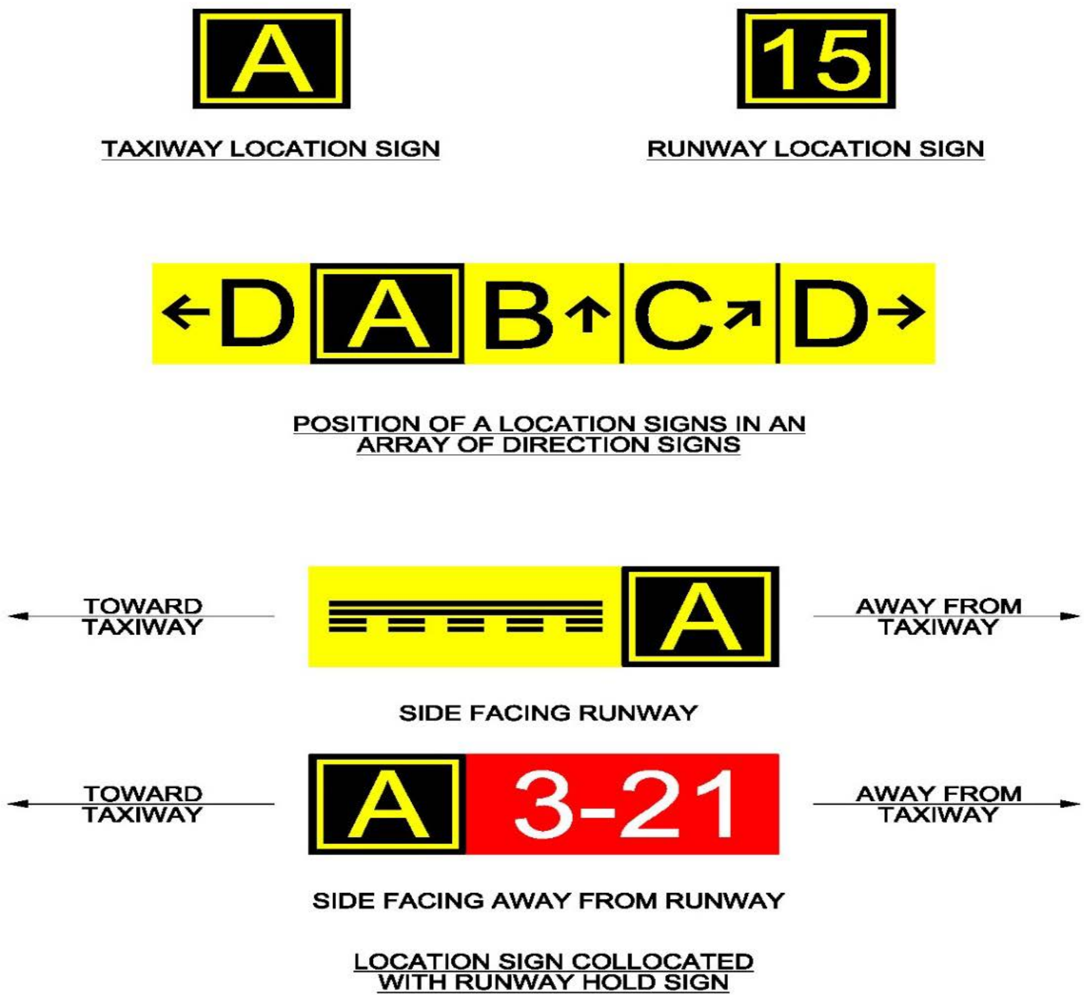
9-4 LOCATION SIGNS.

9-4.1 Purpose.

Location signs identify the taxiway or runway on which the aircraft is located. Examples of location sign messages are shown in Figure 9-4.

Figure 9-4 Typical Location Signs

Note: These signs represent the bulk of existing signs and comply with previous edition of FAA AC 150/5345-44. These signs do not require replacement until the end of their economic lives or with a major renovation to the airfield. See current edition of FAA AC for new sign message elements.



NOTE:

1. LOCATION SIGNS ARE FAA TYPE L-858L, WITH YELLOW LEGEND AND BORDER ON BLACK BACKGROUND, MEETING FFA AC 150/5340-44, SIZE 3, STYLE 2 OR 3.

9-4.2 Installation.

Location signs are typically installed on the left side of a taxiway, but also may be on the right side if this helps visibility. Often taxiway location signs are part of a sign array, hence may be together with a mandatory hold sign or a guidance direction sign (although not with a runway exit sign). Runway location signs may be installed on runways where two runways are in proximity, which could create confusion, and are located to clearly indicate the runways for pilots. Runway location signs are not part of a sign array, and contain the runway designation only for the one runway end.

9-4.2.1 Location signs are subject to the same siting criteria as the direction and information signs in paragraph 9-3. Taxiway location signs may be part of a direction sign array, or may be stand-alone between taxiways where it would be helpful to reinforce pilot information as to location.

9-4.2.2 Location signs may be FAA Size 1, 2 or 3. Size 3 signs are recommended for Category I facilities and higher. Locate signs as indicated in paragraph 9-3.2.8.

9-4.2.3 A location sign may be grouped in a sign array. With mandatory signs, the location sign should always be positioned outboard. With a direction sign array, the location sign is placed so that all turns to the left would be located to the left of the location sign, and all turns to the right or straight ahead would be located to the right of the location sign. An exception is when only two taxiways intersect and the direction sign indicates the crossing taxiway with arrows both ways, in which case the location sign is positioned to the left.

9-4.2.4 Location signs are not always needed in conjunction with a direction sign. The need is determined from evaluating the complexity of the intersection layout, distance from the last location sign, complexity of prior intersections, traffic flow, and typical conditions under which the intersection is used. Do not include a location sign as an array with a destination sign or other information sign. See guidance in paragraph 9-5 for conventions on sign arrays. See FAA AC 150/5340-18 for further guidance on grouping several sign messages in an array.

9-4.3 Characteristics.

See Chapter 13 and FAA AC 150/5345-44 for additional characteristic information.

9-4.3.1 Message.

See paragraph 9-2.3.1.

9-4.3.2 Dimensions.

See paragraph 9-2.3.2.

9-4.3.3 Electrical.

See paragraph 9-1.4.

9-4.3.4 Photometrics.

See paragraph 9-3.3.3.

9-4.4 Power and Control.

Runway location signs are connected to the runway edge lighting series circuit. Taxiway location sign are typically connected to taxiway edge lighting circuits similar to taxiway guidance and information signs in paragraph 9-3.

9-5 SIGNING CONVENTIONS FOR AIRFIELD SIGNS.

9-5.1 There is no standard configuration for signing that applies to all airfields. In laying out signing for an airfield, first conduct a thorough study of the runway and taxiway layout drawings with local traffic controllers and the operational group using the airfield. Signs are not necessarily needed at all potential locations on an airfield, and judgment must be made based on standards, other guidance, and operational need to provide clear, non-conflicting direction to pilots. It is recommended that the appropriate local engineering function maintain and update a master sign plan for the entire airfield.

9-5.2 The following are general signing conventions to be followed for all airfields:

a. Signs should always be placed on the left side of a taxiway as seen by the pilot of approaching aircraft. Exceptions are:

b. Where signs are placed on both sides of a surface (for example, at wide throat entrances to intersections).

c. Where a sign may be placed on the back of a left-handed sign for traffic in the other direction (such as a location or boundary sign on the back of a mandatory hold sign).

d. Where a destination sign might be placed at the top of a “T” at a “T” intersection.

e. Where necessary for clearance requirements.

f. Where it is impractical to install on the left because of terrain or conflicts with other objects.

9-5.2.1 If signs are installed on both sides of a taxiway at the same location, the sign faces should be identical. An exception is for holding position signs, where a location sign in the array should always be outboard of the mandatory sign.

9-5.2.2 All direction signs have arrows. Arrows on signs should be oriented to approximate the direction of the turn. Each designation on an array of direction signs should be accompanied only by one arrow. An exception is when an intersection has only two taxiways where it is permissible to have the designation of the cross taxiway with arrows both ways.

9-5.2.3 Location signs are typically included as part of a direction sign array. The location sign is placed so that the designations for all turns to the left are on the left of the location sign, and all turns to the right or straight ahead (if used) are on the right of the location sign. A location sign installed together with a mandatory sign is always located outboard of the mandatory sign.

9-5.2.4 A direction sign with an arrow indicating a taxiway continues straight ahead (25 degrees or less change in alignment) is usually not needed, unless the designation of the taxiway changes at the intersection.

9-5.2.5 Information signs should not be collocated with mandatory, location, direction, or destination signs.

9-5.2.6 Each designation and its associated arrow in a direction sign array should be delineated from the other designations in the array by a black vertical border. Where appropriate, a location sign may provide this delineation.

9-5.2.7 Destination signs are never grouped with other signs in a sign array. Destination signs may be installed on the back side of a direction sign on the far side of an intersection when the destination referred to is straight ahead. At intersections or junctions of runways, taxiways, or runways and taxiways, where there are alternate routes to a particular destination from a given direction of travel, indicate only one route on the destination sign.

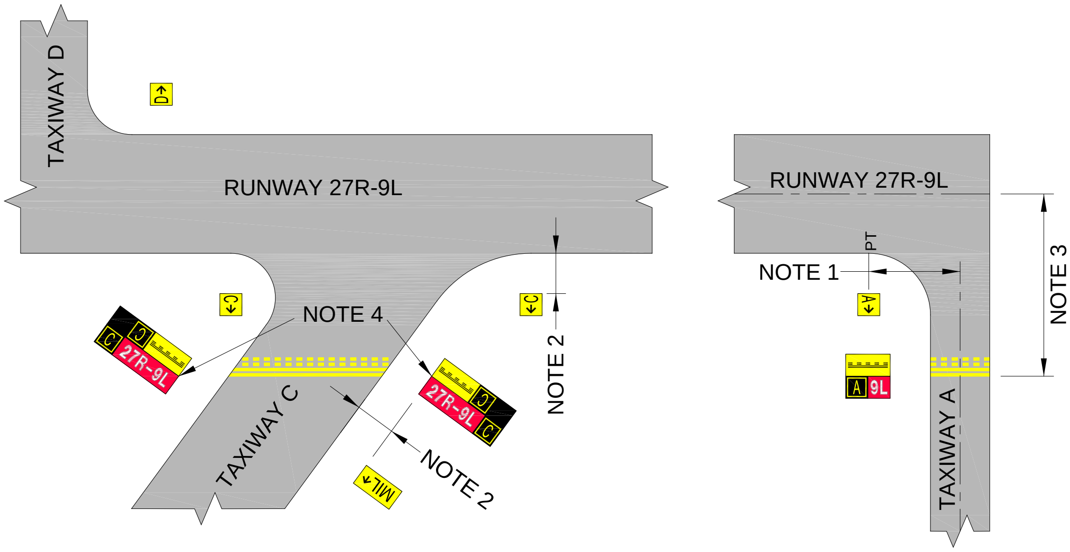
9-5.2.8 Mark outbound routes from their beginning to their termination point with destination signs showing the appropriate runway(s) designation. Outbound routes usually begin at the entrance of a taxiway from an apron area; its termination point is the takeoff end of the appropriate runway. Outbound destination signs may show more than one runway destination number if the direction of travel on a taxiing route is the same to all the runway destinations shown on the sign. In such cases, separate any pair of runway designation numbers by a circular dot.

9-5.2.9 Mark inbound routes from their beginning with destination signs showing the appropriate symbols. Inbound routes usually begin at the entrance to a taxiway from a runway. Mark inbound traffic routes at the beginning with appropriate destination areas on the airfield as required. Typical examples are “APRON,” “FUEL,” “MIL,” and “CARGO” with an arrow indicating the route. This is a general guide and may be varied to meet local conditions, ground traffic, and variations in airport layout.

9-5.3 It is recommended that all mandatory taxiway guidance and information signs, and location signs be of the same size for a runway and associated taxiway complex. FAA Size 3 signs are recommended for facilities that have Category I operational capability, and for other higher volume airfields. An exception can be made at a particular location where a sign must be positioned closer to a runway or taxiway allowed for a Size 3 sign. In this case a smaller sign may be installed within its allowable distance from the surface.

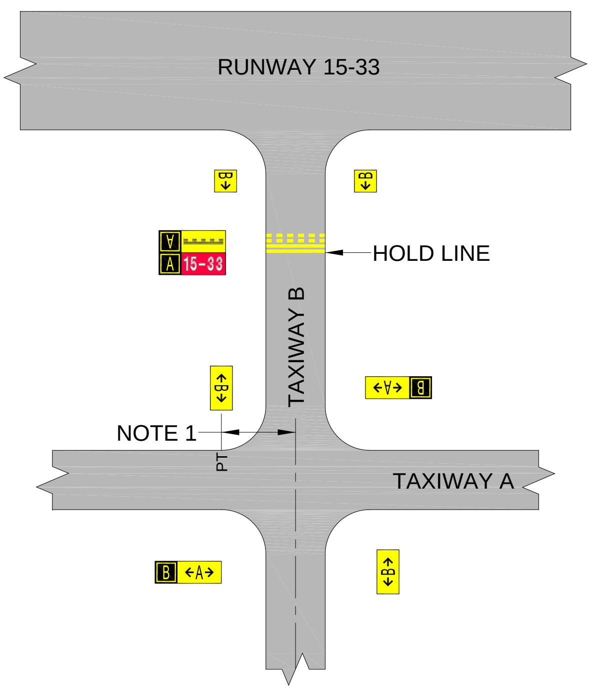
9-5.4 Examples of sign layouts are shown in Figure 9-5 and Figure 9-6. An example for positioning a TACAN checkpoint sign is shown in Figure 9-7.

Figure 9-5 Examples of Signing Conventions



SIGNAGE AT WIDE INTERSECTIONS WITH RUNWAY

TYPICAL SIGNAGE AT END OF RUNWAY



TYPICAL SIGNAGE LAYOUT

NOTES:

1. LOCATE SIGN AT THE RUNWAY/ TAXIWAY PT OR THE DISTANCE FROM TAXIWAY CENTERLINE INDICATED IN TABLE 9-1, WHICHEVER IS GREATER.
2. DISTANCE FROM EDGE OF DEFINED RUNWAY OR TAXIWAY IS 35-60 FT (10.5 - 18 M) FOR FAA SIZE 3 SIGNS.
3. HOLD SIGNS COLLOCATED WITH HOLD MARKING. DISTANCE FROM RUNWAY CENTERLINE IS BASED ON APPROACH CATEGORY AND AIRCRAFT, AND WILL BE DEFINED BY MIL FOR EACH SITE.
4. INSTALL SIGNS ON BOTH SIDES OF DEFINED TAXIWAY WHEN THE WIDTH IS 150 FT (45 M) OR GREATER. SIGN LEGEND ON BOTH SIDES SHALL BE IDENTICAL. THE LOCATION SIGN MUST ALWAYS BE OUTBOARD OF THE MANDATORY SIGN.
5. SEE FAA AC 150/5340-18 FOR MORE INFORMATION ON SIGNAGE CONVENTIONS.

Figure 9-6 Signing Examples

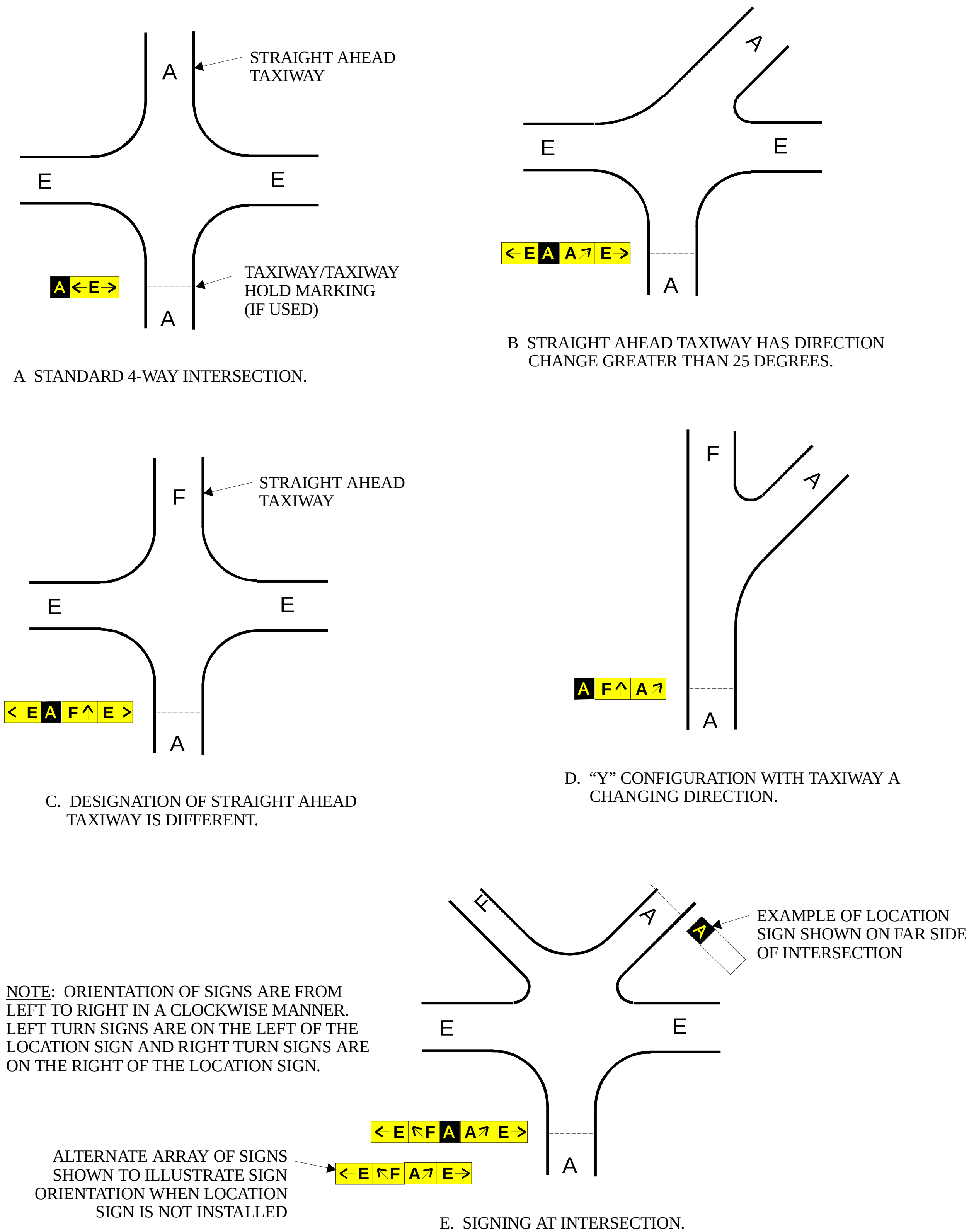
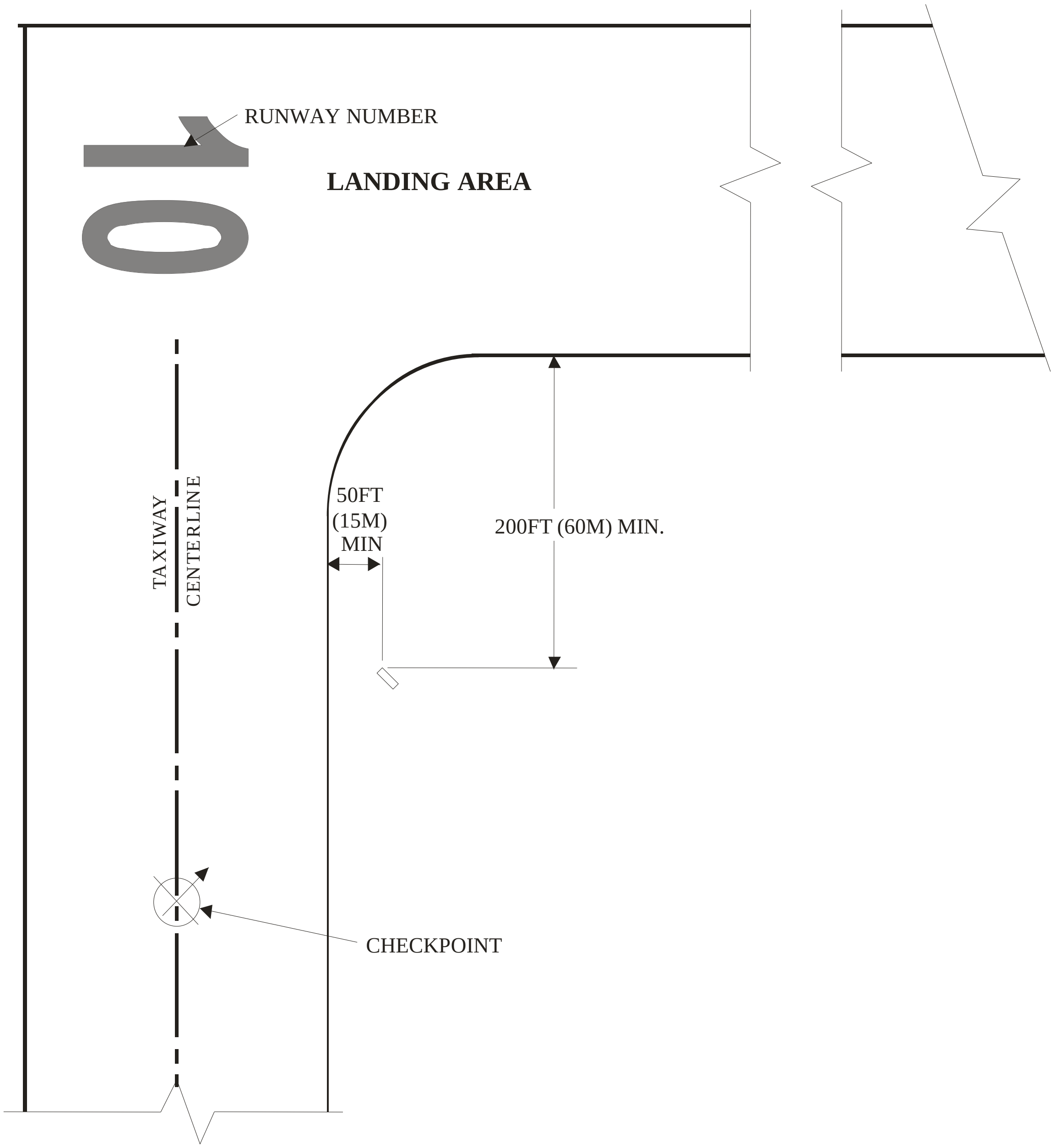


Figure 9-7 TACAN Sign Location



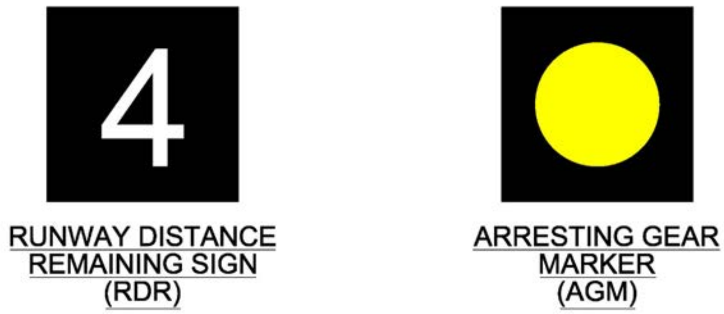
9-6 RUNWAY DISTANCE REMAINING (RDR) SIGNS.

9-6.1 Purpose.

Runway Distance Remaining (RDR) Signs are used to provide distance remaining information to pilots during takeoff and landing operations. The RDR are located along both sides of the runway, and the white numeral on the black background indicates the runway distance remaining in increments of 1,000 feet (metric units are not used). A typical runway distance remaining sign is shown in Figure 9-8.

Figure 9-8 Typical RDR Signs and AGM

Note: These signs represent the bulk of existing signs and comply with previous edition of FAA AC 150/5345-44. These signs do not require replacement until the end of their economic lives or with a major renovation to the airfield. See current edition of FAA AC for new sign message elements.



NOTES:

1. RDM ARE FAA TYPE L-858B, WITH WHITE LEGEND ON BLACK BACKGROUND, MEETING FAA AC 150/5345-44, SIZE 4.
2. AGM HAVE CHARACTERISTICS OF RDM BUT WITH A YELLOW CIRCLE 39" (1M) IN DIA. ON BLACK BACKGROUND, MEETING FAA AC 150/5345-44, SIZE 4.

9-6.2 Installation.

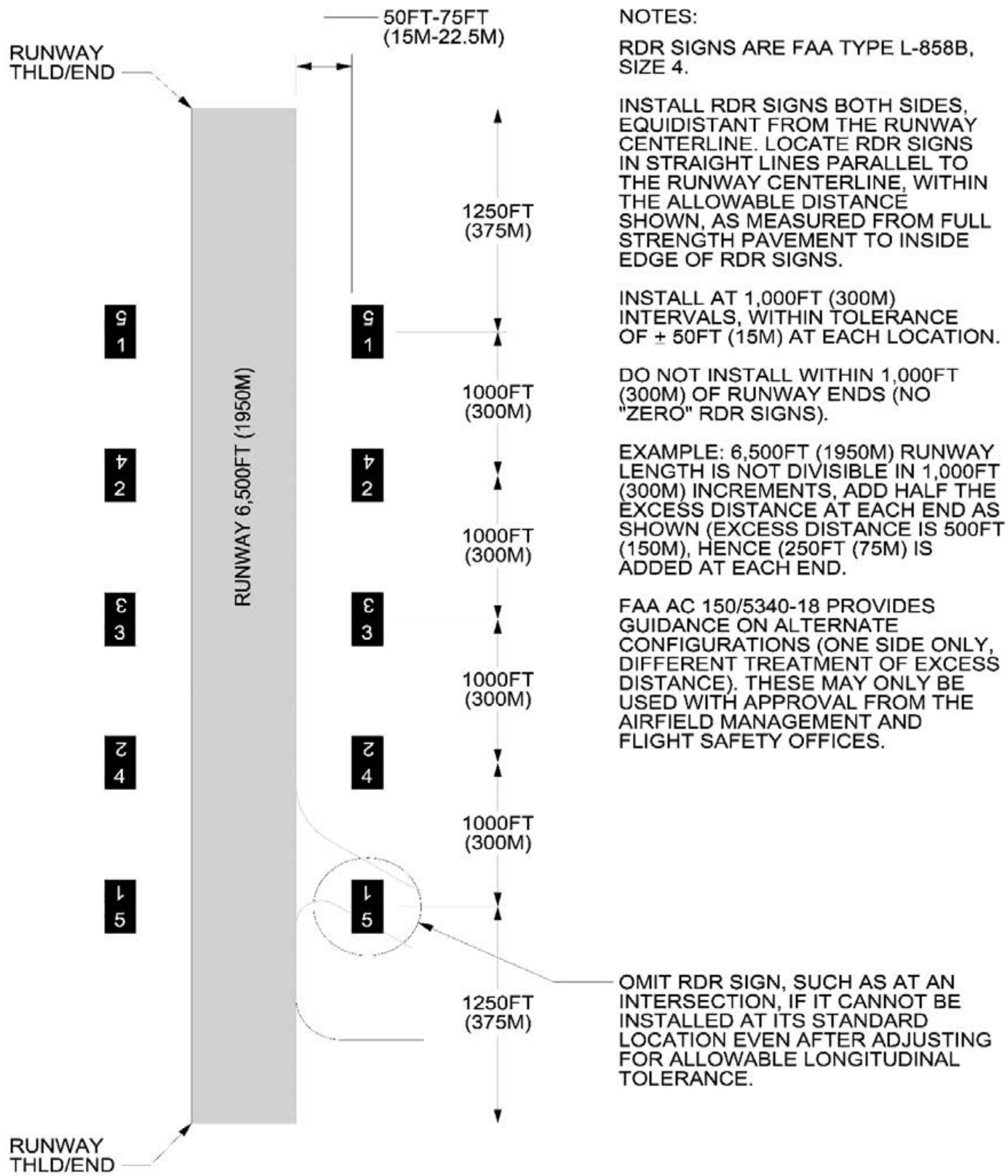
An RDR sign system (previously referred to as a Runway Distance Marker [RDM]) is required for all runways per Table 2-1A and Table 2-1B.

9-6.2.1 The row of markers along each side of the runway is parallel to the runway centerline, and equal distance from the runway edge. FAA Size 4 RDR signs are positioned 50-75 feet (15-22.5 meters) from the runway edge. Use only FAA Size 4 RDRs.

9-6.2.2 RDR signs are spaced at 1,000 foot (300 meter) intervals along the runway, excluding the threshold and runway end. Displaced threshold areas that are used for takeoffs and/or rollout are treated as part of the runway for purposes of locating the markers. Numerals are shown on both faces of the markers so the distance remaining can be seen in either direction of operations.

9-6.2.3 For runway lengths that are not an exact multiple of 1,000 feet (300 meters), one-half the excess distance is added to the distance of each marker for each runway end. For example, for a runway length of 6,500 feet (1,950 meters), the excess distance is 500 feet (150 meters) and the location of the last marker on each runway end is 1,000 feet (300 meters) plus one-half of 500 feet (150 meters), or 1,250 feet (375 meters). A longitudinal tolerance of ±50 feet (±15 meters) is allowed if a marker cannot be installed at its standard location. A marker should be omitted if it cannot be installed within this tolerance. This standard procedure for siting RDR signs is illustrated by Figure 9-9. Alternative methods can be found in FAA AC 150/5340-18, as allowed by the appropriate command.

Figure 9-9 RDR Sign Layout Configuration



9-6.2.4 Runway Distance Remaining (RDR) Signs for military airfields are FAA Size 4, and are located 50-75 feet (15-22.5 meters) from runway edge. The distance indicated is to the inside edge of the sign. Signs are oriented perpendicular to and located equidistant from the runway centerline.

9-6.3 Characteristics.

See Chapter 13, FAA AC 150/5340-18, Chapter 2, and FAA AC 150/5345-44, Appendix 1, for additional characteristic information.

9-6.3.1 Message.

Signs are double face, internally lighted, with retro-reflective message faces that meet the color and reflectivity requirements of ASTM D 4956, Type I Sheeting. The spacing, stroke, and shape of legend characters, numerals, and symbols must be in accordance with FAA AC 150/5345-44, Appendices A-I.

9-6.3.2 Dimensions.

See FAA AC 150/5340-18 for marker and legend height dimensions. The marker should provide at least 12 inches (300 millimeters) clearance between the top of the sign and any part of the most critical aircraft expected to use the runway when the aircraft wheels are at the pavement edge.

9-6.3.3 Electrical.

For new installations, it is required that RDR signs be FAA Style 5 and connected to the 5.5 amp, 1-step RDR circuit. The intent is to have a more reliable sign system by eliminating the electronics required to maintain uniform brightness over the range or a 3 or 5-step regulator.

9-6.3.4 Photometrics.

The average minimum sign luminance for all intensity steps must be white legend, 300 CD/M^2 (88 foot-lamberts). It is recommended that photometric testing be performed on all newly installed RDR signs on site. The purpose of these tests is to verify the installed fixtures meet or exceed the minimum photometric requirements.

9-6.4 Power and Control.

For new installations, RDR signs will be powered from a dedicated 1-step (5.5 ampere) circuit. Control of the circuit will be interlocked with the corresponding runway edge lighting circuit so as to turn on and off with its runway edge lighting.

9-7 ARRESTING GEAR MARKERS.

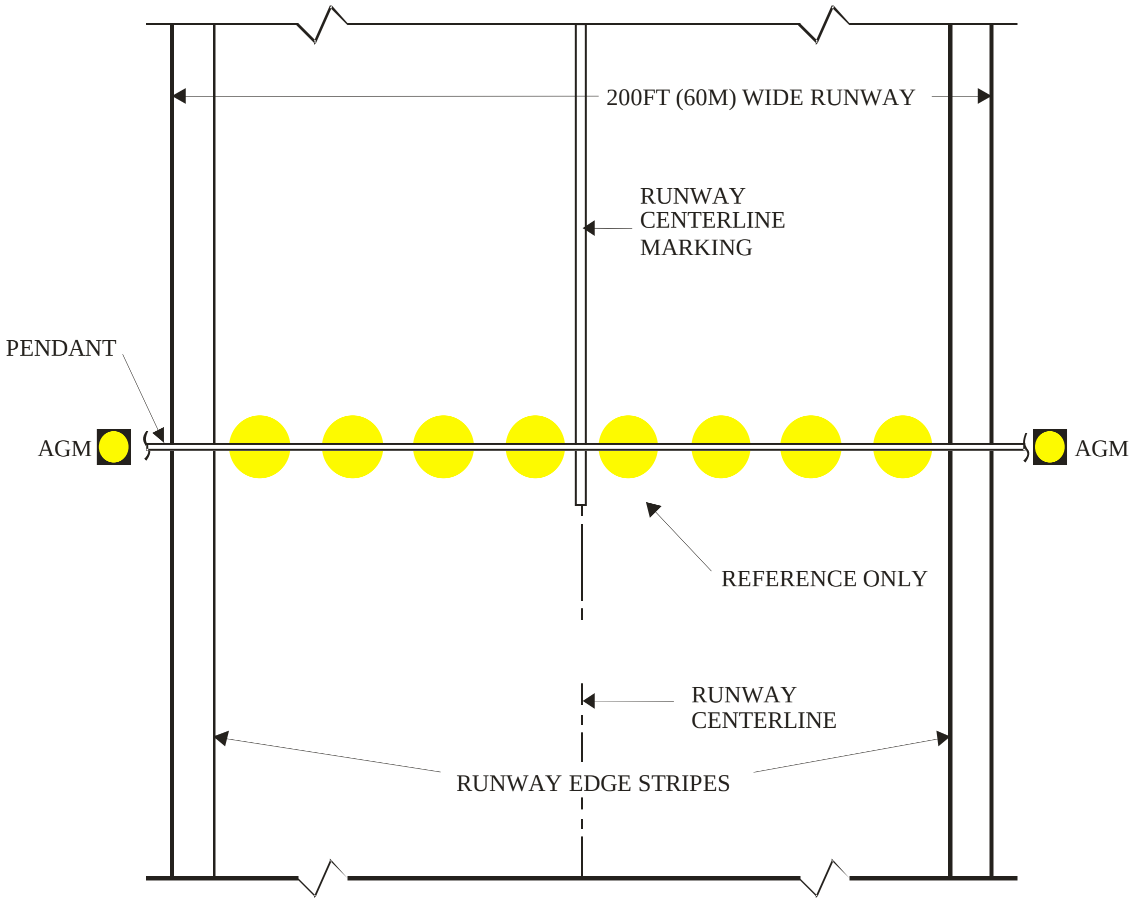
9-7.1 Purpose.

Arresting Gear Markers (AGM) identify arresting gear pendant cables or barriers on the operational runway surface. The AGMs are located adjacent to the location of arresting system cables on the runway. An AGM is shown in Figure 9-8.

9-7.2 Installation.

Arresting pendant cables must be identified by AGM on both sides of the runway. The AGM are located in line with the cable ± 10 feet (3 meters) and equidistant from the runway edge. AGM are similar to Size 4 RDR signs, and are positioned 50-75 feet (15-22.5 meters) from the runway edge. Where RDR signs are installed, locate the AGMs in line with the RDR signs, except where the AGM is within 20 feet (6 meters) of an RDR sign. In this case relocate the RDR sign to be in line with the AGM and 5 feet (1.5 meters) outboard of the AGM. The distance indicated is to the inside edge of the marker. If the arresting gear is in the overrun, signs are not allowed but obstruction lights are required on the structures housing the operating system. See Chapter 6. This is a common requirement for the BAK-15. Markers are oriented perpendicular to the runway centerline. Typical installation of AGM is shown in Figure 9-10.

Figure 9-10 Arresting Gear Marker (AGM) Configuration



NOTES:

1. Install AGM in line with RDR Signs.
2. If an RDR sign is within 20ft (6m) of an AGM, then move the RDR sign even with the AGM and install it 5ft (1.5m) outboard of the AGM.

9-7.3 Characteristics.

See Chapter 13 for additional characteristic information.

9-7.3.1 Message.

Messaging is similar to RDR sign (paragraph 9-6.3.1) except that the white numeral of the RDR sign is replaced with a yellow translucent circle approximately 39 inches (1 meter) in diameter facing both runway directions.

9-7.3.2 Dimensions.

See paragraph 9-6.3.1 for legend dimensions. FAA Size 4 sign has a marker panel height of 48 inches (1,219 millimeters) and overall mounting height of 54-60 inches (1,350–1,500 millimeters). As with RDR, the marker provides at least 12 inches (300 millimeter) clearance between the top of the sign and any part of the most critical aircraft expected to use the runway when the aircraft wheels are at the pavement edge.

9-7.3.3 Electrical.

For new installations, it is required that AGMs be FAA Style 5 and connected to the 5.5 amp, 1-step RDR circuit. The intent is to have a more reliable sign system by eliminating the electronics required to maintain uniform brightness over the range or a 3 or 5-step regulator.

9-7.3.4 Photometrics.

The average minimum sign luminance for all intensity steps must be yellow legend, 44 foot-lamberts (150 CD/M$^{2)}$).

9-7.3.4.1 Photometric Testing.

It is recommended that photometric testing be performed on all newly installed AGMs on site. The purpose of these tests is to verify the installed fixtures meet or exceed the minimum photometric requirements.

9-7.4 Power and Control.

See paragraph 9-6.4. Power the AGM to operate in unison with the runway edge lights. If the runway is used by Remotely Piloted Aircraft (RPA) or Unmanned Aerial Vehicles (UAVs), the Wing Commander may take written responsibility for powering them separately, for the safety of the RPAs or UAVs or a permanent waiver may be processed.

9-8 OTHER SIGNS.

9-8.1 Purpose.

Other signs not listed above may be installed on the airfield to serve special needs. This may include signs that apply only to vehicle traffic and special purpose signs that are not included in current standards but that may meet specific needs.

9-8.2 Installation.

Signs other than those listed in previous paragraphs must not conflict with current sign standards, and must not present confusing situations for ground traffic with respect to the sign's function and the standard signing on the airfield.

9-8.2.1 Signs intended for vehicles only, such as on vehicle service roads or lanes, typically follow the MUTCD. For example, standard highway stop signs may be installed on vehicle roadways at the intersection of each roadway with a runway or taxiway. A yield sign may be used in place of a stop sign at intersections with taxiways. See FAA AC 150/5340-18 for additional information and requirements for vehicle roadway signs. Such signs should not be placed closer than a runway holding position for the same runway. Appropriate safe offset distances from Table 9-1 must also be used where roadways cross taxiways.

9-8.2.2 Special purpose signs other than those listed above should be approved by the appropriate military authority based on a specific need at an airfield. Also, special circumstances may dictate that a standard sign is unsuitable for a particular location sign. Placement of non-standard signs should be as needed, but should not violate the requirements for standard signing listed above in terms of proximity to runways and taxiways. To the extent allowable and as appropriate for the application, non-standard signs should follow the guidelines contained in FAA AC 150/5340-18 and FAA AC 150/5345-44.

9-8.2.3 In some cases standard signs may be painted on a pavement surface to enhance messaging. Painted signs on pavements should conform to UFC 3-260-04.

9-8.3 Characteristics.

Vehicle signs should follow the requirements of the MUTCD. These are normally unlit signs, although in some cases external lighting may be useful. Other special purpose signs will be as required by the need, but must not conflict with or cause confusion with standard airfield signing.

9-9 COMPLIANCE WITH INTERNATIONAL STANDARDS.

9-9.1 AFIC.

Previous AFIC AIR STD 90/27 cancelled.

9-9.2 NATO.

This standard meets the requirements of **\4** AATMP-07 Edition A, ***/4/*** *Airfield Lighting*, for taxiway signs, except for minimum size of signs and the location of some signs at intersections.

9-9.3 Additional Information.

See FAA AC 150/5340-18, FAA AC 150/5345-44, and ICAO Annex 14 for more information.

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CHAPTER 10 STANDARDS FOR MISCELLANEOUS VISUAL AIDS

10-1 AIRPORT BEACONS.

10-1.1 Purpose.

Airport beacons are high-intensity flashing lights which provide a visual signal to pilots to assist in locating and identifying the airfield or a hazardous obstruction at night, or in restricted visibility conditions. These beacons may be rotating or fixed, but must provide the signal through 360 degrees of azimuth. These requirements are to be used for new installations of airport beacons. Existing installations may continue to be used and maintained until the first airfield lighting upgrade project. The absence of a formerly FAA-approved or Mil-Spec NAVAID, or other piece of equipment from the current AC 150/5345-53, Appendix 3 Addendum is not an indication that this equipment is no longer approved for use. Absence from the AC means that particular NAVAID or piece of equipment is no longer manufactured. Beacons fitting this situation, such as the Model DCB-224M military beacon, is still supported for repairs by a sub-party of the former manufacturer and is typically more reliable and powerful than currently marketed beacons. Contact AFCEC/COSM for support information, if repairs to older beacons are required.

10-1.2 Beacon Types.

10-1.2.1 Airfield Rotating Beacon.

Each lighted airfield, except where one rotating beacon serves more than one airfield in close proximity, must use a high-intensity military type beacon (FAA Type L-802M). This beacon must have a double-peaked white beam to denote a military airfield and a single-peaked green beam to indicate that the airfield has lighted facilities for operations at night or in restricted visibility. The two beams must be directed 180 degrees apart. The signal from the beacon must be visible through 360 degrees of azimuth by rotating at six revolutions per minute (RPM). The airfield rotating beacon must be operated during twilight and night hours and during daytime when Instrument Flight Rules (IFR) are in effect. Alternating white and green flashes identify a lighted civil airport, and white flashes identify an unlighted civil airport.

10-1.2.2 Identification or Code Beacon.

For Air Force only, the identification beacon is used only at airfields where the airfield rotating beacon is located more than 6,000 feet (1,800 meters) from the nearest runway or where the airfield rotating beacon serves more than one airfield. The identification beacon is a non-rotating flashing omnidirectional light visible through 360 degrees. This beacon flashes a green coded signal at approximately 40 flashes per minute. The signal is an assigned code of characters to identify the particular airfield. The identification beacon must be operated whenever the associated airfield rotating beacon is operated.

10-1.3 Location Requirements.

See FAA AC 150/5340-30 for information about the location of beacon towers that are less than 200 feet (60 meters) above ground level (AGL). See the same AC for information about the construction of tubular or structural steel towers. For tower construction specific information see FAA AC 150/5370-10, Item L103, Airport Beacon Towers.

10-1.3.1 Visible through 360 degrees of azimuth if possible.

10-1.3.2 Not less than 1,000 feet (300 meters) from the centerline or centerline extended of the nearest runway.

10-1.3.3 Not in the line of sight from the control tower to the approach zone of any runway or to within 75 feet (22.5 meters) vertically over any runway.

10-1.3.4 Located 750 feet (225 meters) or more from the control tower. This is intended to prevent light reflection during foggy conditions which reduce visibility and interfere with light gun signals from the control tower cab.

10-1.3.5 Not more than 6,000 feet (1,800 meters) from the nearest point of usable landing area, except if surrounding terrain will restrict visibility of the beacon through an appreciable angle in some directions or the beacon will serve more than one airfield. If terrain restricts viewing the beacon or the beacon will serve more than one airfield, the distance of the beacon from the nearest runway may be increased to not more than two miles.

10-1.3.6 The base of the beacon must be not less than 20 feet (6 meters) higher than the elevation of the floor of the control tower cab. If the airfield rotating beacon is located more than 6,000 feet (1,800 meters) from the nearest point of usable landing area, an identification beacon must be installed and not more than 6,000 feet (1,800 meters) from the nearest point of usable landing area.

10-1.4 Photometric Requirements.

See FAA AC 150/5345-12 for detailed photometric beacon requirements.

10-1.4.1 Colors.

The color of the emitted light must be standard aviation colors per FAA AC 150/5345-12.

10-1.4.2 Airfield Rotating Beacon.

See FAA AC 150/5345-12 for airfield rotating beacon intensity values and methods of measurement.

10-1.4.3 Identification Beacon.

With the beacon operating steadily (not flashing) at rated voltage, the intensity of the green light must be not less than 1,500 candelas for a distribution through 360 degrees horizontally and 2 degrees vertically. The areas of the beam where the support rods are located may be less than these required intensities.

10-1.5 Aiming.

The vertical aiming of the beacons should be properly focused and aimed when manufactured, and leveling should be all that is required for aiming during installation. The axes of the beams vertically should be approximately five degrees above the horizontal for the rotating beacon. For the identification beacon, the center of the beam must be approximately 3 degrees above horizontal.

10-1.6 Equipment.

The airfield rotating beacon and the identification beacon equipment must be as shown in paragraph 13-12. The identification beacon must be provided with a keyer to flash the assigned identification code. The identification beacon is for Air Force only.

10-1.7 Power Requirements.

See FAA AC 150/5340-30 for additional information about the airport beacon power requirements. See also FAA AC 150/5370-10, Item L-103, Airport Beacon Towers, for construction, wiring, and contract requirements. The electrical power requirement for the beacons is 120 volts. The source of power may be from the airfield lighting vault or from a local source that is continuously available. If the distance from the power source is long and the line voltage drop is large, transmission of power at a higher voltage and step-down to 120 volts at the site may be desirable. Base the KVA rating of the step-up and step-down transformers on the total KVA load of the equipment. Emergency power is not required for the airport beacons, but should be used if it is available.

10-1.8 Control Requirements.

See FAA AC 150/5345-12 for airport/airbase beacon control requirements and description. The controls for the airport beacons are only those required to energize and switch off the beacon and its drive motor or keyer. Preferably, these beacons should be controlled remotely from the lighting control panel in the control tower or the airfield lighting vault. Control may be furnished by an automatic photoelectric switch or a clock-driven timer.

10-1.9 Monitoring Requirements.

There is no requirement for monitoring.

10-1.10 Compliance with International Military Standards.

There are no International Military Standards for airport beacons.

10-2 WIND DIRECTION INDICATORS (CONES).

10-2.1 Purpose.

Wind cones are installed near landing surfaces to provide a clear indication of the direction of the surface wind and a general indication of wind speed. Wind cones are lighted for night operation.

\4

10-2.2 Siting Requirements.

10-2.2.1 Fixed Wing. Locate wind cones not less than 400 feet (120 meters) from the runway centerline and in a location free from the effects of air disturbances caused by nearby objects. If a wind cone is more than 27 feet (8.1 meters) above ground elevation a waiver to UFC 3-260-01 is required.

10-2.2.2 Rotary Wing. See B13-2.19.1 Wind cone mountings are of two types. Type L-806 is mounted on a low-mass supporting structure (frangible); Type L-807 is mounted on a rigid supporting structure (non-frangible). Either type must be located not less than 91.4 meters/300 feet (Class A/Rotary-Wing Runways/Helipads) or 121.9 meters/400 feet (Class B) from the centerline of the runway to the centerline of the wind cone and in a location free from the effects of air disturbances caused by nearby objects. If a waiver is approved to be sited within 300 feet (Class A/Rotary-Wing Runway/Helipads) or 400 ft (Class B) of a runway centerline, only the L-806 (frangible) wing cone will be used. A height of more than 8.23 meters (27 feet) above ground elevation (not including the obstruction light) requires a waiver. **/4/**

10-2.3 Wind Cone Configuration.

10-2.3.1 The wind cones must be in the form of a truncated cone made of fabric. They must have a length of not less than 8 feet (2.4 meters) and a diameter at the larger end of not less than 18 inches (450 millimeters). They must be constructed so it gives a clear indication of the direction of the surface wind and a general indication of the wind speed. Wind cones must extend fully in a fifteen knot wind.

10-2.3.2 The color(s) must be selected with consideration given to the background and to make the indicator clearly visible and understandable from a height of at least 1,000 feet (300 meters). Where practicable, use a single color, preferably white or orange. When a combination of two colors is required to provide conspicuity, the preferred colors are orange and white, red and white, or black and white. The colors must be arranged in 5 alternate bands, the first and last band being the darker.

10-2.3.3 There are two types of wind cone mounting structures: FAA Type L-806 (frangible) and FAA Type L-807 (rigid). Type L-806 is used for supplemental wind cones located near the ends of runways. Type L-807 is used for the primary wind cone. Refer to FAA AC 150/5340-30, for additional information about wind cone installation.

10-2.4 Lighting Requirements.

Illuminate the wind cone with floodlights which are arranged to provide a minimum illumination level of 2 footcandles (20 lux) at any point on the horizontal plane described by a complete rotation of the upper surface of a fully extended cone. The lights must be shielded to prevent light emission above the horizontal. Equip the wind cone support with an obstruction light.

10-2.5 Power Requirements.

Provide a main power source only. If powered from the associated runway edge lights, they will have the provision so the cone floodlight brightness does not vary more than 20 percent with the available light, meeting the requirements of paragraph 10-2.4, at the lowest setting of the runway edge lights. Refer to paragraph 13-6.2 for additional information about runway edge light circuit power.

10-2.6 Control Requirements.

On and off control is the only requirement and may be accomplished via the runway edge light circuit if used.

10-2.7 Monitoring Requirements.

There are no requirements for monitoring wind cones.

10-2.8 Equipment.

The wind indicators must be as shown in paragraph 13-12.3 **\4** (reference UFC 3-535-01, 11 April 2017) **/4/**.

10-2.9 Compliance with International Standards.

There are no AFIC AIR STDs or NATO STANAGs for wind indicators.

10-2.10 Additional Information.

See FAA AC 150/5345-27 and FAA AC 150/5340-30 for additional information.

10-3 RUNWAY AND TAXIWAY RETRO-REFLECTIVE MARKERS.

10-3.1 Purpose.

Reflectors and retro-reflective markers may be used to supplement existing runway and taxiway lighting, or for temporary installations. However, a waiver must be granted by the major command for their use.

10-3.2 Characteristics.

The retro-reflective materials used are designed to reflect light approaching at an oblique angle, back toward the light source.

10-3.3 Equipment.

For additional guidance on the types and styles of the markers refer to FAA AC 150/5345-39 and FAA AC 150/5340-30.

10-4 FLOOD, SECURITY, OR AUXILIARY LIGHTING.

10-4.1 Special Lighting Arrangements.

Special arrangements of lights, such as apron or parking are floodlights and protective and security lighting, may be required at an installation. These lights will not be connected to the airfield lighting circuits. Hangar access aprons (hangar entrances) may be lighted by floodlights installed around the apron or mounted on the hangar. Floodlights provided for these areas are considered as part of the hangar construction.

10-4.2 Floodlights.

10-4.2.1 Purpose.

Hangar areas are typically lighted to 1 foot candle. The functions of the apron floodlights are:

- Assist the pilot in taxiing the aircraft into and out of the final parking position.
- Provide lighting suitable for passengers to embark and debark; for personnel to load and unload cargo and refuel; and to perform other apron service functions.
- Maintain airfield security.
- See UFC 3-530-01 for apron flood lighting requirements.

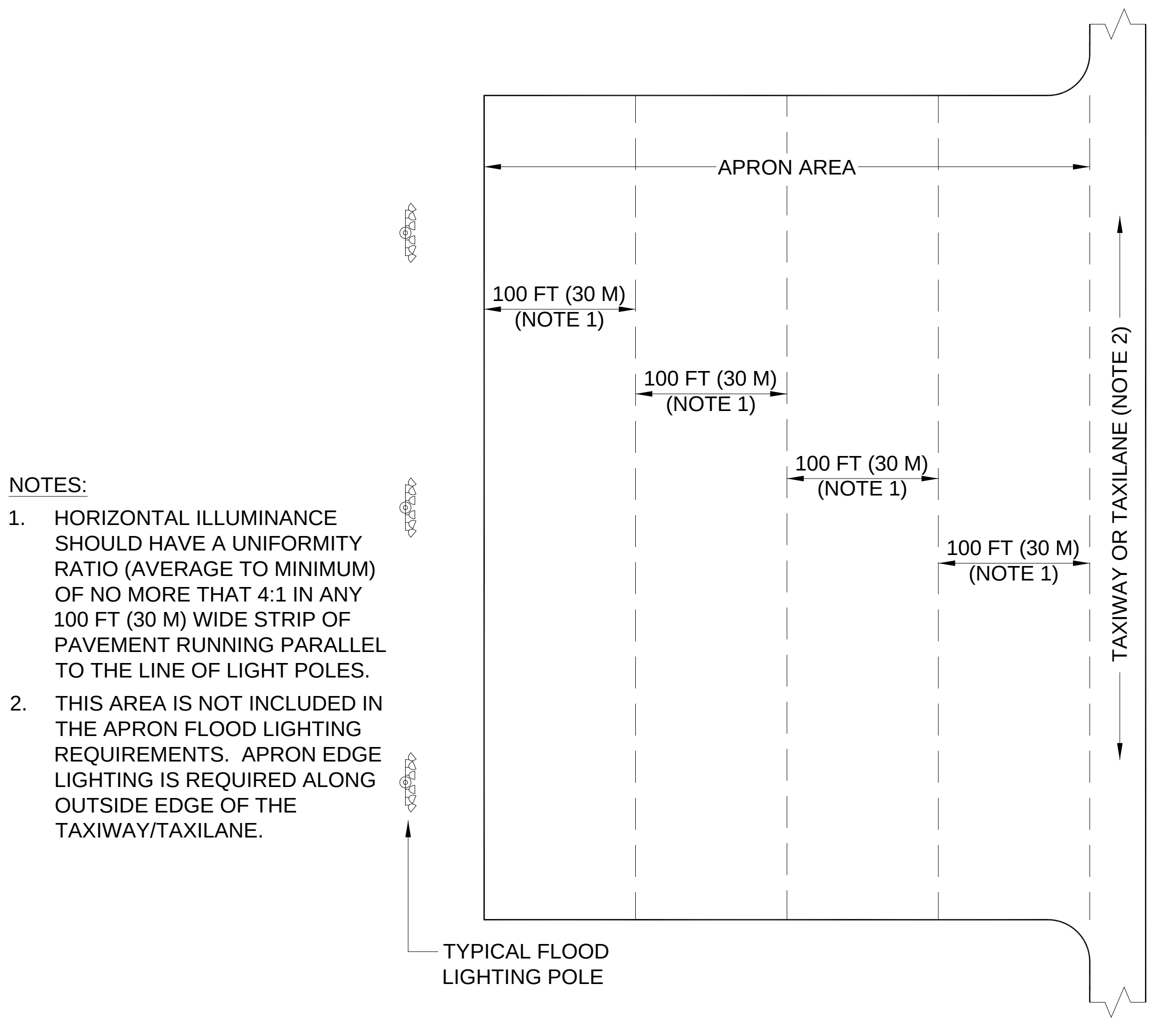
10-4.2.2 Fixed Floodlights Glare Control.

Direct lamp light from the floodlights will be avoided in the direction of a control tower cab and landing and departing aircraft. Aiming of the floodlights should be, as far as practicable, in the directions away from a control tower cab and landing and departing aircraft. Direct light above the horizontal plane through a floodlight must be avoided. To minimize direct and indirect glare, the mounting height of the floodlights should be at least two times the maximum aircraft eye height of pilots of aircraft regularly using the airfield. Also, the location and height of the masts should be such that inconvenience to ground personnel due to glare is kept to a minimum. To meet these requirements, the floodlight light distribution may have to be restricted by use of glare shields. The maximum obtrusive light from all flood lights for the apron project must be no more than 1 lux (0.093 fc). If control tower personnel experience objectionable glare after flood lights are installed, re-aim lights until glare is eliminated.

10-4.2.3 Fixed Floodlights Design Considerations.

Floodlight masts must meet relevant obstacle clearance requirements. Locate and aim the floodlights to minimize shadows. Horizontal illuminance should have a uniformity ratio (average to minimum) of no more that 4:1 in any 100-foot (30 meter)- wide strip of pavement running parallel to the line of light poles. See Figure 10-1. See UFC 3-530-01 for specific illumination values, fixtures specifications, lamp specifications, description of a typical flood lighting pole/mast, and other design requirements other than obstacle clearance.

Figure 10-1 Apron Area Flood Lighting Uniformity Criteria



10-4.3 Lighting Intensities.

The various areas of the airfield, heliport, or helipad requiring normal and/or protective floodlighting will be lighted to meet the following minimum intensities in horizontal footcandles, in the horizontal plane at the pavement surface.

10-4.3.1 Apron Area Floodlighting.

Security Area (1)	0.50
Parking Area	0.50
Loading Area (including hydrant fuel area)	2.00
Other Apron Areas	1.00
Maintenance	2.00

Notes:

(1) Flood lighting for Army Security is required by AFR 190-51 if the installations security authority determines that the apron area is a risk level 3 asset.

(2) Taxiways and taxi lanes on or through aprons do not require flood lighting where apron edge lights are provided.

(3) It is assumed that supplemental lighting for maintenance is provided by portable light plant(s).

10-4.3.2 Protective and Security Lighting.

Boundary	0.20
Entrances	
Active, pedestrian and/or conveyance	5.00
Inactive, normally locked, infrequently used	1.00
Building surroundings	1.00

10-4.4 Additional Guidance.

Additional information on auxiliary lighting can be found in joint services technical manuals:

- Army/Navy/Air Force TM 5-684/NAVFAC MO 200/AFJMAN 32-1082
- UFC 3-260-01 and **\4** UFC 3-550-01 ***/4/***

CHAPTER 11A PORTABLE EMERGENCY LIGHTING

11A-1 GENERAL REQUIREMENTS.

In times of emergency, when standard airfield lighting is not available and aircraft operations must be performed at night, it may be necessary to use portable lighting devices to support operations. The lighting design standards in this section may be suitable for use in VFR night operations but do not qualify the airfield for instrument operations of any kind, except in the case of this UFC's Table 2-3 and Electrical Technical Paper (TP) 22. The standards in this section do not apply to requirements for portable lighting in a Theater of Operations (TO), forward tactical airfields or landing zones; see Table 2-3, Electrical TP 22, and AFI 13-217 for guidance. (Note: Landing zones are addressed in ETL 09-6; access is restricted: "For Official Use Only.") Care should be taken when installing portable lights to ensure that they are secured in a manner that will prevent movement as a result of jet blast or other forces. When application of the criteria in this section would result in a light location in an active paved area, the light must be omitted or relocated. Information on the Army's Airfield Lighting System (ALS), a TO portable ALS, is available from the Army's materiel developer, Program Manager – Air Traffic Control (PM-ATC), at Redstone Arsenal, AL: Tel (256) 955-9008 or (256) 842-4954.

11A-2 RUNWAY LIGHTING.

11A-2.1 Runway Edge Lighting.

Portable edge light configurations generally follow the standard configuration except that the spacing may be a maximum of 300 feet (90 meters) and the offset may be a maximum of 10 feet (3 meters) from the runway edge. The runway edge lights must be white.

11A-2.2 Runway End and Threshold Lighting.

The number of lights required for runway end and threshold lights is reduced to 10. At each end of the runway they must be placed in two groups of 5 with the outermost lights in each group in line with the line of the runway lights spaced at 10 feet (3 meters) intervals toward the center. The line of threshold and runway end lights may be offset no more than 5 feet (1.5 meters) from the end of the runway. The lights must be red toward the runway and green toward the approach.

11A-3 TAXIWAY EDGE LIGHTING.

The techniques for designing an emergency taxiway edge lighting system are generally the same as for a standard system except that the spacing is increased as follows:

11A-3.1 Straight Sections.

The spacing must not exceed 220 feet (66 meters).

11A-3.2 Curved Sections.

The spacing must not exceed 100 feet (30 meters).

11A-4 HELIPAD LIGHTING.

Emergency helipad lighting must follow the standard configurations for perimeter, landing direction, and approach direction lighting except the adherence to light plane criteria is not required.

11A-5 FIXTURES.

Fixtures may be omnidirectional, bidirectional or unidirectional. Where unidirectional fixtures are employed, they must be aimed in the direction of the planned operation. If the operational direction changes they must be installed for the new direction. Unidirectional fixtures generally have better light output for the energy being consumed than the other types. Omnidirectional fixtures meeting MIL-L-19661 Type I may be used with filters as appropriate for the application. Unidirectional and bidirectional fixtures meeting FAA AC 150/5345-50 may also be used. Other portable fixtures that are suitable for outdoor use, meet the duty cycle requirements and meet or exceed the light output of the specified fixtures may be considered.

11A-6 CONTROLS.

The specified lights have individual on/off controls and are not capable of control from a central point. They may have been provided with a flashing mode which must not be used during periods when aircraft operations are being conducted.

11A-7 COMPLIANCE WITH INTERNATIONAL MILITARY STANDARDS.

11A-7.1 AFIC.

Previous AFIC AIR STD 90/20 cancelled.

11A-7.2 NATO.

These standards comply with NATO STANAG 3534 (Edition 7) – Airfield Lighting, Marking and Tone Down Systems for Non-Permanent / Deployed Operations, 6 June 2013.

CHAPTER 11B INTERIM EXPEDITIONARY AIRFIELD LIGHTING SYSTEM (EALS-C – AIR FORCE ONLY)

11B-1 GENERAL REQUIREMENTS.

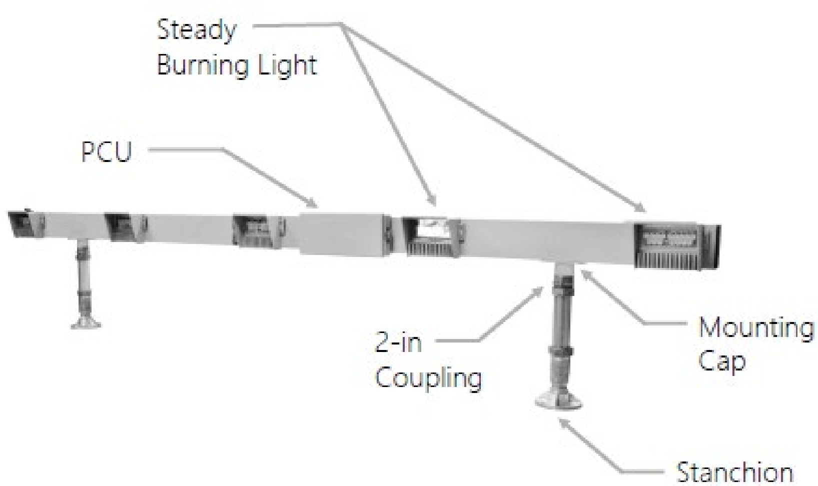
The new EALS (Expeditionary Airfield Lighting System) is the Air Force's the first-ever deployable LED-lighting system that provides significant lighting improvements over the older, legacy EALS. Additionally, the light fixtures contain solar panels and internal batteries that permit operation with or without external power or generators. This not only saves fuel, but also reduces EALS installation times, an important task Civil Engineers are responsible for during airfield damage repair and recovery after attacks. Any references to NGEALS and EALS-B in past guidance are irrelevant. The official name is EALS-C.

11B-1.1 Stand-alone Steady Burning Light.

- Self-contained solar stand alone
- VIS/IR
- 30 per system (15 per MALSR, 7 per SSEALS)
- 5 intensity levels
- 10,000 Cd

11B-1.2 Folding Steady Burning Light.

- Foldable 1- ft. Aluminum
- 5 Steady Burning Lights
- 5 Barrettes per MALSR
- Produces 10,000 Cd
- 5 intensity levels
- PCU side mounted



11B-1.3 Sequenced Flashing Lights.

- Flash in a strobing pattern called “running rabbit”
- Comprised of three subsystems
    - Chassis contains batteries, charging, and PLC

  - o Light head
  - o External solar panel
- Labeled 1 through 5 (with label1 flashing first)5 Steady Burning Lights
- SFL #1 positioned farthest from the runway

Figure 11B-1 Sequenced Flashing Light Fixture

Figure 11B-2a Configuration 1: MALSR Layout

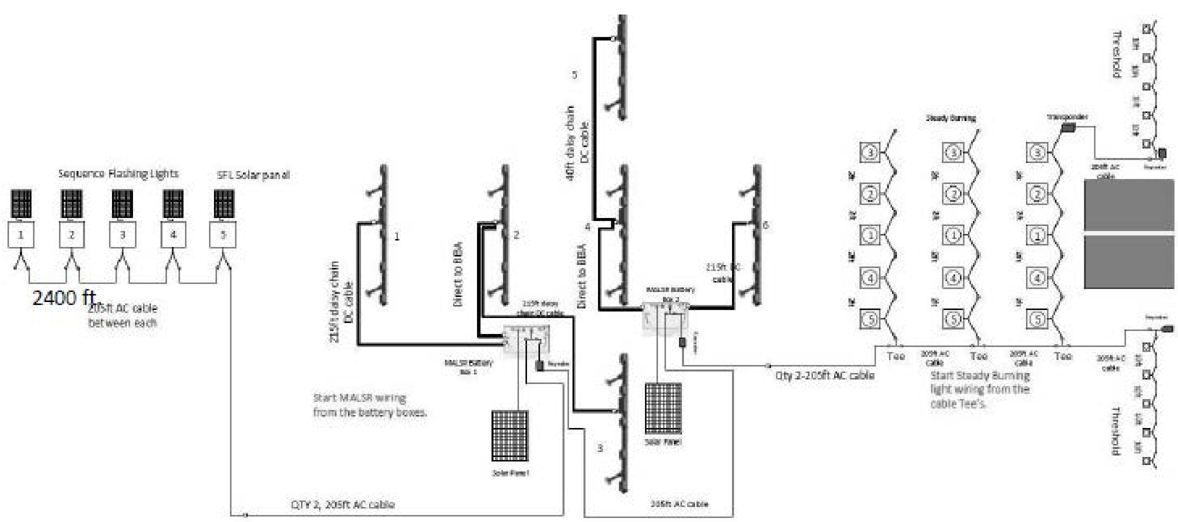


Figure 11B-2b Configuration 1: MALSR Components

Figure 11B-3a Configuration 2: SSEALS Layout

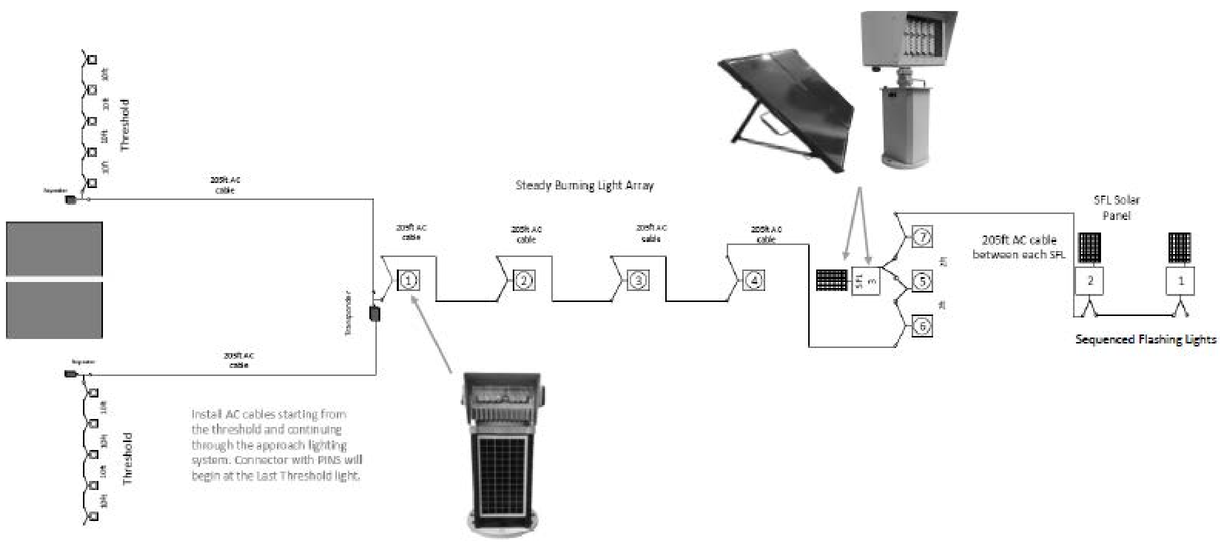


Figure 11B-3a Configuration 2: SSEALS Components

Figure 11B-4 Approach Lighting Layouts

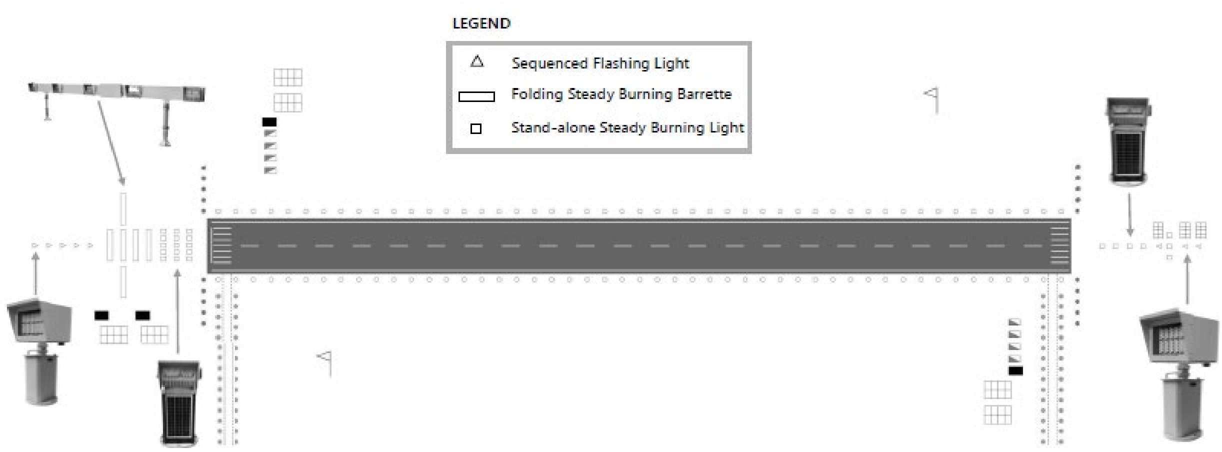


Figure 11B-4a Approach 1: Installation: MALSR

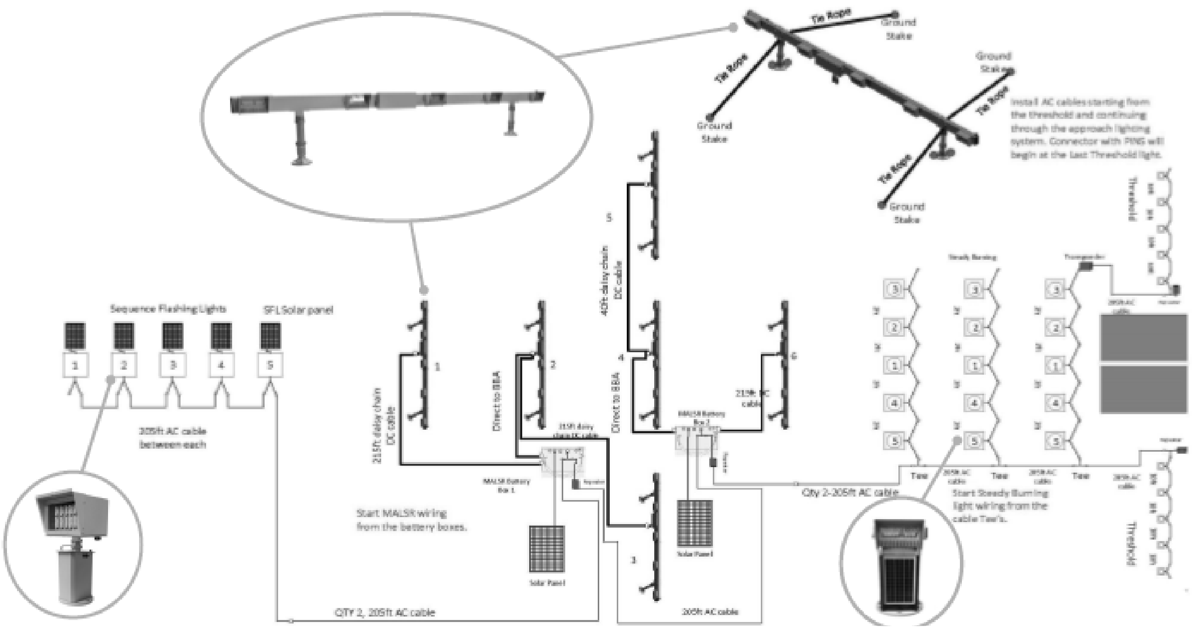


Figure 11B-4b Approach 1: Stand-alone Steady Burning Light (MALSR)

- Central light on extended runway centerline
- 15 lights make up 3 barrettes of 5 lights each
- Barrettes installed at stations 1,2,3 of MALSR

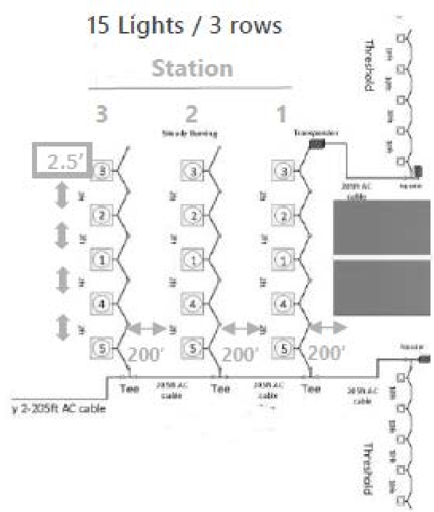


Figure 11B-4c Approach 1: Folding Steady Burning Barrettes (MALSR)

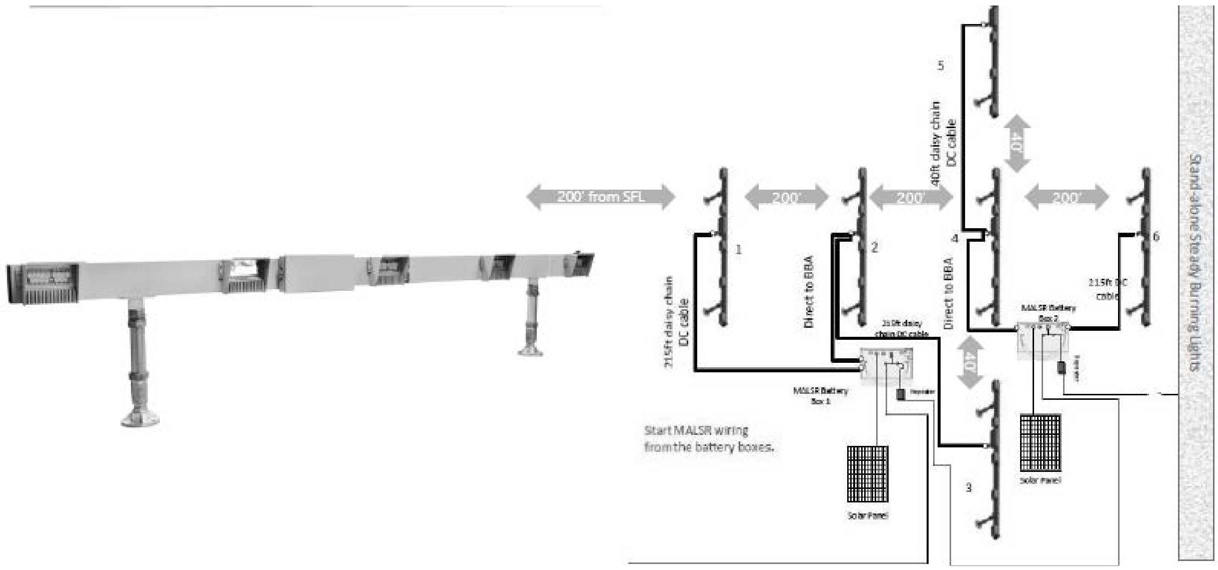


Figure 11B-4d Approach 1: Sequenced Flashing Light (1 of 2) (MALSR)

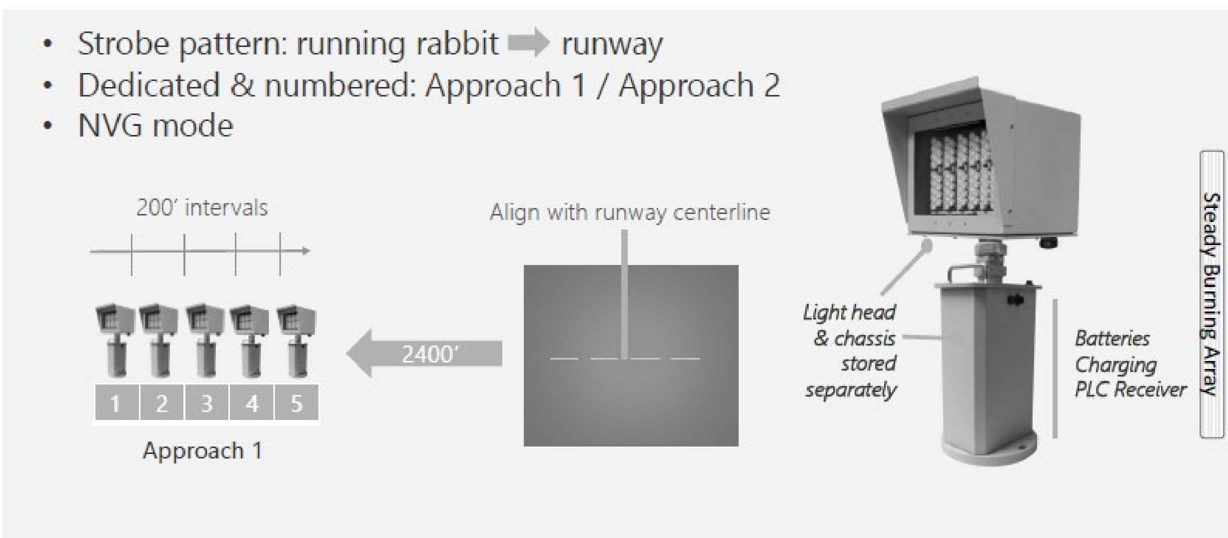


Figure 11B-4d Approach 1: Sequenced Flashing Light (2 of 2) (MALSR)

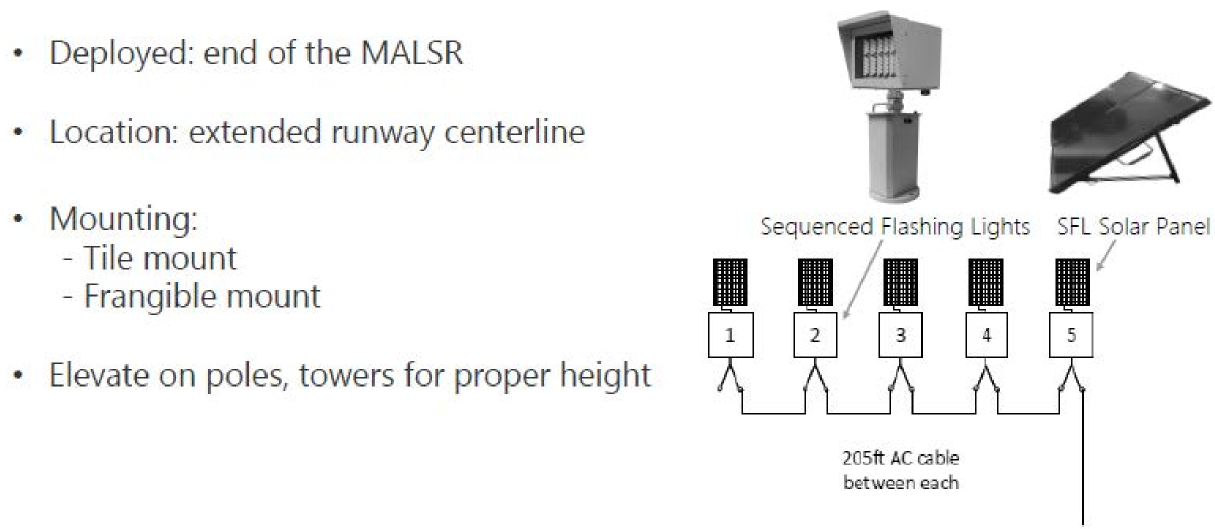


Figure 11B-5a Approach 2: Installation: SSEALS

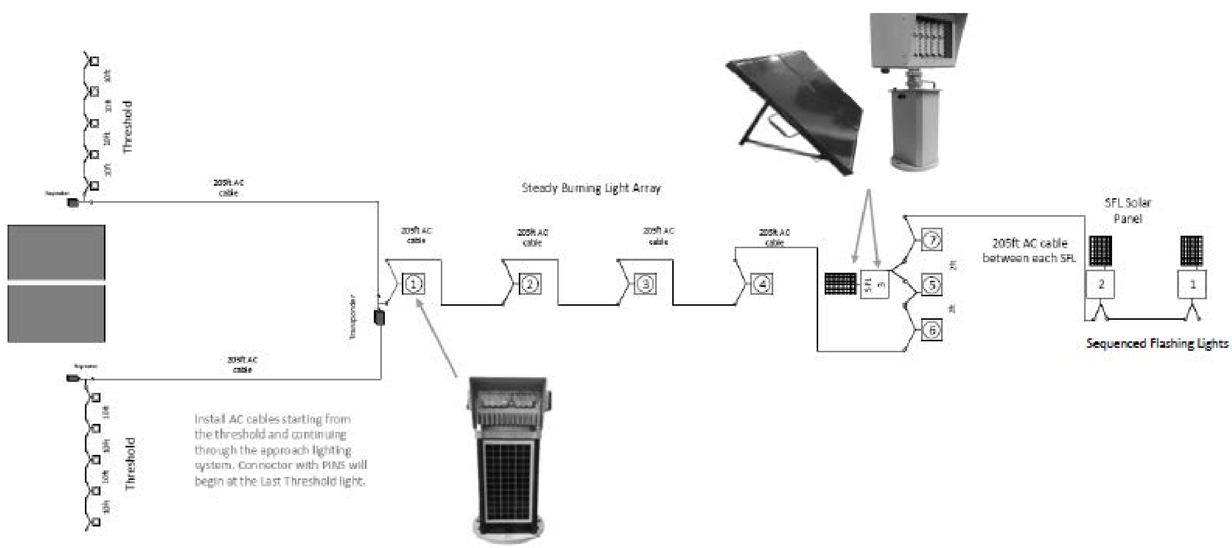


Figure 11B-5b Approach 2: Sequenced Flashing Light (SSEALS)

- Deployed at the end of the Stand-alone Steady-burning Light
- Location: Extended runway centerline
- Mounting:
  - Tile mount
  - Frangible mount
- Elevate on poles/towers for proper height

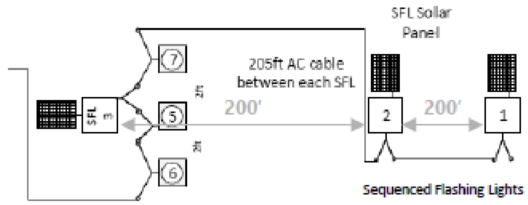
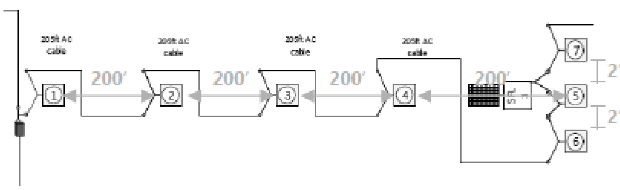


Figure 11B-5c Approach 2: Steady Burning Light (SSEALS)

- Deployed at the end of runway
- Location: extended runway centerline
- Mounting:
  - Tile
  - Frangible
- Elevate on poles/towers for proper height



CHAPTER 11C SOLAR LIGHTING FOR NAVIGATIONAL AIDS (AIR FORCE ONLY)

11C-1 Solar-powered fixtures are approved for use in expeditionary locations, ranges, and areas used only for training for the following applications.

11C-2 Runway/taxiway fixtures shall conform to the minimum intensity requirements in FAA AC 150/5345-50, *Specification for Portable Runway and Taxiway Lights*, Table 1, "Photometric Requirements." Solar-powered runway RDR shall meet the minimum luminance requirement of 10 to 30 foot Lamberts (fL).

11C-3 Solar-powered, steady-burning, non-LED (light-emitting diode), red obstruction lights shall conform to the photometric requirements for L-810 light units in FAA AC 150/5345-43, *Specification for Obstruction Lighting Equipment*.

11C-4 Additionally, solar fixtures are approved for continental United States (CONUS) installations for non-LED obstruction lights where 120-volt power is inaccessible or cost prohibitive; and for temporary uses to facilitate repair of sub-systems, when required by UFC 3-535-01 to be operational, with a waiver.

11C-5 Fixtures shall have an integrated solar panel, with the exception of the obstruction light. Fixtures with integral batteries (inaccessible batteries that necessitate replacing the entire fixture rather than only the batteries) are not approved for use even if they are FAA-approved. Fixtures utilizing lead acid batteries are not approved for use due to lower comparable life with other battery types.

11C-6 Fixtures shall be stored in accordance with manufacturer's instructions and shall not be stored in a location or manner where prolonged self-discharge will render the battery unserviceable (in most cases they cannot be stored in darkness).

CHAPTER 12 DESIGN AND INSTALLATION

12-1 REQUIREMENTS.

When design options exist and operational requirements do not allow a clear choice between them, base the decision on the results of a life cycle cost analysis rather than the lowest first cost. All interior and exterior elements of the airfield lighting systems must meet the requirements of this document. Refer to UFC 3-535-02 for detailed installation information.

\4

12-1.1 Light Fixture Mounting.

12-1.1.1 Wherever practical, mount the light fixtures on bases installed in a concrete envelope. The mounting bases support the light fixture and normally house the isolation transformer. For temporary construction the light fixtures may be stake mounted, and the transformers may be surface mounted. Beyond the shoulders, the top surface of foundations, covers, and frames must not exceed 2 inches (50 millimeters).

12-1.1.2 Frangible couplings and points for new elevated fixtures, signs or NAVAIDS shall meet the design and testing criteria given in ICAO Document 9157, Aerodrome Design Manual, Part 6, “Frangibility”, and UFC 3-260-01. **/4/**

12-1.2 Concrete Foundations.

All foundations for lights, signs, towers, and other equipment must be flush with the grade and the surrounding area stabilized and compacted to prevent erosion and excessive rutting in the event an aircraft strays from the pavement.

12-1.3 Cable and Duct Installation.

12-1.3.1 Wherever practical, install cables in approved underground duct. Cable must be suitable for underground installation, and installed in direct buried duct. (Consider direct burial for locations with a high water table.) For multiple duct installation, spacers are required to maintain proper duct separation. Use concrete encased duct under paved areas. Maintain relative positions of multiple ducts from manhole/hand hole to manhole/hand hole.

12-1.3.2 The ducts under paved areas must have a minimum of 3 inches (75 millimeters) concrete encasement all around. For directional boring, maintain the relative positions of multiple conduit from manhole to manhole (ducts should not cross each other).

When installation under existing pavement is required, the designer must select the best conduit for the application considering strength and corrosion resistance. For temporary construction, the cables may be direct-buried. Make connections between the lighting cable, isolation transformers, and light fixtures with FAA L-823 connectors. Recommendations for the designer to consider regarding cable and duct installation are contained in Table 12-1.

Table 12-1 Considerations for Cable and Duct Installation

14. Install cables in the same location and running in the same general direction in the same trench or duct bank. Whenever possible, route cables in straight duct segments between manholes and hand holes, or between light bases.

When practical, route cables and duct rectilinear (parallel and at right angle) to runways, taxiways, and other surfaces.

2. Separate low voltage (≤ 600V) from higher voltage cables (> 600V – 5,000V). Separate all power cables from control, telephone, and coaxial type cables.
   - place 600V and 5,000V power cables in separate duct, or separate a minimum 4" (100mm) if direct buried in trench.
   - Power cables of more than 5,000V must be separated from all other cables by minimum 12" (300mm).
   - place all power cables in a separate duct bank from all control, telephone, coaxial type cables, or separate a minimum 6" (150mm) if either is direct buried.
3. If cables are placed at more than one level, install so that the minimum vertical separation is the same as the minimum horizontal separation. Do not directly overlap cables, so damage may be avoided during the compaction process.
4. Do not direct-bury cables under paved areas, roadways, railroad tracks or ditches. In these locations, install cable in concrete encased duct schedule 80 PVC, or PVC-coated rigid galvanized steel where encasement is impractical. FOR AIR FORCE, the cable shall be installed in concrete encased duct schedule 40 PVC.
5. Where rock is encountered during excavation, install cable in duct. Remove rock to depth of at least 3" (8 cm) below required depth of duct, and use adequate bedding material to provide uniform support along entire length. Bedrock requires other action. Refer this to the designer.
6. Construct trenches for single-duct lines that are not encased with concrete so that they are not less than 6" (150mm) or more than 12" (300mm) wide. Construct the trench for 2 or more ducts proportionately wider.
7. For duct banks, use interlocking duct spacers at not more than 5' (1.5m) to ensure uniform spacing between ducts and to hold duct in place when concrete encasing. Stagger joints in adjacent duct at least 2' (0.6m).
8. Provide burial below frost line to prevent damage from frost heave if local experience has indicated problems.
9. Concrete encased duct may be used, as appropriate, for areas inhabited by digging rodents or animals to provide additional physical protection.
10. Slope duct lines where practical for drainage towards manholes/hand holes, or duct ends.
11. Provide grounding bushings where rigid conduits enter or leave a manhole.
12. Provide, whenever possible, a spare duct in each duct bank.
13. Where conduit is bound in pavement or other structural feature, provide conduit expansion joints when crossing pavement expansion joints. Consider conduit expansion joints also where local experience has indicated expansion problems.
14. When crossing pavements, large bodies of water and other environmentally sensitive locations, follow guidelines for trenchless directional boring contained in UFC 3-550-01.

[See also typical installation details, UFC 3-535-02**. \4** Ensure changes from 3/4 inch 10 foot (19 mm 3 m) is coordinated with UFC 3-535-02. **/4/**

12-1.4 Manhole/Handhole Design.

12-1.4.1 Each manhole/hand hole must have its own design detail to show orientation (with north arrow). This detail must include the access lid location. It is preferred that manholes/hand holes be cast with only one joint at the top.

12-1.4.2 The assembled manholes/hand holes including their access lids must meet wheel load ratings according to UFC 3-260-01. In areas not addressed by UFC 3-260-01, design manholes and hand holes to take HL-93 wheel loading per AASHTO LRFD Bridge Design Specifications, Section 3, “Loads and Load Factors.” When calculating load ratings for manholes/hand holes, consider heavy tractors and fire trucks that will pass over them.

A project design analysis or basis of design must indicate the manufacture’s information showing that the manhole/hand hole covers and frames will support the design loads. Structural calculations showing that the complete structure can support the required aircraft loading where located in the runway, taxiway, or shoulder areas described in UFC 3-260-01 must also be included.

12-1.4.3 The single wheel load rating for the manhole/hand hole and access lid assembly must be cast in the concrete top of each manhole/hand hole. The year of installation must be cast as “Installed Year - xxxx” in the each concrete top or the metal hatch. The words “Airfield Lighting” must be cast in the top of the each manhole/hand hole metal hatch used for airfield lighting circuits.

12-1.4.4 Design and orient manhole access lids so as to not interfere with cable runs through the manhole.

12-1.4.5 Design and orient manhole access lids and ladder rungs so as to not interfere with sump holes.

12-1.4.6 Manhole/hand hole access lids must be spring-assisted in opening when the access lid weighs over 30 pounds. Minimum opening must be 24" (0.6 meters) to allow portable ladder use. Safety arms used in keeping the lids locked open must not fall down into the hand hole/manhole. Safety arm(s) must not make contact with the cable(s) in the hand hole/manhole. Frames for access lids must have a ground lug attached on the inside of the manhole/hand hole. Access lids must be easily closed and have a minimum of two bolts to keep the lid closed.

12-1.4.7 Tie manhole tops to the side walls with rebar cast into the concrete tops and side walls. Install rebar so that it is not exposed.

12-1.4.8 Coat manholes/hand hole exteriors with a water sealant on the bottom and all sides. Sealant must not be placed on the manhole/hand hole tops, but can be on the sides of the top.

12-1.4.9 Show manhole/hand hole conduit penetration details on the construction contract documents. Female conduit connections cast into the manhole/hand hole are required. Show the outside seal and the inside seal at the concrete/conduit interface in conduit detail(s). The outside seal should not allow water to pass between the outside surface of the conduit and the manhole/hand hole wall. Provide unused conduits with plugs that are removable from within the manhole/hand hole. Seal conduits filled with cable(s) around the cable with duct seal, unless directed otherwise by the base electrical engineer. Cast rebar in place in the manhole/hand hole wall and stubbed out so that it can be used to attach the manhole/hand hole to the concrete-encased conduit system/duct bank it is mating to. Stubbed-out rebar lengths and diameters must be shown in design details.

12-1.4.10 Provide for future duct bank entrances to manhole with cast-in-place removeable window for installing duct bank.

12-1.4.11 Show a fold-down diagram on the construction contract documents for each new manhole. Fold-down diagrams must show conduits on each face, size, and material of conduit, circuits (cables) included in each conduit calling out the name of the circuit, and cable type/size. Use tables together with the fold-down diagrams to help convey the information.

12-1.4.12 It is preferred that cables take the shortest route through the manhole/hand hole. Do not loop cable inside the manhole/hand hole unless specifically directed by the base electrical engineer. If directed to loop the cables in hand holes/manholes, designate such on the construction contract documents.

12-1.4.13 Place non-metallic cable racks on all manhole walls whether currently used or not. Cable racks must be able to support 300 pounds (136 kilograms) without breaking.

12-1.4.14 Tie cables to racks using cable ties.

12-1.4.15 Identify cables with a tag using cable ties.

12-1.4.16 Cable ties and tags must be made of heavy-duty, corrosion resistant material or as directed by the base electrical engineer.

12-1.4.17 **\1**Each manhole/hand hole must have either a low point (sloped floor) or a sump hole. A sump hole will require a drain lid over the sump hole. Place the sump hole or low spot for easy access in lowering a portable sump pump into the manhole/hand hole from outside the manhole/hand hole. Do not allow sump holes to penetrate the floor unless each one is tied to a drain line. Tie drain lines to the base storm drainage system, and drain to daylight, or drain to an approved French drain. Build into the manhole rungs for access to the manhole. When attaching rungs to the manhole wall, use fasteners that will hold at least 300 pounds.**/1/**

12-1.4.18 Each manhole/hand hole must have a **\4** 5/8-inch by 8-foot (16-millimeter by 2.44-meter) **/4/** copper clad ground rod driven through a precast hole in the floor after the manhole/hand hole has been placed into its final position. Seat the precast manhole/hand hole water-tight with a non-corrosive sealant after installation of the ground rod. The ground rod must “stub up” a minimum 6 inches (150 millimeters) above the manhole/hand hole floor, with a ground lug attached for ground connections. Ground connections must be provided to all metal equipment in the manhole/hand hole using a AWG #4 (25 square mm) bare stranded copper cable. This includes the metal frame for the manhole/hand hole lid, cable racks, and system ground wires that feed through the conduits. **\4** The bonding conductor shall be connected to each metallic item within the manhole/handhole in such a manner that the disconnection of any one item will not result in the disconnection of any other grounded item. **/4/** The counterpoise must not be tied to this ground.

12-1.4.19 The soil grade around the manholes/hand holes must start one half inch below the top of the manhole/hand hole and slope one quarter inch per foot away from the manhole/hand hole for 15 feet (4.5 meters).

12-1.4.20 Place manholes/hand holes on undisturbed soil.

12-1.5 Safety (Equipment) Grounding System.

12-1.5.1 The safety ground is a separate system and must never be confused with the counterpoise. A safety ground must be installed at each light fixture. In-pavement (L-868) fixture bases, where the counterpoise is connected to the base can, are exempt. The purpose of the safety ground is to protect personnel from possible contact with an energized light base or mounting stake that may result from a shorted power cable or isolation transformer.

12-1.5.2 The safety ground must be a AWG #6 (16 square mm) solid bare copper conductor with one hole lug bolted to the exterior ground lug at the fixture base. The other end is connected to a **\4** 5/8-inch by 8-foot (16-millimeter by 2.44-meter) **/4/** ground rod installed beside the fixture. Ensure resistance-to-ground of the rod is 25 ohms or less in accordance with manufacturer's requirements.

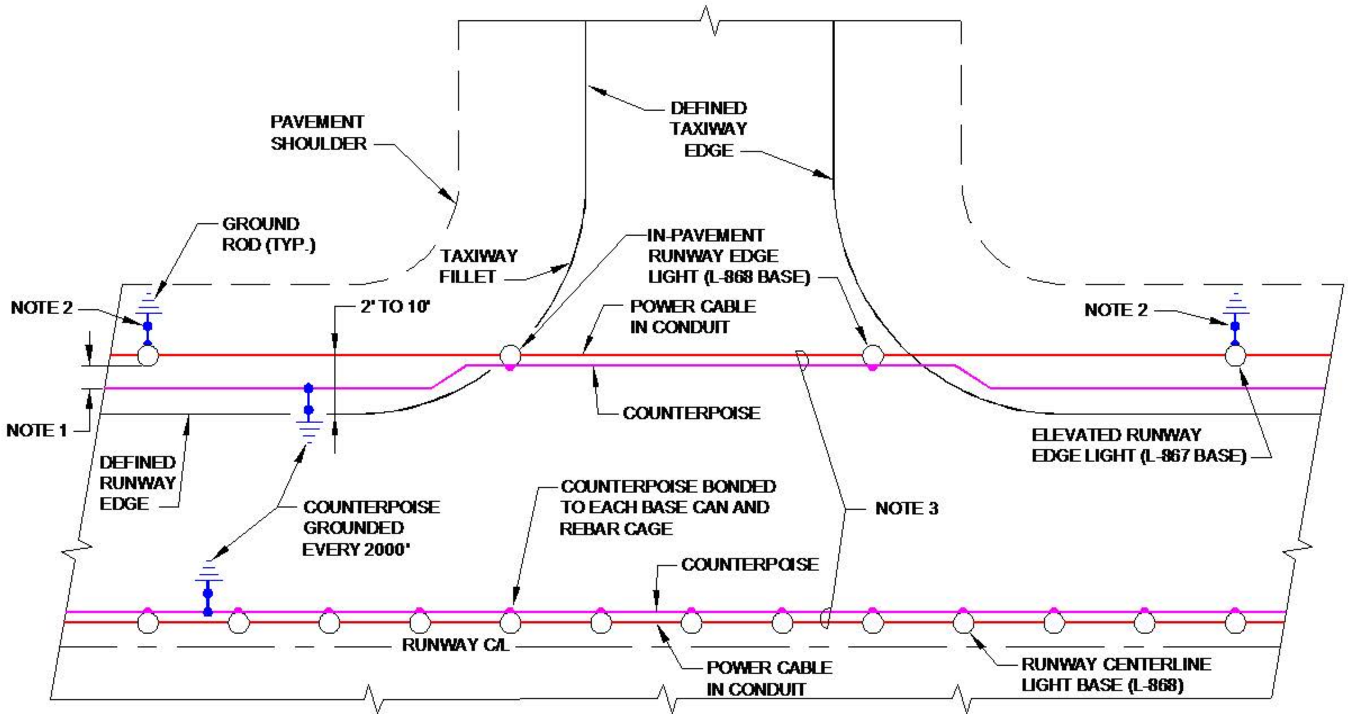
12-1.5.3 Do not exothermically weld connections to a galvanized light base. See FAA AC 150/5340-30, Chapter 12, for additional detailed ground connection information.

12-1.5.4 See the NEC Handbook for additional information about grounding electrode installation and testing. Additionally, in-pavement fixtures and base plates for elevated fixtures must be fitted with a braided ground strap connected to the interior ground lug of the base can. All exterior grounding connections must be bolted exothermic-weld-type. Ground connections interior to the can must be bolted-type connections.

12-1.6 Counterpoise Lightning Protection System.

The purpose of the counterpoise or lightning protection system is to provide low resistance preferred paths for the energy of lightning discharges to safely dissipate without causing damage to equipment or damage which could later cause injury to personnel. The counterpoise is a separate system and must not be confused with equipment safety grounds that provide personnel protection from electrical shock hazards. Provide a continuous counterpoise of minimum AWG #6 (16 square mm) bare, stranded copper wire to protect the entire length of all primary circuits supplying airfield lighting, with a minimum 10 feet (3.0 meter) ground rod installed at least every 2,000 feet (600 meters). Do not connect counterpoise system to the light bases except at in-pavement fixtures. **\4** Reference NFPA 780, Figure 11.4.2.6.2 for pertinent information. **/4/**

Figure 12-1 Counterpoise and Ground Rod Installation



Notes:

1. Install the counterpoise along the pavement shoulder in a separate trench half-way between the line of edge lights and the defined runway edge. Route the counterpoise around the can a minimum of 12 in (0.3 m) toward the runway pavement. Typically, any lighting strike will hit the crown of the pavement first and migrate across the pavement toward the counterpoise.
2. Equipment ground per paragraph 12-1.5.
3. Power cable and counterpoise located in the same trench (counterpoise on top) under pavement subject to routine aircraft traffic.
4. Ground bonds must be exothermic weld type unless and ground lug is provided.
5. Installation of counterpoise for taxiway edge lighting in paved or unpaved shoulders is the same as for elevated runway edge lights.

12-1.6.1 Counterpoise Criteria.

Along runway/taxiway or apron shoulders, install the counterpoise halfway between the pavement and at approximately half the depth of the duct (or cable, if direct buried) if at all possible. If this is not practical, install counterpoise 4-6 inches (100-150 millimeters) above the duct or direct-buried cable. Route the counterpoise around each light base or unit, at a distance of no less than 12 inches (300 millimeters) from the unit; do not connect to the unit. For duct not along a shoulder or for duct bank, lay the counterpoise 4-6 inches (100-150 millimeters) above the uppermost layer of direct buried ducts, or on the top of the concrete envelope of an encased duct bank. Provide only the quantity of counterpoise wires for cables for the same duct bank based on the width and depth of the duct bank as shown in NFPA 780. Connect all counterpoise wires leading to a duct bank to the single counterpoise wire for the duct bank. Lay the counterpoise at least 12 inches (300 millimeters) away from manholes or hand holes. Do not connect the counterpoise to the lighting vault power grounding system. Use exothermic-type weld for all connections. The counterpoise resistance to ground must not exceed 25 ohms at any point using the drop of potential method.

12-1.7 Frangibility and Accident-Avoidance Construction.

In the areas around the runway, including the approach zone, all above-grade structures must be lightweight and of a frangible or low impact resistant construction using breakaway sections to minimize hazards to aircraft. Concrete foundation or mounting slabs must not extend above the finished grade of the surrounding surface.

12-1.7.1 ALSF Frangibility.

A slight trade-off in frangibility can result in significant savings in energy. Older ALSF systems use 300 watt lamps in the outer 2,000 feet (600 meters) to satisfy the photometric requirements, which can actually be met with newer 200 watt lamps. However, the 200-watt lamps are rated at 6.6 amps rather than 20 amps and their use would require a change in isolation transformers. This would not be difficult in major renovations or new installations except that eight additional wires must be installed in low impact resistant and semi-frangible light supports. The major command may accept the slight loss of frangibility to achieve the energy savings.

12-1.8 Airfield Lighting Vault.

Vaults house the regulator and control equipment, emergency generator and power transfer switch, and other electrical equipment needed for operation of the airfield lighting system. The vault may be a separate building or structure, or an enclosure within a larger structure, as appropriate. Vaults must be of concrete or masonry construction meeting all building codes for the type of structure. Vaults constructed in the past generally had a primary service of 4.16/2.4 kV, 3 phase, 60 hertz power. All existing vaults not meeting the above described criteria may be used, provided the existing structure is otherwise adequate to serve the overall purpose or can be modified economically to provide the desired facility. For new construction or major modernization, the following is recommended:

12-1.8.1 Vault Voltage.

Use 480 volts as a primary voltage within the vault for new installations.

12-1.8.2 Vault Location.

Locate vaults a minimum horizontal distance of 350 feet (105 meters) from the control tower to prevent radio interference with control equipment. The maximum horizontal distance between an airfield lighting vault and the control tower where nominal 120 volt control system is used (with L-841 relay panel and multi-conductor control cable) is 7,350 feet (1.4 miles)(2,205 meters). As an alternative, 48 volts dc can be used for long distance control. An existing vault not meeting required locations may be used, provided the existing structure is otherwise adequate to serve the overall purpose or can be modified economically to provide the desired facility.

12-1.8.3 Main Lighting Vault.

\1Design the main airfield lighting vault to contain power distribution and control equipment for runway and taxiway lighting circuits and any other lighting circuits that can be fed from the lighting vault. Provide adequate space for the maintenance of the systems interior to the lighting vault. Auxiliary vaults may be required for other airfield systems depending on the airfield configuration and layout. Locate the vaults above grade in locations that are the most suitable as supply points. For Army airfields, size the vault for the required equipment and work space and space allowances indicated in UFC 3-260-01. Provide a two-hour fire rated wall to isolate the engine generator room from the regulator room.**/1/**

12-1.8.4 Circuit Selector Switches.

For new construction, circuit selector switches are not allowed for Army facilities. For new construction, circuit selector switches are not recommended for Air Force Facilities.

12-1.8.5 Floor Mounted Equipment.

Securely bolt all floor-mounted equipment to the floor to prevent movement during seismic disturbances.

12-1.8.6 Constant Current Regulators.

Constant current regulators require adequate work space for maintenance access and high voltage safety. The following minimum spacing is recommended: 3 feet (0.9 meter) from back wall to regulator and between regulators; 4 feet (1.2 meters) in front of regulator for access.

Cabinet enclosure must meet National Electrical Manufacturers Association (NEMA 1) requirements.

12-1.8.6.1 Environmental requirements.

The equipment must be designed for continuous operation under the following conditions: a. Temperature range is from -40° to 131° Fahrenheit (F) (-40° to 55° Celsius (C)). b. For monitoring circuitry, the temperature range is from 32° to 131°F (0° to 55°C). c. Relative humidity range is from 10 to 95 percent. d. Altitude range is from zero to 6,600 feet above sea level (2,000 meters).

Table 12-2 Constant Current Output

Class	Style	Step	Nominal output amperes (A) root mean square (RMS)	Allowable range (A RMS)
1	1	3	6.6	6.50 – 6.70
		2	5.5	5.40 – 5.60
		1	4.8	4.70 – 4.90
1	2	5	6.6	6.50 – 6.70
		4	5.2	5.10 – 5.30
		3	4.1	4.00 – 4.20
		2	3.4	3.30 – 3.50
		1	2.8	2.70 – 2.90
2	2	5	20.0	19.70 – 20.30
		4	15.8	15.50 – 16.10
		3	12.4	12.10 – 12.70
		2	10.3	10.00 – 10.60
		1	8.5	8.20 – 8.80

12-1.8.6.2 Efficiency.

The efficiency of a CCR operated at its maximum intensity setting, rated input voltage, with 100 percent load at unity power factor (PF) must not be less than the values shown in Table 12-2.

Table 12-3 Constant Current Efficiency

CCR size kilowatts (kW)	Minimum overall Efficiency (percent)
Less than 30	90
30	92
50	93
70	94

12-1.8.6.3 Power Factor (PF).

The PF for CCRs 10 kW or less must not be less than 0.90 (90 percent). and PF for larger than 10 kW the PF must be not less than 0.95 (95 percent).

12-1.8.6.4 Protection for Devices and for Safety.

Open-circuit protection and over-current protection must be provided. The CCR must use a primary switching device that interrupts the input power prior to the current regulating/transformer circuits. The CCR must provide, located for ready access on the CCR, without opening doors or removing covers, a means for the operator to select the remote/local modes and the desired current step.

12-1.8.6.5 Assembly Size.

The overall size of a complete CCR assembly must allow it to pass through an opening 39.0 inches (1.0 meter (m)) wide by 78.0 inches (2.0 m) high.

\4
12-1.8.6.6 Input Power Loss.

If there is a short duration loss of CCR AC input power of up to 500 milliseconds, the CCR must resume operation (CCR is “ON” at the same current step and producing current) within one second after the power interruption (ac input power is restored after 500 milliseconds). ***/4/***

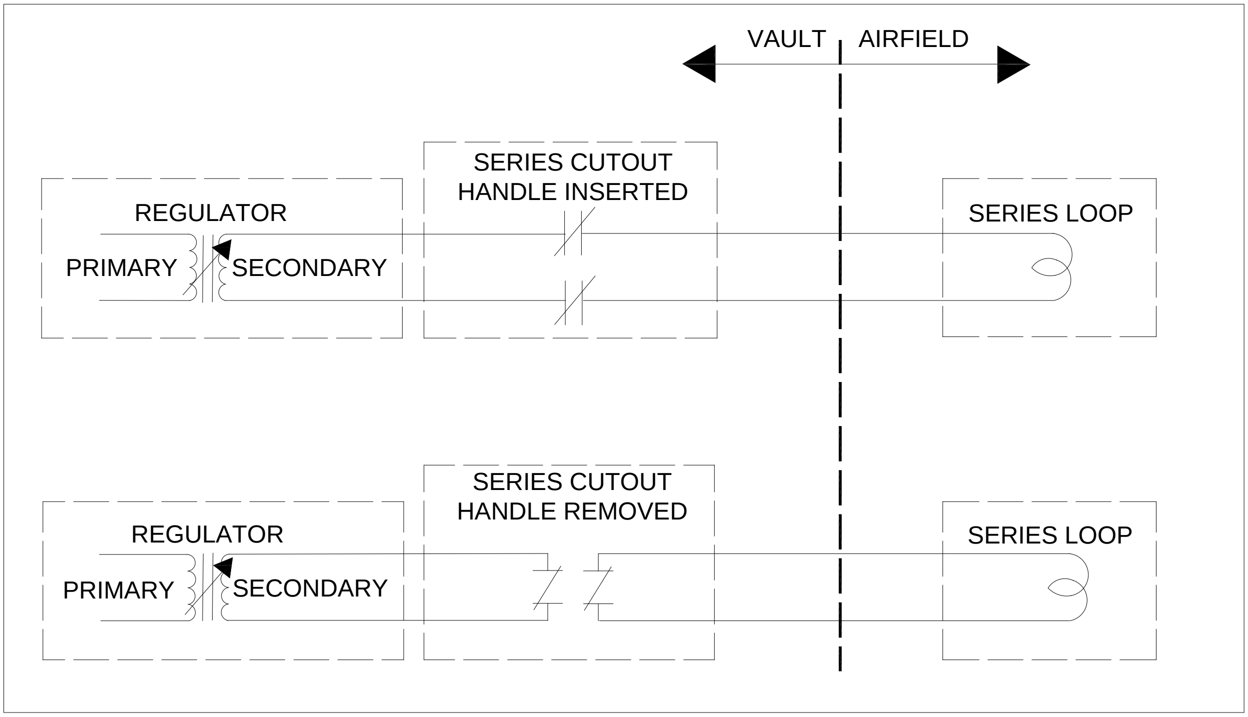
12-1.8.6.7 CCR Monitor.

The monitor must detect the status of the CCR and the series lighting circuit. Type L-829 CCRs must use integral monitoring. A CCR without monitoring is designated Type L-828. A monitor may be offered as a separate module designated Type L-827. If monitoring is added to a Type L-828 regulator, it becomes a Type L-829.

12-1.8.7 Vault Wiring Safety.

Series cutouts provide safety by preventing inadvertent live wires during maintenance on field circuits. These are recommended at the output to field circuits for constant current regulators. Install series cutouts in NEMA 1 enclosures. A circuit diagram for a series cutout is shown in Figure 12-2.

Figure 12-2 Series Cutout Circuit Diagram



12-1.8.8 New Installations.

\4 L-824 conductors are not rated for installation in cable tray, however, the NEC allows this installation when only qualified persons can access, install, or service the cable. For military installations, L-824 conductors will only be installed in cable tray as part of a switchgear regulator assembly. Run L-824 cables outside of switchgear regulator assemblies in rigid galvanized steel (RGS) conduit, intermediate metallic conduit, wireways or other wiring methods allowed by the National Electrical Code (NEC). **/4/** Run low voltage feeders and control wires in rigid galvanized steel (RGS) conduit or intermediate metal conduit when run under the floor slab; in rigid galvanized steel (RGS) conduit, intermediate metallic (IMC) conduit, or electrical metallic tubing (EMT) when run on the walls or ceiling; and in cable trays supported from the ceiling or walls, IAW the NEC, when routing multiple cables or when a future expansion is a possibility within five years. Do not install conduit in concrete slabs on grade. Bring primary series cable from regulators and various other feeders out of the vault in PVC coated rigid steel galvanized conduit minimum 2 feet (0.6 meters) below grade.

12-1.8.8.1 To facilitate installation or replacement of constant current regulators and other heavy equipment, allow at least 8 feet (2.4 meters) of space between rows of equipment to allow access for lifting equipment or a truck to on-load or off-load/offload regulators. Provide a garage door to allow the truck or lifting equipment access to the building and consider installing a ceiling hoist system to install or remove regulators.

12-1.8.8.2 Provide an HVAC system with filtered outside air intake to maintain proper temperatures and humidity within the vault and to minimize dust levels. Insulate the vault envelope to reduce HVAC system run time and to minimize life cycle cost.

12-1.8.9 Installation Compliance.

Comply with the requirements of the NEC (NFPA 70) for the installation of power distribution equipment and control equipment in lighting vaults. See manufactuer's requirements for lightning and surge protection design. It is recommended to review the checklist for vault contained in Chapter 14.

12-1.8.10 Short Circuit Analysis.

Provide a short circuit analysis that complies with NEC Section 110-9, Section 110-10 and Section 110-12; and FAA Order 6950.27, as part of the design (to enhance reliability and safety). Include in the analysis critical points such as:

- Service entrance.
- Switchboards and panelboards.
- Transformer's primary and secondary.
- Transfer switches.
- Load centers.
- Fusible disconnects.

12-1.8.11 Surge Protective Device (SPD)/Lightning Protection.

To protect airfield lighting vault equipment from the effects of transient voltage surges, the main switchboard and panelboards serving regulators and field lighting control equipment must be provided with SPD equipment. Units must be either integral or external to the equipment being protected. Additionally, constant current regulators must have lightning arrestor protection.

12-1.8.11.1 SPD devices must be listed and labeled as defined in NFPA 70, Article 100, by an independent certified testing agency and marked for intended use. Design the SPD protection system for the airfield vault equipment in accordance with IEEE C62.41.1 and IEEE C62.41.2.

12-1.8.11.2 Surge protective device technology must be metal oxide varistor (MOV); silicone avalanche diode technology is not acceptable.

12-1.8.11.3 The short circuit current rating of a protection device must match or exceed that specified for the panel from which the surge protection device is fed.

12-1.8.11.4 For constant current regulators, arrestors of the proper rating to protect the CCR from lightning-induced voltage and current surges must be installed at both the input and output terminals of the CCR. The CCR input lightning arresters must be rated for pulses per IEEE C62.41-1991, paragraph 4.2.17b, Table 6, Category B2, Medium. The CCR output lightning arrestors must be rated for Location Category C3 in IEEE 62.41-1991, Table 4 (A 1.2/50 microsecond (µs) 8/20 µs combination wave at 20 kilovolts and 10 kiloamperes **\4** RMS **/4/** - the nominal ratio of RMS open circuit voltage to RMS short circuit current is 2 ohms). The ground side of the arresters must be connected to the cabinet grounding lug or other electrically equivalent ground location. If a bonding jumper wire is used, it must not be smaller than 6.

12-1.9 Emergency Power.

Provide an emergency generator or other independent power source at each vault which services systems requiring standby power for continuous operation if the principal power source fails. See FAA AC 150/5340-30 for additional design information and requirements for emergency power systems.

12-1.9.1 Engine Generator (E/G).

Where engine generators are installed, provide a separate room or shelter with independent ventilation. Make provision for engine exhaust to the exterior of the shelter. Mufflers may be installed inside or outside the building. If installed inside, they must be insulated. Engine cooling may be provided by externally-mounted radiators or by use of a radiator duct to an external exhaust louver. Make provisions for mounting and cooling resistive load banks for diesel engine testing if the station load is inadequate or cannot be made available for engine testing. Provide fuel storage capacity for 72 hours of uninterrupted operation of the standby power system. Also provide automatic starting and switching capable of supplying the rated load within 15 seconds of a power failure except where Category II instrument operations are conducted. During Category II and III instrument operations, a one-second power transfer is required. This is normally done by providing a remote start capability which permits operation of the lighting systems on the engine generator during Category II or III weather conditions. Standby power availability is then subject only to switching time. The actual procedure used must be locally coordinated. See FAA AC 150/5340-30, Chapter 9, for additional information. Provide an automatic battery charger for the starting batteries. Isolate the E/G foundation slab to reduce vibration and noise transmission to other parts of the vault. Comply with the requirements of the NEC, OSHA and local jurisdictions for emergency power.

12-1.10 Independent Power Sources.

An alternate independent power source qualifies as emergency standby power only if it is generated by a separate generating station and routed over separate power lines. In most cases in the past, careful investigation revealed that seemingly independent sources were so interconnected that failure of one could result in failure of the other. Exercise extreme care when determining the qualifications of alternate power sources before opting against an engine/generator for standby power.

12-1.11 Airfield Lighting Control.

The control system for airfield lighting consists of control panels, relaying equipment, accessories, and circuits which energize, de-energize, select lamp brightness, and otherwise control various airfield lighting circuits based on operational requirements. Control of any one airfield lighting system is normally provided at two points only: the air traffic control tower, and the lighting equipment vault. See Figure 12-3 for a typical lighting vault block diagram. A transfer relay assembly is provided at the vault to transfer control from the remote location to the vault when necessary:

12-1.11.1 Control Voltages.

Standard practice is to provide a 120 VAC control system using low burden pilot relays (pilot relay assemblies) to activate the power switches, contacts, and relays controlling the regulators and transformers supplying power to the airfield lighting circuits. The maximum horizontal distance from the control tower to the lighting vault is limited, for proper function of the pilot relay assemblies, to 7,350 feet (2,240 meters) when using 120 VAC control systems. There may be capacitance issues in long 120-volt ac control circuits. Where the distance between the tower and the vault exceeds the maximum, consider using a 48 VDC control system as described in FAA AC 150/5340-30, Figures 29, 30, and 70. Where both types of control system are installed, ensure the control power systems are isolated. See Figure 12-4 for a high level example of airfield lighting control.

12-1.11.2 Control Circuitry.

Design the control system to ensure the following:

- Lighting on intersecting runways cannot be energized simultaneously.
- All circuits supplying the lights for any one lighting system (for example, runway edge lighting) are energized simultaneously and operated at the same brightness step.
- Runway centerline lights cannot be energized unless the runway edge lights are energized.
- Touchdown zone lighting (TDZL) cannot be energized unless the runway centerline lights are energized.
- Certain systems associated with low-visibility operations (such as runway guard lights, hold-position lights, lead-in lights, land-and-hold-short lights), if installed, may also require linkage of control to runway lights. Recommend following guidance in applicable FAA documents, such as FAA AC 120-57 and FAA AC 150/5340-30.

Figure 12-3 Installation Plan, Power Equipment

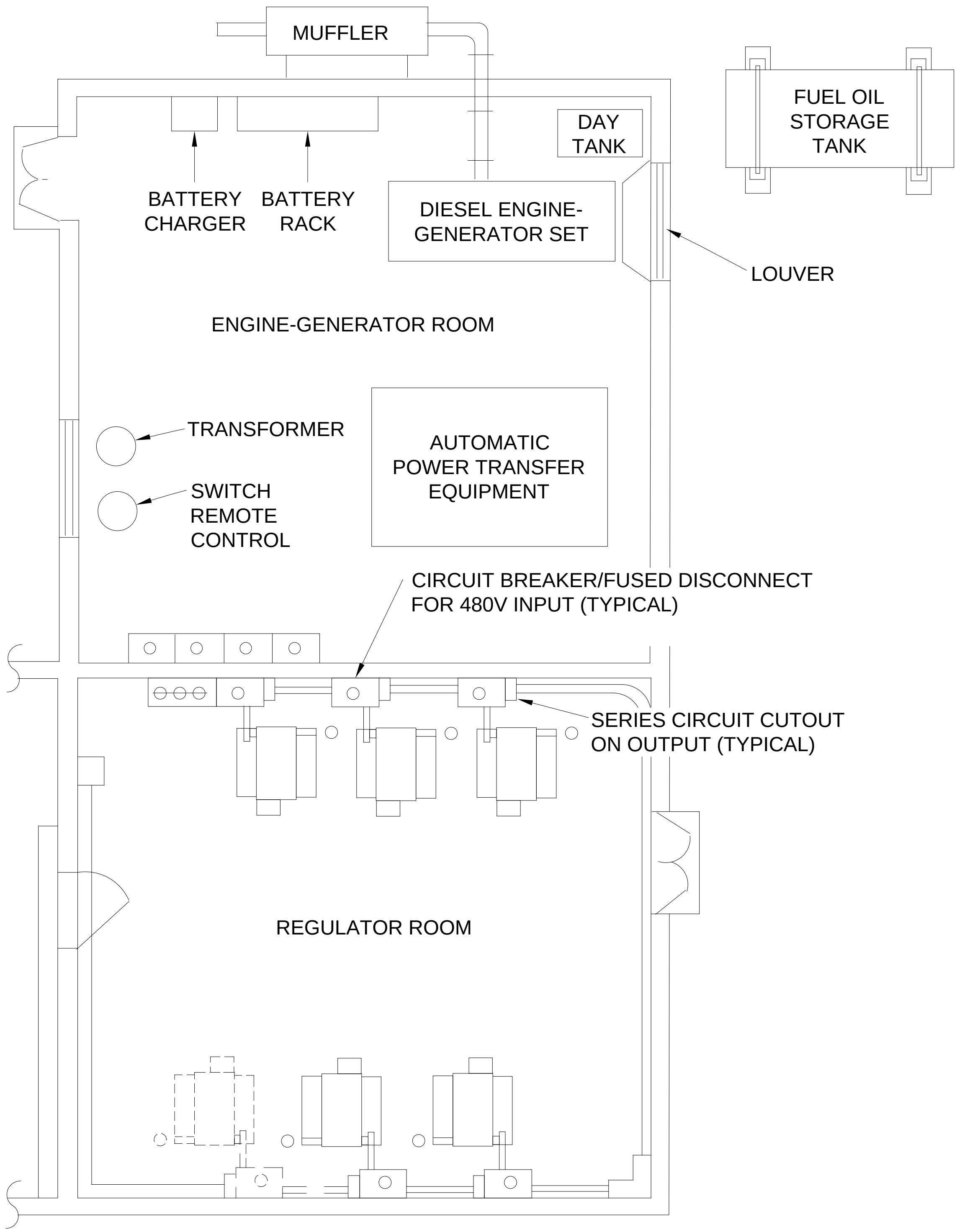
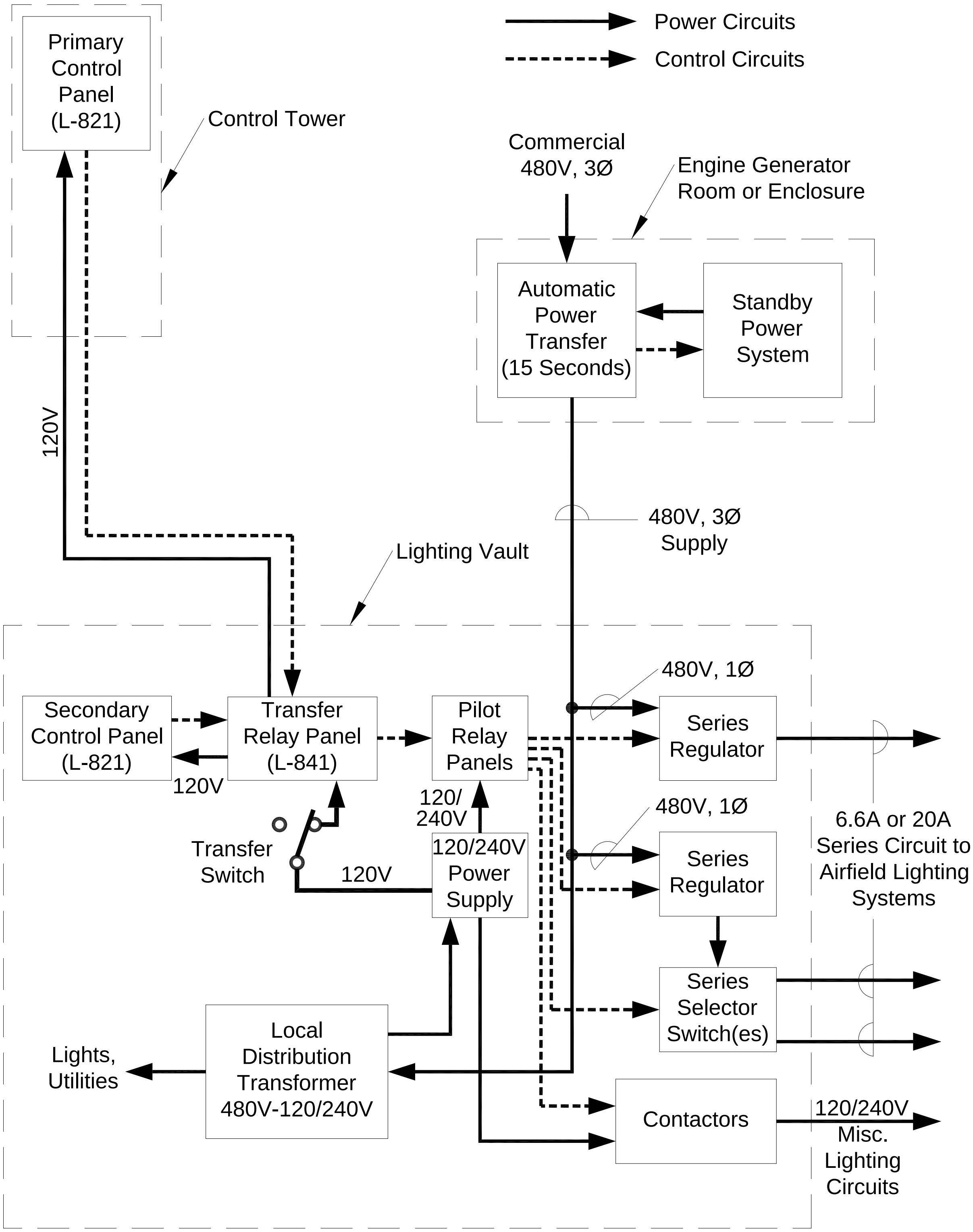


Figure 12-4 Power and Control System Block Diagram



12-1.11.3 Control System Modernization.

Major commands are encouraged to consider the use of control systems, where significant economies or operational improvements can be achieved. If an approved specification is not available, the use of such systems is subject to the requirements of paragraphs 1-11 or 1-12 of this document. Control systems using electromagnetic emissions also require the express approval of AFCEC/COSM. As examples, Figure 12-5 shows a block diagram for a control system using programmable logic controllers (PLC), and Figure 12-6 shows a block diagram for a PC-based control system. Further discussion of computerized control systems is also provided in Chapter 13.

Figure 12-5 Computerized Control System using PLC Block Diagram

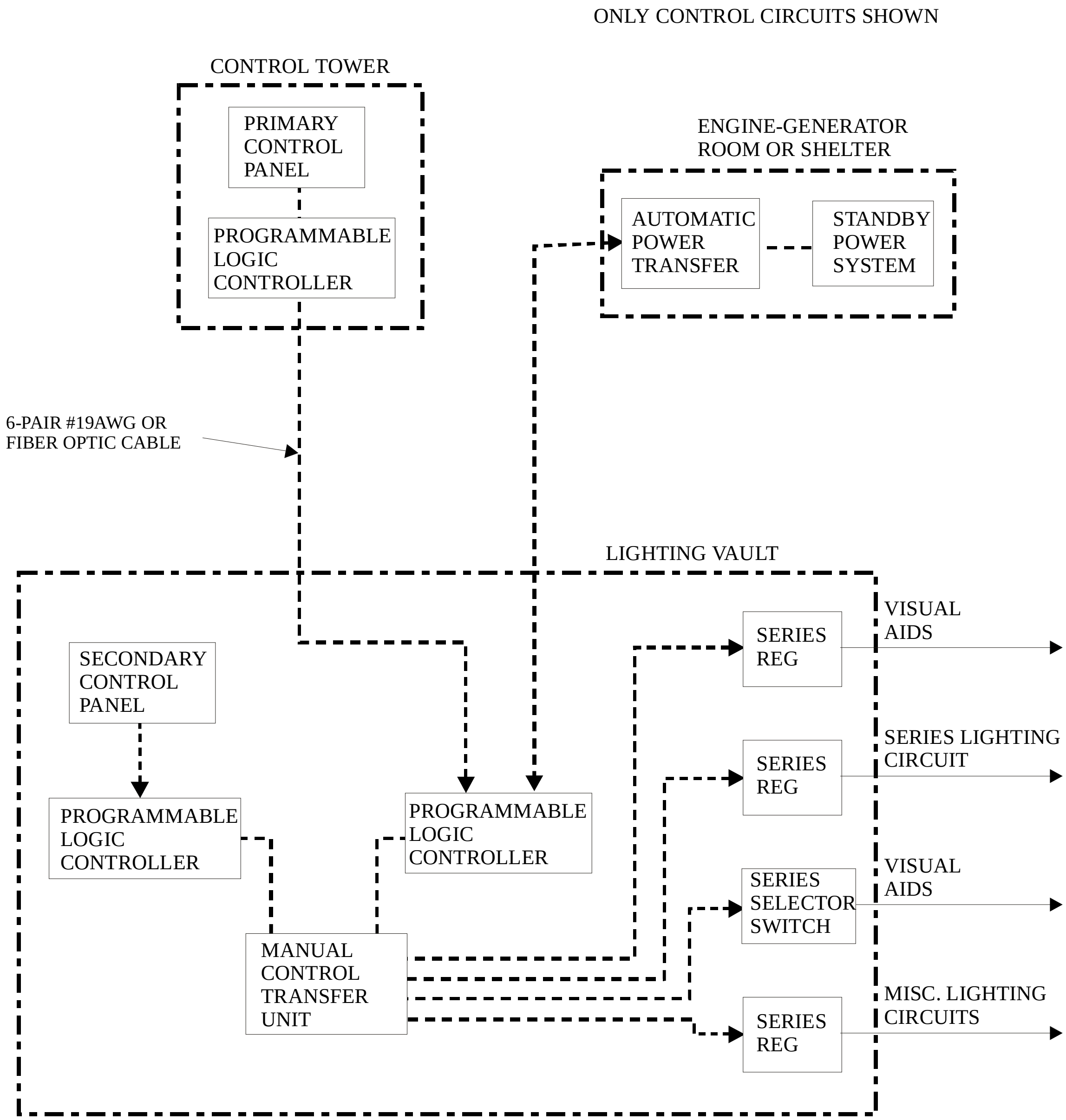
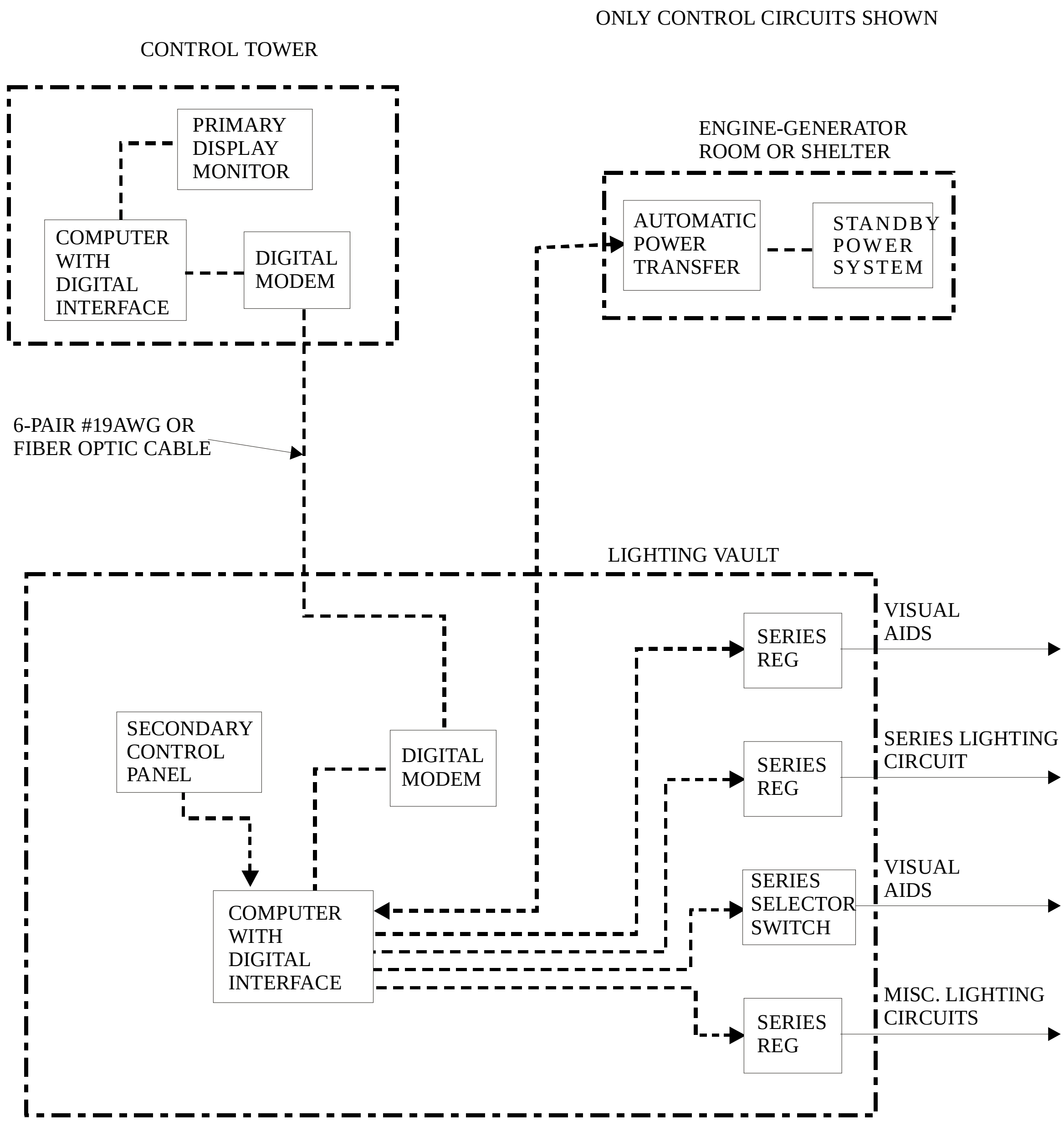


Figure 12-6 Computerized Control System using PC Block Diagram



See FAA AC 150/5345-56 for detailed ALCMS equipment requirements. See also FAA AC 150/5345-30, for ALCMS installation and operational requirements.

12-1.12 Light Colors.

For a complete description of incandescent aviation light colors, see SAE AS25050, the applicable FAA Advisory Circular, and a Chromaticity (CIE) color coordinate diagram.

For light emitting diode color requirements, see FAA Engineering Brief 67.

12-1.13 Light Intensity.

12-1.13.1 The brightness steps for the levels of incandescent lamp intensity are shown in Table 12-2.

Table 12-4 Intensity Requirement Levels for Incandescent Light Circuits

Brightness Step	Amperage Reading 20-Ampere Circuit	Amperage Reading 6.6-Ampere Circuit	Approximate Percent Rated Intensity
1	8.5	2.8	0.16
2	10.3	3.4	0.80
3	12.4	4.1	4.00
4	15.8	5.2	20.00
5	20.0	6.6	100.00

12-1.13.2 The brightness steps for three levels of incandescent lamp intensity are achieved by varying the current in the lighting circuit as follows:

Brightness Level	Service Systems Lamp Current (amps)	Percent Brightness
High	6.6	100
Medium	5.5	30
Low	4.8	10

For light emitting diode intensities, see FAA Engineering Brief 67.

12-1.14 Special Considerations for Series Circuits.

12-1.14.1 Selection of 6.6- or 20-Ampere Circuit.

12-1.14.1.1 See FAA AC 150/5340-30 for detailed information about airport series lighting system design. The FAA no longer allows 50 and 70 kW constant current regulators for new designs; these regulators can be used for replacements only. The FAA also suspended the use of 2400 V AC input regulators for all new designs; these regulators may only be used for replacements.

12-1.14.1.2 The determination of whether to use a 6.6 amperes or 20 amperes series circuit must be based on several factors relating to the characteristics of the circuit and the anticipated conditions under which the circuit will be operated. In general, if a circuit is not expected to operate at highest intensity more than 5 percent of the time, and if design calculations show that the voltage will not exceed 2.4 kV when operated at the midlevel (step 2 for 3-step circuits, step 3 for 5-step circuits), then a 6.6 ampere circuit is recommended. If a circuit is expected to operate at highest intensity more than 5 percent of the time, and if design calculations show that the line voltage will be more than 2.4 kV at the mid-level, then consideration should be given to using a 20 amperes circuit, or alternatively using more than one 6.6 amperes circuit.

12-1.14.1.3 The primary circuit cables are insulated for 5,000 volts. If the load is over 33 kW and operated at 6.6 A, the required voltage would exceed 5,000 volts. Therefore, the circuit should be operated at 20 A to reduce the voltage below the insulation rating of the series lighting circuit high voltage cable.

12-1.14.1.4 Analysis should consider the economics over the expected life of the system, typically 20 years. A more detailed discussion of this can be found in Chapter 13. Recommend designing for multiple 6.6 ampere circuits instead of 20 ampere circuits.

12-1.14.2 REIL on Series Circuits.

REIL (runway end identifier lights) are typically connected to the runway edge lighting series circuit via a power adapter, or to a separate power source of 120/240 volts. If connected to a series circuit, it is necessary to consider the sizing of the regulator carefully to allow for the pulsing type of load. The impact on the constant current regulator may be up to 10 times the power requirement indicated by the manufacturer. More information on this can be found in Chapter 13.

12-2 ADDITIONAL GUIDANCE.

The FAA has published guide specifications for installation of airfield lighting systems. FAA guide specifications come in two forms: advisory circulars in the 5340 series, and FAA-E specifications. A listing of applicable publications is provided below. Where those guides are in conflict with the Air Force requirements listed above, the Air Force requirements take precedence. The FAA has an Advisory Check List AC 00-X.X that provides a list of documents, and how to order them. Contact the FAA at 1-800-FAA-SURE, (fax: 301-386-5394).

12-2.1 FAA Advisory Circulars (ACs).

FAA Advisory Circulars and Engineering Briefs may be downloaded free of charge from the FAA website: http://www.faa.gov/airports/engineering/.

12-2.1.1 FAA AC 150/5340-30 covers runway/taxiway lighting, visual aids (PAPI, REIL, Airport Beacons, Wind Cones, MALSF).

12-2.1.2 FAA AC 150/5340-18 describes the recommended standards for design and installation of a taxiway guidance sign system.

12-3 SITING PAPI.

12-3.1 Considerations.

Siting a PAPI requires consideration of the following: if there is or will be an ILS glide slope, the established glide path (aiming angle, typically 3 degrees), the threshold crossing height (TCH) for the selected aircraft height group, the runway gradient (longitudinal slope) from the threshold to the PAPI location, and other factors.

12-3.1.1 With an ILS glide slope, the PAPI is located the same distance from the runway threshold so that the elevation of the lens center of the light units intercepts the runway at the same location as the virtual source of the ILS glide slope, within a tolerance of ±30 feet (±9 meters), and is aimed at the same angle as the ILS glide slope. The virtual source is the Runway Point of Intercept (RPI), where the glide path intercepts the ground elevation along the runway centerline. PAPI location considers the light beam, where the elevation of the lens center of the PAPI light units should intercept the ground elevation along the runway centerline (within tolerance). For aircraft in height group 4 (Table 3-6) for Army airfields only, the PAPI is sited at the RPI plus an additional 300 feet (90 meters), +50 feet –0 feet (+15 meters –0 meters), from threshold.

12-3.1.2 If there is no ILS or Precision Approach RADAR (PAR) glide slope, the PAPI is sited as shown in Figure 12-7. First determine the following:

12-3.1.2.1 Glide Path.

Typically this is 3 degrees, but it may vary at some locations.

12-3.1.2.2 Threshold Crossing Height (TCH).

See Table 3-6. For the Air Force, the TCH is based on the most predominant aircraft using the runway (the major command will make this determination). For the Army, the TCH is based on the most demanding aircraft height group expected to use the runway (the aviation community will coordinate with USAASA for this determination).

12-3.1.2.3 Runway Gradient.

This may be available from record drawings, or determined by field survey. Usually the grade is given as a percent representing the vertical elevation difference over a longitudinal distance (threshold through approximate PAPI location). For example, a 1 percent grade represents a 12 inch (300 millimeters) height difference over a 100 feet (30 meter) length. This is converted to an angle in degrees, α, using the relationship: $\tan \alpha$ = percent grade (expressed as decimal). With this relationship, a grade of 1 percent represents a runway slope of 0.573 degrees (from the horizontal).

12-3.1.3 Determine the Runway Reference Point (RRP) based on runway gradient, as shown in Figure 12-7, establishing the RRP where the elevation of the lens center of the light units coincides with the elevation of the runway centerline. The method provides a direct solution, based on two equations and two unknowns, when the grade of the runway is relatively uniform. The RRP is based on the PAPI light beam, where the elevation of the lens center of the PAPI light units intercept the ground elevation along the runway centerline (within tolerance). Case 4 in Figure 12-7 provides an iteration method for locating the RRP when the runway grade varies significantly through the first approximately 1,500 feet (450 meters).

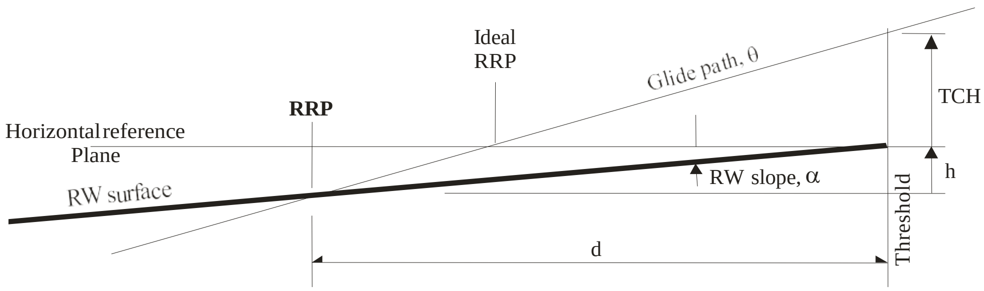
12-3.1.4 Adjust the location of the PAPI for cross slope or other factors, as required. Several examples of how the location of the RRP or location of the PAPI might be adjusted are presented below. Stay within allowable tolerances and other dimensional requirements of paragraph 12-3.2. See Figure 12-8 for guidance on tolerances and adjustments if PAPI cannot be located at the RRP.

12-3.1.4.1 Where the terrain drops off rapidly near the approach threshold and severe turbulence is typically experienced, it would be beneficial to locate the RRP and PAPI farther from the threshold if sufficient runway length is available. In this case consider using the maximum TCH allowed by tolerance in determining the RRP.

12-3.1.4.2 On shorter runways, the RRP and PAPI may be located nearer the threshold to provide the maximum amount of runway for braking after landing. In this case consider using a lower TCH as allowed by tolerance in determining the RRP.

Figure 12-7 Siting PAPI without an ILS Glide Slope (1 of 2)

a. Case 1 - Runway with downward grade.

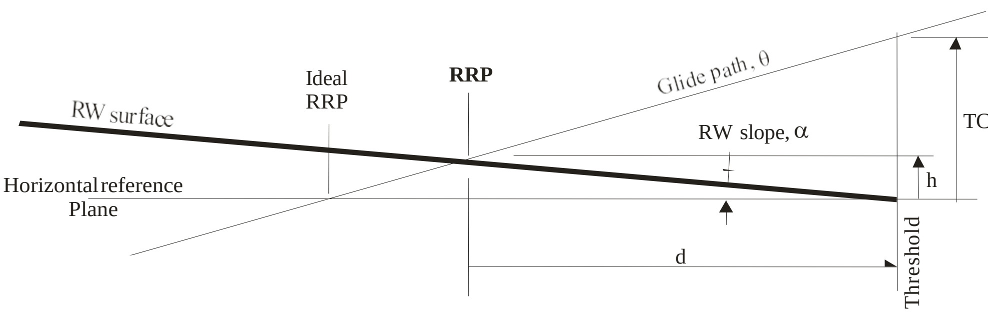


Two relationships can be defined which have two unknowns (d, h):

$\tan\theta = \frac{TCH+h}{d}$, and $\tan\alpha = \frac{h}{d}$

Substituting and solving the above, d is determined directly by: $\mathbf{d} = \frac{\mathbf{TCH}}{(\tan\theta - \tan\alpha)}$

b. Case 2 - Runway with upward grade.



From the relationships, d is determined directly by: $\mathbf{d} = \frac{\mathbf{TCH}}{(\tan\theta + \tan\alpha)}$

EXAMPLES (Assume the following: TCH = 50 feet (15 meters), θ = 3 degrees)

Case 1 (RW with 1% downward grade, α = 0.573 degrees) => d = 50/[tan 3 degrees - tan 0.573 degrees] = 1,179 feet (360 meters)

Case 2 (RW with 1% upward grade, α = 0.573 degrees) => d = 50/[tan 3 degrees + tan 0.573 degrees] = 801 feet (244 meters)

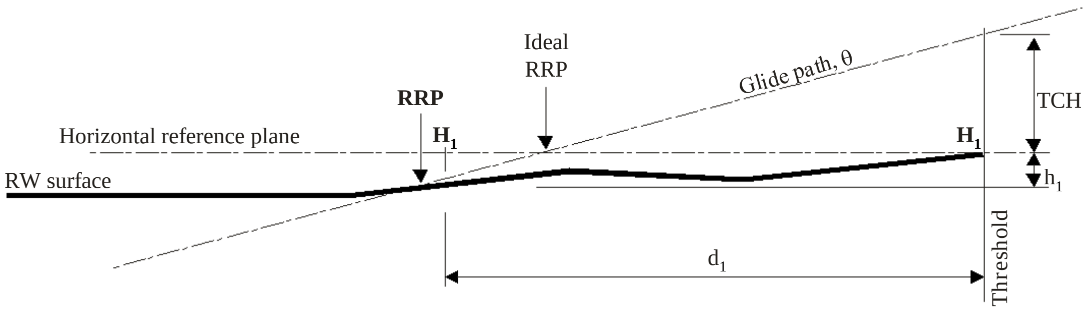
Case 3 (RW is level - 0% grade, α and tan α are both 0) => d = 50/[tan 3 degrees] = 954 feet (290 meters) [*not illustrated*]

While the slope should be constant through the first part of a runway, if the existing slope varies too much to directly apply Case 1, 2 or 3, then a trial method illustrated by Case 4 can be used. In all cases, the location of the glide path intercept with the actual runway surface (RRP) must be determined.

Case 4 - Runway grade varies too much to apply above methods => [*See sheet 2 of 2*]

Figure 12-7 Siting PAPI without an ILS Glide Slope (2 of 2)

c. Case 4 - Runway with varying grade.



Use this method if longitudinal runway grade changes within 2200 feet (671 meters) from the runway threshold.

Consider that a 0.1% change in runway grade at about 500' (150M) from threshold translates to a 6" (15cm) change in elevation at 300M (1,000'), and about a 10' (3M) error in calculating the RRP, using the runway grade beginning at the threshold. The trial method requires elevation data along the runway centerline in proximity of the PAPI site.

(1) Select a trial value for d_1 (“d”). [*Case 1 or Case 2 can be used to select initial trial value*].

(2)At distance d_1, determine elevation difference from threshold ($\mathbf{H_0 - H_1 = h_1}$)

(3) Test d_1 and h_1 in following equation: $\mathbf{\frac{TCH + h_1}{d_1} =? \tan\theta}$

[*NOTE: tan θ = 0.0524 for glide path angle of 3* .]

(4)If value in (3) is larger than tan θ, then increase d, determine new h, and test equation in (3). If value is smaller than tan θ, then decrease d, determine new h, and test equation in (3). Continue until within about ±0.0001 of tan θ [*this yields a value for “d” within about ±2' of where RRP should be located* .

Example data from field survey				
Point	Station	D	H	h
Thld, 0	0+00	0	110.4'	-
1	9+50	950'	114.6'	4.2'
2	10+00	1,000'	115.0'	4.6'
3	10+50	1,050'	115.4'	5.0'

EXAMPLE Case 4 (Assume the following: TCH = 50', θ = 3°).

At d_1 = 950', h_1 = 4.2', and (TCH+h)/d = 0.0571 (too large)

At d_2 = 1,000', h_2 = 4.6', and (TCH+h)/d = 0.0546 (closer)

At d_3 = 1,050', h_3 = 5.0', and (TCH+h)/d = 0.0524 (matches tan θ - OK)

[*NOTE: Suggested longitudinal tolerance for locating PAPI is + or - 10'*.]

DEFINITIONS:

RRP = RW reference point, where PAPI is located based on adjustment for runway grade.

Ideal RRP = RW reference point if runway has 0% grade (no slope).

RW = Runway

TCH = Threshold crossing height

d = Distance PAPI is located from runway threshold, based on adjustment for runway grade.

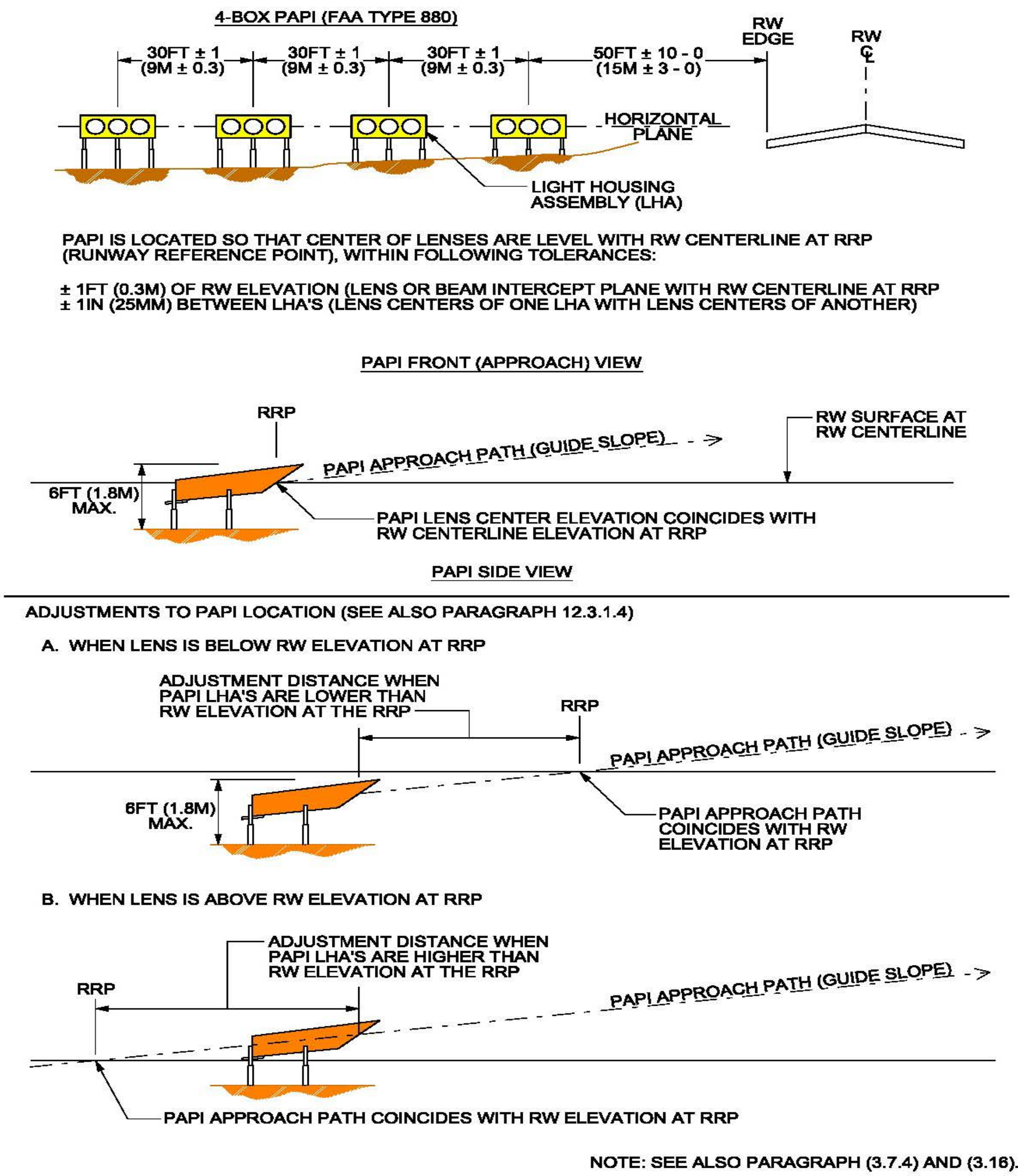
θ = Glide path angle, degrees (from horizontal).

α = Runway slope, degrees (use positive value in above equations).

h = Elevation (height) difference between RW threshold and RRP, measured on RW centerline surface.

H = Elevation at a point along runway centerline.

Figure 12-8 PAPI Positioning Guidance



12-3.1.4.3 At locations where snow is likely to obscure the light beams, the light units may be installed so the top of the unit is a maximum 6 feet (1.8 meters) above ground level. This may require locating the light units farther from the runway edge to ensure adequate clearance for the most critical aircraft. If the light beams are higher than the allowable tolerance, with respect to the elevation of the runway centerline (raising the TCH for the visual glide path), the PAPI may be relocated closer to the threshold to maintain the RRP and TCH.

12-3.1.4.4 The cross slope at the preliminary RRP location may result in the light units sitting too high or too low with respect to the runway centerline elevation. In such cases, the PAPI may be relocated closer to or farther from the threshold to maintain the RRP and TCH and remain within tolerance.

12-3.2 Other Dimensions and Tolerances for PAPI.

12-3.2.1 Distance from Runway Edge.

Install the inboard PAPI light unit no closer than 50 feet, +10 feet –0 feet (15 meters, +3 meters –0 meters) from the runway edge, or from the edge of other runways or taxiways.

12-3.2.2 Separation Between Light Units.

Provide lateral separation of 30 feet (9 meters) between light units. This may be reduced to no less than 20 feet (6 meters) if warranted by conditions. The distance between light units must be equal and not vary by more than 1 foot (0.3 meters).

12-3.2.3 Azimuthal Aiming.

Aim each light unit towards the approach zone on a line parallel to the runway centerline, within a tolerance of ± 0.5 degree.

12-3.2.4 Mounting Height Tolerance.

The beam centers of the four light units must be within ±1 inch (±25 millimeters) of a horizontal plane. This plane must be within ±1 foot (±0.3 meters) of the elevation of the runway centerline at the intercept point of the visual glide path with the runway (RRP), except for adjustments under conditions in paragraph 12-3.1.4.

12-3.2.5 Tolerance Along Line Perpendicular to Runway.

The front face of each light unit in a light bar must be located on a line perpendicular to the runway centerline within a tolerance of ±6 inches (±150 millimeters).

12-3.2.6 Vertical Aiming of Light Beams.

For 4-box L-880 PAPI, the units are aimed as shown in Table 12-4.

Table 12-5 Aiming of FAA Type L-880 PAPI Relative to Glide Path

Light Unit	Aiming Angle (in minutes of arc)	
	Standard installation	Height Group 4 Aircraft on Runway with ILS
Unit nearest runway (#1)	30' above glide path	35' above glide path
Next adjacent unit (#2)	10' above glide path	15' above glide path
Next adjacent unit (#3)	10' below glide path	15' below glide path
Next adjacent (outside) unit (#4)	30' below glide path	35' below glide path

12-4 PULLING CABLE INTO DUCT.

12-4.1 Pull cable into ducts carefully to prevent harmful stretching of the conductor, injury to the insulation, or damage to the outer protective covering. Duct should be verified as open, continuous, and free of debris prior to installing cable. The following summarizes guidance for pulling cable from FAA Specification FAA C-1391. This document may be referenced for additional information.

12-4.2 Seal all cable ends with moisture-sealing tape before pulling, and maintain seals until connections are made. All cables to be installed in one duct should be pulled at the same time. Splices should not be pulled into a duct.

12-4.3 Apparatus for pulling cable at entrances to structures may include a pulling tube or framework and two sheaves. The diameter of the sheaves should be at least 10 times the diameter of the largest cable to be pulled. Cable may be pulled by power winch or by hand. Adequate cable pulling compound should be used of an approved type (do not use petroleum grease).

12-4.4 Structures such as manholes, hand holes, junction boxes, and light bases are typically spaced so as to avoid excessively long cable pulls. The spacing should not exceed 600 feet (180 meters), and spacing not more than 400 – 500 feet (120 – 150 meters) is preferred.

12-4.5 If possible, the maximum allowable cable length to be pulled should be obtained from the cable manufacturer. An estimate of the absolute maximum length of pull based on new, level, straight plastic duct and the use of adequate pulling compound is as follows:

$$L = T/CW$$

Where:
L = Length of cable pulled (in feet)
T = Total tension (in pounds)
C = Coefficient of friction (0.3 for single cables, 0.4 for multiple cables)
W = Weight of all cables being pulled (in pounds/foot)

12-4.6 A dynamometer should be used to monitor the cable tension during pulling. Alternatively, a contractor may adapt a rope harness properly sized to limit pull tension. Types and sizes for ropes used in this manner may be found in FAA C-1391 Table 1. Maximum pulling tension should be no greater than manufacturer's data on allowable cable pulling tension. Any combination of a group of cables to be pulled into a duct must not exceed the sum of individual allowable tension of each cable plus 15 percent. Typical examples of the allowable maximum tension for various types of cable are shown in Table 12-5.

Table 12-6 Maximum Allowable Non-Armored Cable Pulling Tension, Using Dynamometer

Cable	Tension Lb (Kg)
2 – 1/C AWG #8 solid (10 square mm)	275 (125)
3 – 1/C AWG #8 solid (10 square mm)	367 (167)
4 – 1/C AWG #8 solid (10 square mm)	550 (250)
2 – 1/C AWG #6 stranded (16 square mm)	420 (191)
3 – 1/C AWG #6 stranded (16 square mm)	630 (286)
4 – 1/C AWG #6 stranded (16 square mm)	840 (382)
1 – 2/C AWG #8 stranded (10 square mm)	305 (139)
1 – 3/C AWG #8 stranded (10 square mm)	395 (180)
1 – 4/C AWG #8 stranded (10 square mm)	585 (266)
1 – 2/C AWG #6 stranded (16 square mm)	455 (207)
1 – 3/C AWG #6 stranded (16 square mm)	685 (311)
1 – 4/C AWG #6 stranded (16 square mm)	880 (400)
1 – 6/C AWG #12 stranded (4 square mm)	315 (143)
1 – 12/C AWG #12 stranded (4 square mm)	630 (286)
1 – 12 pair AWG #19 solid (0.75 square mm)	230 (105)
1 – 25 pair AWG #19 solid (0.75 square mm)	541 (246)
1 – 50 pair AWG #19 solid (0.75 square mm)	1,061 (482)
1 – 100 pair AWG #19 solid (0.75 square mm)	2,000 (909)

12-4.7 The pressure on a cable or cables being pulled is affected by a radius or bend in a duct. For non-straight segments of duct the following, based on manufacturer information, is recommended as a guide in limiting the tension with duct radius (T is the maximum allowable pulling tension, and R is the radius of the duct):

$$T(lbs) / R(ft) \leq 300 \text{ (English Units) or } T(kg) / R(m) \leq 456 \text{ (Metric Units)}$$

12-5 ICE DAMAGE PREVENTION.

Water in light bases is very common. In cold regions placing several 2 by 8 inch (50 millimeter by 200 millimeter) closed cell foam disks in the light base will help prevent ice damage to the base, light fixture and isolation transformer.

CHAPTER 13 \1\ CHARACTERISTICS OF AIRFIELD GROUND LIGHTING

13-1 GENERAL.

Airfield ground lighting (AGL) typically includes separate series-circuited lighting systems that provide visual guidance to the pilot for aircraft operations. The systems usually have brightness control for adapting to various visibility conditions. The types of lighting systems installed for a particular runway are an important part in determining the conditions under which aircraft operations are allowed (e.g., Visual Flight Rules (VFR), Category I, Category II, or Category III). The various lighting systems that may be installed for a runway are shown in Figure 13-1. Not included in this figure are the several approach lighting systems (ALS) which may also be installed. Details for lighted approach aids, runway lighting systems, and taxiway lighting are provided in Chapter 3, Chapter 4 and Chapter 5, respectively.

13-1.1 Airfield ground lighting is characterized by constant current series electrical circuits, which provide constant current for intensity control of lighting components. This system allows for selectively changing the brightness of the lighting components by increasing or decreasing the level of the constant current in the series loop. While some older systems use constant voltage for shorter length series circuits, most systems today are constant current type. The series circuit provides energy at constant current to each device (such as a light or sign) on the circuit, supplied from a CCR.

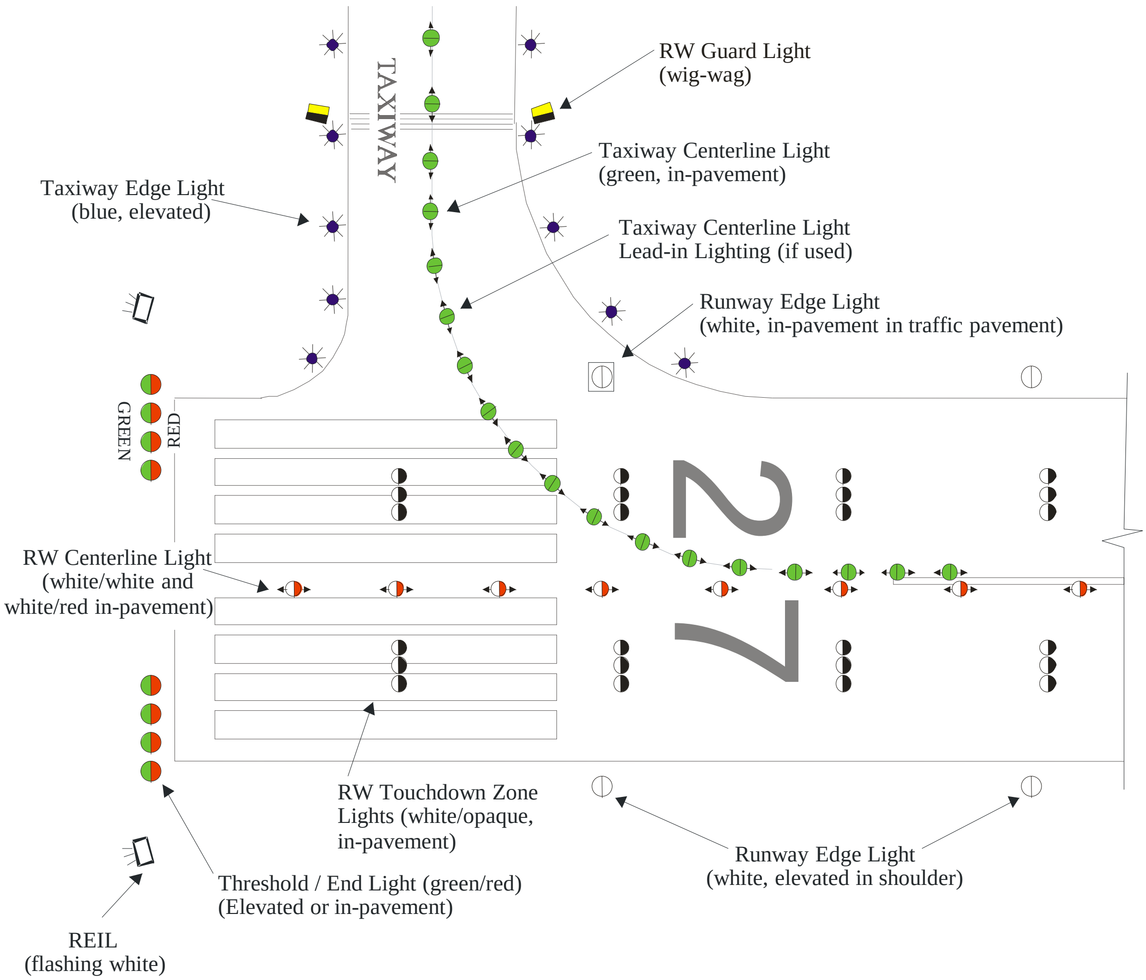
13-1.2 The major parts of a series circuit are: the CCR (power source), the primary circuit cable, isolation transformers, and lighting components (such as lights and signs). The isolation transformers are connected in series on the primary side, with connected loads on the secondary side of each isolation transformer (Figure 13-2). The system is characterized as follows:

- A constant current is delivered along the entire loop on the primary side of the isolation transformers, independent of the number of lighting loads. Power is provided by the CCR.
- The magnitude of the voltage along the series circuit primary depends on the number and size of connected lighting loads. The voltage along the primary cable will measure different at each point. (Calculating voltages for the constant current series circuit is illustrated later in this chapter.)
- The circuit is considered high voltage on the primary side, which typically may be several thousand volts (5kV cable is used), and low voltage on the secondary side or load side of the isolating transformers, which typically is less than 30V.

- The isolation transformer provides an effective short for the primary circuit in the event of a lamp filament failure, which opens the secondary circuit. This prevents failure of a connected light from causing an open condition on the series primary circuit.

- A constant current series circuit can also be used to power equipment with specific voltage requirements. In this case a power adapter is used. The power adapter also serves to isolate the device from the primary side similar to an isolation transformer. Examples of equipment which may be connected to series lighting circuits include: wind cones, PAPI, REIL, and others which typically may require 120/240V power. NOTE: The lighting circuit must be ON for the equipment to receive power with this type of arrangement.

Figure 13-1 Typical AGL Layout



NOTES:

1. RW EDGE LIGHTING: For high intensity system (HIRL) bidirectional, white/white, with yellow on rollout for last 2,000' (610M) (L-862 elevated, with L-850C for in-pavement). Runway edge lights are spaced about 200' (61M) apart.

2. THRESHOLD/END (T/E) LIGHTS: Group of 4 or 5, spaced 10' (3M) apart symmetrical about centerline. Outer light in each group lines up with RW edge lights. Groups may be wing-out bars, where inner light in each group lines up with RW edge lights.

   T/E lights show green to aircraft approaching for landing, and red to landing aircraft coming to end of the RW.

3. RW CENTERLINE LIGHTS: Bi-directional white/white, with alternating red/white and white/white from 3,000' to 2,000' (915M to 610M) from end of RW, and red/white for last 2,000' (610M) of RW.

4. RW TOUCHDOWN ZONE LIGHTS: Uni-directional, with white towards approaching aircraft.

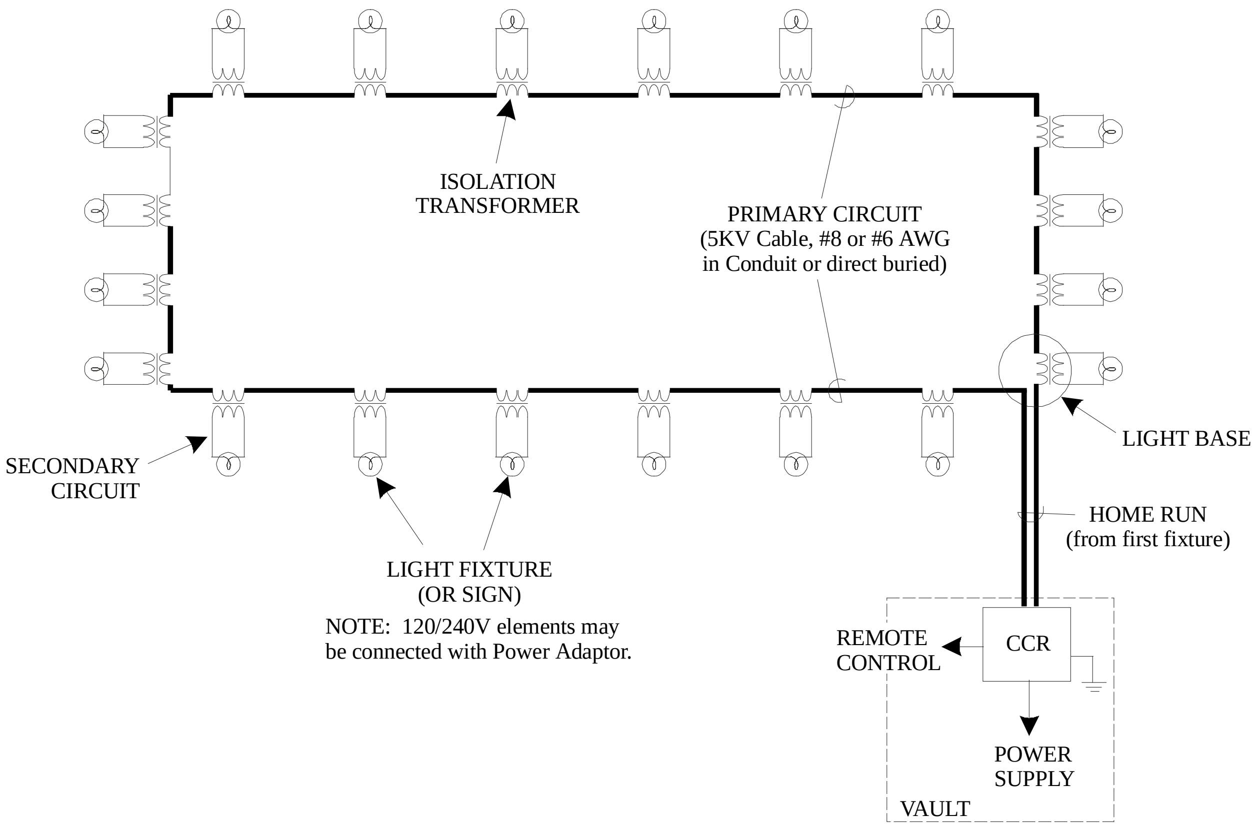
5. TW EDGE LIGHTS: Omni-directional blue (L-861T).

6. TW CENTERLINE LIGHTING: Bi-directional green/green, but may be green/yellow or yellow/yellow for some conditions.

7. REIL: Runway End Identifier Lights, discharge type flashing white lights (about 90 times/min.), Aimed 15 deg outward and 10 deg above horizontal.

8. RW GUARD LIGHT: Uni-directional, flashing yellow. Elevated outside TW, or may be bar of in-pavement across pavement (L-804).

Figure 13-2 Typical AGL Series Lighting Circuit



13-1.3 Parallel circuits are briefly discussed as these may be used to serve facilities such as wind cones, PAPI, REIL, and others. This may be directly from a power source, or via power adapter from a series lighting circuit.

13-2 POWER.

Upstream power for the CCR feeding the AGL may be from a variety of sources. Equipment vaults for AGL may be fed from a variety of sources, and in many cases have emergency standby generator power with automatic transfer in case of outages. Older systems typically feed the CCR at 2400V, while newer installations feed vault CCRs at 480V; 2400V input CCR equipment is for replacement only. The upstream power distribution feeding the CCR is not covered in this section.

13-3 CONTROL AND MONITORING SYSTEMS.

Traditional control/monitoring systems, both military and commercial, are relay systems. L-821 relay panels are very reliable and are suitable for nearly all military airfields. Typically, cables required for these types of systems are multi-pair (50 or more pairs) cables to connect the airfield lighting vault on the airfield with the air traffic control tower. On many air bases, the distance between the two facilities is great, resulting in a costly cable installation with the cable vulnerable to possible damage or failure of one or more pairs in the cable. In addition, these communications cables require separate duct systems to eliminate interference from the power cables. The traditional relay panel and multi-conductor control cable can also be simplified by using a multiplexer, which requires only one pair cable to communicate between the vault and tower (or other station). A multiplexer can also be built into a PLC system.

13-3.1 Some airfield control/monitoring systems have been installed using Programmable Logic Controllers (PLCs). The PLC industrial systems use high I/O modules that reduce the need for multi-pair cable installation. Cables with 2 to 6 pairs are typically needed, although fiber optic cable can also be used.

13-3.2 PC-based systems are currently being used, with computers (Windows 7 operating system is approved by AF Chief Information Officer) located in the tower, the vault, and/or other work stations. These systems have the capability of displaying the necessary information on a monitor. This is the most flexible system in use today, with off-the-shelf units readily available. Typically, standard operating software is used, and off-the-shelf graphics software is tailored for a specific site. The communications cable requirements are 2 to 6 pairs of cable or fiber optics. Fiber optic cable eliminates the need for separate ducts since there will be no interference between power cable and fiber optic cable. The control panel typically is a touch-screen type. At the time of this writing the essential system PCs are recommended to have the following characteristics: 19" (480 millimeter) rack mount form factor, fully enclosed metal housing, redundant hot-swappable solid state software and data storage devices, redundant hot-swappable cooling system, redundant hot-swappable power supplies. The systems incorporate uninterruptible power supplies (UPS) for primary power to all system components required for normal operation for a duration of fifteen minutes.

13-3.3 Compared to the traditional FAA Type L-821 control/monitoring systems, the PLC or PC-based systems are easily expanded and provide data for the air traffic controller and maintenance personnel. Refer to FAA AC 150/5345-56. Some industrial standards the PLCs meet are NEMA ICS1, NEMA ICS2, NEMA ICS 3, UL 508, ANSI/IEEE C 37.90.1-1989, CAN/CSA C22.2 No. 142, MIL-STD-461B, MIL-STD-810 and ISO 9000.

13-3.4 Often, the computerized system is based on one specific manufacturer's equipment. This limits the facility to one manufacturer for both service and parts. A good system design will avoid this by establishing competitive parameters in the procurement document.

13-3.5 Considerations for the design of a computerized control/monitoring system are in paragraph 13-18.6.

13-3.6 Factors for consideration when selecting a control system:

- Monitoring AGL equipment: the PLC based system must be customized for each type of CCR.

- For PC based systems, software has been developed and tested, and is easily configured to monitor AGL equipment. Software developed for PC systems is specific for the task and works with all types of CCRs and other related AGL equipment.
- With PLC systems there are established industrial standards and criteria for mean-time-between-failure (MTBF).

13-4 CONSTANT CURRENT SERIES CIRCUITS.

A constant current series circuit is an ungrounded system, where circuit elements are connected in a string with the same current flowing to each element. The circuit is one continuous loop starting and ending at the power source (the constant current regulator for the AGL circuit). The CCR maintains a constant current independent of the load on the circuit.

13-4.1 Circuit Failure.

With constant current, a short-circuit across the output of the CCR is a no-load condition, and an open-circuit is an overload. In a simple series circuit, a lamp failure would cause an open-circuit. For this reason a bypass device such as an isolating transformer is installed between the primary side and secondary side as part of each light fixture connection, or for connecting other loads such as guidance signs. In certain cases, such as for approach lights where 5 steady-burning lights are on a single secondary circuit isolated from the primary series circuit by one or more isolation transformers, a film disc cutout may be used. Film disc cutouts operate in such a way that when a lamp burns out, the film-disc cutout shorts the failed lamp, thereby allowing current to flow to the remaining connected fixtures.

13-4.2 Advantages of Series Lighting Circuits.

- All lamps operate at the same current, hence same intensity.
- Single-conductor cable of one size and insulation voltage rating can be used throughout the circuit.
- Intensity control of lights can be obtained over a wide range.
- A single ground fault along the circuit will not affect light operation.
- Ground faults are easily located.

13-4.3 Major Disadvantages of Series Lighting Circuits.

- Installation costs are high when considering the CCR and isolating transformers.
- Poor efficiency in use of electrical power.
- All components on the primary side must be insulated for full voltage.

- An open-circuit anywhere on the primary side makes the entire circuit inoperative and could damage cable insulation or the CCR.
- Locating faults such as open-circuit conditions can be time-consuming and may be difficult.

13-4.4 Typical Usage.

Series circuits are usually used for runway and taxiway lighting systems and most steady-burning lights of approach lighting systems because they provide more uniform intensity and better intensity control of the lights.

13-5 CONSTANT CURRENT REGULATORS.

The power input to the AGL circuits is controlled by the CCR to which the circuit is connected. While the CCR produces constant current to the circuits depending on the brightness step setting, the voltage input to the circuit varies with the actual load.

13-5.1 Basically, there are three types of constant current regulators used at airports:

- Resonant network circuit (ferro-resonant type using a resonant network control system to produce output current).
- Saturable reactor (ferro-resonant type, where the amount of reactor saturation via closed control loop determines output current).
- Silicon controlled rectifier (SCR) (uses SCR type thyristors to convert constant voltage source to constant current output, with solid state control circuiting). These are not ferro-resonant and are not approved for new installations.

13-5.2 The first two types have been reliable over the years, but fluctuations in input voltage will cause corresponding changes in the output current. Most CCRs now manufactured are SCR type.

13-5.3 Tests have shown that, as circuit load increases toward the rated capacity of a CCR, harmonic distortion is reduced and the wave form approaches a sine wave. This suggests that loading closer to rated capacity results in better circuit performance. However, lamp failures and other factors may increase the output voltage, and this needs to be considered when matching circuit load to CCR size.

13-5.4 CCRs have "taps" for adjustment to accommodate loads. Some manufacturers have introduced taps which automatically adjust to the circuit load, while others use manual taps which are typically set when the CCR is installed, but can be changed later to accommodate changes in the load.

13-5.5 The allowable tolerances in CCR output current are shown in FAA AC 150/5345-10. The allowable tolerances are small, because small changes result in large changes in light output. For a 6.6 amp circuit, reducing the current by 3 percent (to 6.4 amps) will reduce the light output over 15 percent, and reducing the current by 6 percent (to 6.2 amps) will reduce the light output by over 30 percent. The impact is the opposite on lamp life, where a current lower than maximum will significantly increase lamp life, and a higher current will reduce lamp life. The percent of full brightness obtained at each of the nominal current levels for 3 and 5 step systems can be found in paragraph 12-1.11.

13-5.6 15KW through 30KW CCRs may be selected for either 20 or 6.6 amperes output current. Intensity steps are either 5-step or 3-step for all CCRs.

13-5.7 50 kW and 70 kW regulators operating with 20A output current are not approved for new installations and are allowed for replacement only. Regulators with 2400V input are not approved for new installations.

13-6 REGULATOR SIZING.

13-6.1 For steady burning loads such as edge, centerline and touchdown zone lights sizing the regulator is fairly straight forward. Steady burning lights and circuit conductors are resistive loads and therefore will vary as the current varies. Current transformers are impedance loads and have the same electrical characteristics as resistive loads. See Figure 13-3A for calculating the load as the current varies; i.e., at the lowest brightness step. Using Ohms Law (P=IE), the maximum load at the lowest brightness level for a five-step regulator is determined by the ratio of the currents; i.e., (2.8/6.6) or (8.5/20) or 42.4% of the regulator rating. For a three-step regulator it is 4.8/6.6, or 72.7% of the regulator rating. It can be seen that these load percentages are greater than the ones calculated in Figure 13-3A. Therefore, a regulator fully loaded only with lights (and associated transformers) will not overload at the lowest current level.

Figure 13-3A Calculation of Steady Burning Load at the Lowest Brightness Level

DATA:

P = Steady Burning Light Load

I = Regulator Current

R = Steady Burning Light Load Resistance

Subscript $_H$ is the value at the Highest Brightness Step

Subscript $_L$ is the value at the Lowest Brightness Step

Ohms Law: $P = I^2 \times R$

CALCULATIONS:

$P_H = (I_H)^2 \times R \rightarrow R = P_H / I_H)^2$

$P_L = (I_L)^2 \times R \rightarrow R = P_L / (I_L)^2$

The resistance of the lamp filaments remains constant, therefore

$P_L / (I_L)^2 = P_H / I_H)^2 \rightarrow P_L = P_H \times (I_L)^2 / I_H)^2 \rightarrow P_L = P_H \times (I_L / I_H)^2$

The effective load of the steady burning fixtures at the lowest brightness step (P_L) is the load at the highest brightness step (P_H) times the squared ratio of the low (I_L) and high (I_H) currents.

For a 6.6A five step regulator the current ratio squared is $(2.8/6.6)^2$ or 0.18 or 18%.

For a 20A five step regulator the current ratio squared is $(8.5/20)^2$ or 0.18 or 18%.

For a three step regulator the current ratio squared is $(4.8/6.6)^2$ or 0.53 or 53%.

SUMMARY:

For five step regulators the load of steady burning lights at the lowest brightness step is 18% of the load at the highest brightness step.

For three step regulators the load of steady burning lights at the lowest brightness step is 53% of the load at the highest brightness step.

13-6.2 When loads such as REILs, PAPIs, windsocks and airfield signage are connected to a series circuit, consideration must be given to accommodate the effect of these loads on the regulator. Loads such as these have unique power requirements. PAPIs, signs and windsocks must maintain a constant level of light output and require a constant input voltage. When they are connected to a series circuit that has varying current levels the power from the current regulator must be converted to a constant voltage source within the equipment. Airfield signs are required to maintain a constant level of illuminance on the sign face and electronics are needed to operate them from a varying current source. The commonality with all these loads is that they present a constant load to the regulator regardless of current level on the circuit. When the circuit is a combination of steady burning lights and signs or other constant loads, the engineer must insure that the calculated load at the lowest brightness level does not exceed the percentage of the regulator rating as indicated above. Figure 13-3B shows an example where the regulator is over loaded at the lowest brightness step. Although most regulators will continue to operate when over loaded there are risks associated with that. Depending on the degree of overloading, negative effects may include the regulator's inability to stay within the FAA current tolerances. The result would be improper brightness levels. Operating an overloaded regulator can also lead to the premature failure of critical components because the regulator will raise the output voltage to maintain the required current level.

13-6.3 In its Advisory Circulars, the FAA does not address the load imposed on the CCRs by the constant current to constant voltage adapters necessary for REIL operation, or the REIL that are connected into series circuits. With the constant flashing of the lights and the resulting discharging of the capacitor, the REIL place a very short, but heavy, pulsing load on the regulator. Occasionally, this type of pulsing load results in pulsation of the illumination of the steady burning lights on the circuit. This "reflective" pulsation depends on the characteristics of the regulator powering the circuit and on the characteristics of the REIL connected into the circuit. The design engineer needs to ascertain from the regulator manufacturer which type of CCR will handle the overall series circuit load with the addition of the REIL pulse-type load without adverse effect. It has been shown that the problem will be minimized if the REIL are connected into series circuits that have primarily incandescent loads and the circuit load approaches the capacity of the regulator.

13-6.3.1 The actual regulator capacity needed to operate the REIL properly is much greater than the rated load indicated in the typical product literature. Usually the average power requirement is provided; however, the regulator has to accommodate the instantaneous, or pulsing, load to provide the flashing characteristics of the REIL. That REIL may be rated to require only 400 watts to operate, but may actually require up to 4 kilowatts of regulator capacity to meet the pulsing load requirements when also including the impact of the series circuit adapters between the series circuit and the REIL. The series circuit adapters convert 6.6 amps to 120 volts for REIL operation, and often have low efficiency that imposes higher than expected loads on the regulator. The proper sizing of the regulator requires careful consideration of the types of loads on the circuit and the true impact of those loads on the regulator.

Figure 13-3B Sample Calculation of CCR with High Signage Load

DATA:

CCR: 30KW, 480V input, 5-step (2.8A – 6.6A)

Cable: AWG #6, 5kV, L-824 Type C, 20,000 feet primary circuit

Circuit Loads:	Steady Burn Lights	13,000 W
	Transformer Losses (26% of Light Load)	3,380VA
	Signage	13,000 VA
	Cable losses (19 VA / 1,000’)	383 VA

Circuit power factor is assumed to be 0.85.

CALCULATIONS:

1. Total connected load, VA = 13,000 + 3,380 + 13,000 + 383 = 29,763 VA
2. CCR Rated Load @ Lowest Brightness Step: (Reference paragraph 15-6.1)

   30KW x (2.8/6.6) = 12.72 KW or 14.97 KVA

3. Calculated Load @ Lowest Brightness Step: Reference Figure 3-13A(Reference Figure 15-3A)

   (Lights + Losses) x $(2.8/6.6)^2$ + Signage =
   ((13,000 + 3,380 + 383) x 0.18) + 13,000 = 16,017 VA

Because the signage load does not change for the various brightness steps the resulting demand on the regulator at the low step (16.02 KVA) is higher than the rated load for the regulator at the low step (14.97 KVA). While the load at the highest step (29.76 KVA) is less than the rating of the regulator, it will be overloaded at the lowest step; therefore, do not operate in this load configuration.

Loads such as signs, REILs, PAPIs and windsocks are constant regardless of the brightness level and must be carefully considered in circuit design and regulator sizing.

Where:

E = volts (V)	W = Wattage of light fixtures
I = Current, in amperes (A)	VA = Volt-Amps
P = Power Load	kW = kilowatts
	kVA = kilovolt-amps
	P.F. = Power Factor

Ohms Law: P = IE, E=IR, $P=I^2R$

13-6.3.2 As described in paragraph 13-6.1, the REIL can impose significant loads on the CCR powering the circuits to which they may be connected. It is preferable, if the budget permits, to have separate circuits with 240/120 volt service to power the REILs, thereby eliminating any adverse impacts on series lighting circuits.

13-6.3.3 Sample calculations and comparison with test data, as well as guidance for setting taps, are shown in Figure 13-4. A table format for calculating airfield lighting series circuit loads is shown in Table 13-1. Carefully consider the notes in Table 13-1 when determining load values.

13-6.3.4 Normally the airfield signage load on a circuit is less than the steady burning light load. When the sign load is significant on a circuit, care must be taken to prevent overloading the regulator at the lowest brightness step. Figure 13-3B shows an example calculation where the sign load is high enough to present a problem.

13-7 CABLE.

The primary series circuit utilizes FAA L-824 Type B or C cable. L-823 connectors are used for connections. For 6.6 ampere primary series AGL circuits, an AWG #8 conductor is normally used. An AWG #6 conductor is used with 20 ampere circuits. For the secondary side lighting loads, a two-conductor AWG #10, 600V insulation is normally used.

13-7.1 The cable is installed in conduit, although it may be direct buried (L-824 cable is rated for direct burial). It is important that insulation is intact and that proper connections are made. Deteriorated or damaged cable can result in current leakage and may present a high voltage hazard to maintenance personnel. While installation in conduit may cost more, this method usually provides longer circuit life, and makes troubleshooting and replacement of cable segments easier. Where cable is installed in the regulator vault it must be in conduit, wireway or conduit or wireway in a floor trench with a solid top. L-824 cable is not rated for installation in cable tray.

13-7.2 The types of faults associated with series circuit cable are open circuit conditions and shorts-to-ground. An open circuit condition will turn off all the lights. A single short-to-ground will not impact the lighting, but multiple shorts-to-ground can cause dimming of lights or outages for portions of the circuit or for the entire circuit.

Figure 13-4 Sample Calculation of CCR Test Data

(1 of 2)

SAMPLE CALCULATIONS, CCR TESTING

DATA: CCR: 30KW, 480V input, 5-step (2.8A - 6.6A), with Power Factor of 0.43

Cable: AWG #8, 5kV, L-824 Type C, 20,000 feet primary circuit

Circuit Load: 70 Edge lights @ 120W (100W transformer)
16 Threshold/end lights @ 200W (200W transformer)

10 signs @ 100VA (at step 5)
5 signs @ 200VA (at step 5) } *(at the input to the isolation transformer*)
3 signs @ 300VA (at step 5)

1 REIL system (2 units) @ 400W, connected by power adapter. [Note that in this example the REIL is only adjusted for PF. Some REIL may require further adjustment, based on manufacturer's information.]

Cable losses (resistance) @25°C: 0.68Ω/1,000'
Fixture losses (obtain from Mfg - This example assumes 18 percent for 120W, and 11 percent for 200W lights)

CALCULATIONS:

1. CCR rated output voltage, V_{RMS} = 30KW/6.6A = 4,545V

2. Total connected load, KVA = $\frac{[W_{lamps} + W_{REIL} + VA_{signs}]/PF + Fixture\ Loss + Cable\ loss}{1,000}$

Fixture losses = (70 x 120 x 0.18) + (16 x 200 x 0.11) = 1,864W

Cable losses = $I^2R = [6.6]^2 \times (0.68 \times 20)$ = 592W

TOTAL KVA = $\frac{[(70x120) + (16x200) + (400) + (10x100 + 5x200 + 3x300)]/0.43 + 1,864 + 592}{1,000}$

= 17.57 KVA

where:

KVA = kilovolt-amperes
V = volts
A = amperes
KW = kilowatts
CCR = Constant Current Regulator
R = Resistance in Ohms, Ω
V_{RMS} = Rated output voltage of CCR
W_{lamps} = Wattage of light fixtures
W_{REIL} = Wattage of REIL
PF = Power Factor
I = Current, in amperes

Figure 13-4 Sample Calculation of CCR Test Data (Cont.)

(2 of 2)

SAMPLE CALCULATIONS, CCR TESTING (Cont.)

NOTE: Traditional method for determining the load KW assumes that the CCR powers a unity power factor lamp circuit. With REILs, new type signs, and runway guard lights (wig-wags), a unity power factor is not representative, and power factor must be considered.

MEASURED RESULTS (Case 1):

- Output current at Step 5 = 6.52A
- Output voltage at Step 5 = 2,880V

Total KVA Load based on measurements = 6.52A x 2.88kV = 18.8KVA

CONCLUSIONS: The output current is within FAA tolerance. The total KVA measured is slightly higher than the calculated load. This may be due to slightly higher actual fixture losses than assumed values. Overall, the CCR is operating satisfactorily.

MEASURED RESULTS (Case 2):

- Output current at Step 5 = 6.52A
- Output voltage at Step 5 = 1,880V

Total KVA Load based on measurements = 6.52A x 1.88kV = 12.3KVA

CONCLUSIONS: The output current is within FAA tolerance. The total KVA measured is significantly less than the calculated load. The results suggest a partial shorting of the load.

MEASURED RESULTS (Case 3):

- Output current at Step 5 = 6.30A
- Output voltage at Step 5 = 2,550V

From test results, Total KVA Load = 6.30A x 2.55kV = 16.1KVA

CONCLUSIONS: The output current is below that allowed by FAA tolerance. The total KVA measured is below the normal value (2,880V) as found in first test. Results indicate faulty CCR. Perform a short circuit test on the CCR before it is used.

NOTE: Analysis compares KVA with KW. This is because the rated output of the CCR is specified in KW in compliance with FAA AC 150/5345-10. However, load measurements result in KVA. The requirement for total load in KVA to be below the CCR output in KW under operational conditions ensures that the CCR is not overloaded.

Table 13-1 AGL Series Circuit Load Calculation Data Sheet

CKT No.	Regulator (CCR) (Runway or Taxiway, Etc.)	CKT Type (Amps)	Cable Size (AWG)	CCR Rating (KVA) (1)	CCR Input (V)	Steady Burning Light Load (KVA) (2)	Sign Load (KVA) (3)	Other Loads (KVA) (4)	Total Connected Load (KVA)	Transformer Losses (KVA) (5)	Cable Length FT or M)	Cable Losses (KVA) (6)	Calculated CCR Load (KVA)

NOTES:
(1) CCR rating may be in KW. To determine KVA, divide KW by power factor (PF) and CFR efficiency (EF) based on full load. Obtain PF and EF from manufacturer.
(2) To determine KVA for steady burning lights by summing "[no. of fixtures] x [lamp wattage] / 1000" for all lights on circuit. Steady burning lights can be runway edge lights, threshold/end lights, centerline lights, touchdown zone lights, taxiway edge and centerline lights, and approach lights.
(3) Determine KVA for signs based on manufacturer rating or specified limit VA for each size and length (modules or width) of sign on circuit.
(4) Other loads may be pulsing lights such as REIL. Determine KVA based on manufacturer data for each type.
(5) Isolation transformer losses may be estimated at 26% of connected load.
(6) Determine cable losses based on cable length and manufacturer cable data on conductor resistance. Loss per unit length is typically based on the relationship I^2R = W and assumed PF of unity for the cable.
Typical values for cable losses are: 34VA / 1,000ft (34VA / 300M) for 6.6A circuits with uncoated stranded #8 AWG conductor, and 196VA / 1,000ft (196VA / 300M) for 20A circuits with uncoated stranded #6 AWG conductor.

Refer to Paragraph 5-3.2.3, Color Coding.

13-8 TRANSFORMERS.

The isolation transformer provides: electrical isolation between the high voltage series circuit and the low voltage secondary feeding the lighting load (such as a fixture or sign), constant current output for a constant current input at the correct ratio, and an effective short circuit in the event of an open condition in the light fixture, for example with lamp filament failure.

13-8.1 Isolation Transformers.

With the isolation transformer, only low voltage is brought to the light fixture (via the secondary circuit), and failure of the light does not cause an open condition on the primary circuit that would result in other lights and other connected loads to be shut off.

Isolation transformers for AGL are covered by FAA Specification L-830 (for 60 Hz) and FAA Specification L-831 (for 50 Hz), and are typically 6.6 amperes on the secondary side, with either 6.6 amperes or 20 amperes on the primary side for series lighting circuits at the highest intensity step. The wattage of the isolation transformer is approximately matched to the connected load on the secondary side.

13-8.2 Transformer Load.

Ensure the load powered by the transformer is within ±10 percent of the transformer wattage rating to maintain isolation transformer efficiency. Light fixture manufacturers have their fixtures certified using a specified wattage for the isolation transformers. Use the light fixture manufacturer’s recommended size for isolation transformers.

\4\ 13-8.3 Series Circuit Selector Switches.

Use switches in accordance with FAA AC 150/5345-5, Type L-847. Series circuit selector switches can be high-maintenance equipment and should be avoided whenever possible.

13-8.4 Control Cables.

Control cables for 120 VAC control systems must be multi-conductor, 600 volts, 12 AWG copper, rated for direct earth burial. Cables for 48 VDC control circuits must be multi-conductor, stranded 19 AWG copper, with 300 volt polyvinyl insulation suitable for installation in wet locations and meeting REA Bulletin 345-14 or 345-67. Color-code all conductors.

13-8.5 Constant Current Regulators (CCR).

Use CCRs per FAA AC 150/5345-10 of a suitable type and style. The size selected should normally provide for approximately 20 percent expansion of the load.

13-8.6 Engine/Generators.

Use engine/generators meeting Specification FAA-E-2204 with Type I automatic power transfer. Also see AFMAN 32-1062 and UFC 3-540-01.

13-8.7 Series Cable Selection.

Cables must be unshielded, 5000 volt FAA AC 150/5345-7 (Latest Issue) L-824 cable.

13-8.8 Connectors.

Use connectors meeting FAA AC 150/5345-26 for L-823 plug and receptacle cable connectors to interconnect fixtures, isolation transformers, and distribution cables.

13-8.9 Isolation Transformers.

Use isolation transformers meeting FAA AC 150/5345-47. When specifying, ensure the input/output currents are compatible with the regulator and current rating of the lamp.

13-8.10 Mounting Bases and Transformer Housings.

Use bases meeting FAA AC 150/5345-42. When specifying FAA type bases, use Type L-867 for non-traffic areas (such as elevated light systems located on the edges of runways and taxiways) and Type L-868 for load bearing applications (subject to loading by aircraft, including overruns) containing lights that are in-pavement. Non-metallic bases (FAA Class II) must not be used.

13-8.11 Frangible Supports.

If frangible mounting is required and the device is not provided with an integral fracture mechanism, mount the device on electric metallic tubing (EMT) or intermediate metallic conduit attached to the mounting base by a frangible coupling meeting FAA Drawing C-6046. For additional detailed information about and requirements for frangible supports, see FAA AC 150/5220-23.

13-8.12 Fixtures, Filters, and Lamps.

Use fixtures and lamps as specified for each system. If more than one fixture is connected to an isolation transformer, the fixture must have a shorting device or bypass relay to avoid multiple light outage if a lamp fails. Filter colors must meet the latest FAA Advisory Circular criteria, also refer to the CIE color coordinate diagram. (See Figure 13-1.)***/4/***

13-9 LAMPS.

The connected load typically includes light fixtures, lighted guidance signs, and in some cases other lighted visual aids such as REIL, PAPI, or lighted wind cones.

(a) Runway and taxiway lights may have newer quartz-type lamps or incandescent-type lamps. Quartz-type lamps provide improved photometrics at lower wattage for higher intensity systems, hence lower energy consumption. Quartz lamp life can be significantly reduced if the lamp is installed with bare hands. Fingerprint (oil) deposit on the quartz lamp will cause premature failure.

(b) Light fixtures basically provide a resistive type load on a series circuit. Some items, such as flashing REIL, or signs using electronics to provide light output within a certain range at all circuit intensity steps, introduce other reactive type loads into a circuit, which may distort the waveform and have an adverse effect on performance and control. Incandescent lamps have an initial cost lower than quartz lamps.

(c) Current levels have been established such that, for 5-step system, the light output (brightness) is 100 percent, 20 percent, 4 percent, 0.8 percent, and 0.16 percent. A system with 3-step control provides light output at 100 percent, 30 percent and 10 percent at the respective brightness steps.

(d) FAA-specified types of connected loads that may be used for AGL systems are:

<u>Elevated Light Fixtures</u>

L-860	RW edge, low intensity
L-860E	RW threshold/end, low intensity
L-861	RW edge, medium intensity
L-861SE	RW threshold/end, medium intensity.
L-861E	RW threshold/end, medium intensity (may be used instead of SE for RWs with either REIL, PAPI or medium approach lighting (MALS).
L-862	RW edge, high intensity
L-862E	RW threshold/end, high intensity
L-861T	TW edge
L-804	Runway guard light.
L-862S	Runway stop bar light

<u>In-pavement Light Fixtures</u>

L-850A	RW centerline, high intensity
L-850B	RW touchdown zone, high intensity
L-850C	RW edge, high intensity
L-850D	RW threshold/end, high intensity
L-852A	TW centerline, for straight portion (narrow beam) (non-Category III). Also used for caution bar.
L-852B	TW centerline, for curved portion (wide beam) (non-Category III).
L-852C	TW centerline, for straight sections (narrow beam) (Category III)

L-852D	TW centerline, for curved portion (narrow beam) (Category III)
L-852E	TW intersection (non-Category III)
L-852F	TW intersection (Category III)
L-852G	Runway guard light
L-852S	Runway stop bar light
L-852T	Taxiway/Apron edge

<u>Light Bases for Lights or as Junction Boxes.</u>

L-867	Non-load bearing (used in shoulder areas or other non-traffic areas).	
L-868	Load bearing (used in RW and TW pavements and other aircraft load areas).	
Sizes	A - 10" (25 cm) dia. (L-868 only)	C - 15" (38 cm) dia. (L-868 only)
	B - 12" (30 cm) dia. (L-867 & L-868)	D - 16" (40 cm) dia. (L-867 only)
L-869	In-pavement junction box (used with cables in saw kerfs, 6" (15 cm) dia.)	

<u>Airfield Signs</u>

L-858Y	Direction, Destination and Boundary. Black legend on yellow background.
L-858R	Mandatory Instruction. White legend on red background.
L-858L	TW and RW Location. Yellow legend and border on black background.
L-858B	Runway Distance Remaining. White legend on black background.

<u>Other Examples</u>

L-849	REIL
L-880	PAPI system with 4 light units
L-881	PAPI system with 2 light units

Some of the above have variations specific for certain military applications.

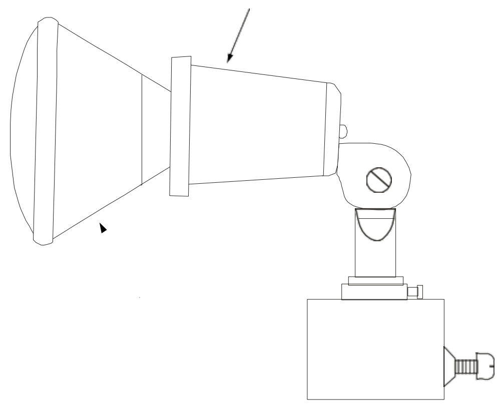
13-9.1 Medium Intensity Approach Light System with Runway Alignment Indicator Lights (MALSR).

See paragraph 3-5.10

13-9.1.1 Centerline Light Barrettes.

Use fixtures meeting FAA-E-2325, PAR-38 lamp holders. (See Figure 13-4.)

Figure 13-5 FAA-E-2325, Elevated, Unidirectional, PAR-38 Lamp Holder



LAMPHOLDER: PAR-38, OUTDOORS, COMMERCIAL TYPE AS DETERMINED BY THE MANUFACTURER.

LAMP: 120V 120W PAR-38
TYPE 120PAR/SP ENERGY SAVING, OR 120V 150W PAR-38

TYPE 150PAR/SP.

POWER UNIT: (NOT SHOWN) DISTRIBUTION VOLTAGE TO 120V RATED, 3-INTENSITY SETTINGS AS REQUIRED BY MANUFACTURER (ONE UNIT FOR SYSTEM)

LAMPHOLDER

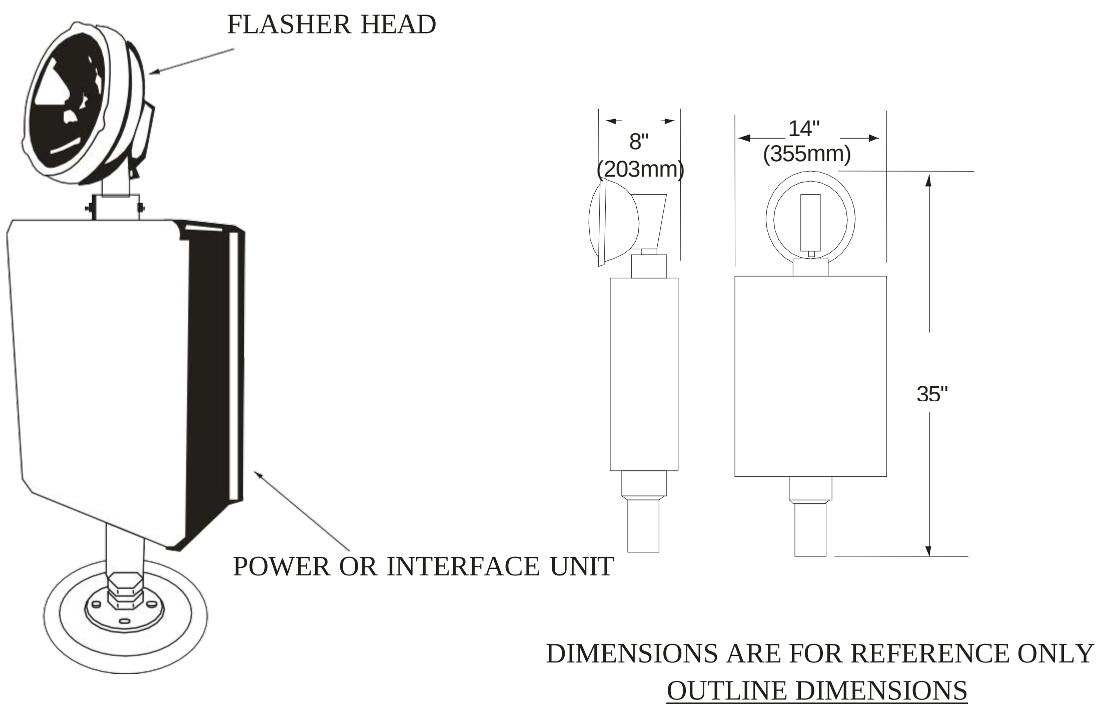
13-9.1.2 General Lamp Guidelines.

Use lamps recommended by the manufacturer to meet the requirement. Different manufacturers may meet the requirement using different lamps. In the interest of energy conservation, the lower wattage lamps are preferred. When using lamps rated at 6.6 amps, they must be connected to individual 6.6/20A isolation transformers. When using lamps rated at 20A, they must be connected to individual 20A/20A isolation transformers. Use 200W isolation transformers, or as otherwise recommended by the lamp manufacturer. If the overall mounting height is greater than 6 feet (2 meters), the lights in a light bar must be connected in series to the transformer specified in paragraph 13-9.5.1. Fixtures connected in series to a single isolating transformer must have bypass relays to bypass failed lamps.

13-9.1.3 1,000-foot Light Bar.

See paragraph 13-9.5.1.

Figure 13-6 FAA-E-2628, or FAA L-849E, Elevated, Condenser Discharge (Sequenced Flashing Light)



LIGHT: SEQUENCE FLASHING, ELEVATED, FAA-E-2628, OR FAA AC 150/5345-51,

TYPE L-849 STYLE E.

LAMP: PAR56, FLASH TUBE, TYPE AS DETERMINED BY MANUFACTURER

POWER OR INTERFACE UNIT: TYPE AS DETERMINED BY MANUFACTURER

MASTER CONTROLLER:

(NOT SHOWN) AS DETERMINED BY MANUFACTURER

13-10 PARALLEL CIRCUITS.

Parallel (or multiple) circuits have circuit elements connected across the conductors to which input voltage is applied. In theory, the same voltage is applied to each light, although voltage drop occurs along the conductor, which can be significant for longer circuits. The reduced voltage can reduce the intensity of lights at the far end of a circuit. If intensity control is required for this type lighting circuit, tapped transformers of inductive-voltage regulators are used, which increases the cost and reduces efficiency of the circuit.

13-10.1 Advantages of Parallel Lighting Circuits.

- Lower cost installation, particularly if voltage regulation and intensity control are not required.
- More efficient utilization of electrical power.
- Easy to add to or reduce an existing circuit.
- Circuits are more familiar to most people.
- Cable faults such as open-circuits are easier to locate.
- An open-circuit may not disable entire circuit.

13-10.2 Disadvantages of Parallel Lighting Circuits.

- Intensity of lights decreases with line voltage drop along the circuit. This could be misinterpreted if noticeable in a pattern of many lights.
- Two conductors are required along the complete circuit, and larger conductors may be needed to reduce voltage drop.
- Lamp filaments are usually longer which may require larger optics and larger light fixtures.
- Intensity control, particularly at the lower intensity, is more difficult to achieve without added equipment cost.
- A single ground fault on the high voltage feeder will disable the circuits.
- Ground faults are difficult to locate.

13-10.3 Common Uses.

Parallel circuits are used for most area illumination, individual or small numbers of visual aids, and power distribution. AGL systems typically using parallel circuits are apron floodlighting, other apron lights, sequence-flashing lights, special purpose visual aids such as beacons and wind direction indicators, some obstacle lights, and electrical distribution circuits.

13-11 CURRENT AND VOLTAGE ON SERIES CIRCUITS.

The output current for AGL constant current series circuits have become standardized at either 6.6 amperes or 20 amperes (at highest intensity). The loaded output voltage from the CCR is limited to 5,000 volts because the cable used for the primary lighting circuit is rated for 5kV.

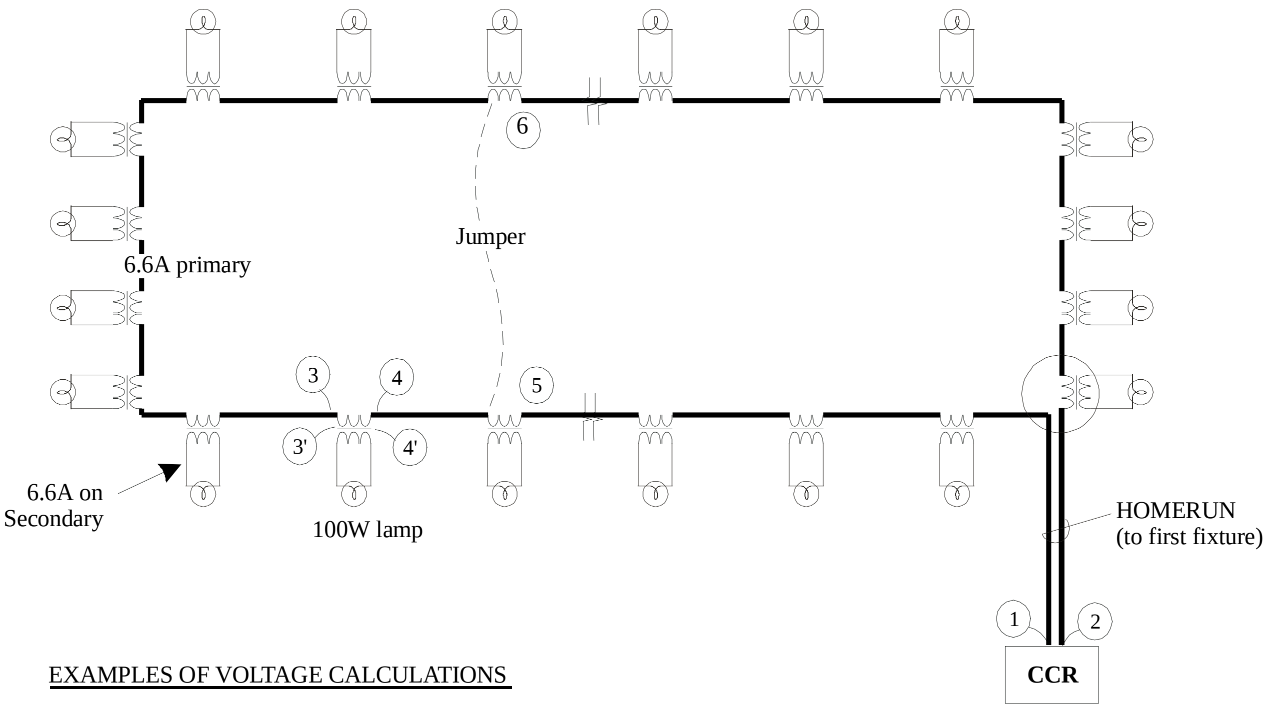
13-11.1 The voltage will vary depending on the load. Figure 13-4 illustrates the constant current and varying voltage through several examples. As seen from Figure 13-4, the voltage measured across the outputs of the CCR (at highest intensity step) is simply the total watts divided by 6.6 A (assuming power factor of 1.0), or 3,030V for 200 each 100W lamps (such as light fixtures or signs). With 200W lamps, the voltage is calculated at 6,060V, which exceeds the 5kV cable rating of the primary circuit. However, if a 20A circuit is used, the voltage calculates to be only 2,000V at the CCR. Similarly, if 45W lamps are used in the above example, the voltage across the CCR output terminals is calculated at 1,364V.

13-11.2 The examples above show that the voltage on the primary circuit is additive and will vary with the load, but the current will remain the same. The secondary circuit is always 6.6A (highest intensity step), with a 6.6A/6.6A isolation transformer used with 6.6A primary circuits, and 20A/20A or 20A/6.6A isolation transformers used with 20A primary circuits.

13-11.3 Figure 13-5 shows that measuring the voltage across the secondary circuit for a 100W light fixture will yield 15.15V. Similarly, the voltage will be 30.3V with a 200W light, and only 6.8V with a 45W light. This illustrates the much lower voltage that is present on the secondary side of a lighting circuit. From the examples it can be seen that:

- The current is constant regardless of load (within limits), while the voltage is will vary with load.
- The low voltage on the secondary side is isolated from the high voltage primary side by the isolation transformer.

Figure 13-7 Current and Voltage Illustration



EXAMPLES OF VOLTAGE CALCULATIONS

ASSUMPTIONS 200 lights on 6.6A primary series circuit
Each light 100W (fixture or sign, etc)
Power factor of 1.0 for all components.

1. Measured across homeruns at CCR, (1) & (2) voltage = $\frac{200\text{ea} \times 100\text{W}}{6.6\text{A}}$ = 3,030V

   If only 100 lights, then voltage is 1,515V

2. Measured across isolation transformer primary (3) & (4) or secondary (3') & (4')

   Voltage = $\frac{100\text{W}}{6.6\text{A}}$ = 15.15V

   With 200W light, voltage on secondary = $\frac{200\text{W}}{6.6\text{A}}$ = 30.3V

   With 200W lamps, voltage at CCR = $\frac{200\text{ea} \times 200\text{W}}{6.6\text{A}}$ = 6,060V

3. With 200W lamps and a 20A primary, voltage at CCR = $\frac{200\text{ea} \times 200\text{W}}{20\text{A}}$ = 2,000V

4. If jumper across at light fixtures (5) & (6), the voltage at CCR is based on load remaining on circuit.

5. If 85 each 200W lights remain on 6.6A circuit: Voltage = $\frac{85\text{ea} \times 200\text{W}}{6.6\text{A}}$ = 2,576V

Note that: (1) Current is constant regardless of load, while voltage varies and is additive, depending on load.

(2) The low voltage secondary side is isolated from the high voltage primary side by the isolation transformer.

13-11.4 When more than one light is connected to a secondary circuit, they are connected in series. An isolation transformer is designed to provide a proper variable operating voltage on its secondary. This forces a constant load current to flow so that each light in the secondary will receive the same current regardless of the wattage of the lamp or the quantity of lamps (within the design limits of the transformer). This approach may be seen on light bars for approach lighting systems, on runway centerline lights configured as smaller segments with several lights on a single transformer, and other applications.

13-11.5 It is important to recognize that the isolation transformer, which is similar to a current transformer, operates differently than the standard voltage transformer. The current will remain constant even when the secondary side is shorted. The output terminals of the CCR are not grounded, hence the airfield lighting series circuit is an ungrounded system. The result is that one short-to-ground in the primary circuit will not shut down the system. When the secondary side is open (for example a burned out lamp), the instantaneous voltage present at the lamp socket can be very high, presenting a potential hazard for maintenance personnel. This can be the condition when changing lamps and a short occurs between the socket terminals and the body of the light fixture. Maintenance personnel are prohibited from working on energized circuits.

13-12 CONSIDERATIONS FOR CIRCUIT DESIGN.

Two major considerations in designing an airfield lighting series circuit are: maximum allowable voltage on the primary series cable (discussed in paragraph 15-12 in the selection of 6.6A or 20A circuit); and the insulation resistance of the entire primary circuit.

(a) FAA has established a minimum insulation resistance of 50 megohms for new installations. Experience from many projects has shown that this value is achievable in most installation configurations. However, insulation resistance depends on the length of the primary series cable, the number of splices on the circuit, soil conditions, and primarily the number of isolation transformers of the circuit. Consider all these factors in configuring a lighting circuit.

(b) From the standpoint of economy, life expectancy and reliability, it may be practical to use 50 megohms as the minimum insulation resistance. The selected value depends on the specific configuration of the particular system being designed. It is recommended the following criteria be applied in optimizing design of new airfield lighting circuits:

- Limit the voltage to 2.4 kV, at least for 90 percent of the operational time (assume this to be step 2 for 3-step CCR, step 3 for 5-step CCR).
- Limit the number of isolation transformers on any one primary circuit to not more than 130.

- Limit the number of splices on any one primary circuit (not including those connecting isolation transformers) to not more than 8.

\4\ 13-12.1 Runway Threshold Lighting.

See paragraph 4-4.

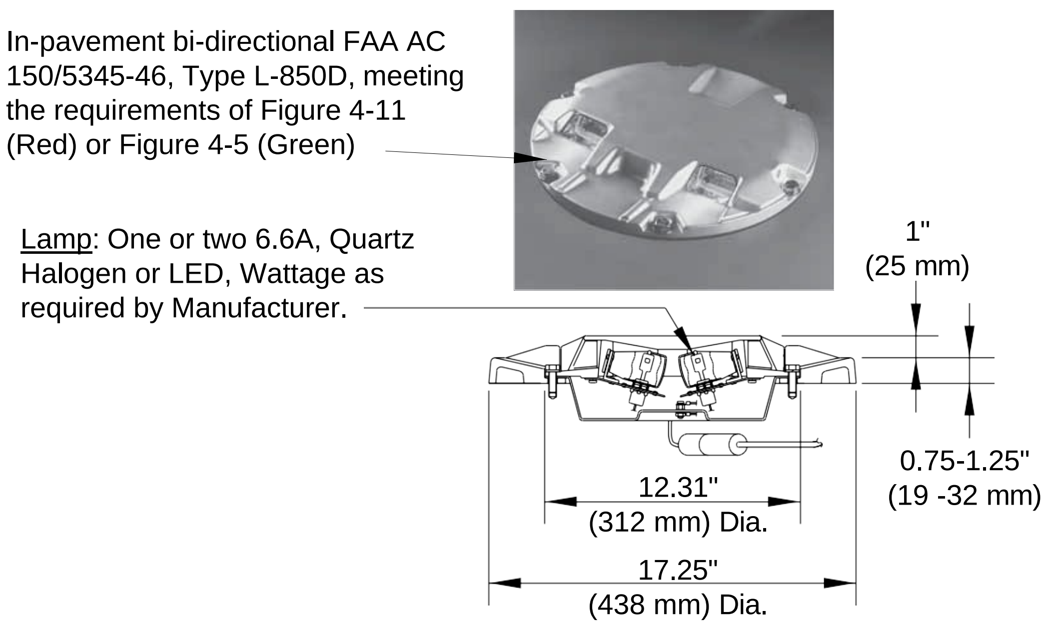
13-12.1.1 In-pavement Fixtures, Unidirectional, Green or Red.

Use light fixtures meeting FAA AC 150/5345-46, Type L-850E and photometric requirements in Figure 4-6 (for green light) or Figure 4-11 (for red light). (See Figure 13-13.) FAA Type L-850D (Figure 13-13) does not meet the threshold light photometric requirements so are not acceptable. For displaced thresholds and thresholds adjacent to strengthened pavements, in-pavement fixtures must be used for in-board threshold lights.**/4/**

13-12.2 High Intensity Elevated Light Fixtures.

Use Par 56 fixtures meeting FAA –E-982. For Army installations only, fixtures meeting FAA AC 150/5345-46 Type L-862E may be used.

Figure 13-8 FAA-L-850D, In-pavement, Bi-directional



(Dimensions are for reference only)

13-13 CIRCUIT CONFIGURATION.

There are three circuit configurations that are normally used to power runway and taxiway systems:

13-13.1 Single Circuit per Lighting System.

This is the standard FAA configuration, with a single circuit for each of the different lighting systems (for example, one circuit for the runway edge lights, one for the touchdown zone lights, or one for the runway centerline lights). It is the most economical configuration. In some cases, however, this approach may create very high voltages on the primary series circuit, which can reduce the life and reliability of the system and increase the potential hazards for maintenance personnel. In addition, in the event of a fault in the circuit, the entire circuit is out of service. Also, the trouble-shooting of line faults can be a lengthy, time consuming process because of the length of the circuit.

13-13.2 Multiple Circuits per Lighting System - Split Circuits.

Advantages include easier troubleshooting and reduction in circuit voltages. A disadvantage with this configuration is the higher cost compared with a single circuit, particularly if the available space in the vault or the duct system is limited. Consider the possible consequences of a partial system failure. For example, where two circuits power a runway edge lighting system, the failure of one circuit leaves the other circuit to light only half the runway, indicating a much shorter available runway to the pilot. It may be necessary to install an interlock between the regulators so that both circuits will shut down if either circuit fails.

13-13.3 Multiple Circuits per Lighting System - Interleaved Circuits.

This is the type of circuit configuration specified by ICAO. Although this is the most expensive configuration, requiring more cable, it has the advantage of preserving the full pattern of the airfield lighting system for the pilots in the event of one circuit failure, hence provides a measure of additional operational safety. Further, it has the advantages noted for the split circuit configuration. Because of operational disadvantages, this is not recommended for Air Force airfields.

13-14 PARALLEL CIRCUITS.

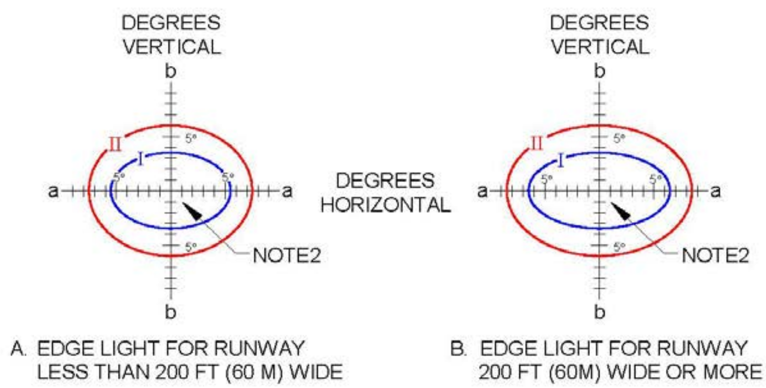
Parallel (or multiple) circuits have circuit elements connected across the conductors to which input voltage is applied. In theory, the same voltage is applied to each light, although voltage drop occurs along the conductor, which can be significant for longer circuits. The reduced voltage can reduce the intensity of lights at the far end of a circuit. If intensity control is required for this type lighting circuit, tapped transformers of inductive-voltage regulators are used, which increases the cost and reduces efficiency of the circuit.

13-15 PHOTOMETRIC CHARACTERISTICS OF LIGHT FIXTURES.

13-15.1 Airfield Lighting.

Airfield lighting provides visible light to pilots for guidance during landing and taxiing operations. The guidance provided is a function of configuration of the lights, light color, and strength and "shape" of the light output (photometric performance). The strength is the brightness or intensity of the light output, measured in candelas. The required shape of the light "beam" from a light fixture is typically represented by an ellipse (an "isocandela curve" of same values), although for some fixtures the requirements may be rectangular or simply numerical. Examples are shown in Figure 13-6 (high intensity white or "clear" runway edge light) and Figure 4-6 (high intensity green threshold light), which illustrate the photometric requirements at highest intensity step for the type of light.

Figure 13-9 Runway Edge Light Photometric Requirements



	I=50%	II=10%
a	5.5°	7.5°
b	3.5°	6.0°

	I=50%	II=10%
a	6.5°	8.5°
b	3.5°	6.0°

NOTES:

1. ALL CONTOURS ARE ELLIPSES CALCULATED BY EQUATION: $(X/a)^2 + (Y/b)^2 = 1$
2. THE MINIMUM AVERAGE INTENSITY OF THE MAIN BEAM (INSIDE CONTOUR I) IS 10,000 CD WHITE OR 5,000 CD YELLOW. MAXIMUM INTENSITY SHOULD NOT EXCEED 1.5 TIMES ACTUAL AVERAGE INTENSITY.
3. CONTOURS I AND II INDICATE THE MINIMUM PERCENT VALUES OF THE MAIN BEAM INTENSITY.

13-15.2 Wattage.

The wattage of lamp(s) and other light fixture characteristics are determined by each manufacturer to meet the photometric requirements for a particular type of light, which are tested and certified for compliance with the requirements. A light fixture design is based on achieving the required photometric output at full rated lamp wattages, in fixtures connected on a 6.6 amperes series lighting circuit. The lower current steps of series lighting circuits are based on achieving lower levels of light output.

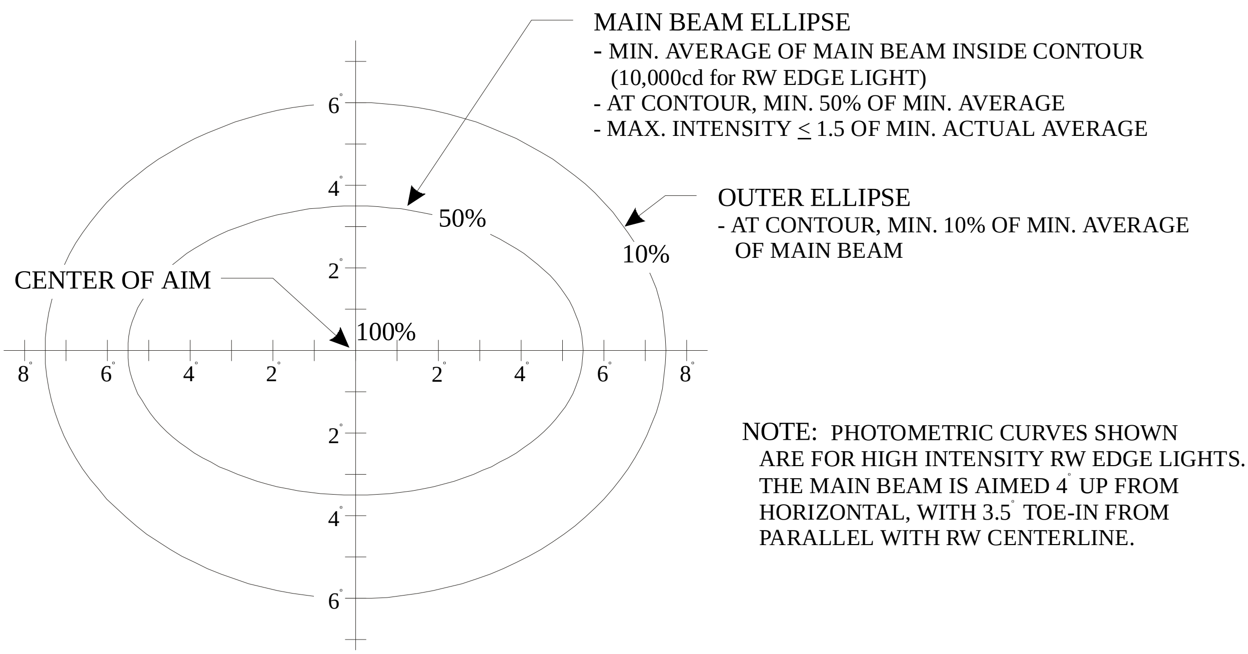
13-15.3 Isocandela Curves

Figure 15-7 shows a typical photometric requirements or “isocandela curves” for a runway edge light. The ellipses are defined by degree of angle from the center along vertical and horizontal axes. The requirements for the inner ellipse, or “main beam,” are:

- Minimum average intensity (10,000 cd, aviation white in the example).
- Minimum intensity no less than 50 percent of the minimum average intensity (5,000 cd in this case).
- Maximum intensity should not exceed 1.5 times the actual average intensity.

For the outer ellipse, the minimum intensity should not be less than 10 percent of the minimum average intensity (1,000 cd in the example).

Figure 13-10 Photometric Isocandela Curves



13-15.4 Main Beam Ellipse.

For the example shown by Figure 13-7 (high intensity runway edge light for runways less than 200 feet (60 meters) wide), the inner or main beam ellipse is defined by ±5.5 degrees on the horizontal axis and ±3.5 degrees and –3.5 degrees on the vertical axis, while the outer ellipse is defined by ±7.5degrees on the horizontal axis and ±6degrees on the vertical axis. Note that in Figure 13-6, the runway edge lights have a wider beam ellipse for runways 200 feet (60 meters) or more wide, providing broader light coverage. The runway edge lights are "toed-in" 3.5 degrees and aimed up 4 degrees above the horizontal. Threshold lights are parallel with the runway centerline and aimed up 4.5 degrees. Other lights may also have a toe-in or aimed vertically upward; however, this is identified separately and not indicated on the photometric curves.

13-15.5 Photometric Testing of New Airfield Lighting Systems.

Photometric testing:

New airfields or construction: Photometric testing can now be as simple as having a company, with proper photometric equipment mounted on a vehicle, drive the airfield with lights energized, for the purpose of presenting a data driven report of recorded photometrics. This should be part the acceptance testing for new projects and may include the evaluation of a variety of factors in the lighting system being tested, depending upon the equipment used.

For existing airfields: Photometric testing may be a routine test at intervals determined by the Airfield Manager. As airport runway access time is limited, photometric measurement runs need to be completed as quickly as possible and can be conducted at speeds up to 60 km/hr without affecting accuracy. The test report generated provides the candela value of each light and identifies any defect requiring action to be taken.

While field testing the photometrics of installed lights has not been practical in the past, the same technology described above enables the testing of an existing system. in a relatively short period of time.. In addition to verifying the photometric performance of installed light fixtures, testing can also help identify the following:

- Possible leakage on the secondary side of the isolation transformer.
- Improper alignment of fixtures.
- Loose sockets and brackets.
- If improper lamps have been installed.
- Possible damage to lenses from sandblasting or other source of abrasion.
- Improper current output from the constant current regulator.

- These types of deficiencies may cause significant reductions in the photometric output of a fixture, as well as the quality of the overall system performance. The cost of photometric testing is relatively inexpensive compared with the cost of a new airfield lighting system, while providing assurances for operational safety. The testing can usually be performed with minimal disruption to airfield operations, and is typically performed at night during periods of low or no aircraft traffic.

- **\4** Fixtures that may have become unlevel due to elevation/drainage changes. Lack of aiming can appear as inadequate photometrics. **/4/**

13-15.6 Photometric Testing of Existing Lighting Systems.

Photometric testing can provide benefits similar to acceptance testing of new lighting systems. Typically, photometric performance deteriorates over time, and periodic testing will provide an up-to-date evaluation of performance. When photometric output is validated at between 50 percent and 70 percent of the minimum specified output, document and investigate for the possible cause and for possible corrective action. Two options are replacement of small sections or repair-by-replacement of the system(s) in question. Test results enable the airfield to repair/replace fixtures on a “need” basis rather than scheduled basis, with possible cost savings plus the assurance that the lighting system is providing the proper light output.**/1/**

\4 If deteriorated cable insulation is suspected, megger the cable to verify. Cable insulation should be 1 M-ohm if new. If system is below 100 k-ohms, locate the failing section. Note that a single 200-foot section of runway cable may not always correct the issue, but may move the issue down the circuit (direction away from the vault). A new piece of cable with proper resistance can cause the next section of cable to fail – evidenced by smoke coming out of the ground. If below 100 k-ohms, replaclement cable should be planned and budgeted for. **/4/**

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\4\ CHAPTER 14 LANDING ZONE REQUIREMENTS

14.1 LANDING ZONE LIGHTING.

Airfield lighting systems are used during nighttime operations to provide visual cues to pilots about the location and dimensions of the LZ runway. The type of lighting system installed may vary between the minimum requirements for temporary applications and the long-term-use system. Equipment selection will depend on the available equipment and mission requirements. Lights are not required if night operations are not anticipated. Lighting that is planned to be permanent should be compatible with NVD.

14.1.1 Minimum Lighting Requirements for Temporary Applications.

14.1.1.1 Lights.

If available, lights should be omni-directional, steady-burn or flashing, with a minimum output rating of 15 candela for night operations. In accordance with AFI 13-217, virtually any type of overt lighting system is acceptable if all participating units are briefed and concur with its use. Contingency lighting kits **(**Expeditionary Airfield Lighting System (EALS-C)**)** or other materials may be used, as available and determined to be suitable by the STT.

14.1.1.2 Location.

There are three types of airfield lighting patterns for LZs, designated AMP-1, AMP-2, and AMP-3, as defined in AFI 13-217. AMP-4 is lights-out, no markings, and used only for appropriate special operations. The STT will decide which arrangement of lights will be installed. The AMP-1, AMP-2, and AMP-3 layouts are illustrated in Figures 14-1, 14-2, and 14-3. Although AMP-2 is also defined in AFI 13-217, the AMP-2 configuration will not be used for newly constructed, temporary or permanent LZs by AMC. When constructing new LZs, even if the immediate operational need is for AMP-3, consideration should still be given to installing the light bases and conduits to support the AMP-1 configuration.

14-1.2 Lighting Requirements for Permanent Applications.

When intended for long term use, use permanently installed lights of the type and in the locations described below.

14.1.2.1 Light Fixtures.

All light fixtures must be certified and listed in FAA AC 150/5345-53, Airport Lighting Equipment Certification Program, and FAA AC 150/5345-46, *Specification for Runway and Taxiway Light Fixtures***.** Per paragraph 11.7, listed fixtures must be used with infrared (IR) filters as covert fixtures.

14.1.2.1.1 Runway high-intensity edge light fixtures should be used for permanent LZ lighting installations. Runway edge lights should be elevated FAA Type L-862. Use the L-850C when an insert light is required in place of the L-862. If all edge lights are in-pavement edge lights, use the FAA Type L-850A, Style 3 (Runway, Uni-directional) towards the approach. (Where circling guidance is needed, bi-directional light fixtures may be used.). LZ light lens colors shall be as indicated in Figures 14-1, 14-2, and 14-3. Five-step regulators should be installed. (Steps 1 through 3 are compatible with NVG operations using a five-step regulator.)

14.1.2.1.2 Taxiway medium-intensity edge light fixtures should be used for permanent lighting installations. Taxiway edge lights should be elevated FAA Type L-861T. If needed, in-pavement edge lights should be FAA Type L-852T, Style 3 (Taxiway, Omni-directional). Taxiway and turnaround edge light lenses shall be blue. Three-step regulators should be installed for intensity control.

14.1.2.1.3 Flashing Strobe Lights (FSL) (Sequenced Flashers - SFL) are located at the end of the LZ in the AMP-3 and AMP-2 configurations and at each side of the approach threshold in the AMP-1 configuration. These lights are unidirectional and must flash at a rate of 28 to 34 flashes per minute, producing a white light. In-pavement fixtures (FAA-E-2952, Style A, white) should be installed with the edge of the fixture extending no more than 1.5 millimeters (0.0625 inch) below and 0.0 millimeter (0.0 inch) above the pavement top. Aim the fixture(s) down the runway parallel to the centerline for AMP-2 and AMP-3 and towards the approach for AMP-1.

14.2 LIGHT BASES.

Light fixtures must be attached to full-depth light bases (L-868, Class IB). Light bases must be offset so the fixture center is a minimum of 0.6 meter (2 feet) from any pavement joint. Light bases shall be installed in accordance with UFC 3-535-02, Figures 11A, 11B, 12, 13, and 14. For elevated light fixtures, provide steel adaptor rings (see Jaquith Industries part numbers AF5402 and AR5421; Olson Industries part numbers 128TS and 128S; or equivalent).

Light construction tolerances are:

- Longitudinal ± 13 millimeters (0.5 inch) from stationing
- Transverse ± 13 millimeters (0.5 inch) transverse from centerline
- Base orientation Parallel to T/W centerline ± 0.5 degree
- Elevation +0 to -1.5 millimeters (+0 to –0.0625 inch) from finished pavement surface, flush with the surrounding grade or pavement.

14.3 LIGHT LOCATIONS.

14.3.1 LZ Lights.

If the LZ is built on an existing runway or taxiway where normal flight operations are conducted, then use in-pavement light fixtures.

14.3.1.1 AMP-1.

Place lights at each threshold and at 152 meters (500 feet) from each threshold. Intermediate lights shall be 152 meters minimum/305 meters maximum (500 feet minimum/1000 feet maximum) spacing throughout the length of the runway, as illustrated in Figures 14-1 and 14-4. Spacing should be consistent through the intermediate lights. If a conflict with the lights exists on one or both sides of the LZ (e.g., at locations where a taxiway connects to the LZ), that light should be an in-pavement light. Install synchronized FSLs at the threshold as illustrated in Figures 14-1 and 14-4. Install steady-burning light fixtures at 1.6 meters (5 feet) plus 0.6 meter (2 feet) to minus 0.0 meter (0.0 foot) from the edge of the LZ surface (i.e., within the shoulder pavement). Position light pairs perpendicular and equidistant from the runway centerline to be symmetrical about the runway or LZ centerline.

14.3.1.2 AMP-2.

Place lights at each threshold and at 152 meters (500 feet) from each threshold. Intermediate lights shall be 152 meters minimum/305 meters maximum (500 feet minimum/1000 feet maximum) spacing throughout the length of the runway, as illustrated in Figure 14-2. Spacing should be consistent through the intermediate lights. If a conflict with the lights exists on one or both sides of the LZ (e.g., at locations where a taxiway connects to the LZ), that light should be an in-pavement light. An FSL is also installed on the centerline of the departure end threshold not more than 1.6 meters (5 feet) from the threshold or overrun end. Locate the FSL as close to the runway centerline as possible. Install steady-burning light fixtures 1.6 meters (5 feet) plus 0.6 meter (2 feet) to minus 0.0 meter (0.0 foot) from the edge of the LZ surface (i.e., within the shoulder pavement). For covert applications see paragraph 14.7.

14.3.1.3 AMP-3.

Light locations and colors are derived from the AMP-3 configuration in AFI 13-217, Figure 3.6. Place steady-burning lights at the threshold and at 152 meters (500 feet) from the approach end threshold, forming a box, as shown in Figures 14-1, 14-5, and 14-6. An FSL is also installed on the centerline of the departure end threshold not more than 1.6 meters (5 feet) from the threshold or overrun end. Locate the FSL as close to the runway centerline as possible. Install steady-burning light fixtures at 1.6 meters (5 feet) plus 0.6 meter (2 feet) to minus 0.0 meter (0.0 foot) from the edge of the LZ surface (i.e., within the shoulder pavement). For covert applications see paragraph 11.7.

14.3.2 Turnaround, Taxiway, and Apron Edge Lights.

Install all lights at 1.6 meters (5 feet) plus 0.6 meter (2 feet) or minus 0.0 meter (0.0 foot) from the edge of the load-bearing surface. On straight sections of taxiway or turnaround, space lights evenly with a maximum of 152 meters (500 feet) between lights. See Figures 14-7 and 14-8, for typical turnaround and taxiway edge light locations. Reduce light spacing to between 3 meters and 10.6 meters (10 feet and 35 feet) on curves and at corners or intersections. On curved sections, space lights evenly from point of tangency (PT) to PT, with the maximum spacing between lights equal to half the taxiway width. For all corners and all curves exceeding 30 degrees of arc, there must be a minimum of three lights. See Chapter 5 for additional edge light location details.

14.3.3 Overrun Edge Lights.

Overruns do not normally require edge lights; however, for overruns used as taxiways or turnarounds, edge lights may be installed using the location criteria stated in paragraph 11.3.2. In addition, the first pair of edge lights installed on overruns should not be more than 30.5 meters (100 feet) from the runway threshold.

14.4 LIGHT CIRCUITS AND CONTROLS.

Designers should investigate all required configurations of lighting (AMP-1, AMP-3, Infrared AMP-3, etc.) and develop a circuit and control system that can achieve all the required configurations and operations.

14.4.1 Ferro-Resonant Regulators.

All new regulators used for LZ lighting systems shall be ferro-resonant type (See FAA AC 150/5345-10, Specification for Constant Current Regulators and Regulator Monitors**).**

14.4.2 Multi-Regulator Systems.

In this configuration, separate regulators will be needed to control lights for AMP-1, AMP-3 Overt, AMP-3 Covert, and taxiway circuits.

14.4.3 Single-Regulator Systems with Addressable Lights.

Systems are now available to have “assignable control” of individual lights via a carrier signal. For this type of configuration, all LZ runway lights could be powered by one regulator, with each configuration assigned to a different control setup.

14.5 LIGHT REFLECTOR PANELS (OPTIONAL).

Light reflectors may be installed at the midpoint between LZ runway edge lights or taxiway edge lights. Contact the STT for information on obtaining light reflector panels.

14.6 OVERT AMP-3 LZ LIGHTS SUPERIMPOSED ON STANDARD OPERATIONAL RUNWAYS.

In some cases, it may be desirable to use a standard full-length runway for LZ training operations. Only the AMP-3 configuration should be installed in this situation. For this purpose, the LZ lighting scheme illustrated in Figures 14-5 and 14-6, shall be applied, subject to the following conditions. MAJCOM approval is required before installation of AMP-2 configuration.

14.6.1 LZ Light Fixtures.

High-intensity light fixtures must be installed flush with the pavement surface to allow traffic to pass over them. In-pavement lights shall be FAA Type L-850A, Style 3, uni-directional, or an International Civil Aviation Organization (ICAO) equivalent. LZ light lens colors shall be white. Five-step regulators should be installed on the LZ circuit(s) for light intensity control compatible with NVG operations (steps 1 through 3 are compatible with NVG operations).

14.6.2 LZ Location on the Runway.

When possible, the LZ threshold should be sited between 91 meters (300 feet) and 152 meters (500 feet) from the runway threshold. This will ensure aircraft loads are concentrated in the portion of the runway designed for heavier loads and avoid conflicts with runway pavement markings.

14.6.3 LZ Lighting Conflicts with Standard Runway Markings.

The LZ should be sited so the LZ light fixtures do not conflict with threshold markings, runway designation markings, touchdown zone markings, or fixed distance markings. An ideal location for the LZ threshold is 91 meters (300 feet) from the runway threshold. This will position the LZ light fixtures in the gaps between the standard runway markings. If LZ lights fall within a standard marking, the light fixture should be masked whenever repainting occurs and removed when repainting is accomplished.

14.6.4 LZ Lighting Conflicts with Approach Lights and Touchdown Zone (TDZ) Lights.

Runway approach lights and TDZ lights are spaced every 30 meters (100 feet) throughout the overrun and for the first 914 meters (3000 feet) of the runway. TDZ lights are installed in groups of three, starting 11 meters (36 feet) each side of the runway centerline and spaced over a 3-meter (10-foot) light bar. LZ lights for C-17s will not conflict with TDZ lights because LZ lights are 15 meters (50 feet) each side of the centerline. C-130 LZ lights are installed 10.5 meters (35 feet) each side of the centerline, so conflicts should not occur. If TDZ lights are installed on the runway, move the LZ lights closer to the LZ edge to position them inside the TDZ lights.

14.7 AMP-3 COVERT INFRARED (IR) LIGHTS.

14.7.1 Installation.

At some locations, IR lights may be needed in addition to standard visual spectrum lights. IR lights can be installed in accordance with Figures 14-4, 14-5, 14-6 and 14-8.

14.7.2 IR Light Fixtures.

These fixtures should be FAA L-850A Style 3 fixtures, with a special IR filter installed on the lens. Infrared transmitting filters must meet the specifications in Table 14-1 and be certified to comply with the specifications in this paragraph by an FAA-approved laboratory (currently Intertek Test Lab). Before installation on-site, the manufacturer must supply an FAA-approved lab (currently Intertek Test Lab) report certifying compliance.

Figure 14-1 AMP-1 Lighting Plan

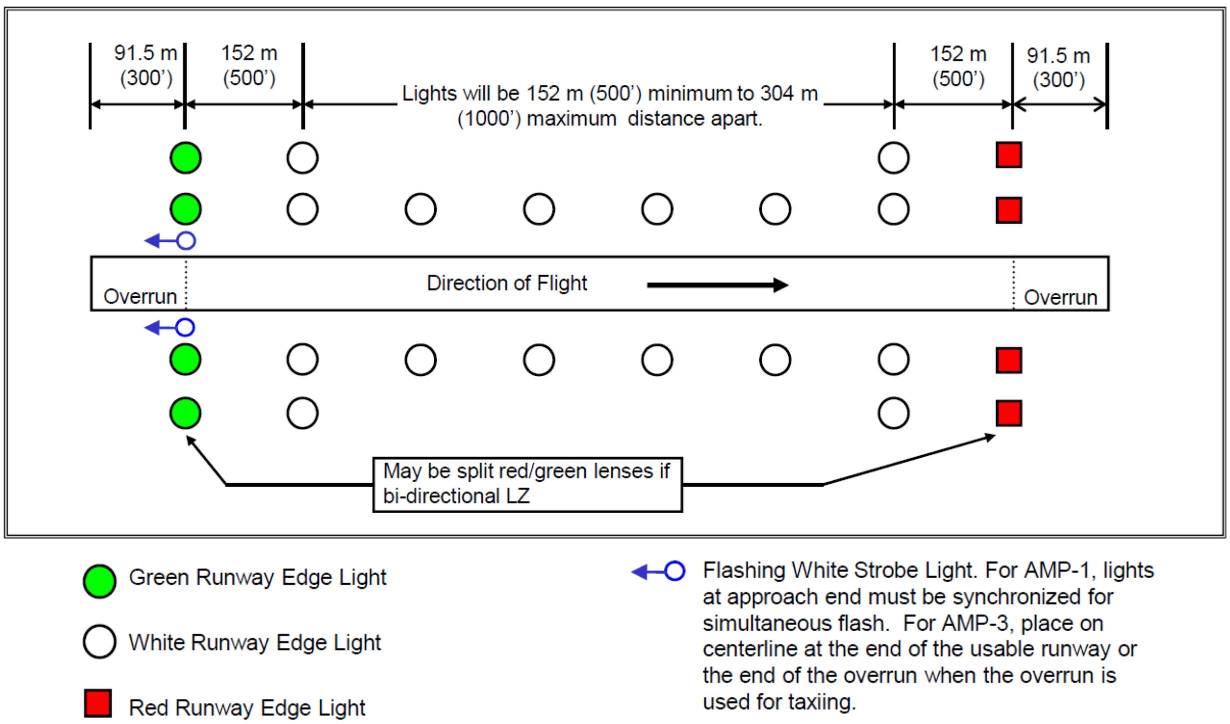


Figure 14-2 AMP-2 Lighting Plan

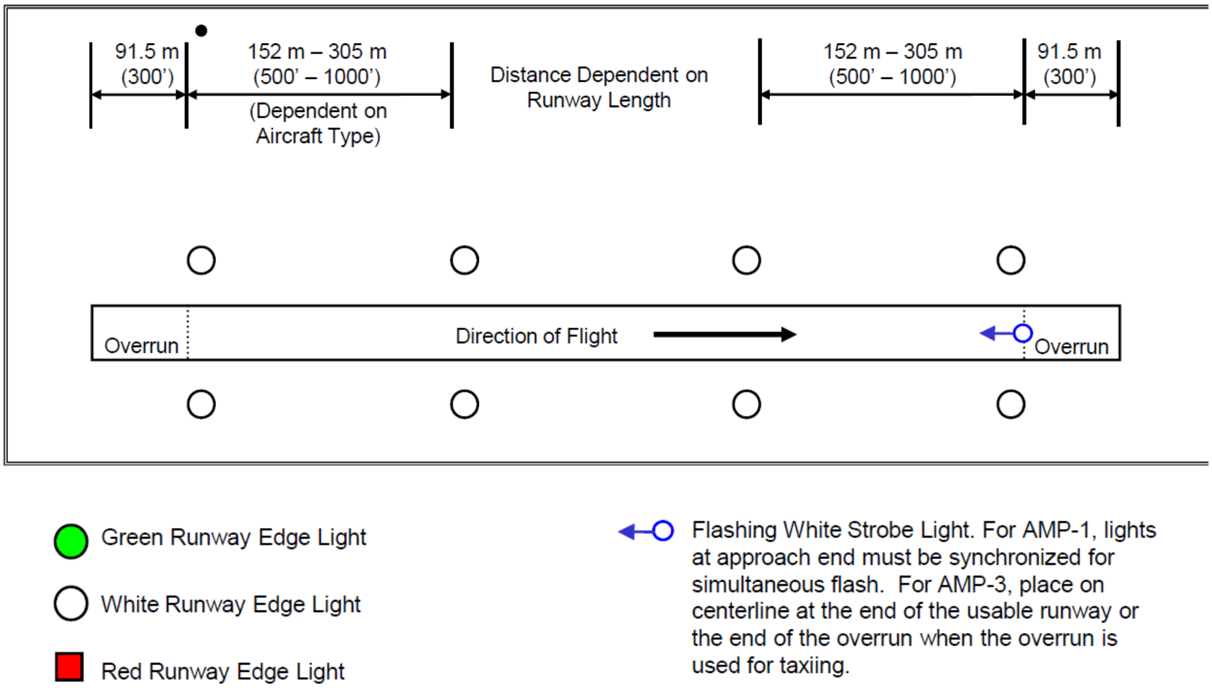


Figure 14-3 AMP-3 Lighting Plan

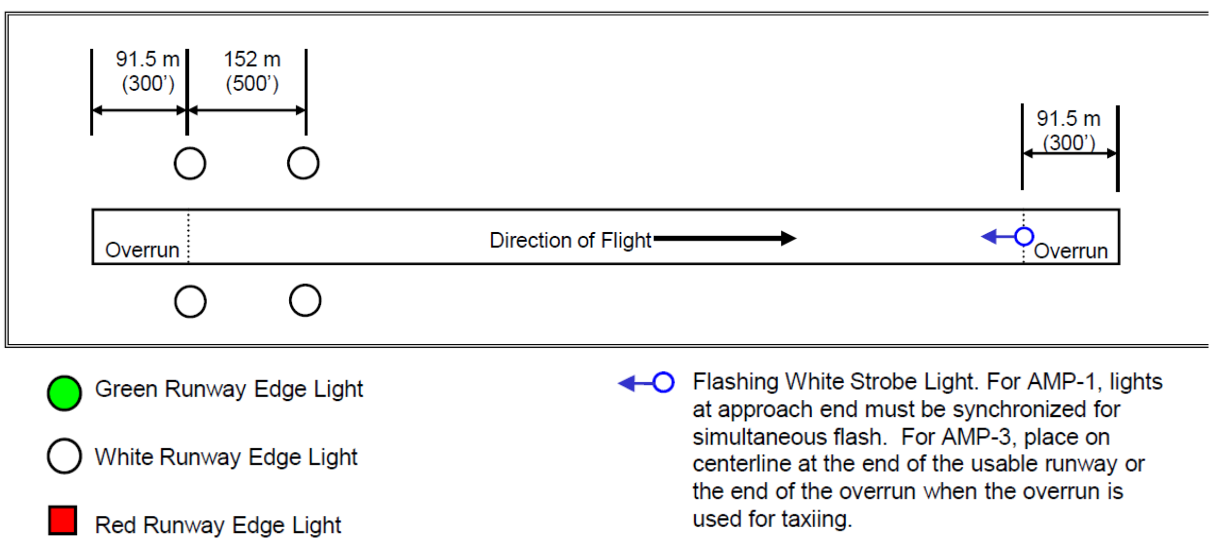
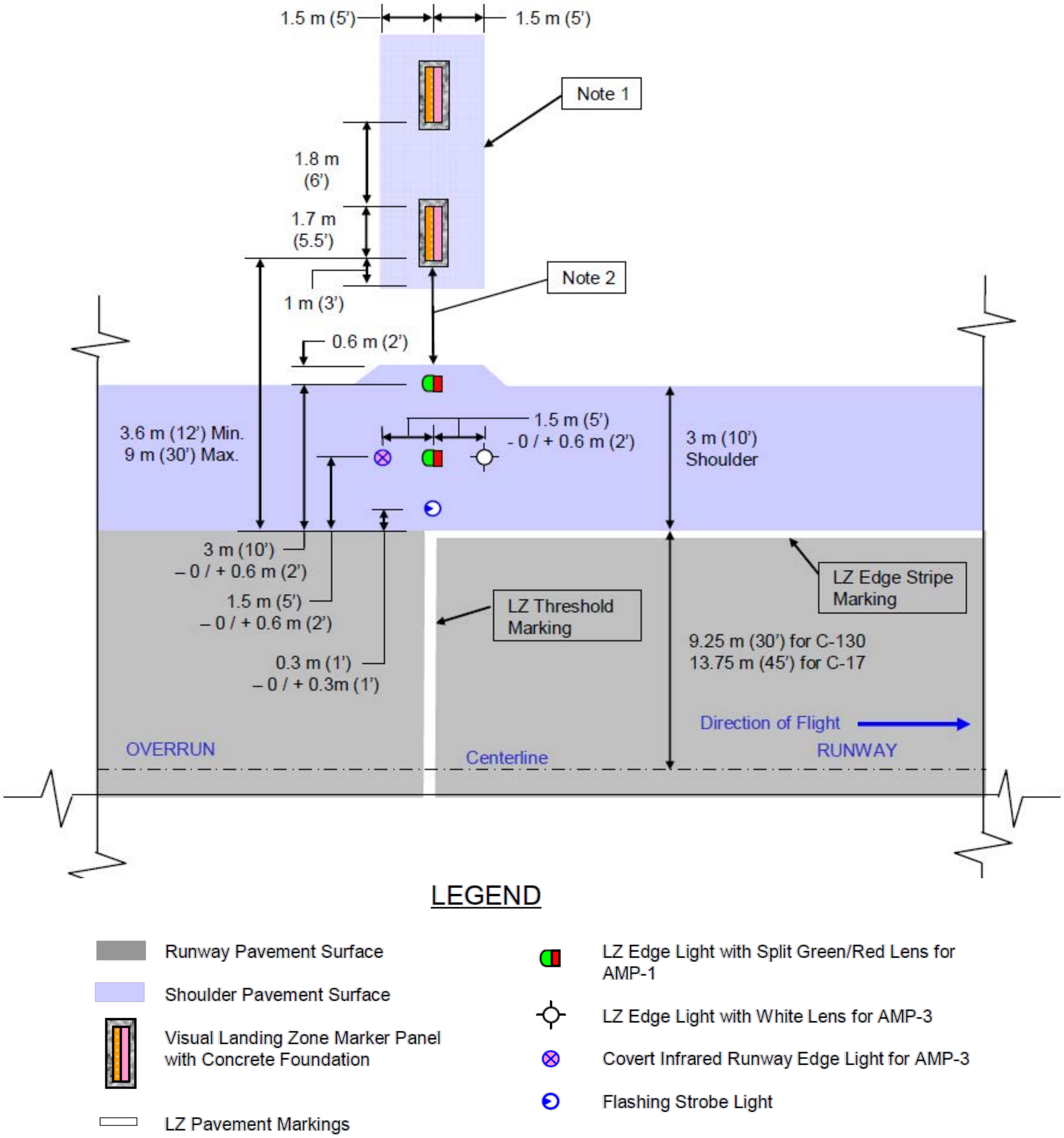


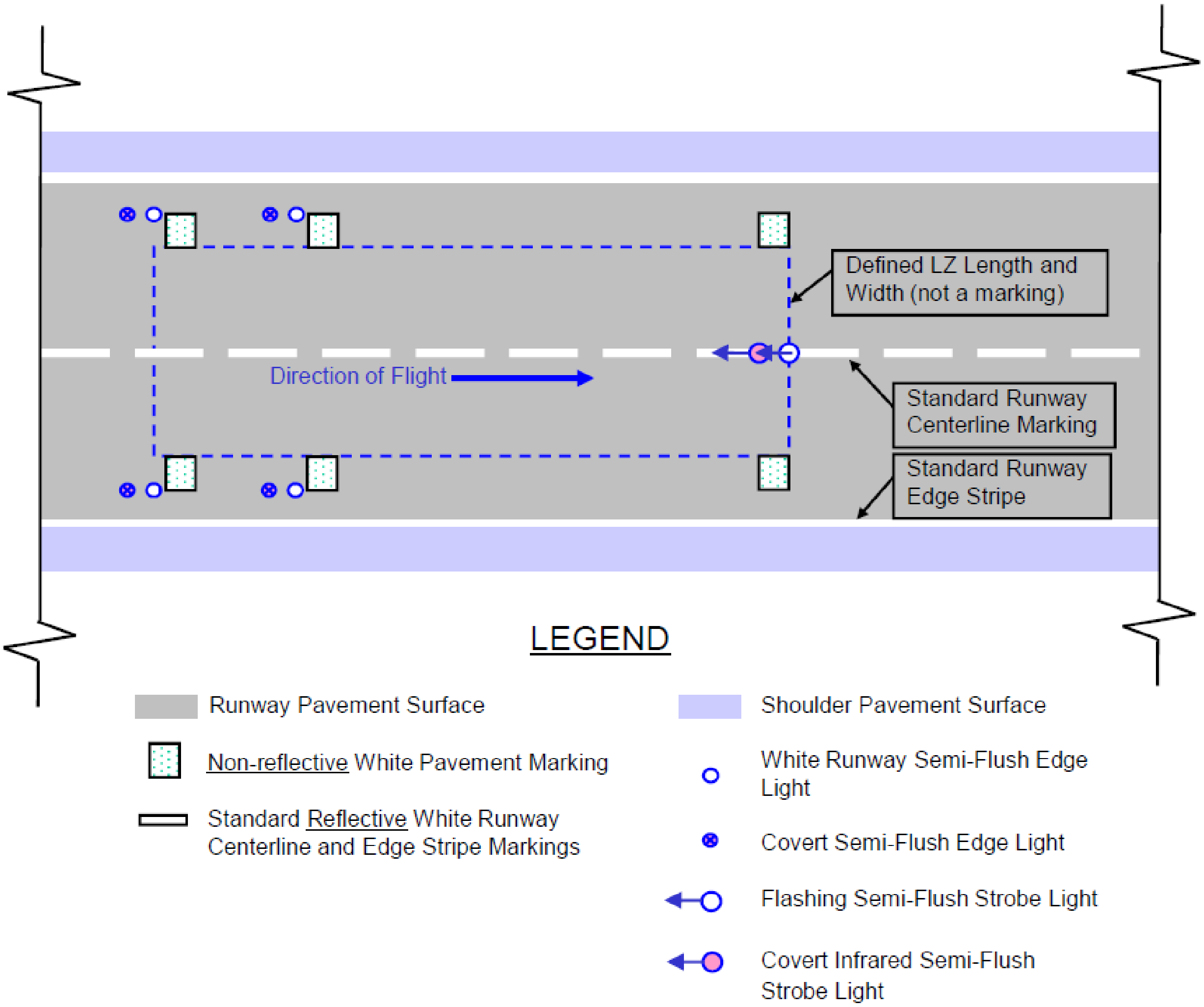
Figure 14-4 Light and Marker PANEL Layout Detail on a Landing Zone with Combination AMP-1, AMP-3 Overt, and AMP-3 Covert



Notes:

1. Paved pad surrounding sign bases is recommended to eliminate need for mowing close to and between signs.
2. If gap between paved shoulder and sign foundation is less than 2.4 m (8'), pave entire gap.
3. LZ edge lights must be on the same longitudinal alignment throughout the length of the LZ. Pairs of lights should be perpendicular and equidistant from the centerline.
4. All LZ lights should be located at least 0.6 m (2') from PCC pavement joints.
5. Minimum 1.2 m (4') spacing between flashing strobe and inboard edge light. Minimum 1.5 m (5') spacing between edge light pairs.

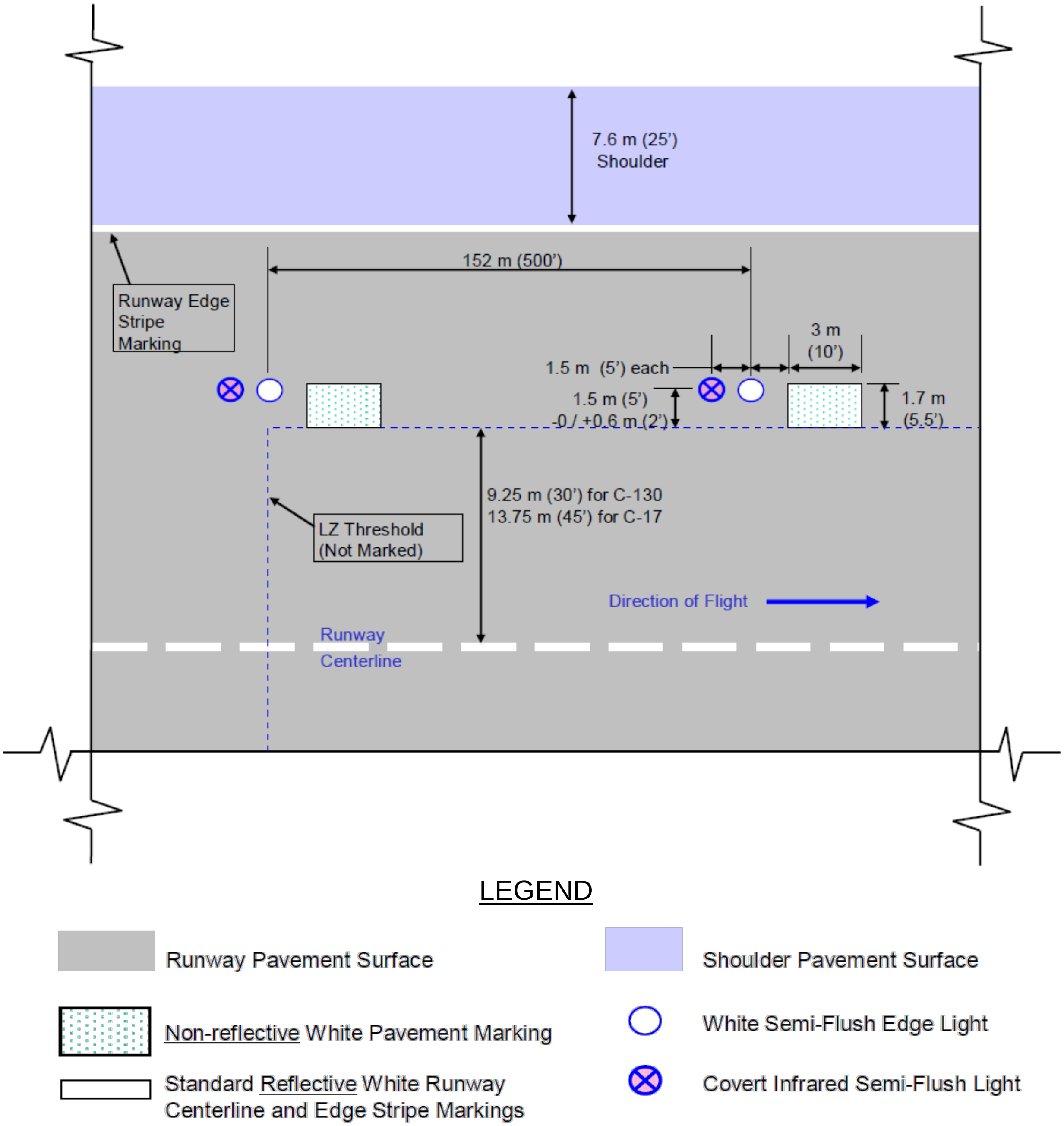
Figure 14-5 AMP-3 Lighting and Marking Scheme for LZ Superimposed on Standard Class B Runway



Notes:

1. LZ pavement markings should be installed with the inside edge aligned with the edge of the LZ. The back edge should be aligned with the measurement from the threshold. Markings should be 3.0 m (10') long (parallel to runway centerline) and 1.7 m (5.5') wide.
2. If the flashing strobe light is not semi-flush, install at the end of the usable runway.

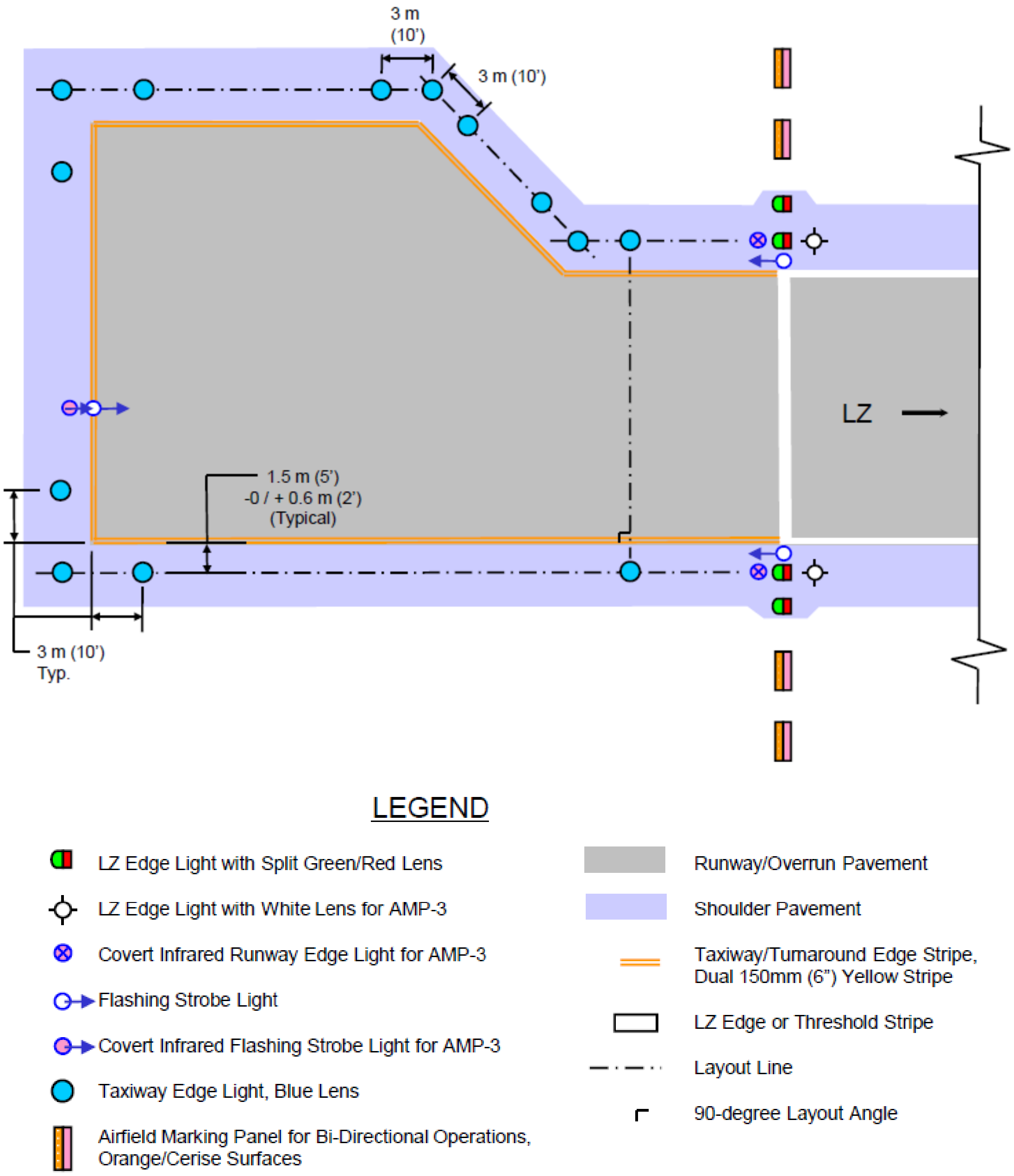
Figure 14-6 AMP-3 Overt and Covert Lighting and Marking Layout Detail for LZ Superimposed on Standard Class B Runway



Notes:

1. LZ threshold should be sited so that conflicts with standard lights and markings are avoided.
2. All LZ lights should be located at least 0.6 m (2') from PCC pavement joints.

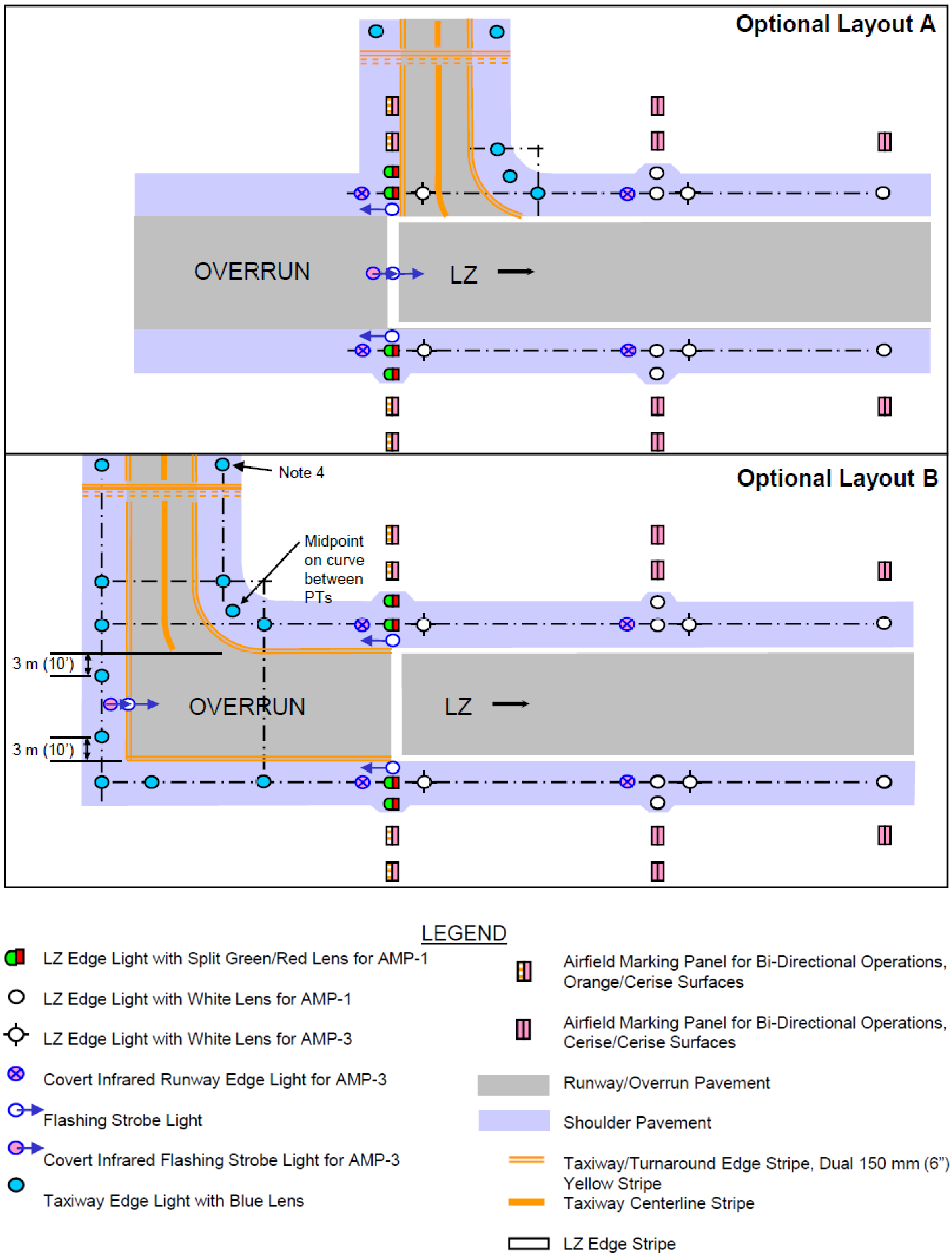
Figure 14-7 Typical Turnaround Marking and Lighting Layout



Notes:

1. LZ is configured for bi-directional operations.
2. All taxiway lights must be equidistant from taxiway/turnaround edge. Design tolerance is 1.5m (5') – 0/+ 0.6m (2').

Figure 14-8 Typical Bi-Directional Runway/Taxiway Marking and Lighting Layout



Notes:
1. LZ is marked and lighted for bi-directional operations.

2. Taxiway lights must be equidistant from taxiway/turnaround edge. Design tolerance is 1.5m (5′) – 0.6m (2′).

3. Locate taxiway lights behind the hold line according to this UFC, but no more than 60m (200′) from the point of tangency.

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APPENDIX B GLOSSARY

B-1 ACRONYMS

A	ampere
AATMP	Allied Air Traffic Management Publication (AATMP)
AASHTO	American Association of State Highway and Transportation Officials
AC	Advisory Circular
AC, ac	alternating current
AF/A3X	AF Director, Future Operations
AF/A8XX	Air Force International Standardization Office
AFCEC	Air Force Civil Engineer Center
AFCEC/CO	AFCEC Operations Directorate
AFCEC/COSM	AFCEC, Mechanical Division
ACMU	addressable control and monitoring unit
AFI	Air Force Instruction
AFIMSC/IZB	Air Force Installation Management Support Center, Engineering Support Division
AFJMAN	Air Force Joint Manual
AFPD	Air Force Policy Directive
AFR	Air Force Regulation
AGL	airfield ground lighting
AGM	arresting gear marker
AIR STD	Air Standard
ALCMS	airport lighting control and monitoring system
ALS	approach lighting system
ALSF	approach lighting system with sequence flashing lights
ALSF-1	approach lighting system with sequence flashing lights for Category I
ALSF-2	approach lighting system with sequence flashing lights for Category II or Category III
AMC	Air Mobility Command
ANG NGB	Air National Guard National Guard Bureau
ANSI	American National Standards Institute
\2 AFIC	Air Forces Interoperability Council **/2/**

ASTM	American Society for Testing and Materials
AT&A	air traffic and airspace
ATCT	air traffic control tower
AWG	American Wire Gauge
AWS	American Welding Society
BIA	Bilateral Infrastructure Agreement
CAN/CSA	Canada/Canadian Standards Association
CCR	constant current regulator
cd	candela
cd/m^2	candela per square meter
CFR	Code of Federal Regulations
CHAPI	chase helicopter approach path indicator
cm	centimeter
CV	vice commander
DAF	Department of the Air Force
DASD	Deputy Assistant Secretary of Defense
DCS	Deputy Chief of Staff
DoD	Department of Defense
DO	Director of Operations
E/G	engine generator
EALS	emergency airfield lighting system
EALS-C	expeditionary airfield lighting system (term for Interim System)
EB	Engineering Brief (FAA)
EFVS	enhanced flight vision system
EIA	Electronic Industries Association
EM	Engineer Manual
EMT	electrical metal tubing
ETL	Engineering Technical Letter (Air Force)
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
fc	footcandle
fL	foot-lambert

ft	foot
GPS	global positioning system
HIRL	high intensity runway edge light
HNFA	Host Nation Funded (Construction) Agreement
HQ AFFSA/A3A	Air Force Flight Standards Agency, Flight Operations
HQ AFSEC/SEFF	Air Force Safety Center, Flight Safety
HQ USACE	Headquarters, U.S. Army Corps of Engineers
HVAC	heating, ventilation, and air conditioning
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronics Engineers
IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
ISO	International Standards Organization
ksi	kips per square inch
kW	kilowatt
LED	light emitting diode
LIR	low impact resistant
m	meter
MACOM	major command (Army)
MAJCOM	major command (Air Force)
MALS	medium (intensity) approach light system
MALSR	medium intensity approach light system with runway alignment indicator
MIL-STD	Military Standard
MIRL	medium intensity runway edge light
MLS	microwave landing system
mm	millimeter
MO	Maintenance & Operation (NAVFAC manual)
MOV	metal oxide varistor
mPa	milli-pascal
MTBF	mean-time-between-failure

MUTCD	Manual of Uniform Traffic Control Devices (Air Force use AFPAM 32-1097, *Sign Standards Pamphlet*)
NA	not applicable
NATO	North Atlantic Treaty Organization
NAVAID	navigational aid
NAVAIR	Naval Air Systems (Command)
NAVFAC	Naval Facilities (Command)
NAVSEA	Naval Sea Systems (Command)
NAVWARSYSCOM	Naval Information Warfare Systems Command
NEC	National Electrical Code (NFPA 70)
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NR	not required
NSO	NATO Standardization Office
NVG	night vision goggle
OC	on center
OFZ	obstacle free zone
OPT	optional
P.E.	Professional Engineer
PAPI	precision approach path indicator
PAR	parabolic aluminized reflector
PAR	precision approach radar
PCU	power control unit
PLASI	pulsed light approach slope indicator
PLC	programmable logic controller
PVC	polyvinyl chloride
PT	point of tangency
RCL	runway centerline light
RDR	runway distance remaining sign
REIL	runway end identifier light
RGL	runway guard light
RMS	root mean squared

RPI	runway point of intercept
RPM	revolutions per minute
R	required
REA	Rural Electrification Administration
RRP	runway reference point
RVR	runway visual range
RW	runway
SAE	Society of Automotive Engineers
SAFO	Safety Alert for Operators (FAA)
SALS	short approach light system
SCR	silicon controlled rectifier
SES	Senior Executive Service
SFL	sequenced flashing lights
SME	subject matter expert
SOFA	Status of Forces Agreement
SPAWARSYSCEN	Space and Naval Warfare Systems Center
SPD	surge protection device
SSALR	simplified short approach light system with runway alignment indicator lights
STANAG	Standardization Agreement (NATO)
SOF	Special Operations Forces
SR	square root
STT	Special Tactics Team
TACAN	tactical air navigation
TCH	threshold crossing height
TDZL	touchdown zone lights
TERPS	terminal instrument procedures
TM	Technical Manual (Army)
TO	Theater of Operations
TP	Technical Paper
TSEWG	Tri-Service Electrical Working Group
TSMCX	Director, USACE Transportation Systems Center

TW	taxiway
UAS	unmanned aircraft system
UAV	unmanned aerial vehicle
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriters Laboratory
UPS	uninterruptible power supply
USAASA	US Army Aeronautical Service Agency
USAAVNC	US Army Aviation Center
USASC	US Army Safety Center
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics
US	United States
Vac	volts alternating current
VASI	visual approach slope indicator
VFR	visual flight rules
VGLEAP	Visual Guidance Lighting Equipment Approval Program
VMC	visual meteorological conditions
V	volt
W	watt

B-2 DEFINITION OF TERMS

Approach Light Plane: An imaginary plane that passes through the beam centers of the lights in the system. The plane is rectangular, centered on the ALS centerline, starting at the landing threshold and extending 200 feet (60 meters) beyond the last light at the approach end of system. The plane may have irregularities. The width varies according to the lighting system.

Decision Height: The height above the highest elevation in the touchdown zone, specified for a glide slope approach at which a missed approach procedure must be initiated if the required reference has not been established.

Displaced Threshold Area: An area of full strength pavement on the approach slope of the threshold intended for use during takeoff or during rollout after landing from the opposite direction.

Footcandle: One lumen per square foot (10.8 lux).

Frangible Support: A support for elevated fixtures or other devices composed of a supporting element with a fracture mechanism at its base. It is designed to present a minimum of mass and to break at the base when impacted.

Helipad: A prepared area designated and used for takeoff and landing of helicopters (includes touchdown and hoverpoint). May be located at facilities with fixed and rotary wing aircraft.

Heliport: A facility designed for the exclusive operating, basing, servicing and maintaining of rotary-wing aircraft (helicopters). The facility may contain a rotary-wing runway and/or helipads.

In-pavement Fixtures: Fixtures whose surface are within 0.5 inches above the runway surface. Note that terminology has changed from "Semi-flush", but some references remain titled with the term "Semi-Flush." These terms should be interchangeable.

Instrument Runway: A runway served by non-visual aids giving directional guidance adequate for a straight in approach. It may be further classified as:

Non-Precision Approach Runway: A runway with two-dimensional operations conducted under IFR using lateral guidance but not vertical guidance.

Precision Approach Runway, Category I: A runway served by an instrument landing system (ILS), microwave landing system (MLS), or precision approach radar (PAR) and visual aids intended for operations down to 200 feet (60 meters) decision height, and down to a runway visual range (RVR) on the order of 2,400 feet (720 meters). These criteria also apply to visual lighting aids supporting Air Force precision approach radar approaches down to a decision height of 100 feet (30 meters) and an RVR on the order of 1,200 feet (360 meters).

Precision Approach Runway, Category II: A runway served by ILS or MLS and visual aids intended for operations down to 100 feet (30 meters) decision height and down to an RVR on the order of 1,200 feet (360 meters).

Precision Approach Runway, Category III: A runway served by ILS or MLS (no decision height being applicable) and:

Category IIIa: By visual aids intended for operations down to an RVR on the order of 700 feet (210 meters).

Category IIIb: By visual aids intended for operations down to an RVR on the order of 150 feet (45 meters).

Category IIIc: Intended for operations without reliance on external visual reference. (The RVR is 0).

Light Bar: A set of lights arranged in a row perpendicular to the light system centerline, also known as a barrette.

Lux: One lumen per square meter (1/10 (0.0929)) footcandle).

Message Element: the use of characters, symbols, or a combination of characters and symbols in its simplest form used to communicate a location, direction, or action where aircraft operate. (See paragraph 9-1.)

Overrun: An area on the approach side of the runway threshold which is stabilized or paved but is not intended for normal operational use. It serves as a safety area for aircraft which overrun the end of the runway or touch down short of the threshold.

Positive Slope: A slope of the approach light plane upward and outward from the landing threshold.

Rigid Support: A support for elevated lights or other devices which has been designed to support the lights under all foreseeable weather conditions without regard for impact resistance. Do not use these supports in new construction for systems in safety clearance zones or where there is present danger of impact by aircraft.

Runway Centerline: A line halfway between the edges of the surface designated for normal aircraft landing and takeoff operations.

Runway Edge: The sides of a runway designated as full strength and capable of supporting aircraft wheel loads; any area beyond that point is a non-operational area.

Runway End: The longitudinal limit of usable runway opposite the runway threshold. It often, but not always, coincides with the threshold of the opposite direction runway surface.

Runway Visual Range (RVR): The maximum distance in the direction of take-off or landing from which the runway (or the specified lights or markers delineating it) can be seen from a position above a specified point on the runway centerline and at a height corresponding to the average eye level of pilots at touchdown.

Semi-Flush fixtures: Fixtures whose surface is within 0.5 inches above the runway surface. Note that terminology has changed to In-pavement fixtures, but some references remain titled with the term “Semi-Flush.”

Semi-frangible Support: A two element support for light fixtures or other devices designed for use in applications where the mounting is over 40 feet (12 meters) above the ground and exceeds the design limits for low impact resistant supports mounted on a rigid support and a means to lower the lights for servicing.

Sign array: message elements that may be within multiple individual housings (see paragraph 9-1.)

Special Tactics Team: Special Tactics Teams (STTs) are elite USAF special operations units who operate on the ground, often alongside other Special Operations Forces (SOF) such as Rangers, Special Forces and Navy SEALs.

Theater of Operations: (TO) An operational area defined by the geographic combatant commander for the conduct or support of specific military operations. (Joint Publication 3-0)

\2\ APPENDIX C LIGHT EMITTING DIODES AND NIGHT VISION DEVICES

DoD personnel responsible for the content of UFCs are constantly monitoring changes made to FAA documents and are working closely with industry on military needs as these fixtures evolve to be safe for all aviation contexts. This appendix clarifies the operational characteristics of NVDs and their interaction with LEDs to assist users of FAA, ICAO, and DOE standards and regulations.

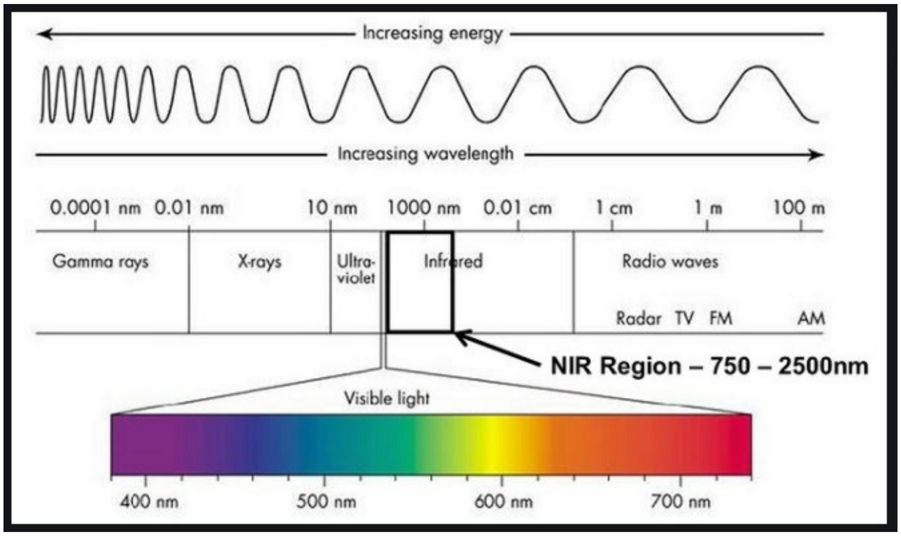
When one reads documents created by FAA, ICAO, DoD, DoE, etc., one must be familiar with the definitions and parameters of specific terms found within those documents. Because assumptions may be inherently associated with the use of a term, it is important to know if the term is specific; i.e., including assumptions, or is generic. The topic of this appendix is interaction between night vision devices (NVDs) and light emitting diodes (LEDs).

C-1 NVDs, NVGs, AND EVDS DEFINED.

Night vision devices include night vision goggles (NVGs) and enhanced vision devices (EVDs). While all NVGs are NVDs, all NVDs are not NVGs. Night vision goggles (NVGs) operate on the principle of multiplying whatever light is present. NVGs require at least some amount of ambient light or there is nothing to multiply. Common NVGs require about 0.3 foot-candles of ambient light or the device detects no light and provides no output. NVDs operate on the principle of a measure of heat energy, which cannot be seen with the naked eye.

All NVDs operate in the spectrum area just above the visible light spectrum. The Infrared region lies between the visible and microwave portions of the electromagnetic spectrum. Infrared rays are invisible to the human eye but they can be focused, reflected and polarized, just like visible light. This region is divided into three parts: Near-Infrared, Mid-Infrared and Far-Infrared.

Figure C-1 Electromagnetic Spectrum with Near IR Region Designated



The infrared portion of the electromagnetic spectrum ranges from 750 nm to 2500 nm, and is broken up into three parts, near IR (NIR), medium IR (MIR), and far IR (FIR). NVGs operate between visible light (just after the red) and almost 900 nm.

C-2 IR EMITTERS FOR AIRFIELD LIGHTING.

Typical IR emitters added to LED airfield lighting fixtures for visibility with NVGs operate optimally between 830 and 870 nm. Other NVDs, such as forward-looking infrared (FLIR), operate in the near-to-medium IR region of 2500 nm to 4000 nm. Therefore, IR emitters for NVG don't support FLIR.

The lower wavelengths for each show that emitters for NVGs do not work for FLIRs and other NVDs such as EVDs:

830 nm = 0.000000830 meters or 830 billionths of a meter (for NVGs)

2500 nm = 0.000002500 meters or 2.5 millionths of a meter (for FLIR devices)

Equation C-1 Relationship of Energy to Wavelength Where h and c Are Constants (Reference Figure A-1)

$$E = \frac{hc}{\lambda}$$

Where:
E = energy
H = Planck's constant
C = speed of light
Λ = wavelength

C-3 FAA GUIDANCE.

FAA Airport Engineering Brief 98, *Infrared Specifications for Aviation Obstruction Light Compatibility with Night Vision Goggles (NVGs),* paragraph 7-7.5, states, "Provide LED obstruction lights where the users and airfield manager can verify that night vision goggles (NVG) or vision enhancement systems are not used…" The same clarifications regarding compatibility with NVGs are addressed in FAA Advisory Circular (AC) 150/5345-43, *Specifications for Obstruction Lighting*.

Note that unlike civilian airfield managers, military airfield managers must be delegated this decision-making authority by the appropriate installation or wing commander.

Also note that, in AC 150/5345-53D, *Airport Lighting Equipment Certification Program, November 2020 Addendum*, the following statement is at the bottom of every page listing certified equipment: [1]

> *"Any runway fixture listed above that uses a LED lighting source may not be compatible with Enhanced Flight Vision Systems that use IR energy emissions for imaging. 3 (L) Indicates LED fixture IR element present is not tested nor certified under this program as to compatibility with any night vision equipment."* ***/2/***

[1] https://www.faa.gov/documentLibrary/media/Advisory_Circular/150-5345-53d-addendum.pdf

UFC 3-535-02
21 May 2018

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN DRAWINGS FOR VISUAL AIR NAVIGATION FACILITIES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-535-02
21 May 2018

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN STANDARDS FOR VISUAL AIR NAVIGATION FACILITIES

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source: Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Subject: UFC 3-535-02, *Design Drawings for Visual Air Navigation Facilities*

Supersedes: UFC 3-535-02 (Draft), 30 JUNE 2014

Description of Changes: This revision updates the graphics details that have been in a draft document into the form of a UFC document required by UFC 3-100-01. Each graphic detail has been updated to be consistent with UFC 3-535-01 and NAVAIR 51-50 AAA-2. The details have been provided with updated designer notes and notes to be used with the drawings. AutoCAD cells of these graphics details and drawing notes will be located on a public web site for use by designers of airfield lighting projects. The details will be readily accessible and easily modified for each project. Where the technical content varies according to the needs of the military services (Air Force, Army, Navy) service-specific technical content has been provided in the details.

Reasons for Changes:

- The changes were made to bring the draft details up to the current state of military airfield lighting practice. The previous details were not consistent in graphic style, and did not meet current military graphics standards. They were not suitable for use on new projects without re-drawing each detail for each project.

Impact: Cost impact is negligible. However, the following benefit should be realized:

- Designers will have a better understanding of the design requirements.

Unification Issues

- Chapter 9 Wave-off & Wheels-up Lighting Systems and Chapter 10 Simulated Carrier Deck Systems are Navy only requirements from NAVAIR 51-50AAA-2 General Requirements for Shorebased Airfield Marking and Lighting.
- Lighting base can details may indicate a drain, this drain can be used on Army/Air Force projects, but is not used on Navy projects. This service difference will be indicated throughout this UFC wherever there is a light base can.
- Lighting base can details have service differences for the counterpoise lightning protection system. The Navy has differences in connecting the counterpoise wire to all metal objects on the airfield. Army/Air Force requirements are

selective on where the counterpoise is connected. This service difference will be indicated throughout this UFC wherever there is a light base can.

- Figures 50A, 50B, 50C, 51, 56 and 57 are service specific due to the runway threshold lighting configurations being different between the services. For the Navy this requirement is from NAVAIR 51-50AAA-2.

Table of Contents

List of Figures

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE.

This document provides drawing details for design and construction of individual components of visual navigation facilities. Use this document when designing, planning, constructing, and installing new systems.

1-2 SCOPE.

This document applies to United States Air Force, Army, Navy, Air National Guard, Army National Guard, Air Reserve, Army Reserve and Naval Reserve bases with responsibility for maintaining their airfield facilities. Existing systems and components are not required to be upgraded to these drawing details unless as part of a major rehabilitation.

This document contains the drawing details for design and construction for visual air navigation facilities, except marking, at Air Force, Navy, and US Army facilities.

Additional Navy requirements are currently contained in Naval Air Systems Command (NAVAIR) 51-50AAA-2. When using the NAVAIR document, be certain that the complementary markings are installed and that no conflict occurs with the placement of light fixtures.

1-3 SUMMARY OF CHANGES.

This edition of UFC 3-535-02, *Design Drawings for Visual Air Navigation Facilities*, supersedes the draft version dated 30 June 2014. Drawings are representative and not to scale. The English units govern.

1-4 APPLICATION.

This volume is not intended as a design specification or an instruction manual for untrained persons. A trained person is one who has the skills and knowledge related to the design, construction and operation of the airfield lighting systems and has received technical and safety training to design, construct and operate airfield lighting systems while recognizing and avoiding the hazards.

When using this manual, be certain that the complementary markings are installed and that no conflict occurs with the placement of light fixtures.

Specifically, this document contains figures that reference individual AutoCAD files containing the drawings, individual files containing the notes to designer for each diagram (text also provided within this document), and figure numbers for cross-referencing the drawings with this document.

1-5 FAA STANDARDS.

The Army and Air Force generally follow FAA standards that are primarily published as Advisory Circulars (ACs), handbooks, and specifications. However, when FAA documents are in conflict with the Air Force or Army requirements, this UFC takes precedence.

1-6 INTERNATIONAL MILITARY STANDARDS.

1-6.1 This UFC satisfies the requirements of international military standards to the greatest extent possible.

1-6.1.1 NATO STANAGs are promulgated by the NATO Standardization Office (NSO).

1-6.1.2 ASIC Air Standards (AIR STD) are promulgated by representatives of the military air forces of Australia, Canada, New Zealand, United Kingdom, and the United States. AIR STDs governing airfield lighting and marking, obstructions, helipads, and heliports have been cancelled.

1-6.2 Applicable international military standards take precedence over standards in this UFC as follows:

1-6.2.1 NATO.

NATO STANAGs apply at Army and Air Force facilities in NATO theater countries except the United States and Canada, or wherever NATO funding is provided for the work, regardless of location.

1-6.2.2 ASIC.

At Army and Air Force facilities in New Zealand and Australia, contact:
AF/A8XX - USAF International Standardization Office
ASIC (Air & Space Interoperability Council)
Andrews AFB MD
+1.240.612.4237 DSN 312.612.4237

1-7 BASE RIGHTS AGREEMENTS.

When the Army or Air Force builds an airfield in a foreign country, the United States obtains a Base Rights Agreement. Provisions of the Base Rights Agreement must be observed and may require that construction complies with standards of the host nation. Under such an agreement, and whether or not international standards conform with standards of the host nation, the host nation must approve all plans. It may also be desirable to use equipment produced in the host nation.

1-8 METRICATION OF DIMENSIONS.

Generally, all dimensions are provided in English units with metric units following in parentheses. It is expected that designers who use these details will be using the English dimensions for stateside construction projects, and the metric dimensions for international projects. The alternate dimensions will be deleted from the graphic details for each project.

English and metric units for manufactured products are described to the precision of the manufacturer's published dimensions.

English conduit sizes are standard trade sizes listed in the National Electrical Code (NEC). Metric conduit sizes are the metric designation for the same conduits listed in the NEC. They are not the same as the metric sizes for conduits provided on the international market.

English wire sizes are standard trade sizes listed in the NEC. Metric wire sizes are metric wire sizes that are available on the international market.

English and metric units for field construction dimensions are nominal dimensions that allow for the normal variance in field construction. The round-off from English to metric units follows the convention used in ICAO standards, as follows: 1 inch = 25 mm, 12 inches = 300 mm, 5 feet = 1.5 meters, 10 feet = 3 meters, 100 feet = 30 meters, 1000 feet = 300 meters, etc.

Note that Executive Order 12770 requires use of metric units in procurement of supplies and services.

1-9 PHOTOMETRIC REQUIREMENTS.

Photometric requirements in this UFC are based on standards established by the ICAO and FAA. They have been modified as necessary to accommodate Air Force requirements.

1-10 STRUCTURAL DESIGN.

Details that indicate the construction of steel-reinforced concrete structures, pads and foundations must be designed by a licensed or registered structural engineer. Concrete used in underground structures, such as manholes, handholes and foundations must be designed with minimum 28-day structural strength of 4000 psi, except structures in areas where freeze AutoCAD files for the details in this UFC can be downloaded from the following site:
http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-535-02

and thaw conditions are common. They must be designed with concrete with minimum 28-day structural strength of 4500 psi. Concrete used for non-structural equipment pads, mowing buffers and similar items must be designed with minimum 28-day structural strength of 2000 psi.

1-11 SUPPLEMENTAL INFORMATION.

This volume supplements UFC 3-535-01, *Design Standards for Visual Air Navigation Facilities* (Army and Air Force only). Technical Manual NAVAIR 51-50AAA-2, *General Requirements for Shorebased Airfield Marking and Lighting* (Navy only), provides the guidance and detailed information on standard configurations and equipment, and is generally in compliance with the FAA criteria. Use these manuals when designing, planning, constructing, and installing new systems. AutoCAD files for the details in this UFC can be downloaded from the following site:

http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-535-02

CHAPTER 2 UNDERGROUND CABLE, CONDUIT AND DUCTS

2-1 DIRECT BURIED DUCT/CONDUIT DETAILS.

2-1.1 Figures 1A, 1B.

2-1.1.1 Notes to Designer.

1. Where duct / conduit is installed under pavement, specify the type of pavement to be installed on top of the trench. Where trench is cut through existing pavement, specify that the pavement on top of trench match existing material and strength.

2. Location of Counterpoise:

   a. For Air Force / Army projects, the counterpoise is located half way between the full-strength runway or taxiway pavement and the row of edge light fixtures. The counterpoise is not connected to the light base cans for elevated light fixtures. The counterpoise is connected to the light base cans for in-pavement light fixtures.

   b. For Navy projects, the counterpoise is located above the conduits between the light base cans. The counterpoise is connected to each light base can.

3. All counterpoise must be solid bare copper wire (conductor) #6 (16 square mm) minimum for Air Force/Army and stranded bare copper wire (conductor) #4 (25 square mm) minimum for Navy, and will be bonded to ground rods using exothermic welds.

4. All ground rods must be ¾" (20mm) diameter minimum and 10' (3m) long.

5. Refer to UFC 3-535-01, Chapter 1 for more information. Refer to Figures 6A, 6B and 6C for more requirements.

6. Where soil is highly corrosive, refer to NFPA 780, Chapter 11 for more information.

2-1.1.2 Drawing Notes for Figure 1A (Air Force / Army).

1. Ducts under full strength pavement must be concrete encased with a minimum of 3" (75mm) concrete encasement on top, bottom, and sides. Ducts under turf or paved shoulders must be installed in a bed of sand backfill.

2. Locate counterpoise half way between full-strength runway or taxiway pavement and center line of light base cans. Install counterpoise 8" (200mm) minimum below finished grade.

3. Provide minimum conduit slope of 0.5 percent, where possible.

4. Where duct or conduit is below a paved shoulder, the patch material must match the existing pavement.

2-1.1.3 **Drawing Notes for Figure 1B (Navy).**

1. Ducts under full-strength pavement, turf or paved shoulders must be installed in a bed of sand backfill.

2. Locate counterpoise above the conduits between the light base cans. Install counterpoise 8" (200mm) to 12" (300mm) above top duct / conduit.

3. Provide minimum duct / conduit slope of 0.5 percent where possible.

4. Where duct or conduit is below a paved shoulder, the patch material must match the existing pavement.

2-1.2 **Figures 2A, 2B.**

2-1.2.1 **Drawing Notes for Figure 2A (Air Force / Army).**

1. Locate counterpoise half way between full strength runway or taxiway pavement and center line of light base cans. Install counterpoise 8" (200mm) minimum below finished grade.

2. See Figure 3A for grounding connection to external lug on light base can.

3. If light base cans are spaced more than 5' (1.5m), the cans are isolated and must each have a ground rod.

4. Install counterpoise ground rods every 2000' (600M) maximum on straight runs of ducts/conduits.

2-1.2.2 **Drawing Notes for Figure 2B (Navy).**

1. Locate counterpoise above the conduits between the center line of light base cans. Install counterpoise 8" (200mm) to 12" (300mm) above top duct / conduit.

2. See Figure 3B for connection to external lug on light base can.

3. Install ground rods every 2000' (600m) maximum on straight runs of ducts / conduits.

2-1.3 **Figures 3A, 3B.**

2-1.3.1 **Notes to Designer.**

1. These details show the grounding connections to light base cans.

2. Location of Counterpoise:

    a. For Air Force / Army projects, the counterpoise is located half way between the full-strength runway or taxiway pavement and the row of edge light fixtures. The counterpoise is not connected to the light base cans.

    b. For Navy projects, the counterpoise is located above the conduits between the light base cans. The counterpoise is connected to each light base can.

3. Install the ground rod on the side of the trench that is closest to the pavement.

4. All counterpoise and grounding conductors must be #6 (16 square mm) solid bare copper minimum bonded to ground rods using exothermic welds for Air Force/Army projects. Use #4 (25 square mm) for Navy projects.

5. All ground rods must be 3/4" x 10' (20mm x 3m).

6. Where soil is highly corrosive, refer to NFPA 780, Chapter 11, for additional information.

2-1.3.2 **Drawing Notes for Figure 3A (Air Force / Army).**

1. Each light base can must have an external one-hole ground lug. Connect an exothermic one-hole lug to grounding cable. Connect cable lug to base can lug with bronze or stainless steel bolted hardware.

2. Connect grounding cable to reinforcement cage, if one is provided. Use exothermic weld.

3. Connect ground rods to counterpoise at 2000' (600m) maximum spacing for straight runs, using exothermic welds. Do not break counterpoise.

4. Locate counterpoise half way between full-strength runway or taxiway pavement and center line of light base cans.

5. Install the ground rod on the side of the trench that is closest to the runway or taxiway pavement. Ground rod must be separated from counterpoise by minimum 12" (300mm).

2-1.3.3 **Drawing Notes for Figure 3B (Navy).**

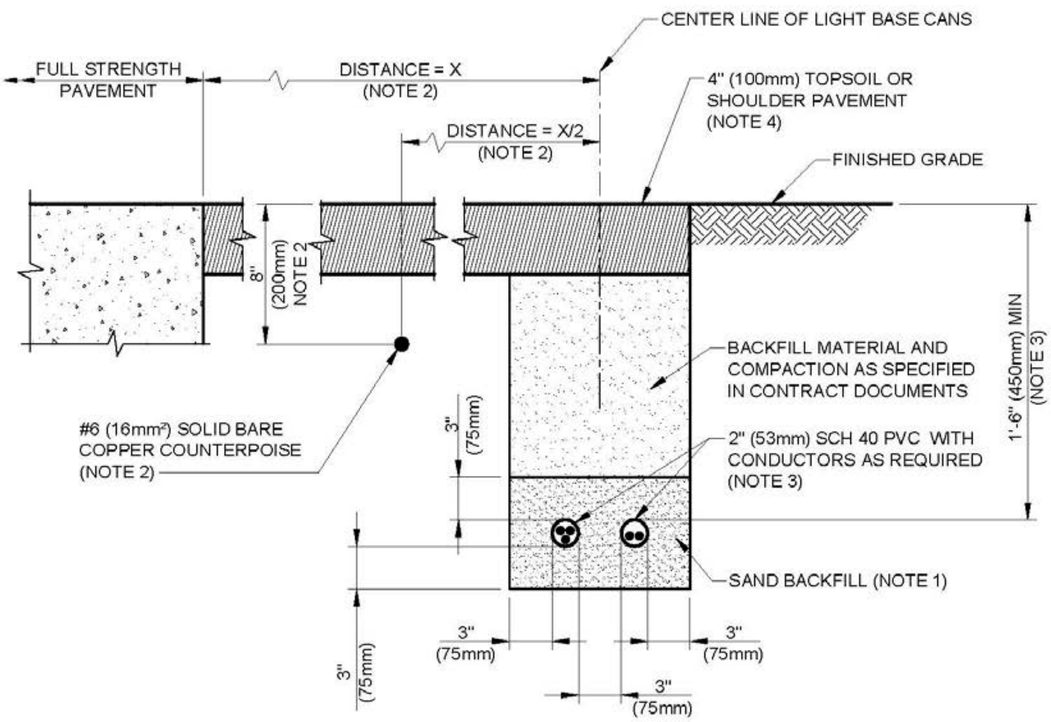
1. Each light base can must have an external one-hole ground lug. Connect an exothermic one-hole lug to grounding cable connected to counterpoise. Connect cable lug to base can lug with bronze or stainless steel bolted hardware.

2. Connect ground rods to counterpoise at 2000' (600m) maximum spacing for straight runs, using exothermic welds. Do not break counterpoise.

3. Locate counterpoise above the conduits between the light base cans.

4. Install the ground rod on the side of the trench that is closest to the runway or taxiway pavement.

Figure 1A. Edge Lighting Direct Buried Duct / Conduit Detail (Air Force/Army)



EDGE LIGHTING DIRECT BURIED DUCT/ CONDUIT DETAIL (AIR FORCE/ ARMY)

SCALE: NTS

REFERENCE FIGURE: 1A

CAD FILE: 1_1_(Figure_1A)_Edge_Lighting_Direct_Buried_Duct_Conduit_Air_Force_Army.dwg
SEE NOTES TO DESIGNER FILE: 1_1_(Figure_1A)-NTD.dwg

Figure 1B. Edge Lighting Direct Buried Duct / Conduit Detail (Navy)

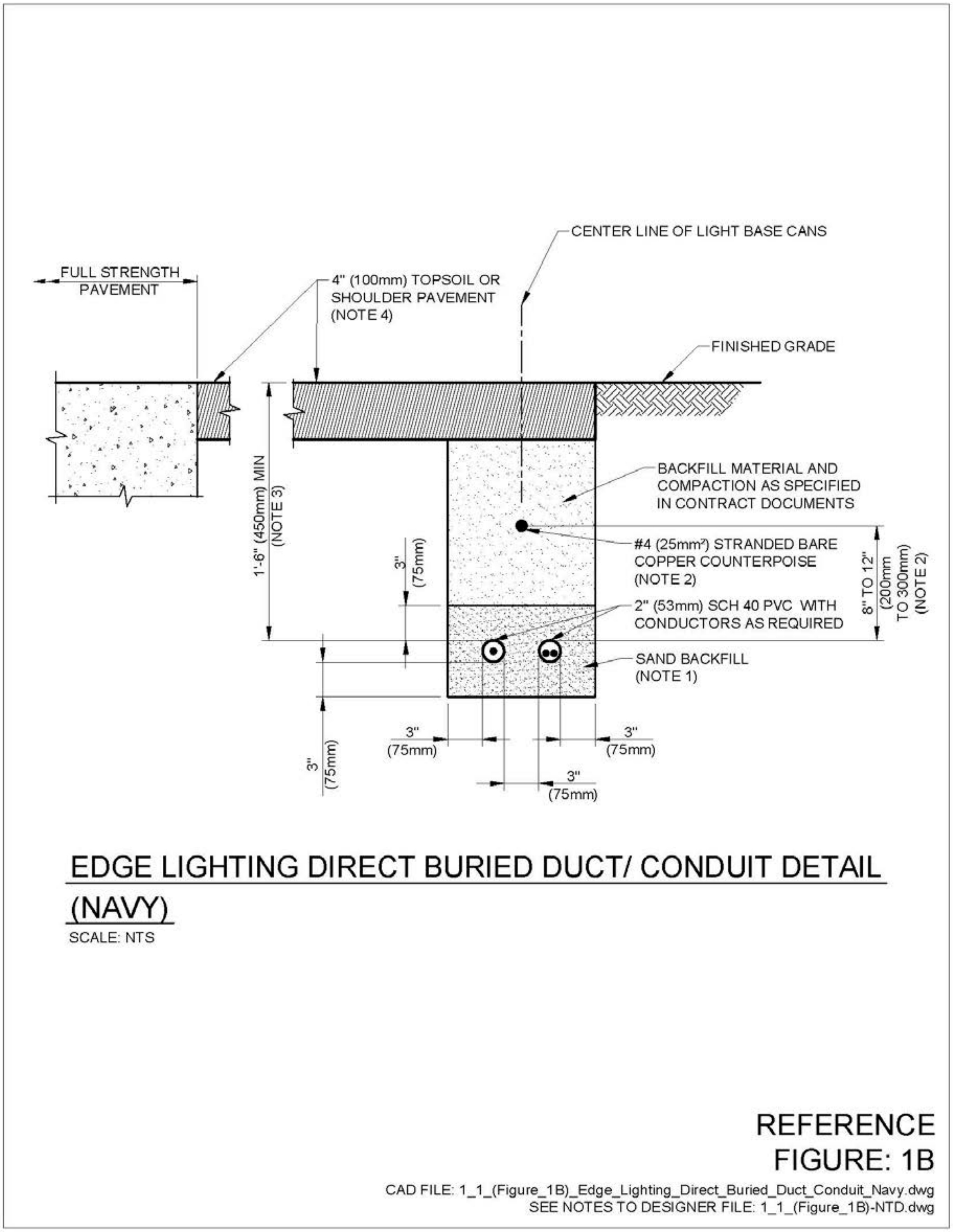


Figure 2A. Grounding for Light Base Cans (Air Force / Army)

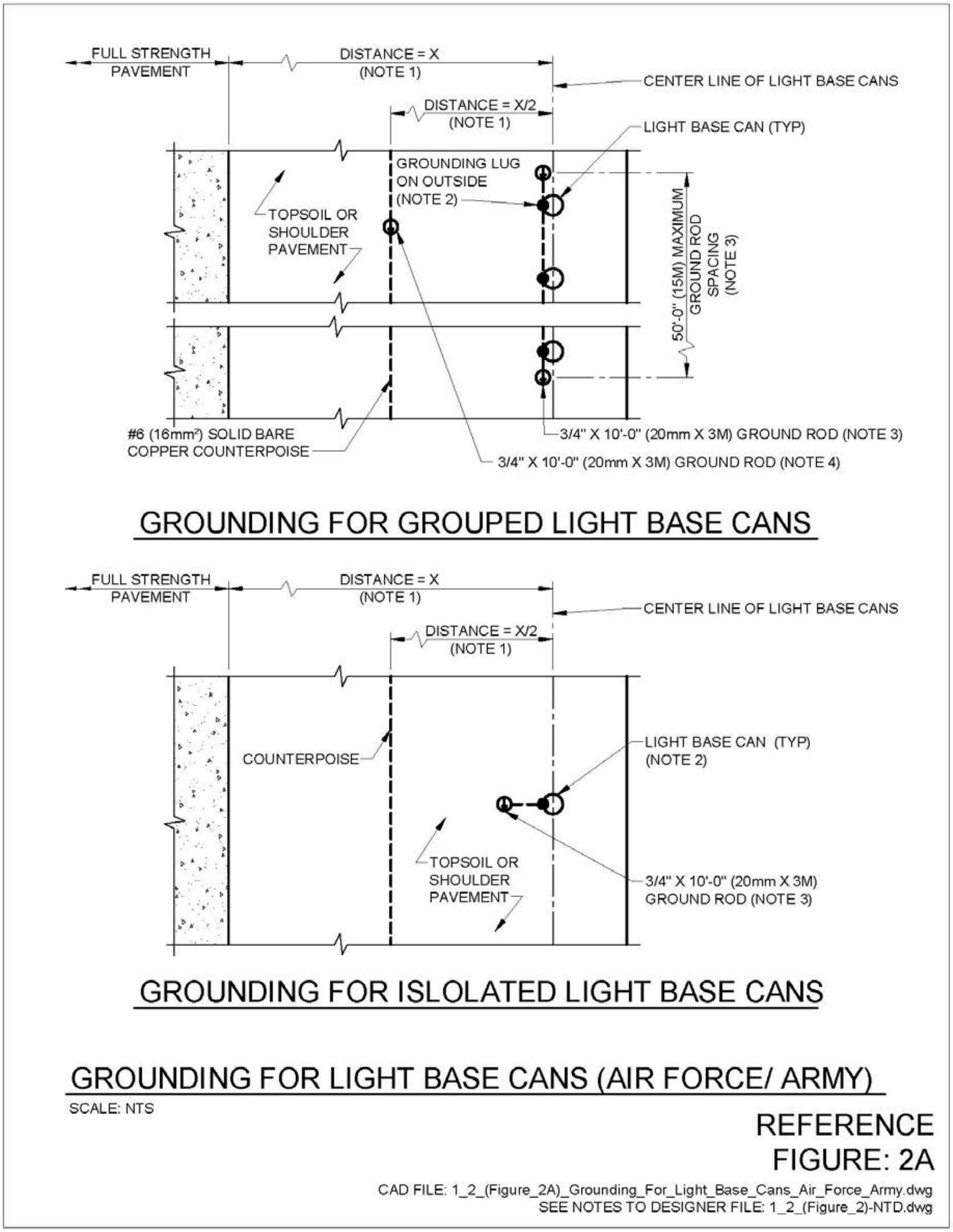


Figure 2B. Grounding for Light Base Cans (Navy)

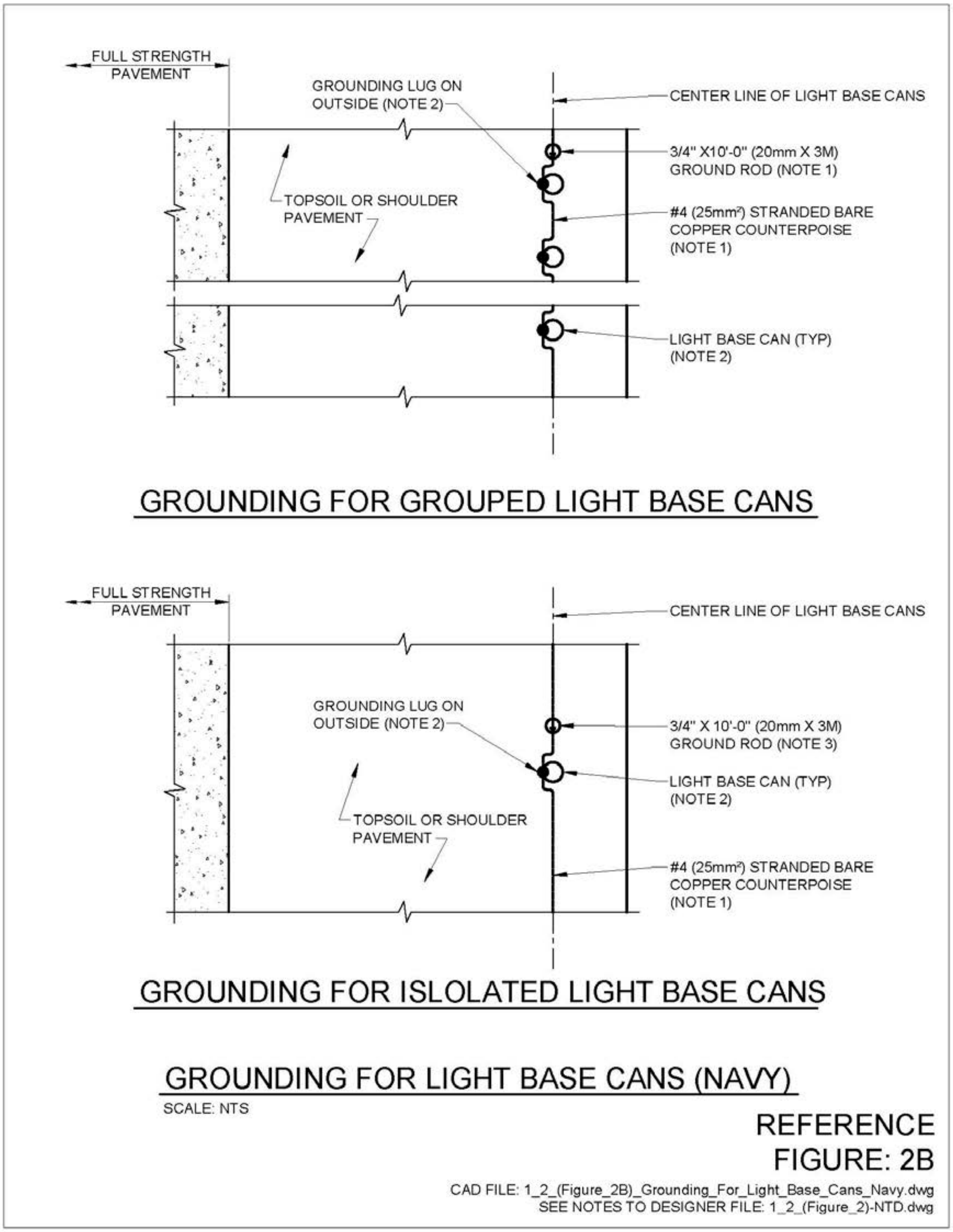


Figure 3A. Grounding Connections to Light Base Can (Air Force / Army)

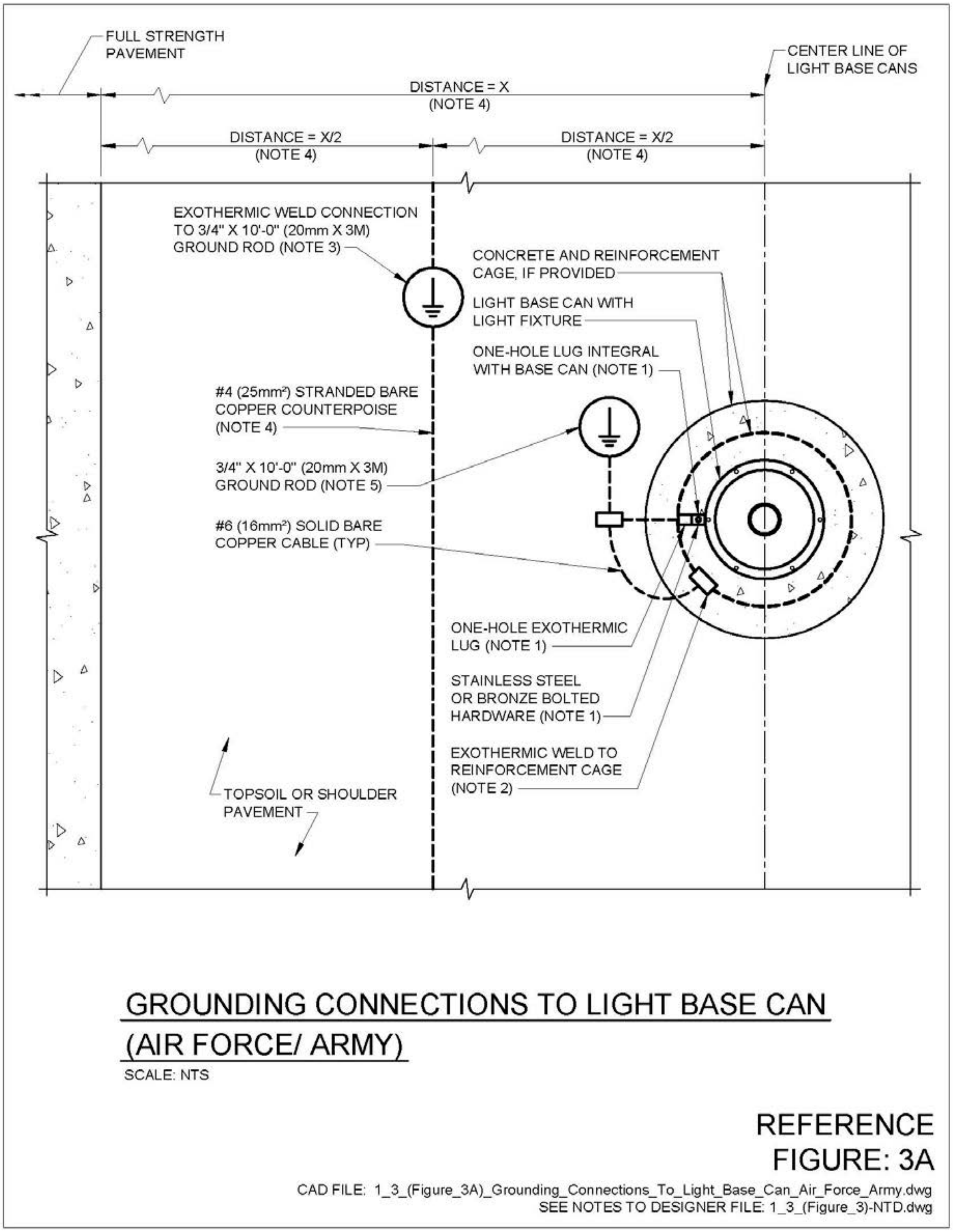
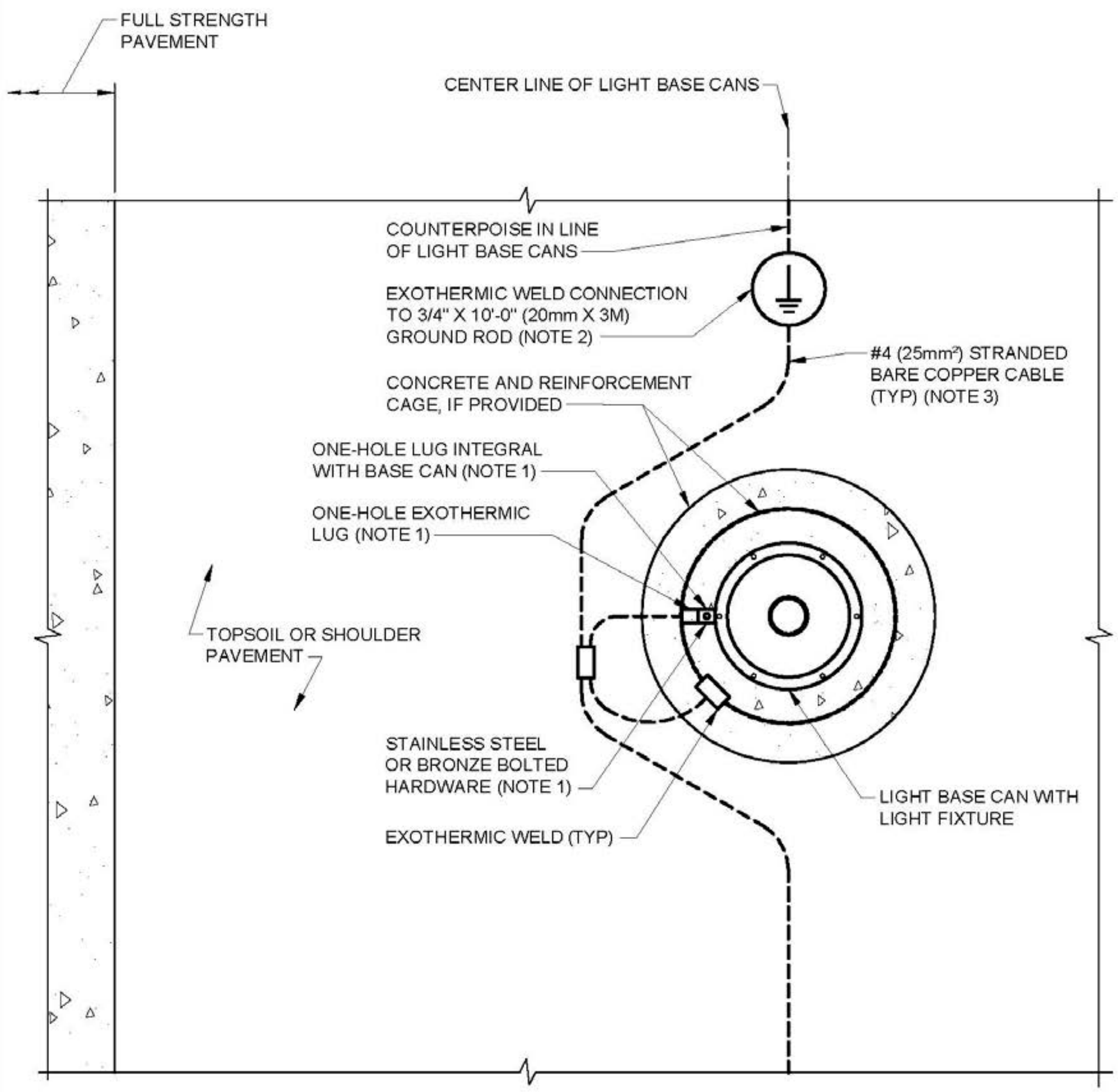


Figure 3B. Grounding Connections to Light Base Can (Navy)



GROUNDING CONNECTIONS TO LIGHT BASE CAN (NAVY)

SCALE: NTS

REFERENCE
FIGURE: 3B

CAD FILE: 1_3_(Figure_3B)_Grounding_Connections_To_Light_Base_Can_Navy.dwg
SEE NOTES TO DESIGNER FILE: 1_3_(Figure_3)-NTD.dwg

2-2 Marker Installation at Pavement Edge.

2-2.1 Figure 4.

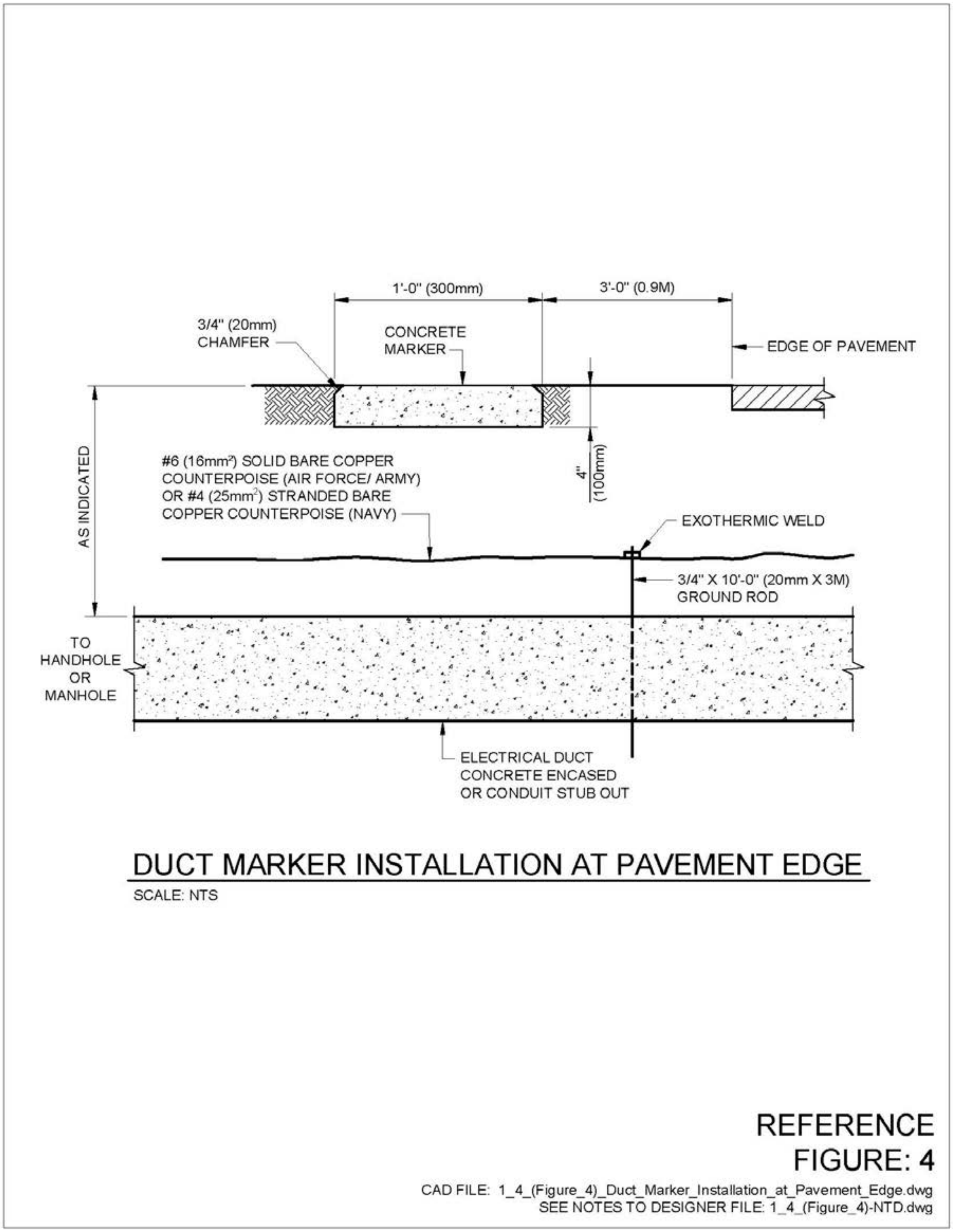
2-2.1.1 Notes to Designer.

1. An option for installing the counterpoise would be to ground the counterpoise to a ground rod 3' (0.9m) before the runway or taxiway pavement and not install counterpoise over duct bank where duct run is beneath pavement.

2. The depth of the duct bank below pavement should be indicated in the duct bank details.

3. All counterpoise must be solid bare copper wire (conductor) #6 (16 square mm) minimum (Air Force/Army) and stranded bare copper wire (conductor) #4 (25 square mm) minimum (Navy), and must be bonded to ground rods using exothermic welds.

Figure 4. Duct Marker Installation at Pavement Edge



2-3 Duct Markers.

2-3.1 Figure 5.

2-3.1.1 Notes to Designer.

1. Duct markers are placed directly over the cable trench with the arrows indicating direction of duct run. Maximum spacing of markers should not exceed 200' (60m) and place the duct run changes direction. No markers are required where the duct runs in a straight line from light base to light base.

2. Duct markers are typically used at the edges of pavement to locate duct crossings beneath pavement. Where the entire lighting system is in ducts or conduit, locate the duct markers the same as cable markers.

2-3.1.2 Drawings Notes for Figure 5, Typical Duct Marker Layout.

1. Install duct markers at each change of direction.

2. Install duct marker every 200' (60m) along straight runs with no access structure.

3. On straight runs less than 200' (60m) install duct marker at midpoint.

4. Install duct marker at ends of ducts that are not terminated at manholes.

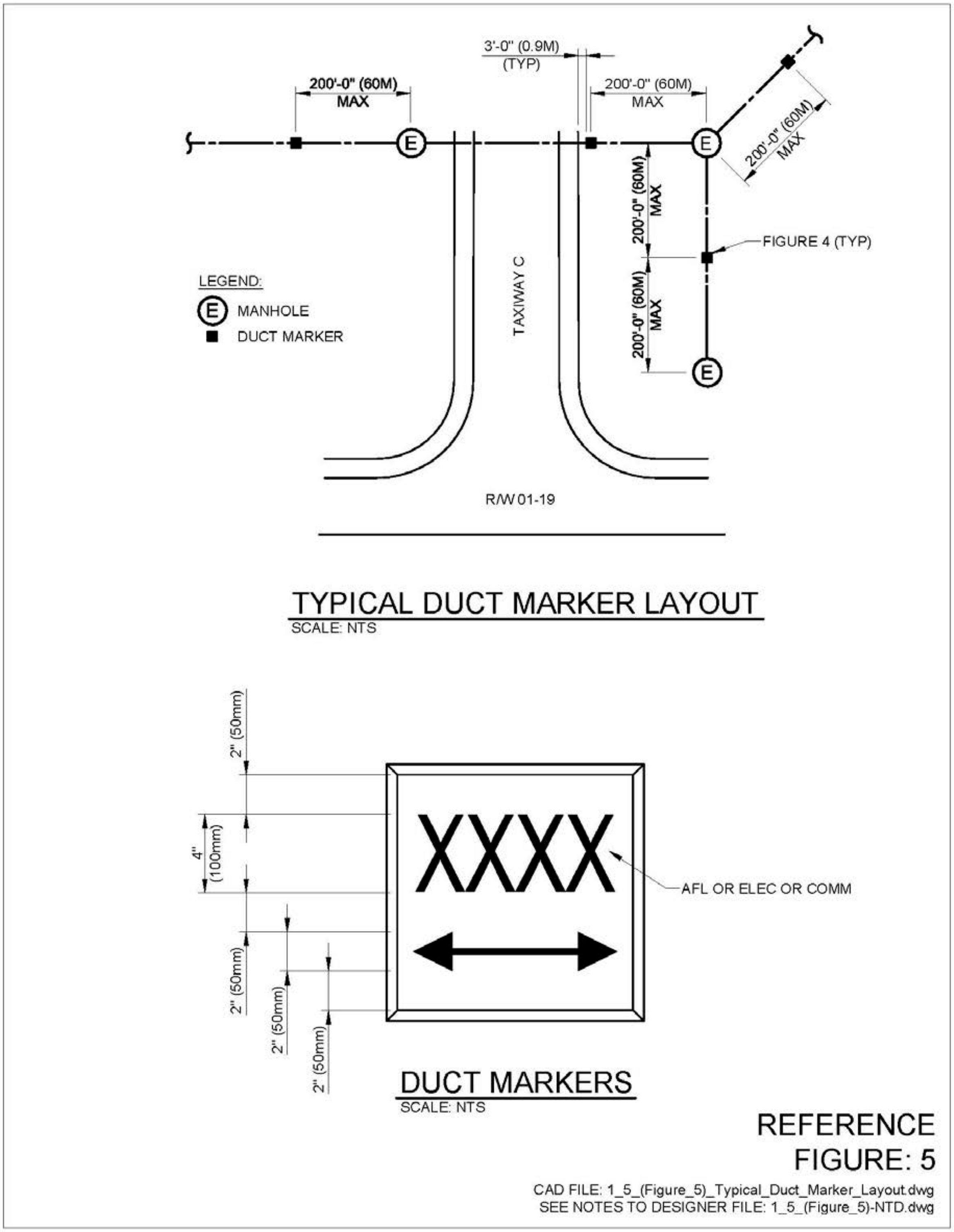
2-3.1.3 Drawings Notes for Figure 5, Duct Markers.

1. Hand lettering not allowed on markers. Lettering is to be boldly impressed. Line width must be 1/2" (13mm) minimum. Depth of impression must be 1/4" (6mm) minimum.

2. Arrow on marker to indicate direction of ducts (where applicable).

3. All markers are concrete with a minimum of 4" (100mm) in thickness.

Figure 5. Duct Markers



2-4 Concrete Encased Duct Bank Details – Typical Arrangements.

2-4.1 Figures 6A, 6B, 6C.

2-4.1.1 Notes to Designer.

1. Indicated to minimize weak points in the duct bank.

2. Several types of duct spacers will accomplish the required duct spacing. Some spacers allow for installation of several tiers on a single duct spacer thereby requiring less labor for installation.

3. It is recommended the minimum depth of the duct bank be at least 12" (300mm) below frost line.

4. If there are no communication ducts intended, they may be deleted from the details.

5. Ducts should terminate in handholes, junction plazas, or manholes wherever possible. The handholes or manholes should be located outside of the runway or taxiway safety areas, if feasible.

6. Slope duct lines (minimum 0.5% slope) where practical for drainage towards manholes/handholes, or duct ends. Where handholes or manholes do not exist at the ends of duct banks for drainage, consider the use of available natural features that are environmentally-approved or environmentally-friendly. Drainage should be designed to limit possible wildlife entrance.

7. Spacing of ducts indicated is minimum in power group for series circuits. Refer to Article 310 in the National Electrical Code, NFPA-70, when ducts are carrying parallel (constant voltage) AC circuits.

8. Number and size of ducts will vary depending on project. Adjust duct number, arrangement and layout accordingly.

9. Red concrete is recommended for Air Force and Army projects. Red concrete is not required for Navy projects.

10. Use UG plates for Navy projects.

11. All counterpoise will be solid bare copper wire (conductor) #6 (16 square mm) minimum (Air Force/Army) and stranded bare copper wire (conductor) #4 (25 square mm) minimum (Navy), and will be bonded to ground rods using exothermic welds.

12. See Paragraph 2.1, UFC 3-535-02, UFC 3-585-01 and NFPA 780, Chapter 11 for location of counterpoise(s) above duct banks.

2-4.1.2 **Drawings Notes for Figures 6A and 6B, Duct Banks.**

1. For size and number of conduits as well as duct bank formation, see plans.

2. Separate the communications conduit group from the power group on either left or right side as indicated on plans.

3. Concrete cover on top; bottom and sides must be 3" (75mm) minimum.

4. Duct banks may be bored under existing pavement. No open cutting of the pavement may occur without base approval. All installation techniques, methods, materials, etc., must be submitted to contracting officer for review prior to starting work. Refer to UFC 3-550-01, and NAVAIR 51-500 AAA-2 for guidance.

5. Conduit and duct bank runs must be straight (±4" (100mm) of centerline between manholes, handholes, and base cans) except where designated differently on design drawings.

6. Conduit temperature must be at burial temperature for 24 hours before covering or making manhole/handhole connections.

2-4.1.3 **Drawings Notes for Hold Down Bar, Figure 6C.**

1. The hold down bar is used to prevent duct flotation during the concrete pour.

2. Drive rebar into the ground at an angle of approximately 15 to 25 degrees off perpendicular. Drive rebar until hold down bar is slightly deformed. Use additional rebars according to number of ducts used.

3. Install retaining ring above hold down bar. Place rebar cover above retaining ring.

4. Place hold down bars up to 5' (1.5m) apart unless conduit is stacked more than one duct high. It may be necessary to place hold down bars closer together if it is not possible to get a good anchor in the ground with the rebar.

5. Contractor must watch concrete pour to ensure that concrete does not hit one end on the hold down bar and cause bar to rotate and release ducts.

Figure 6A. Concrete Encased Duct Bank Details – Typical Arrangements

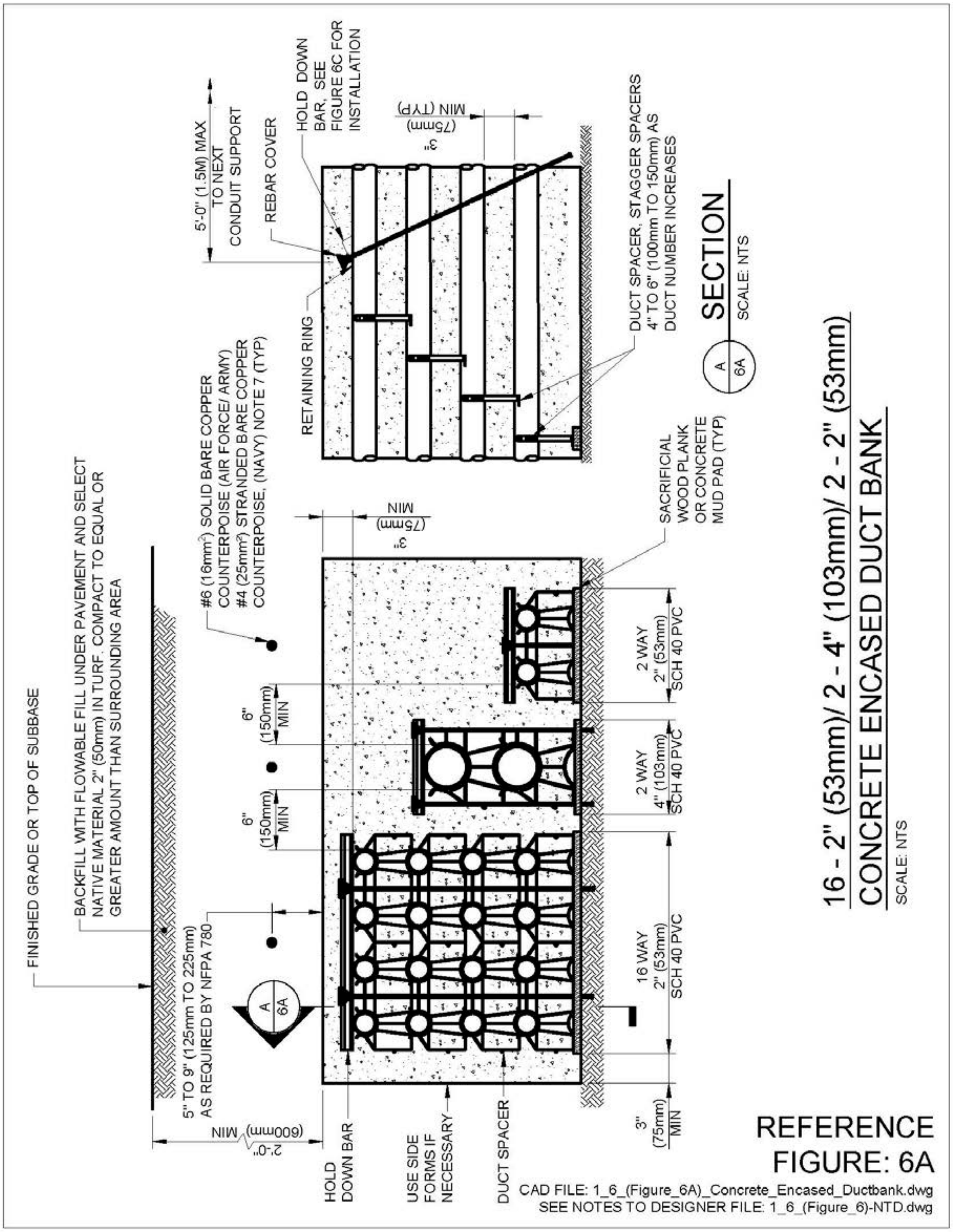


Figure 6B. Concrete Encased Duct Bank Details – Typical Arrangements (continued)

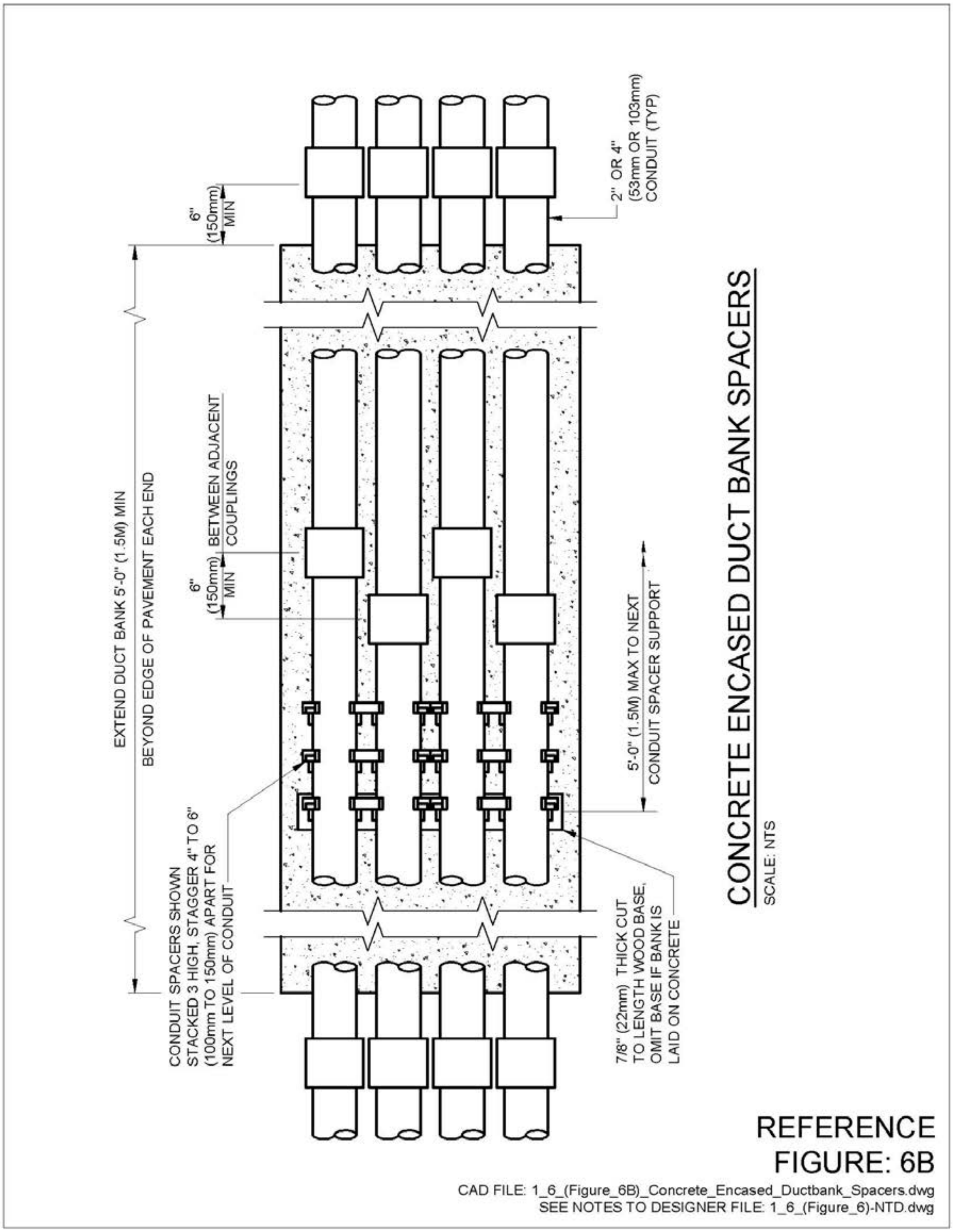
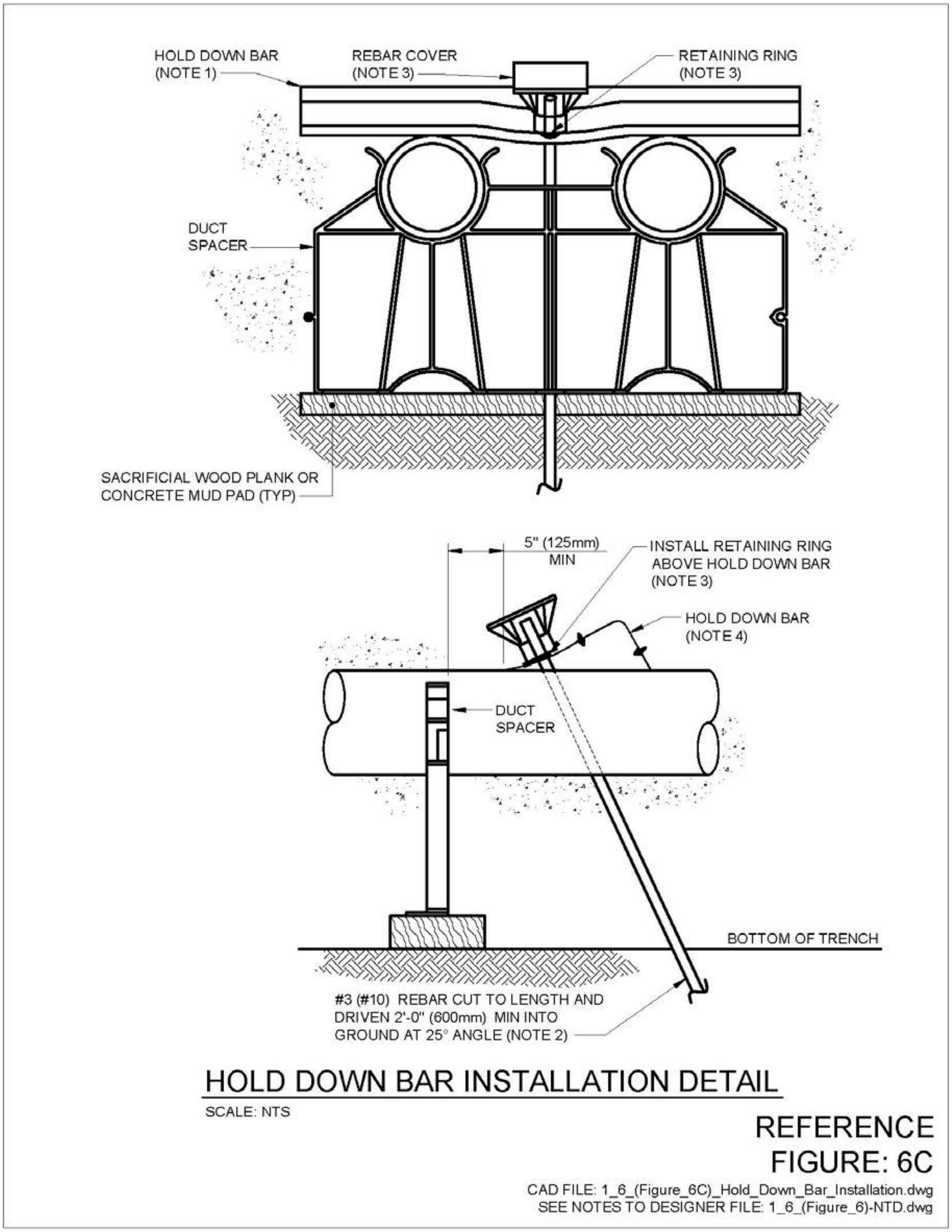


Figure 6C. Hold Down Bar Installation Detail



2-5 Field Attached Plug-in Splice FAA Type L-823.

2-5.1 Figures 7A, 7B.

2-5.1.1 Notes to Designer.

1. If heat-shrink tubing is used, it is recommended that single piece heat-shrink tubing and sealant be applied only at each end of the splice. Tubing with sealant coated on the entire interior will actually adhere to the L-823 connector thereby requiring a new connector be installed every time the splice is entered.

2. The cable ties act as an indicator to maintenance personnel for the location of the mating faces on the connector. When maintenance personnel need to enter the splice, the tubing is cut between the two ridges formed by the cable ties. Each piece of the tubing may now be rolled back to expose the connector. To re-seal the splice, the old tubing is removed and a new piece of heat-shrink with sealant at ends is installed.

3. The designer should contact several manufacturers of L-823 splice connectors and become familiar with their recommended installation requirements. See Figure 7B.

4. Make cable conductor connections using a crimping tool designed to make a complete crimp before the tool can be removed.

2-5.1.2 Drawings Notes for Figure 7A.

1. Interior pin and sockets are not indicated for clarity.

2. Attach each cable tie 1/8" (3mm) from the mating face of the connector housing. Tighten cable tie enough to hold in place without compressing housing. Trim off excess cable tie.

3. Installation of L-823 and heat shrink tubing must be in strict conformance with manufacturer’s requirements.

2-5.1.3 Drawings Notes for Figure 7B.

1. Contractor must provide cable circuit identification markers attached to both sides of each cable connection.

2. Attach cable identification markers with corrosion resistant material.
3. Thoroughly clean the cable prior to the installation of the L-823 connector kit.

4. Complete installation of the pin/receptacle with “crimping” tool supplied or recommended by the manufacturer and designed for this specific purpose. Two crimping tools must be turned over to the government upon completion of the project.

5. Attach each cable tie enough to hold in place without compressing housing. Trim off excess cable tie.

6. Installation of complete kit connector must be in strict conformance with manufacturer’s requirements.

Figure 7A. Field Attached Plug-in Splice FAA Type L-823

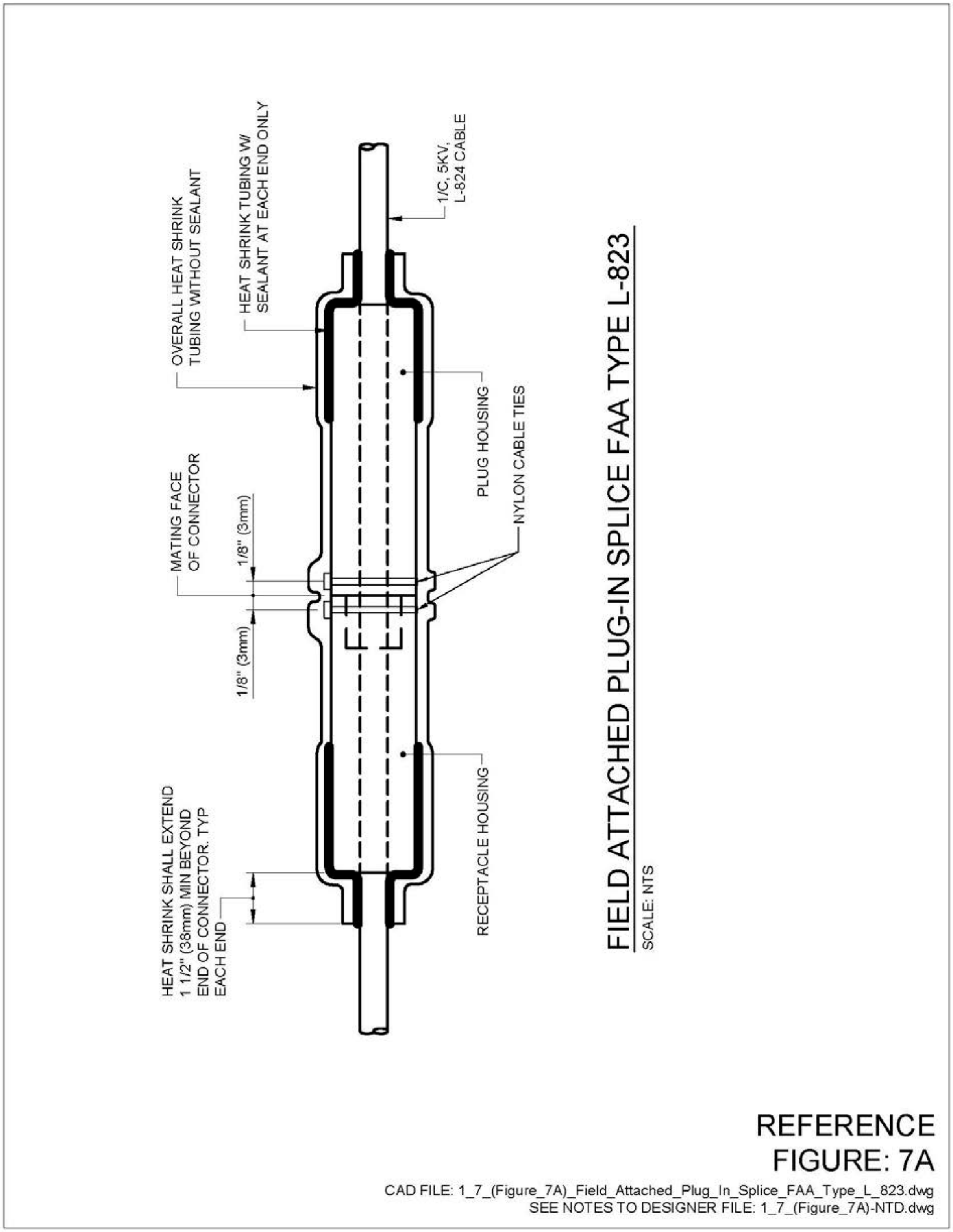
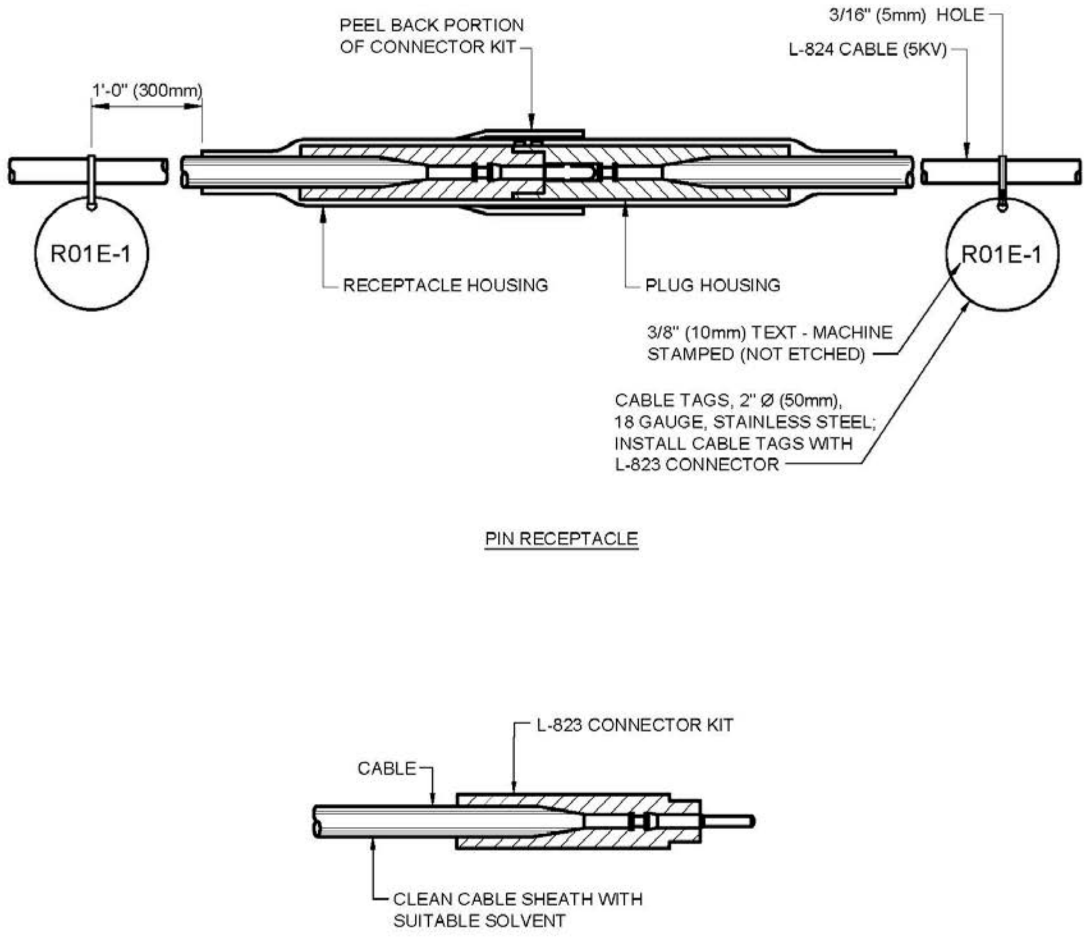


Figure 7B. Typical L-823 Connector Detail Without Heat Shrink



TYPICAL L-823 CONNECTOR DETAIL
WITHOUT HEAT SHRINK
SCALE: NTS

REFERENCE
FIGURE: 7B

CAD FILE: 1_7_(Figure_7B)_Typical_823_Connector_Detail_Without_Heat_Shrink.dwg
SEE NOTES TO DESIGNER FILE: 1_7_(Figure_7B)-NTD.dwg

CHAPTER 3 Runway and Taxiway Lighting

3-1 Fixture Installation Tolerances.

Figure 8. Reserved.

3-1.1 Notes to Designer.

Tolerances below must be indicated in the airfield lighting system specifications.

Light Fixture Installation Tolerances

	IN-PAVEMENT	ELEVATED
ELEVATION (relative to finished pavement surface for in-pavement; relative to finished grade at fixture for elevated)	+0", -1/16" (1.6mm) (fixture edge on low side in snow areas or on high side in non-snow areas) +1/4" (6mm), -0"	
AZIMUTH (*) (w/respect to line parallel to RW/TW centerline)	±1/2 degree	±1/2 degree
LEVEL	±1/2 degree	±1/2 degree
STATIONING (in line parallel to RW/TW centerline)	±2" (50mm)	±2" (50mm)
OFFSET (perpendicular to RW/TW centerline)	±1/4" (6mm)	±1/4" (6mm)

3-2 Base Mounted Elevated Fixture Installation.

3-2.1 Figure 9.

3-2.1.1 Notes to Designer.

1. Flexible conduit, if required, allows for minor adjustments in alignment during installation and also allows flexibility of the conduit runs during freeze/thaw cycles in cold climates. Conduit must meet the requirements of NEMA TC12 and should be at least 12" (300mm) long.

2. Many contractors will purchase L-867 bases and send them to pre-cast shops for the concrete encasement. Conduit stubs are slid through the grommets prior to casting. A minimum of 6" (150mm) should be protruding from the encasement to allow installation of the conduit couplings.

3. Some installations have underdrains around the runway or taxiway. The designer should review the profile of the lighting system together with the profile of the pavement. For Air Force and Army airfields, bases at the low point should be ordered with an additional hub and a 2" (53mm) conduit should be connected between the underdrain and the light base. Where there is no underdrain exists, the conduit may run to the closest storm water catch basin. For Navy airfields, the bottom drain is not used. Maintain slope so that water drains out of light base toward underdrain or catch basin.

4. All counterpoise will be solid bare copper wire (conductor) #6 (16 square mm) minimum (Air Force/Army) and stranded bare copper wire (conductor) #4 (25 square mm) minimum (Navy), and will be bonded to ground rods using exothermic welds.

5. For installations in existing pavement that do not require new conduit, and where no counterpoise is available, add an external ground rod outside of light base, and connect it to the base can with #6 (16 square mm) solid bare copper wire (Air Force/Army) or #4 (25 square mm) stranded bare copper wire (Navy). Use exothermic welds to connect the ground wire to the ground rod. Exothermically weld a one-hole ground lug to the wire, and bolt the lugs together.

3-2.1.2 Drawings Notes for Figure 9.

1. Standard height is 14" (350mm). Height may be adjusted in areas subject to snow conditions.

2. Air Force / Army Airfields: Ground rod location is outside the base can on the side adjacent to the counterpoise and connected to the external ground lug and reinforcement cage. Provide 12" (300mm) separation from counterpoise. Navy Airfields: Connect the counterpoise to the external ground lug and reinforcement cage.

3. Air Force / Army Airfields: Bottom drain is optional. Navy Airfields: Bottom drain not required.

4. Provide 48" (1200mm) braided copper grounding strap equivalent to #6 (16 square mm) wire.

Figure 9. Base Mounted Elevated Fixture Installation

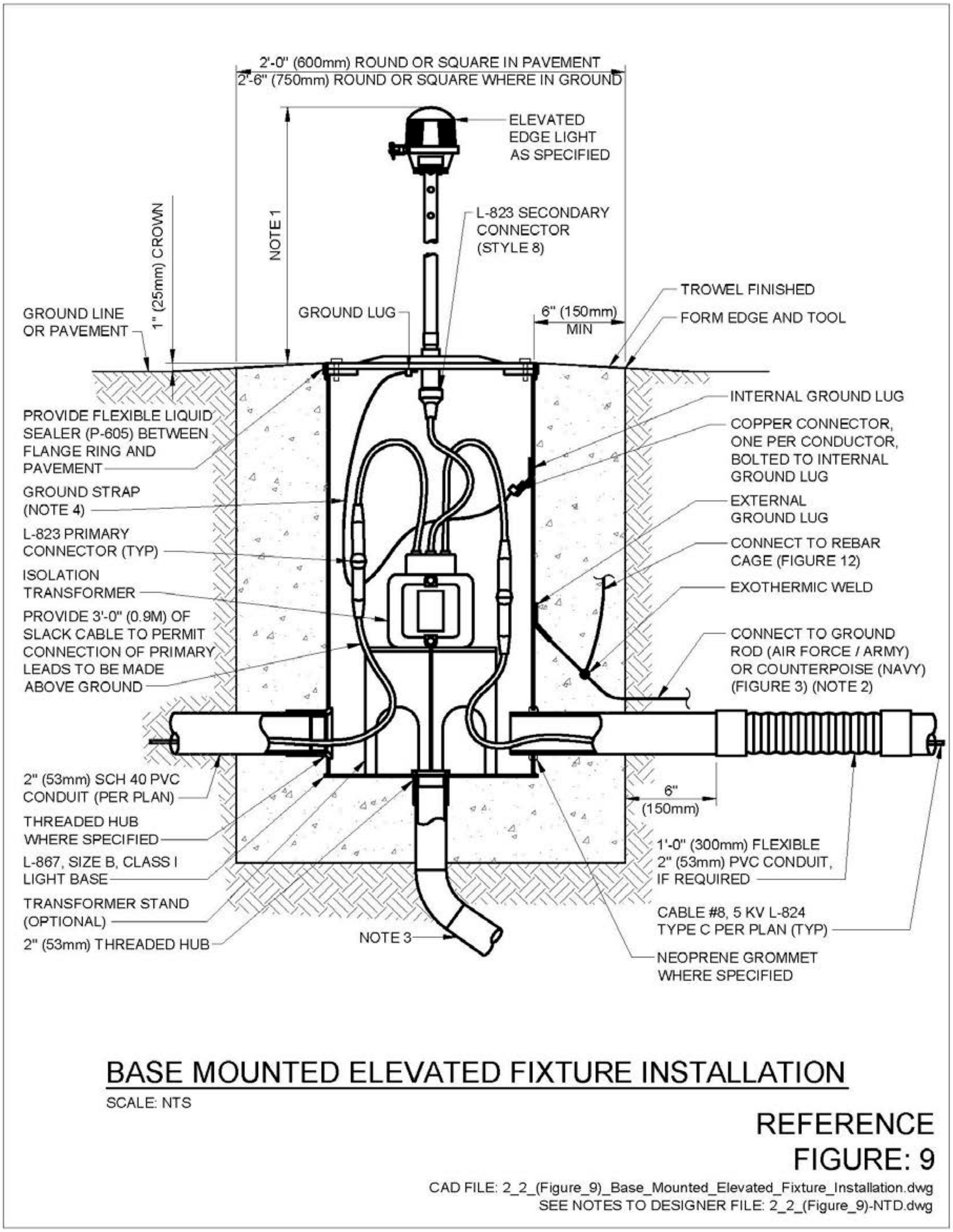


Figure 10. Reserved.

3-3 In-Pavement Runway Light (Deep Base).

3-3.1 Figures 11A, 11B.

3-3.1.1 Notes to Designer.

1. All in-pavement lights should be installed on a load-bearing base FAA type L-868. The diameter of the base will depend on the fixture manufacturer and type of fixture being installed.

2. It is recommended that the fixture be set inside a flange ring that has an integral pavement ring. Spacer rings (or shims) should be set on top of the base and the flange ring will mount on top of the spacer rings. This allows lowering of the fixture in flexible pavements if the pavement is slumping. No more than 2 spacer rings should be used.

3. The sealing compound must be compatible with the adjacent pavement material and the contractor must follow the manufacturer's preparation instructions.

4. It is recommended that the designer should review the profile of the in-pavement lighting system and provide drainage at the low points.

5. Installation methods for in-pavement fixtures are also contained in advisory circular (AC) 150/5340-30, Design and Installation Details for Airport Visual Aids.

6. For installations in existing pavement that do not require new conduit, no counterpoise is required.

7. This detail covers runway and taxiway airfield lighting fixtures installed in a deep base.

3-3.1.2 Drawings Notes for Figure 11A.

1. Refer to Figure 12 for base installation details.

2. Air Force / Army Airfields: Ground rod location is outside the base can on the side opposite the counterpoise and connected to the external ground lug. Navy Airfields: Connect counterpoise to external grounded lug and reinforcement cage.

3. Air Force / Army Airfields: Bottom drain is optional. Navy Airfields: Bottom drain not required.

4. Provide 48" (1200mm) braided copper ground strap between light base can and light fixture. Strap must be equivalent to No. 6 (16 square mm) cable.

3-3.1.3 **Drawings Notes for Figure 11B.**

1. Refer to Figure 12 for base installation details.

2. Two-piece stainless steel locking washer. Do not use split-ring type.

3. Spacer rings may be required for proper alignment of the light fixture.

4. Do not use anti-seize compound on ceramic-metallic fluoropolymer coated bolt.

Figure 11A. In-Pavement Fixture Installation (Deep Base)

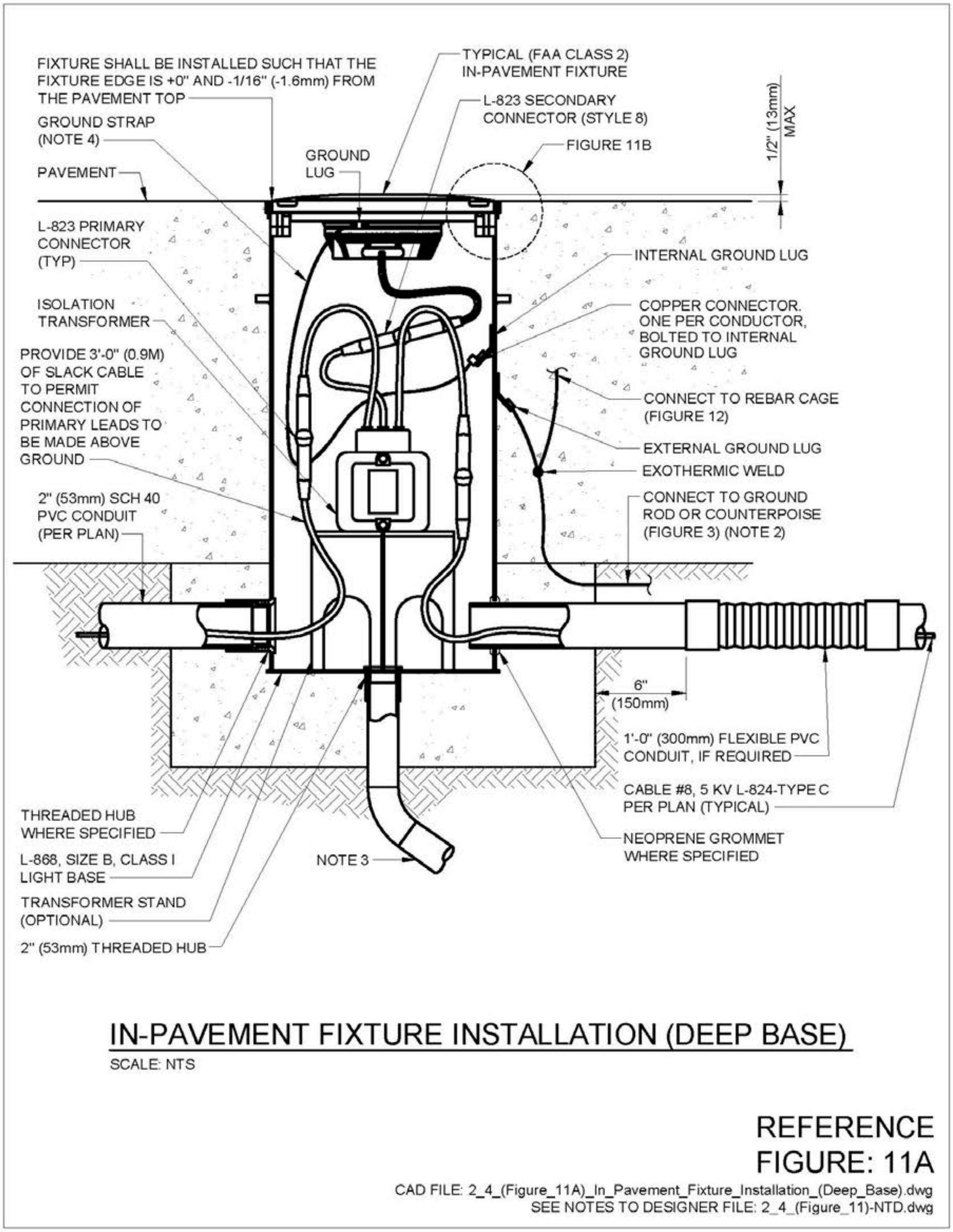
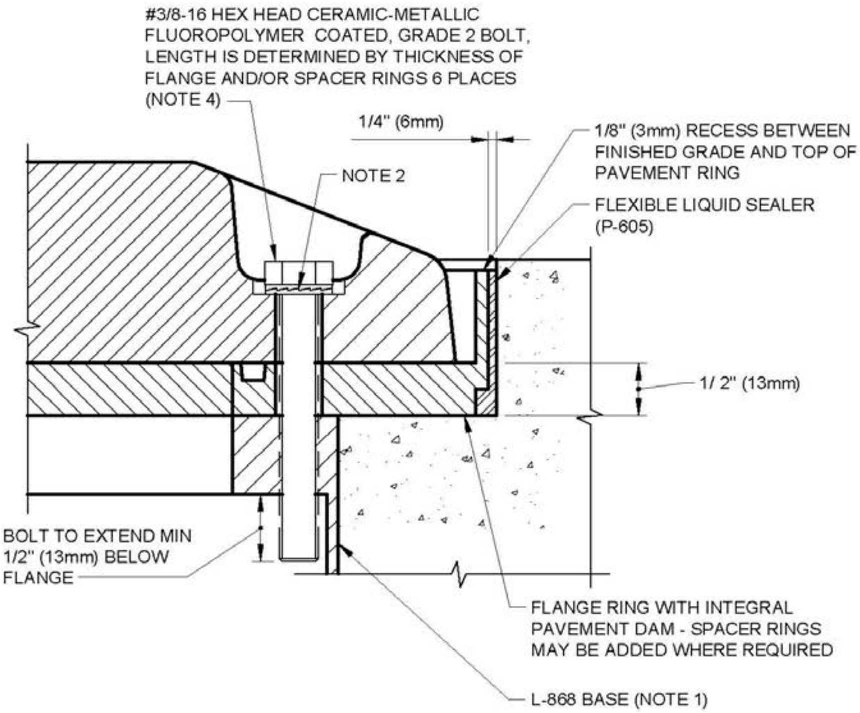


Figure 11B. In-Pavement Light Detail (Deep Base)



IN-PAVEMENT LIGHT DETAIL (DEEP BASE)

SCALE: NTS

REFERENCE
FIGURE: 11B

CAD FILE: 2_4_(Figure_11B)_In_Pavement_Light_Detail_(Deep_Base).dwg
SEE NOTES TO DESIGNER FILE: 2_4_(Figure_11)-NTD.dwg

3-4 Base and Anchor Details (New Construction).

3-4.1 Figure 12.

3-4.1.1 Notes to Designer.

1. Construction methods will be specified in the project specifications for the type of pavement. Details should be indicated on the drawings in enough detail to complement the specifications.

2. Preparation for the base and anchor in either rigid or flexible pavement is the same. At each light location a hole is excavated in the sub base which will be minimum 12" (300mm) wider than the light base and 6" (150mm) below the bottom of the light base. A trench is excavated between the light base locations for the conduit. Depth of the trench must provide a minimum 2" (50mm) cover over and 3" (75mm) below the conduit and also allow the conduit to enter the base at the proper elevation.

3. A single section light base is used in rigid pavements and a two or three section light base (depending on pavement depth and lifts) must be used in flexible pavements.

4. The flexible conduit allows for minor base adjustments before the concrete anchor hardens.

5. A reinforcement cage is installed around the light base in rigid pavement.

6. For flexible pavement, a 2-piece light base may be used as an alternative to a 1-piece base.

7. See The Design, Installation, & Maintenance of In-Pavement Airport Lighting (Reference book by Arthur S. Schai). Available from FAA website:

http://www.faa.gov/airports/engineering/airport_lighting/media/schai_airport_lighting.pdf

3-4.1.2 **Drawings Notes for Figure 12.**

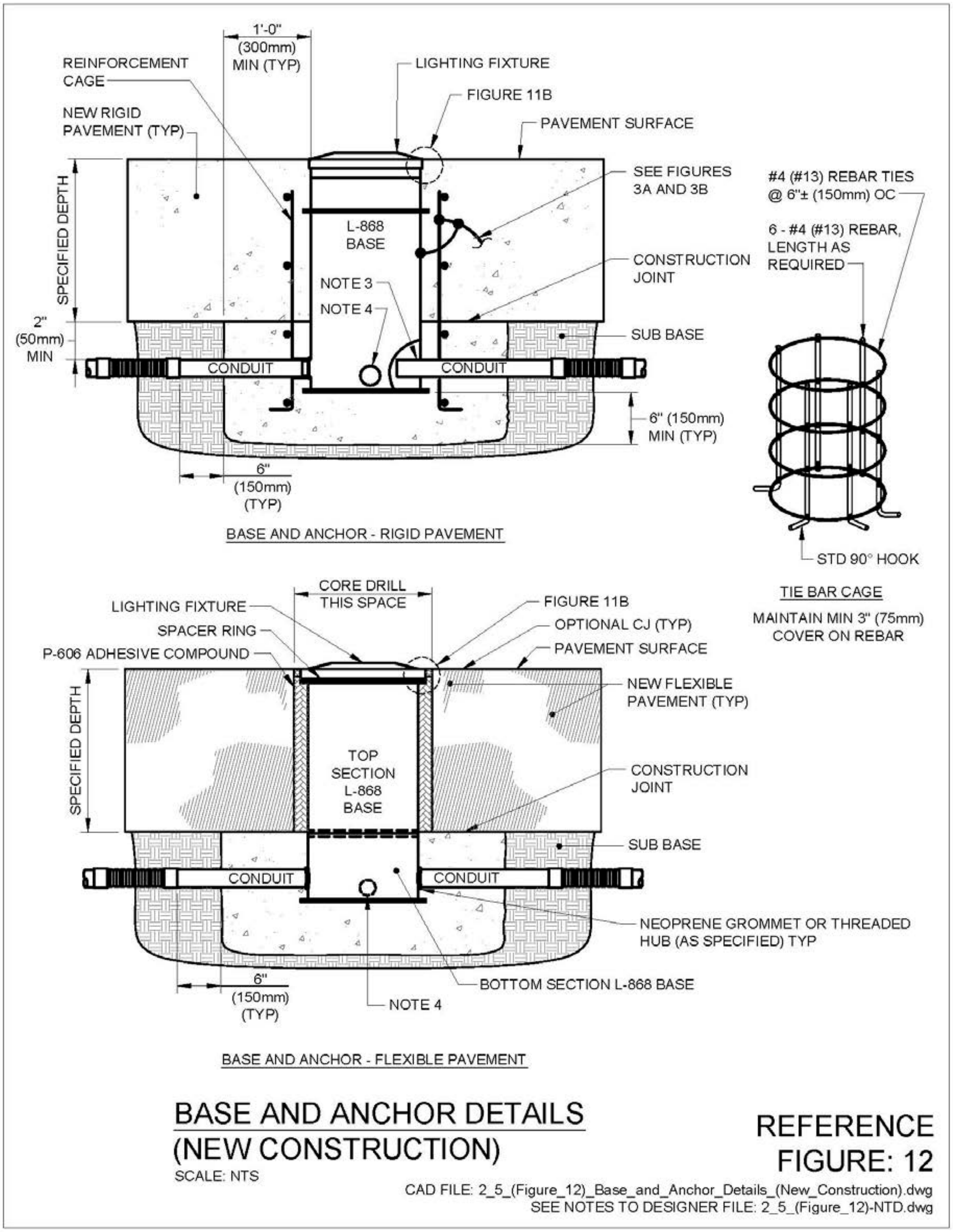
1. The use of mud plates, spacer rings, extensions, etc., is dependent on paving techniques.

2. Orientation tolerance for the base is ±1/2 degree from the centerline indicated on the plans.

3. Conduit entrance can be made with either a hub or grommet. If grommet is used, conduits must protrude into light base not more than 3/4" (19mm) for steel and 1" (25mm) to 1-1/2" (38mm) for PVC.

4. Air Force / Army Airfields: 2" (53mm) PVC conduit to nearest catch basin or French drain is optional, typically at each low point of lighting system. Navy Airfields: Side drain not required.

Figure 12. Base and Anchor Details (New Construction)



3-5 Deep Base Installation in Rigid Pavement (New Construction).

3-5.1 Figure 13.

3-5.1.1 Notes to Designer.

1. Light location, elevation, azimuth (direction of the light beam measured in a horizontal plane) is extremely critical. It is recommended that contract documents require all points for setting the lights be accomplished by survey and a mandatory construction meeting be included with representatives from the Architect-Engineer (A/E) team, contractor, government and field personnel. The purpose of this meeting will be to review the proposed construction techniques.

2. For flexible pavement, a two-piece light base may be used as an alternative to a one-piece light base.

3. See The Design, Installation, & Maintenance of In-Pavement Airport Lighting (Reference book by Arthur S. Schai). Available at the FAA website:

http://www.faa.gov/airports/engineering/airport_lighting/media/schai_airport_lighting.pdf

3-5.1.2 Drawings Notes for Figure 13.

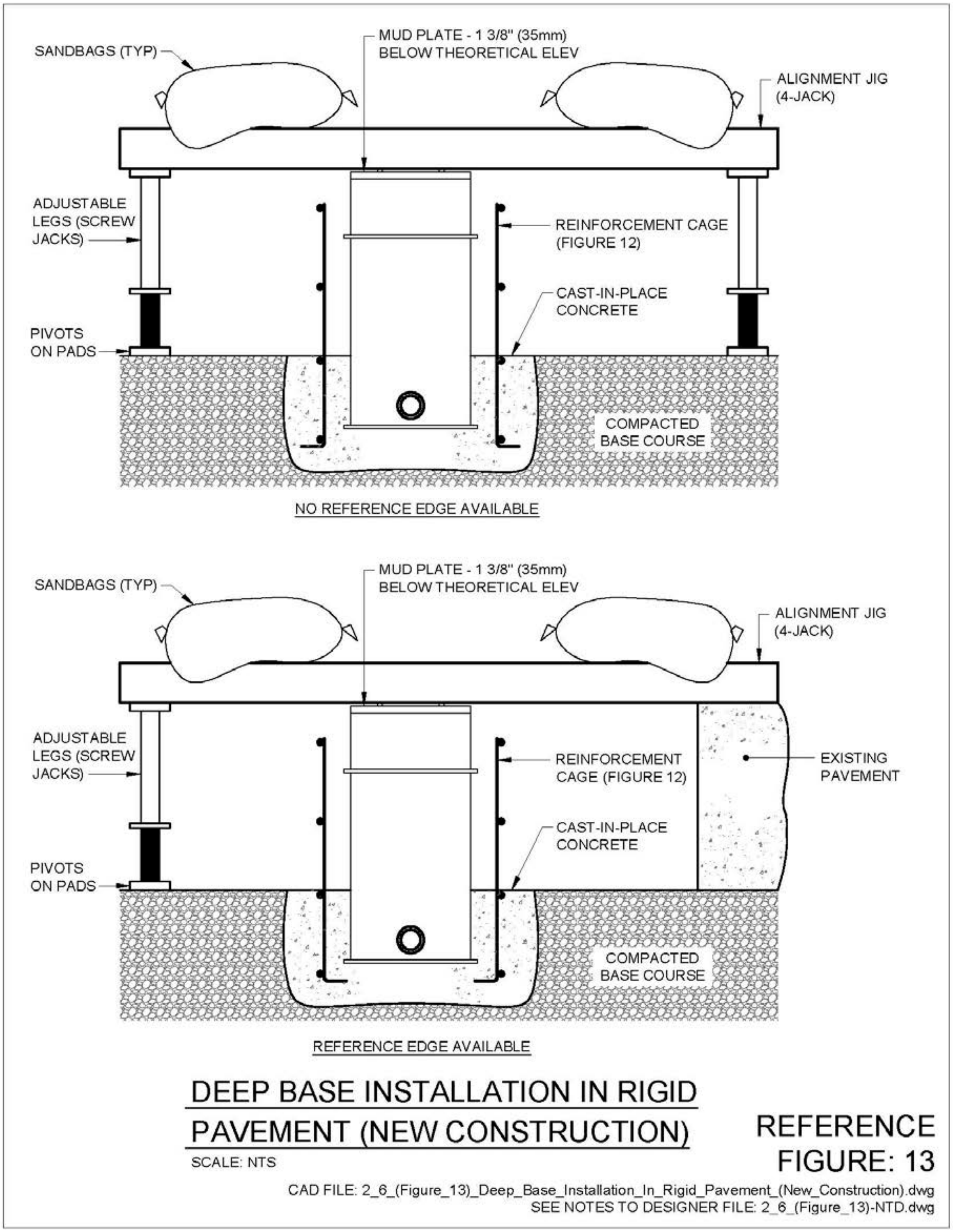
1. Install the alignment jig per the base manufacturer's requirements. The jig should be provided with adjustable legs for setting elevation and alignment pins for setting azimuth.

2. Once light bases are set at correct elevation, conduit is installed between the bases and reinforcement cages are formed around the base. Sufficient weight, such as sand bags, should be placed on top of the jig to prevent the light base from floating during concrete installation. The concrete anchor is poured around the base and along the conduit trench. Instruct the contractor to ensure that all voids or loose material beneath the conduit have been eliminated prior to encasing in concrete. Concrete should be flush with sub base and not protrude above sub base.

3. Once the concrete has cured a minimum of 24 hours, the jig may be removed.

4. Paving cannot commence until light base concrete anchor has cured for 3 days or reached a strength of 3000 psi.

Figure 13. Deep Base Installation in Rigid Pavement (New Construction)



3-6 Flexible Pavement or Overlay (Flexible, Rigid) Installation.

3-6.1 Figure 14.

3-6.1.1 Notes to Designer.

1. Installation in flexible pavement is similar to rigid except a sectional base is used and there is no reinforcement cage.

3-6.1.2 Drawings Notes for Figure 14.

1. Typical installation in new flexible pavement or overlay of flexible or rigid (PCC) pavement.

2. Two-piece stainless steel locking washer. Do not use split-ring type.

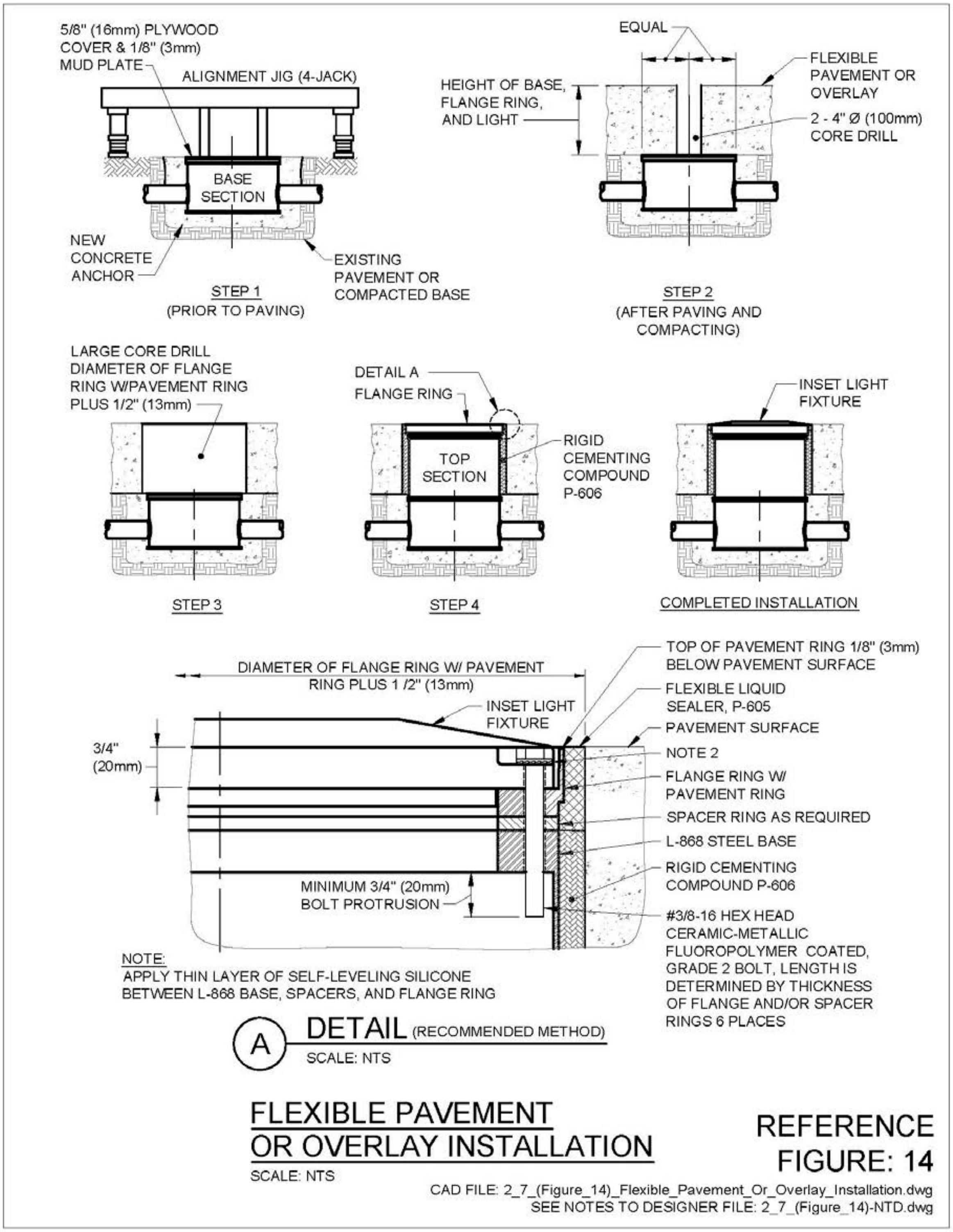
3. The bottom section of the light base is set at an elevation such that the top of the plywood cover and mud plate is flush with the surrounding base course. The concrete anchor is poured and allowed to cure for 24 hours.

4. The jig may then be removed and paving operations may be accomplished.

5. Ensure core drilling for the light bases is accomplished after compaction has been completed and the pavement has been accepted by the government.

6. Rigid Cementing Compound P-606 is used to firmly set the top section or base extension in place and bond to pavement. The flexible P-605 is installed from the top of the top section or base extension to the top of the finished pavement surface. This allows future adjustment of the fixture by removing or adding spacer rings without disruption of the base. Both P-606 and P-605 must be specified as being compatible with type of pavement being installed.

Figure 14. Flexible Pavement or Overlay Installation



3-7 In-Pavement Light Fixture on Full Base and Snow Plow Ring in Rigid (PCC) Pavement.

Figure 15. Reserved.

Figure 16. Reserved.

3-7.1 Figures 17A, 17B, 17C, 18A, 18B, 19A, 19B.

3-7.1.1 Notes to Designer.

1. Figures 18A, 18B, 19A and 19B show the installation of an in-pavement light fixture in PCC pavement. The fixture is mounted in a snow plow ring in lieu of the standard flange ring with pavement dam. The purpose of the snow plow ring is to minimize the potential for damage to the fixture by snow plow blades (snow plow blades must be rubber or some other flexible material) during snow removal operations. Special attention should be paid to the thickness and diameter of the ring and the installation elevation.

2. Where the pavement may be higher at one side of the base than the other, the use of beveled spacer rings may be required. This allows an adjustment of the ring to compensate for the slope of pavement at the outside edge of the ring.

3-7.1.2 Drawing Notes for In-Pavement Fixtures, Figures 18A and 18B.

1. Install corner edge of snow plow ring flush with pavement surface with a tolerance of +0", -1/16" (1.6mm).

2. Submit all base can installation techniques, methods, materials, etc., to the government for review and approval prior to the start of work.

3. Before paving may proceed, the contractor must demonstrate to the government that the base cans are at the correct location, elevation, azimuth and rotation and that the proper clearance exists between the base can and the paver.

4. The spacer ring is designed as a nominal 3/4" (19mm) thickness. The spacer ring may be required to be thinner or thicker depending on base can installation and paving techniques / tolerances. This contractor must measure and determine the required thickness of each individual spacer ring required to put the airfield lighting fixture at the correct elevation, azimuth and rotation. The contractor may use multiple spacer rings of varying heights. No more than 3 spacer rings may be used on any one light installation. The maximum height displacement for one or more spacer rings will be 2" (50mm) or less.

5. The finished pavement surface must be protected from foreign substances which could cause staining, i.e. concrete, oil, etc. The contractor must immediately clean all spills and correct/clean any stained surfaces at the contractor's expense.

6. The base can cover mounting bolts must extend thru the base can mounting flange into the base can a minimum of ½" (13mm). The bolts must be threaded the full length of the bolt.

7. For blank base cans, delete light fixture and install ¾" (19mm) steel blank cover.

8. Connect to ground rod (Air Force/Army) or counterpoise (Navy) to base cans.

9. Install top of edge of snow plow ring flush with pavement surface with a tolerance of +0", -1/16" (1.6mm).

10. If the distance between the edge of the snow ring and concrete is 1/8" (3mm) or less, seal top of opening with P-605 silicone sealant and delete the P-606 compound.

11. The top of fixture must not exceed the top of the snow plow ring (+0", -1/8" (3mm)).

12. The contractor must pre-assemble in-pavement light fixture with snow plow rings to assure each individual unit assembly is within tolerance. Use a straight edge to verify the fixture is level (to 1/8" (3mm)). Any units not within this tolerance will be rejected. Assure snow plow rings are configured with correct number and width of openings.

    The contractor must install a 25" (635mm) deep base can where the PCC pavement thickness is 15" (375mm) and must install a 30" (750mm) deep base can where the pavement thickness is 20" (500mm).

13. Contractor must ensure sealant installation is in accordance with elevation tolerances of light fixture installation.

14. Contractor must ensure snow plow rings are compatible and appropriate for use with base cans and fixtures.

15. Use drainage layer and concrete for Air Force/Army installations.

16. Use the following installation tolerances for Figure 18B:

Installation Tolerance

Item	**Tolerance**
Light beam orientation	±1/2" (13mm)
Lateral spacing	±1/4" (6mm)
Fixture level	±1/2 degree in X and Y direction
Fixture elevation (low side of pavement)	+0 - 1/16" (1.6mm)
Longitudinal spacing	±1/4 degree

3-7.1.3 **Drawing Notes for Straightedge Check, Figure 19B.**

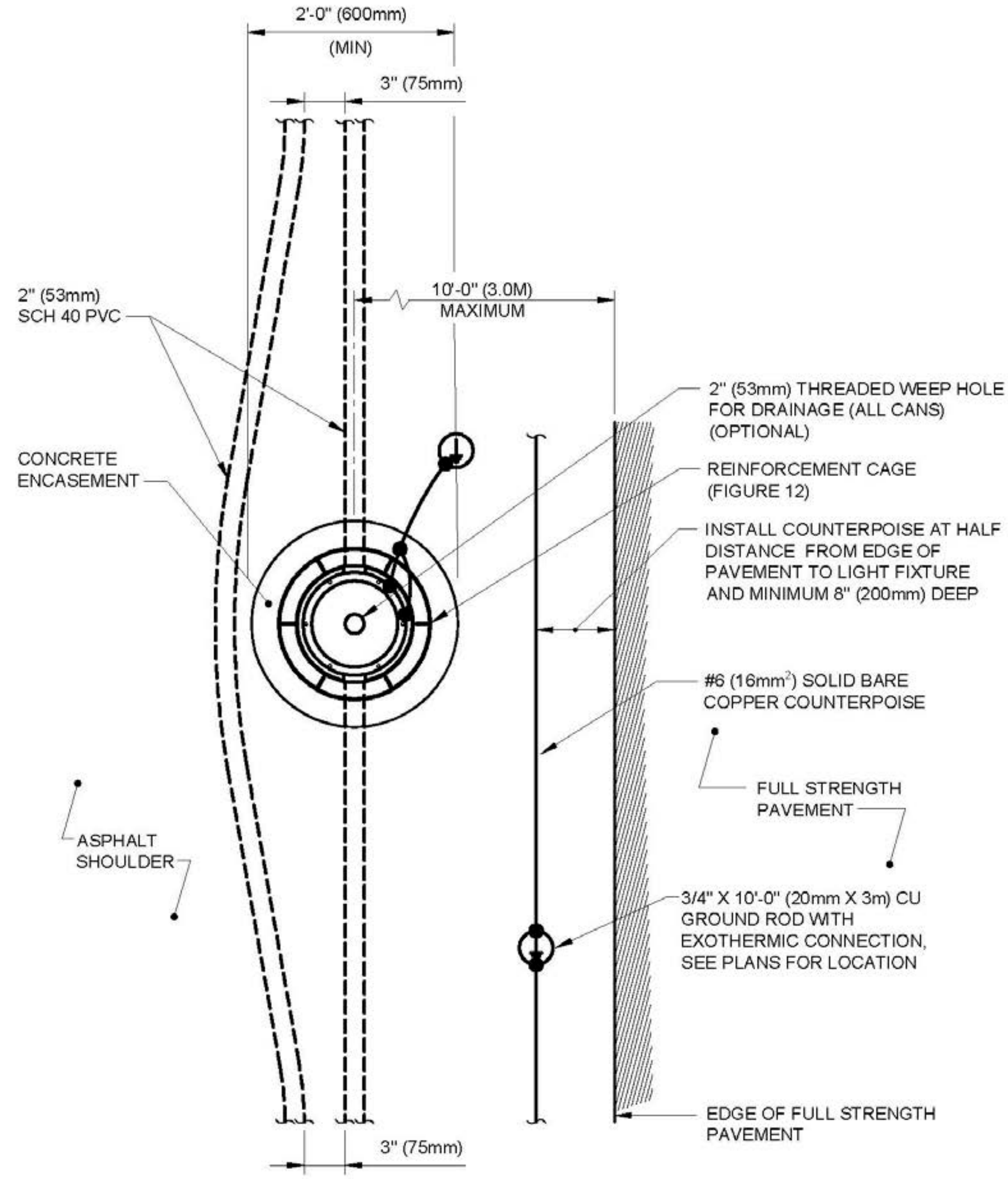
1. Straightedge should be 10' (3m) long. Notch approximately 1" (25mm) high, and about 1"-2" (25mm-50mm) longer than fixture diameter.

2. A 1/16" (1.6mm) Allen wrench is a good tool to use to determine height tolerance of fixture (or snow plow ring) relative to low side of pavement. Slide straightedge on to fixture or snow plow ring edge to measure. If straightedge rides up on the edge, fixture is too high. If edge is more than 1/16" (1.6mm) below straightedge, the fixture is too low.

3. Check straightedge in both directions to verify there is no unusual pavement build-up in the proximity of the light that might block part of the light beam.

4. A level on top of the straightedge can verify compliance with level tolerance.

Figure 17A. Light Base Mounting in Shoulder Pavement Plan (Air Force / Army)



LIGHT BASE MOUNTING IN SHOULDER PAVEMENT PLAN
(AIR FORCE/ ARMY)
SCALE: NTS

REFERENCE
FIGURE: 17A

CAD FILE: 2_8_(Figure_17A)_ Light_Base_Mounting_In_Shoulder_Pavement_Plan_Air_Force_Army.dwg
SEE NOTES TO DESIGNER FILE: 2_8_(Figure_17)-NTD.dwg

Figure 17B. Light Base Mounting in Shoulder Pavement Plan (Navy)

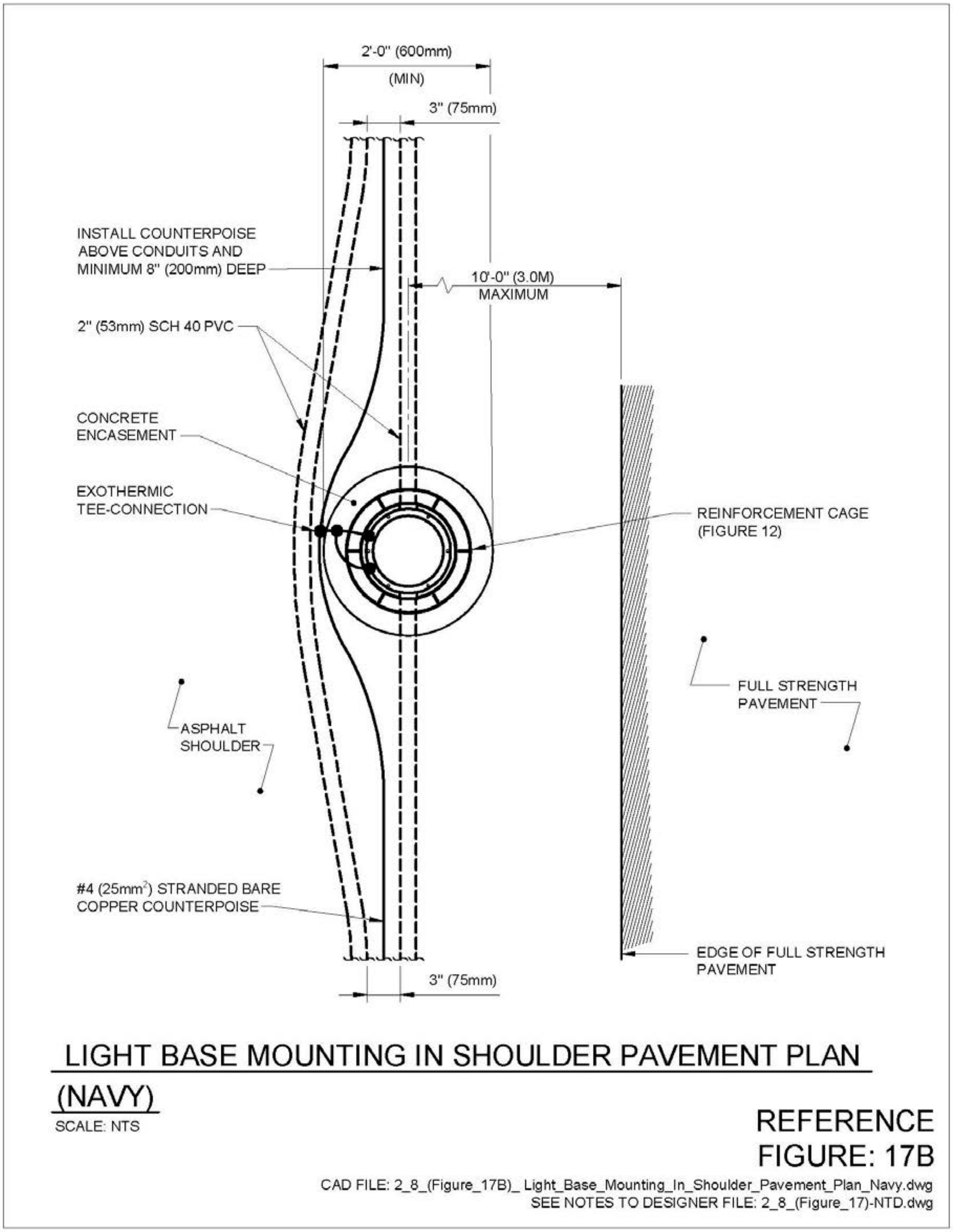
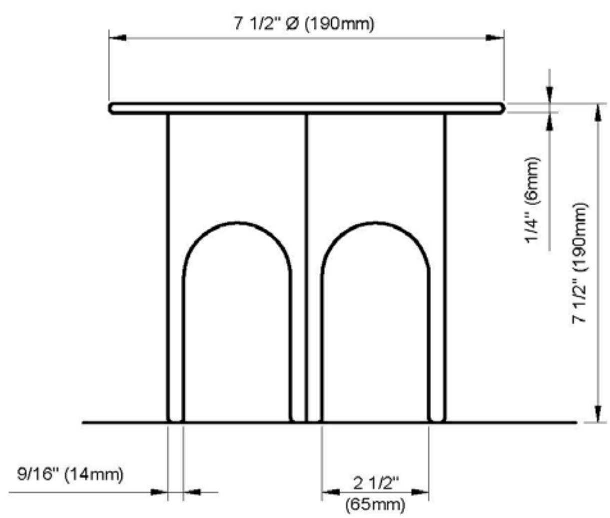


Figure 17C. Airfield Isolation Transformer Platform



AIRFIELD ISOLATION TRANSFORMER PLATFORM

SCALE: NTS

REFERENCE
FIGURE: 17C

CAD FILE: 2_8_(Figure_17C)_Airfield_Isolation_Transformer_Platform.dwg
SEE NOTES TO DESIGNER FILE: 2_8_(Figure_17)-NTD.dwg

Figure 18A. In-Pavement Light Materials

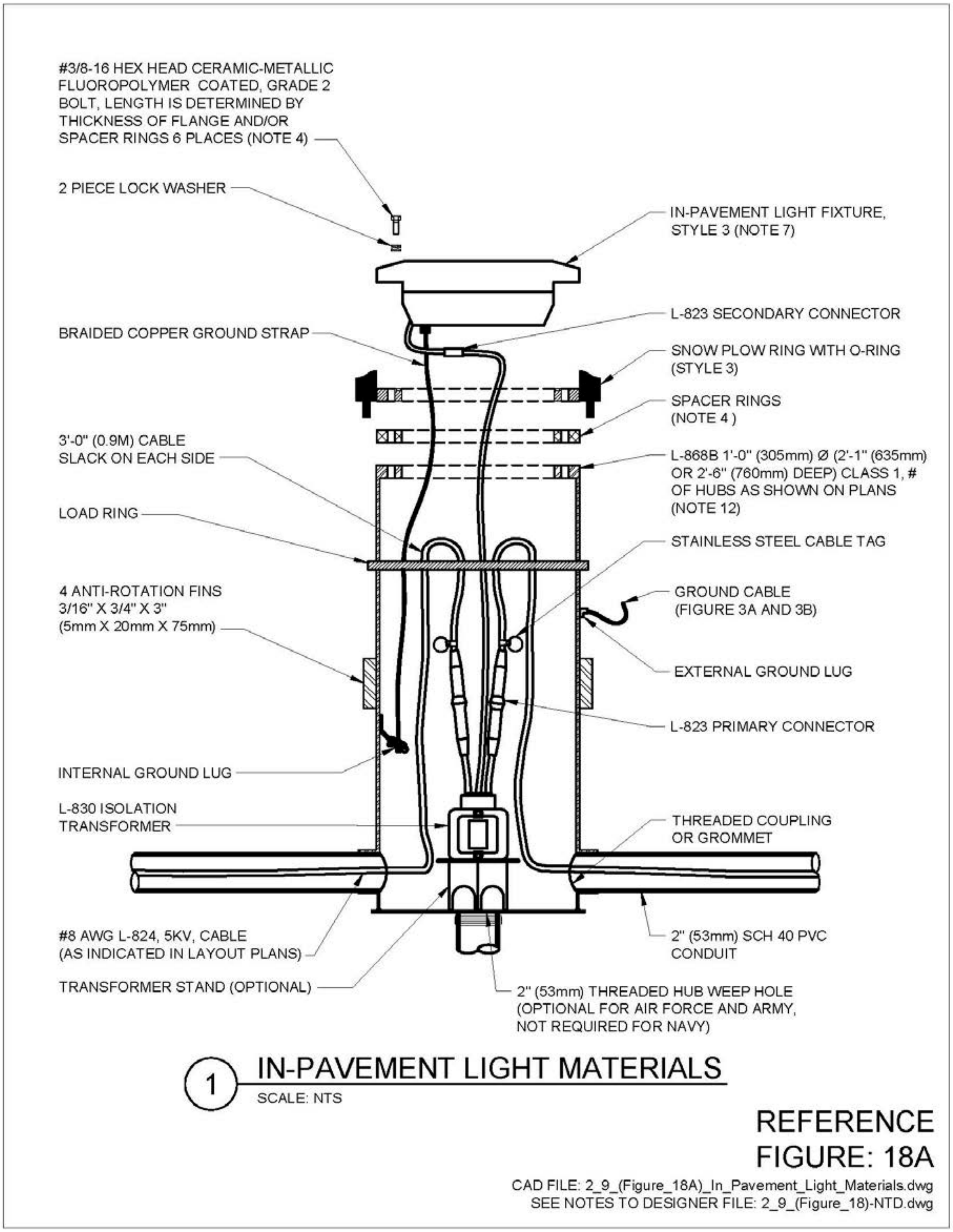


Figure 18B. Flush Light in Full Strength PCC

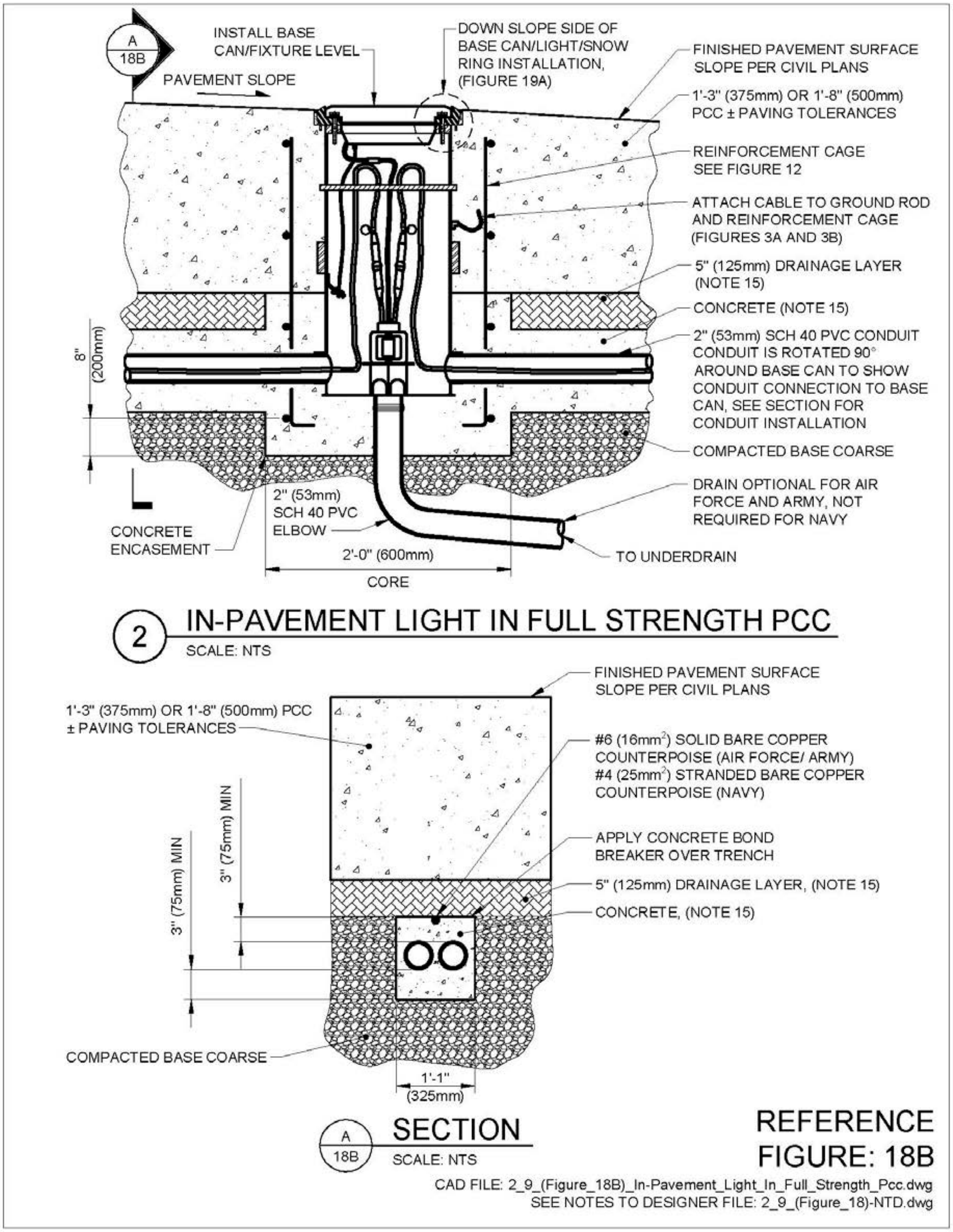


Figure 19A. In-Pavement Light Fixture Mounting

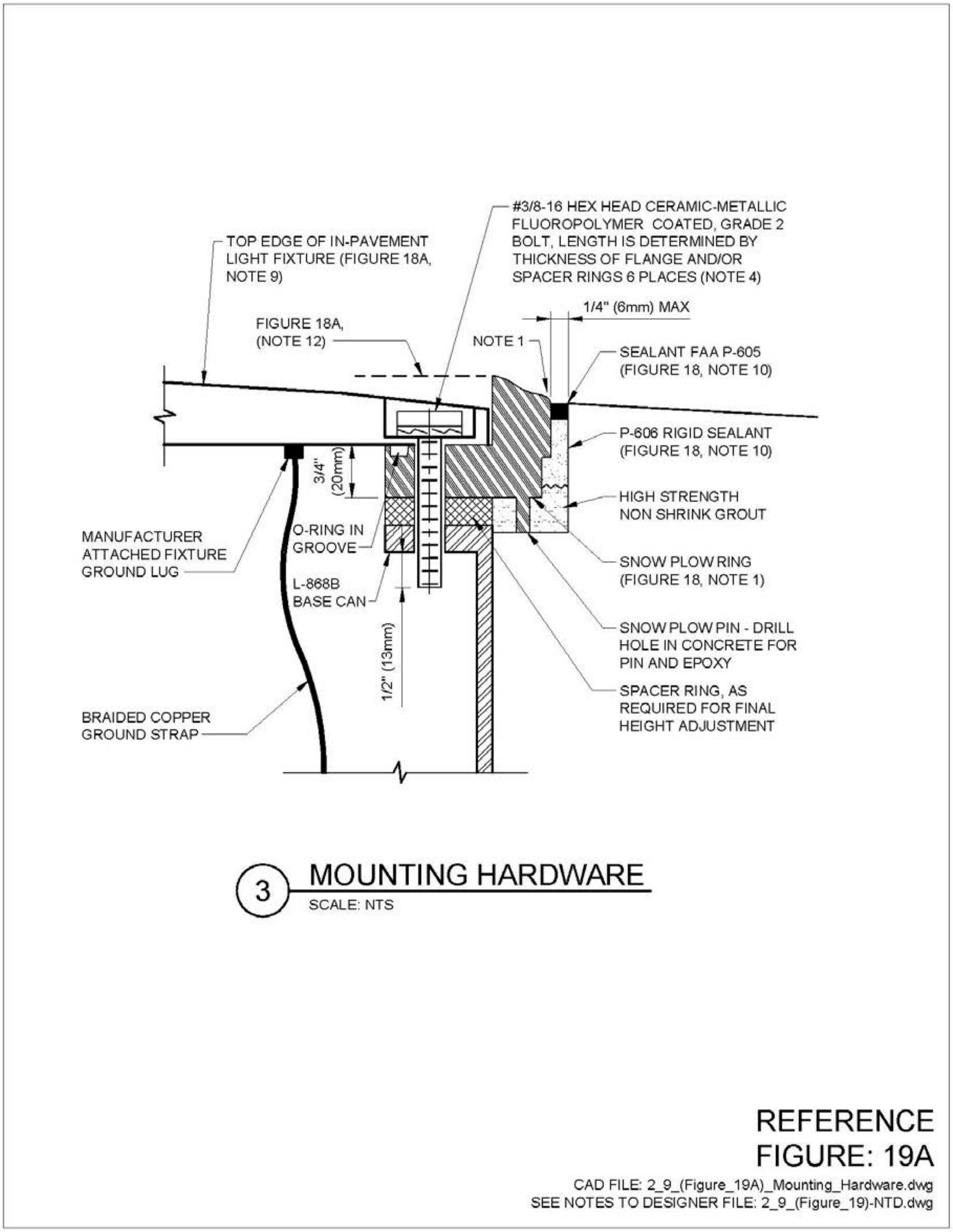
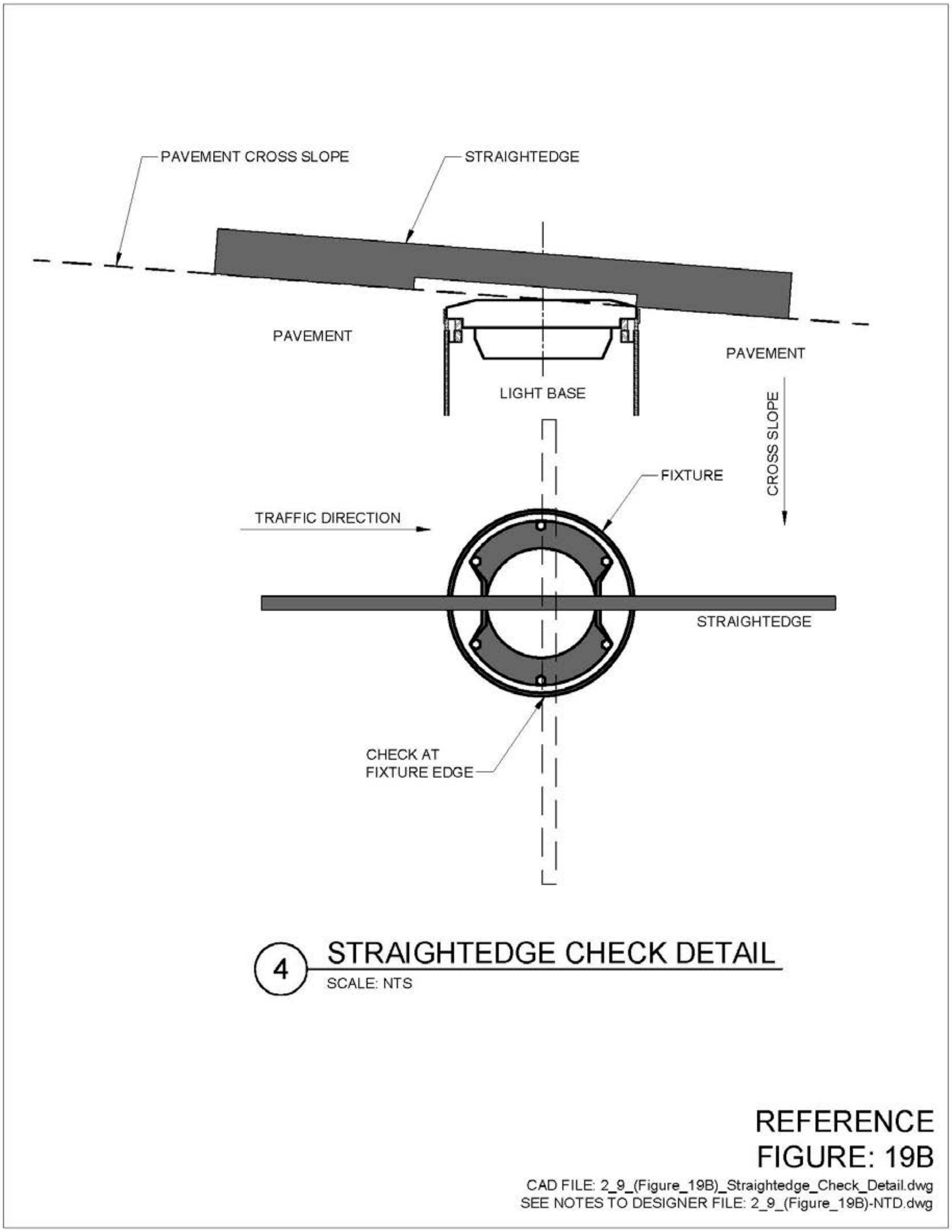


Figure 19B. In-Pavement Light Fixture Mounting (continued)



3-8 Elevated Runway Guard Light/Holding Position Edge Light Detail.

3-8.1 Figures 20A, 20B.

3-8.1.1 Notes to Designer.

1. Holding position edge lights (HPL) are similar fixtures for Navy facilities. Designer must refer to NAVAIR 51-50AAA-2 for Navy requirements.

2. Elevated runway guard lights are optional at Army facilities and optional at Air Force facilities for Category I precision approach runways down to a runway visual range (RVR) of 2400' (720m). They are required at Air Force facilities that conduct operations at Category II (down to an RVR of 1200' (360m).

3. Installation of the base can and top section is similar to the installation of an elevated fixture in shoulder pavement. See Figure 9.

3-8.1.2 Drawing Notes for Runway Guard Lights, Figures 20A and 20B.

1. Power the elevated runway guard lights (RGL/HPL) from the circuit indicated.

2. Before coring in pavement may proceed, the contractor must demonstrate to the contracting officer that the base cans are at the correct location. Before casting concrete around base can, the contractor must demonstrate to the contracting officer that the base cans are at the correct elevation, azimuth and rotation.

3. Air Force/Army Airfields: Bottom drain is optional. Navy Airfields: Bottom drain not required.

4. The inside edge of the RGL housing must be 10' (3m) to 17' (5.1m) from the edge of full strength pavement. The inside edge of the HPL must be not less than 3' (0.9m) beyond the outside edge of the holding position sign for Navy airfields.

5. The finished pavement surface must be protected from foreign substances which could cause staining, i.e. concrete, oil, etc. The contractor must immediately clean all spills and correct/clean any stained surfaces at the contractor’s expense.

6. The contractor must use a heavy duty base plate for installation of the L-804 RGL/HLP. Provide stainless steel tether for RGL/HLP.

7. Installation of the base can is similar to the installation of an elevated fixture in shoulder pavement. See Figures 20A and 20B.

8. Provide braided cooper ground strap between light base can and light fixture. Strap must be equivalent to No. 6 (16 square mm) cable.

Figure 20A. L-804 Elevated Runway Guard Light/Holding Position Edge Light Installation Materials

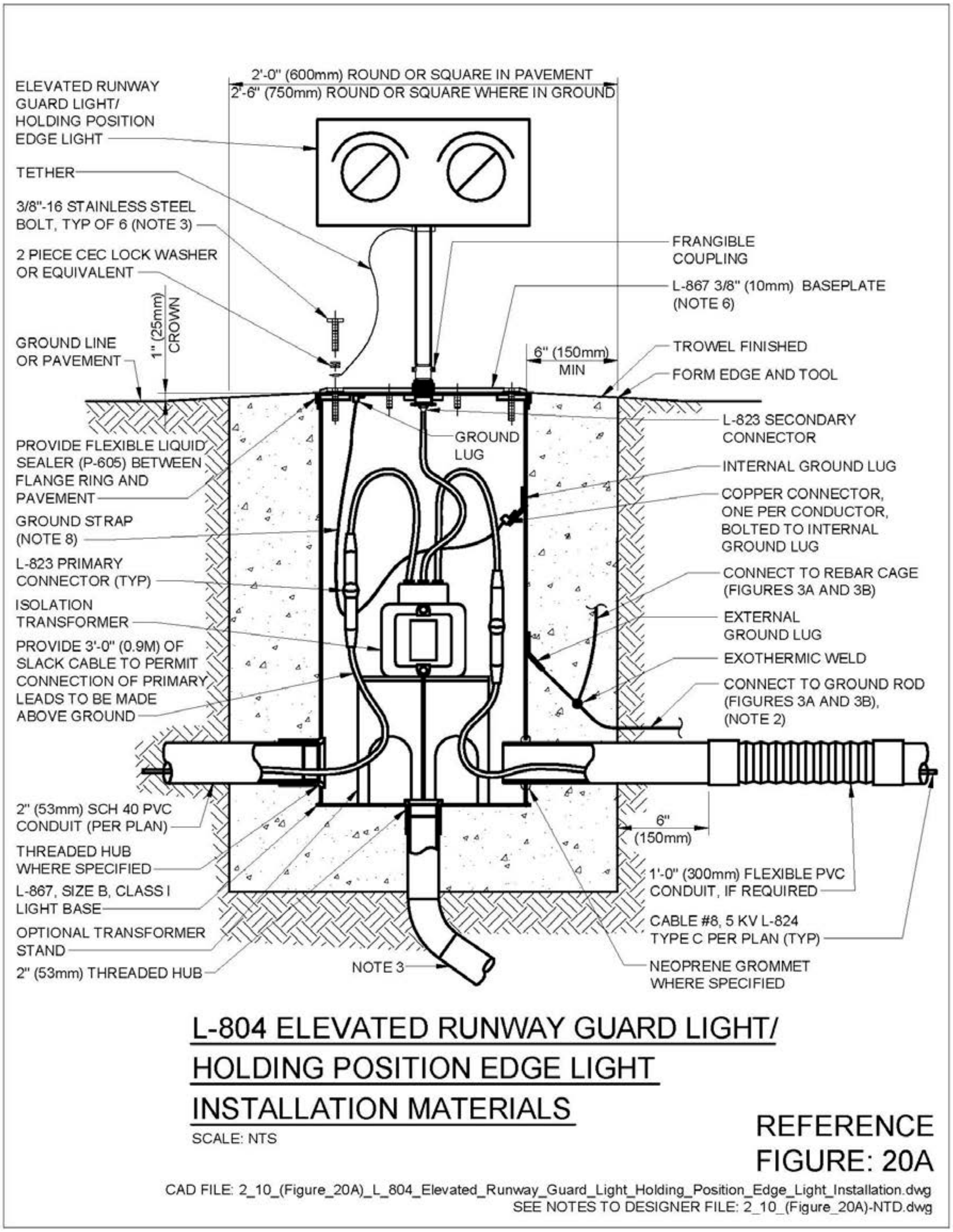
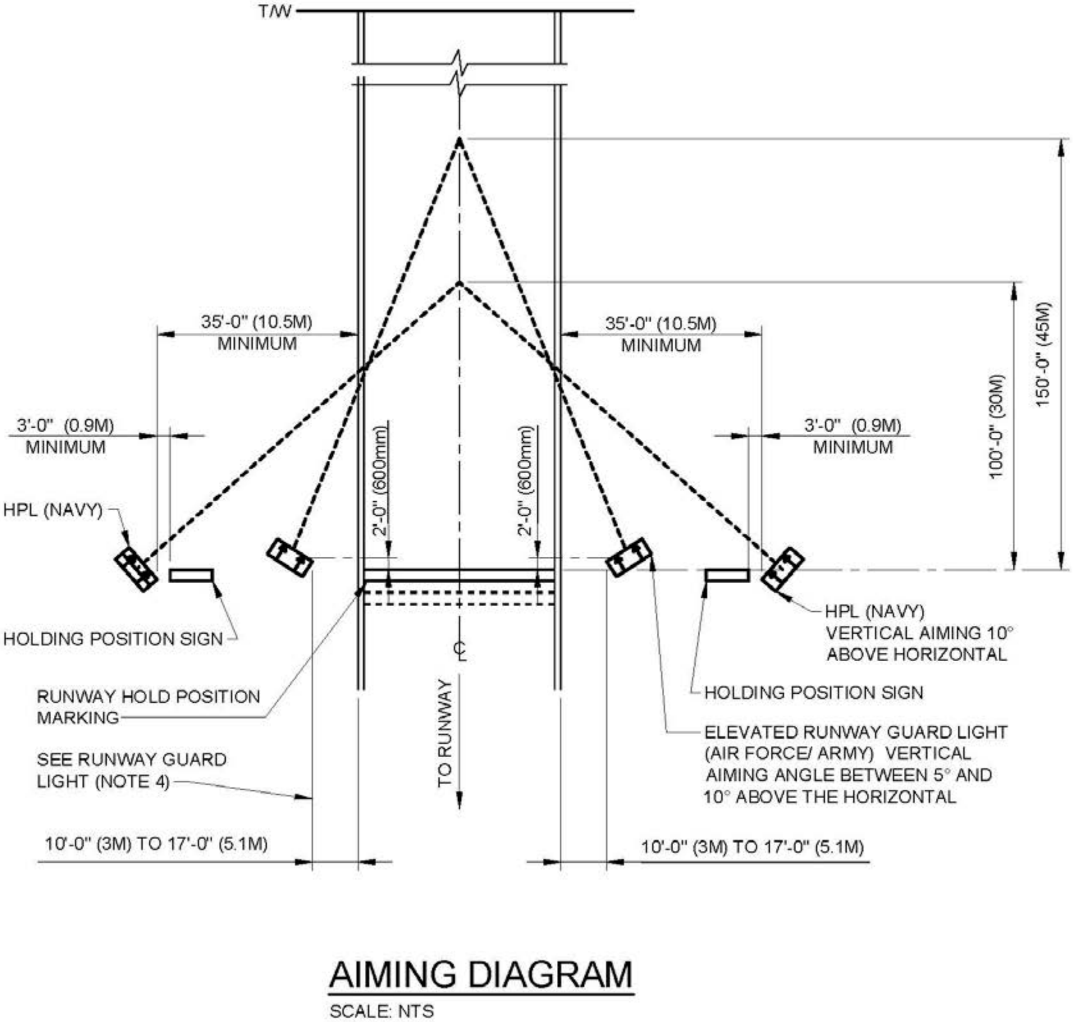


Figure 20B. L-804 Elevated Runway Guard Light Aiming Diagram



L-804 ELEVATED RUNWAY GUARD LIGHT (RGL)
(AIR FORCE/ ARMY)
HOLDING POSITION EDGE LIGHT (HPL) (NAVY)
SCALE: NTS

REFERENCE
FIGURE: 20B

CAD FILE: 2_10_(Figure_20B)_L_804_Elevated_RGL_HPL_Aiming_Diagram.dwg
SEE NOTES TO DESIGNER FILE: 2_10_(Figure_20B)-NTD.dwg

Figure 21. Reserved.

Figure 22. Reserved.

Figure 23. Reserved.

Figure 24. Reserved.

Figure 25. Reserved.

Figure 26. Reserved.

Figure 27. Reserved.

Figure 28. Reserved.

CHAPTER 4 Airfield Guidance Signs

4-1 Airfield Guidance Sign Detail.

4-1.1 Figures 29A, 29B.

4-1.1.1 Notes to Designer.

1. The L-867 base houses the sign's isolation transformer. It is typically mounted separately from the sign but within 3' (900mm) from the sign's adjacent edge. This is done to allow access to the transformer without removing the sign. The following points should be noted about the installation of the power wiring to the sign:

    a. A secondary jumper cable must be provided to connect the transformer's output cable to the sign's input cable. Though the output cable on an isolation transformer is 48" (1.2m) ± in length, do not connect this to the sign's input cable since it would defeat the purpose of mounting the isolation transformer separately.

    b. The type of retaining clips (or cable clamps) will depend on the type of mounting used for the sign's power leg (i.e. L-867 base or 2" (53mm) conduit and floor flange) and the style of L-823 connector on the secondary jumper cable. The retaining clips hold the secondary jumper cable in place below the frangible coupling.

2. Recommend the project contract documents contain specifications for the maximum VA load allowed for each size of sign. VA load should include the losses in the sign's isolation transformer.

3. The guidance sign foundation should be designed by a licensed structural engineer. The foundation will vary in thickness and reinforcing depending on the number of sign modules, sign size, and wind loading (jet blast) either 200 mph or 300 mph. Some of the factors that must be taken into account for the foundation design are:

    a. Are the signs located in an area where there is a potential for high soil saturation?

    b. Breaking point of the frangible couplings (wind speed of 200 mph or 300 mph).

c. Soil bearing capacity.

d. Concrete weight.

e. Sign weight including one, two, three or four modules.

f. Minimum 1.2 factor of safety against overturning.

g. Minimum 1.2 factor of safety against sliding.

h. Soil conditions regarding passive pressure consideration for the transformer base can below the footing.

i. There should be no tolerance for sign foundation movement.

j. Considerations for freeze/thaw conditions in areas prone to frost.

4-1.1.2 **Drawing Notes for Figure 29A.**

1. Air Force / Army: Do not connect counterpoise to the transformer base. Connect transformer base and counterpoise to separate ground rods.

2. Sign pad must have a 1/2" (13mm) chamfer on all exposed horizontal edges. Extend pad 36" (900mm) clear on all sides of sign. Slope the top surface to drain away from sign, approximately 1% (1/8"/ft) (3mm/300mm). The top of the pad must be approximately 1" (25mm) above the surrounding grade.

3. Maximum overall sign length: size 3 - 14'-2"(4290mm).

4. One tether at each end of the sign if separate sign modules are connected together within a continuous frame.

5. The frangibility point must be no greater than 3" (75mm) above the grade adjacent to the pad.

6. Surrounding grade must slope 1/4" (6mm) per foot away from the pad for 15' (4.5m). Sod or seed as required.

7. Pad thickness and reinforcing will vary depending on the length and number of sign modules installed as well as the wind loading (jet blast) expected.

4-1.1.3 **Drawing Notes for Figure 29B.**

1. Navy: Delete grounds rods. Connect counterpoise to base can.

2. Sign pad must have a 1/2" (13mm) chamfer on all exposed horizontal edges. Extend pad 36" (900mm) clear on all sides of sign. Slope the top surface to drain away from sign, approximately 1% (1/8"/ft) (3mm/300mm). The top of the pad must be approximately 1" (25mm) above the surrounding grade.

3. Maximum overall sign length: size 3 - 14'-2"(4290mm).

4. One tether at each end of the sign if separate sign modules are connected together within a continuous frame.

5. The frangibility point must be no greater than 3" (76mm) above the grade adjacent to the pad.

6. Surrounding grade must slope 1/4" (6mm) per foot away from the pad for 15' (4.5m). Sod or seed as required.

7. Pad thickness and reinforcing will vary depending on the length and number of sign modules installed as well as the wind loading (jet blast) expected.

8. For Navy Size 2 signs, distance from RW or TW can be 25' to 35' (7.5m to 10.5m) if sign height is not more than 2'-0" (0.6m) above RW or TW edge of full-strength pavement.

Figure 29A. Airfield Guidance Sign Detail (Air Force / Army)

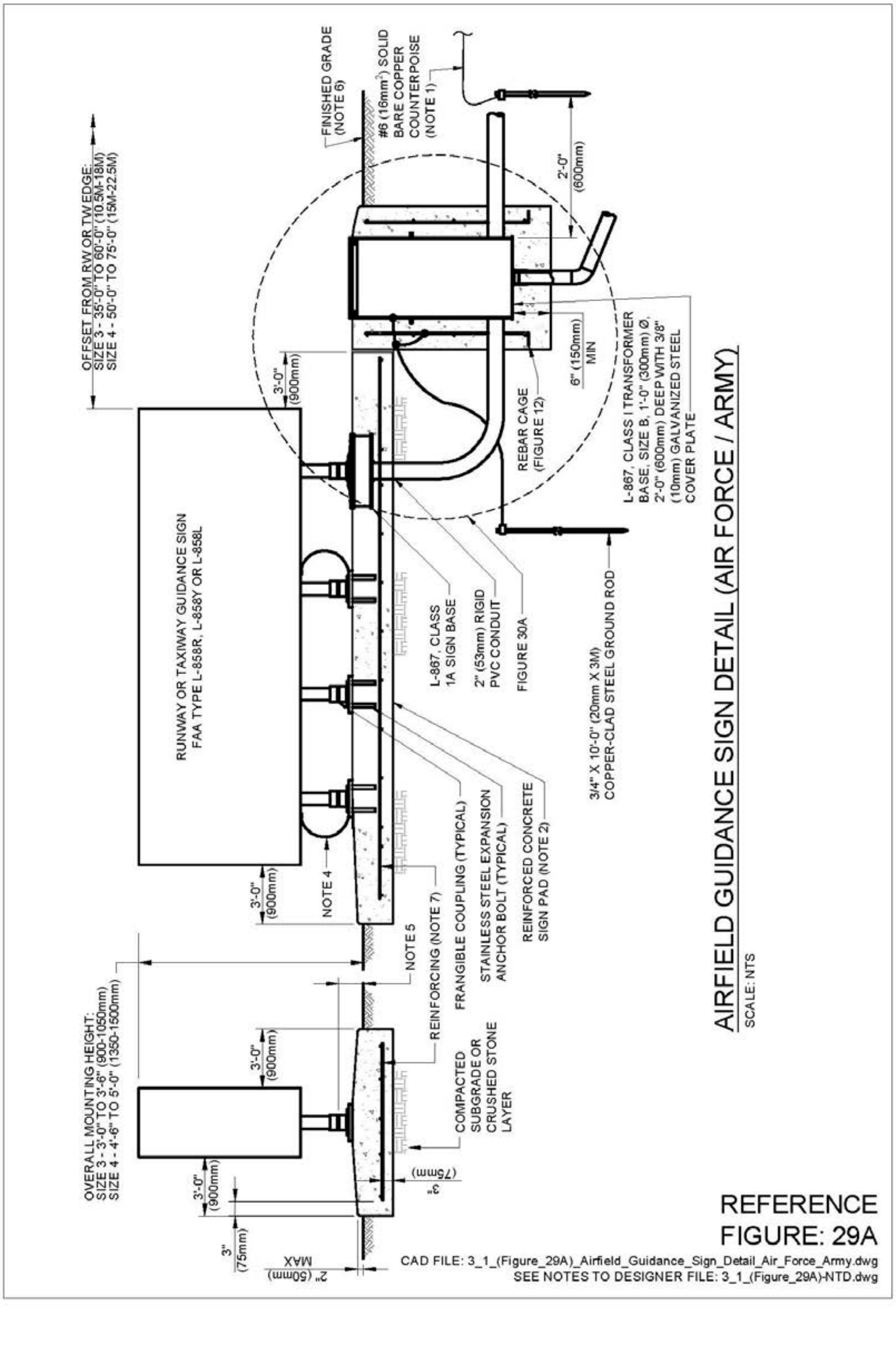
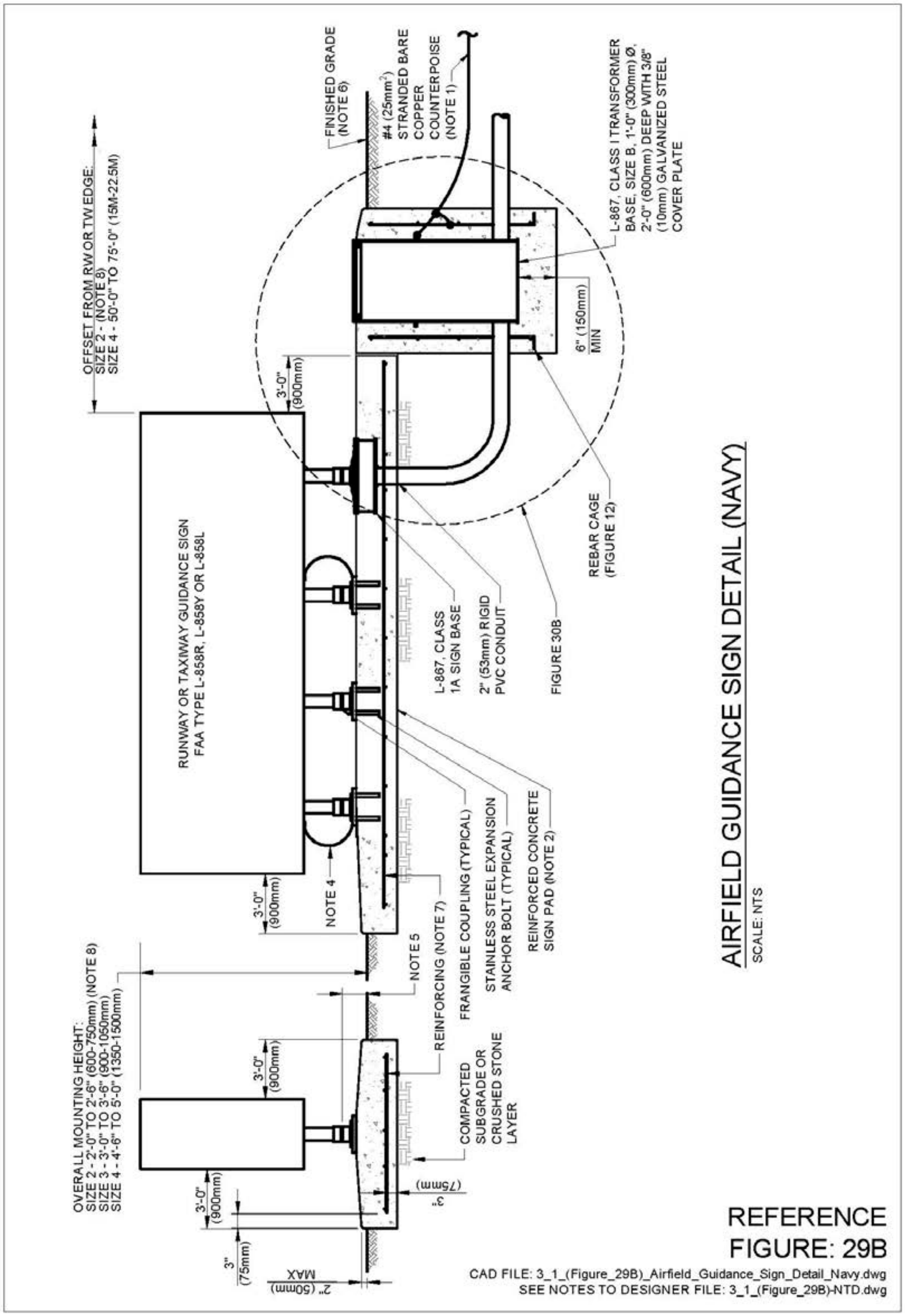


Figure 29B. Airfield Guidance Sign Detail (Navy)



4-2 Sign Base Power Leg Mounting Detail.

4-2.1 Figures 30A, 30B.

4-2.1.1 Notes to Designer.

1. The mounting for the power leg of the sign will usually be determined by the sign designer and manufacturer options. The following details show several approved options. Details indicated on contract documents should state that installation must be in accordance with the sign manufacturer's requirements.

4-2.1.2 Drawing Notes for Figures 30A and 30B.

1. See specifications for additional grounding requirements inside the sign.

2. Grounding conductors must be THWN-2 or XHHW-2.

3. Gravel sump below fixture base is not required where drain line is run to pavement under-drain system. The preferred method for draining the base can is to route the drain line to pavement under drain system or closest catch basin. If a gravel sump (French drain) is installed, caution should be taken to prevent the undermining of the sign foundation.

Figure 30A. Sign Base Power Leg Mounting Detail (Air Force / Army)

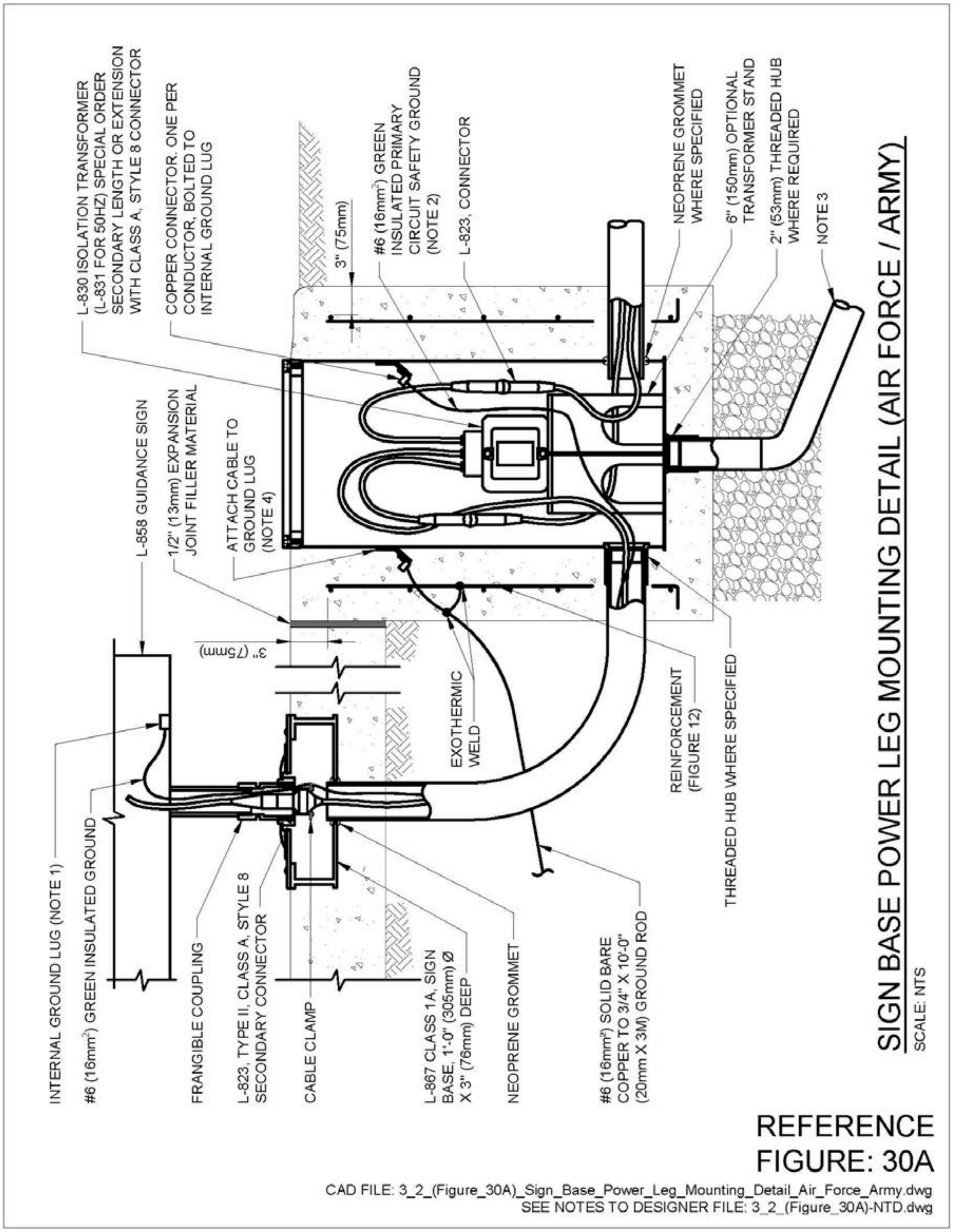
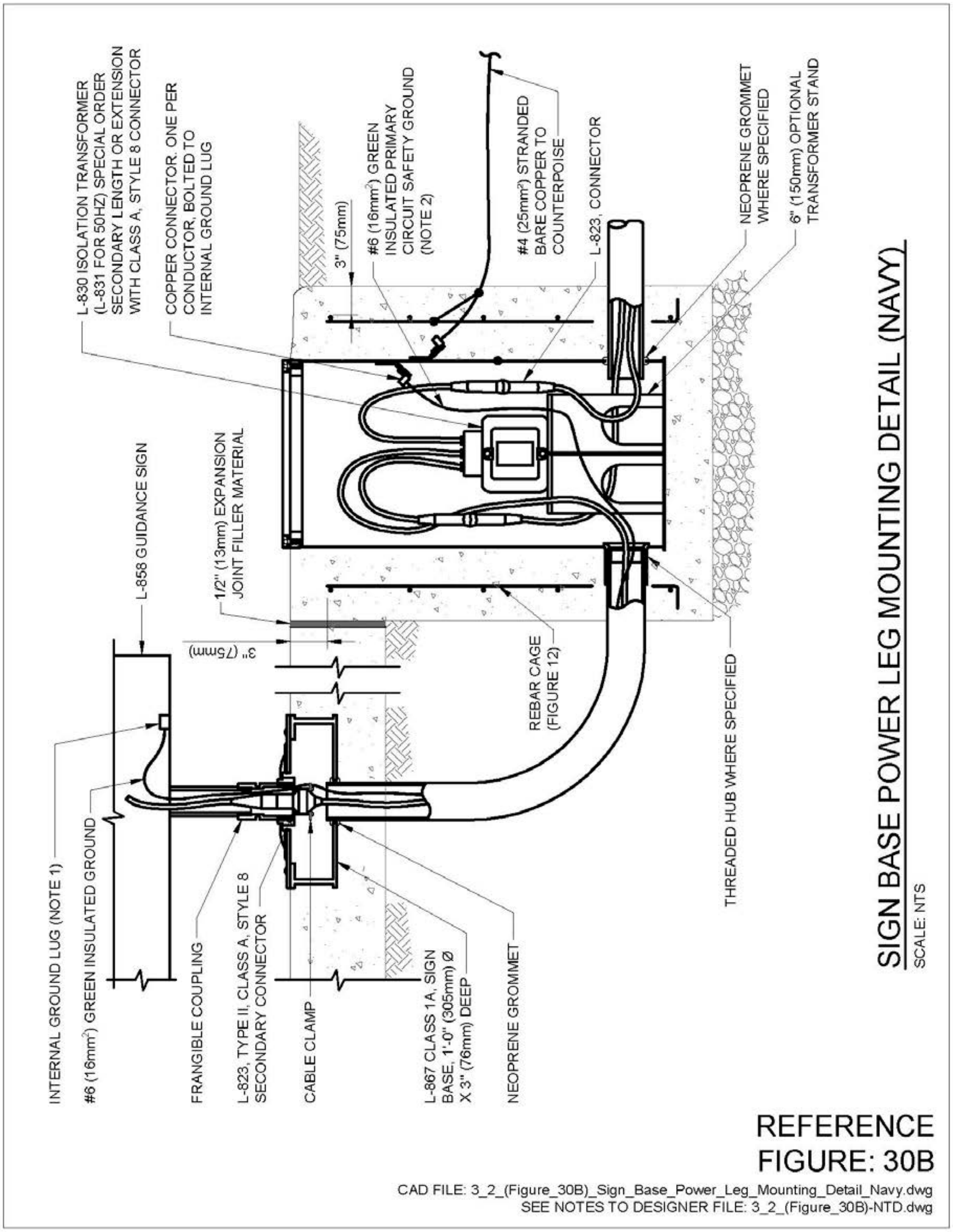


Figure 30B. Sign Base Power Leg Mounting Detail (Navy)



CHAPTER 5 Approach Lighting Systems

5-1 L-867 Size D Handhole.

5-1.1 Figure 31.

5-1.1.1 Notes to Designer.

1. A handhole is required at each sequenced flasher station and tower-mounted approach light station to house isolation transformers. Handholes must contain any hardware which may aid with cable pulling.

2. The flexible conduit allows for movement during freeze/thaw cycles in cold climates thereby reducing the possibility of shearing the conduits.

3. The 2" (53mm) conduit between handholes is a minimum. The actual dimension depends on the number of cables being routed. Ensure contract documents specify hub size.

5-1.1.2 Drawing Notes for Figure 31.

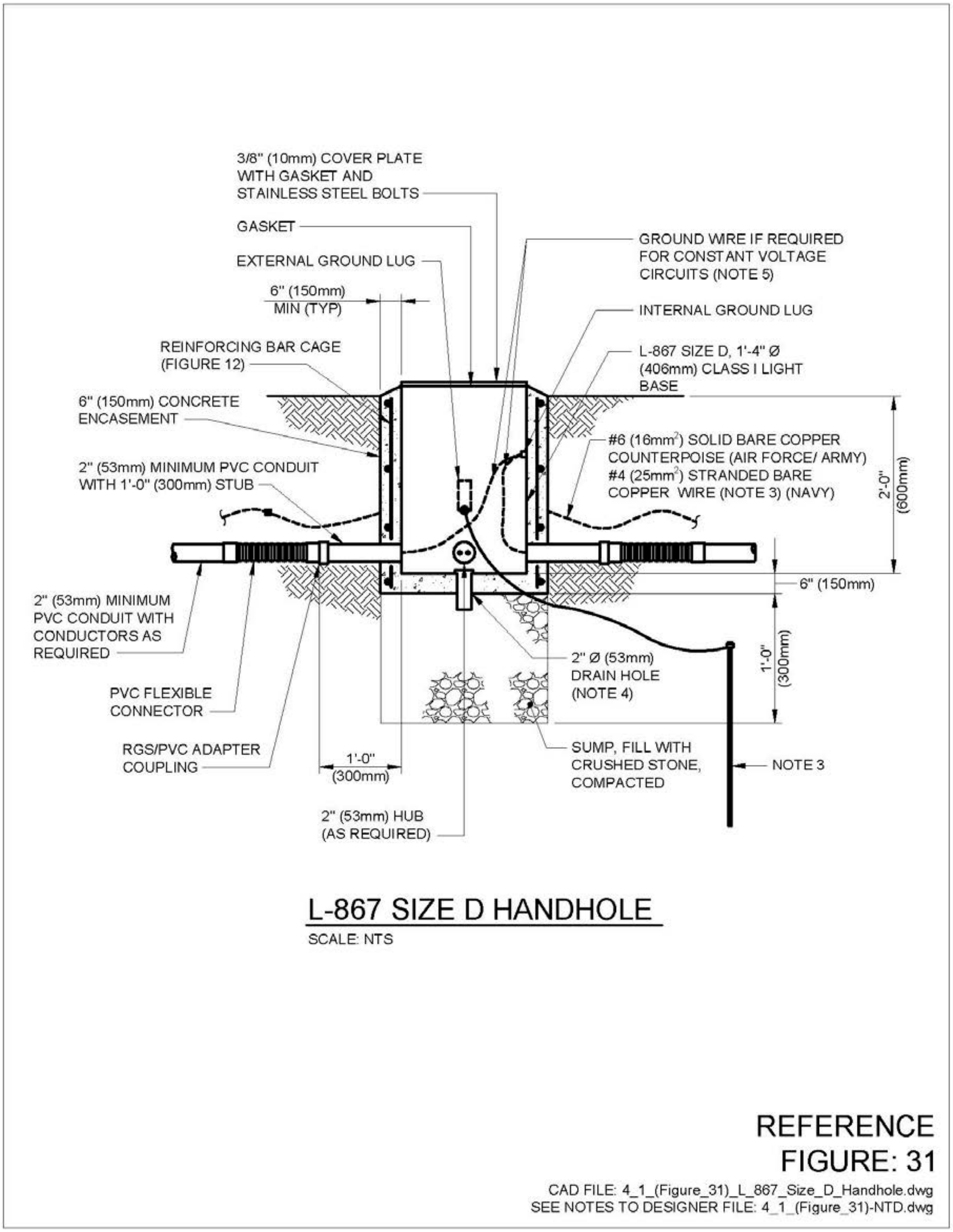
1. If constant voltage circuits are routed through the handholes the minimum #6 (16 square mm) equipment ground must be routed with the system conductors in the conduit and connected to the ground lug in each light base. It must also be bonded to the electrical ground at the system's substation (vault) power supply ground bus. Provide green insulated THWN-2 or XHHW-2 ground wire sized per NEC for constant voltage circuits.

2. The flexible connector must be PVC.

3. For Air Force / Army Airfields, connect ground rod to handhole external ground lug with #6 (16 square mm) solid bare copper and let counterpoise pass the handhole without connection. For Navy airfields, connect #4 (25 square mm) stranded bare copper counterpoise to external ground lug. Do not provide ground rod at handhole.

4. For Air Force / Army Airfields, bottom drain is optional. For Navy airfields, bottom drain is not required.

Figure 31. L-867 Size D Handhole



5-2 Voltage Driven Sequenced Flasher Power Supply and Junction Box Mounting Detail

5-2.1 Figure 32.

5-2.1.1 Notes to Designer.

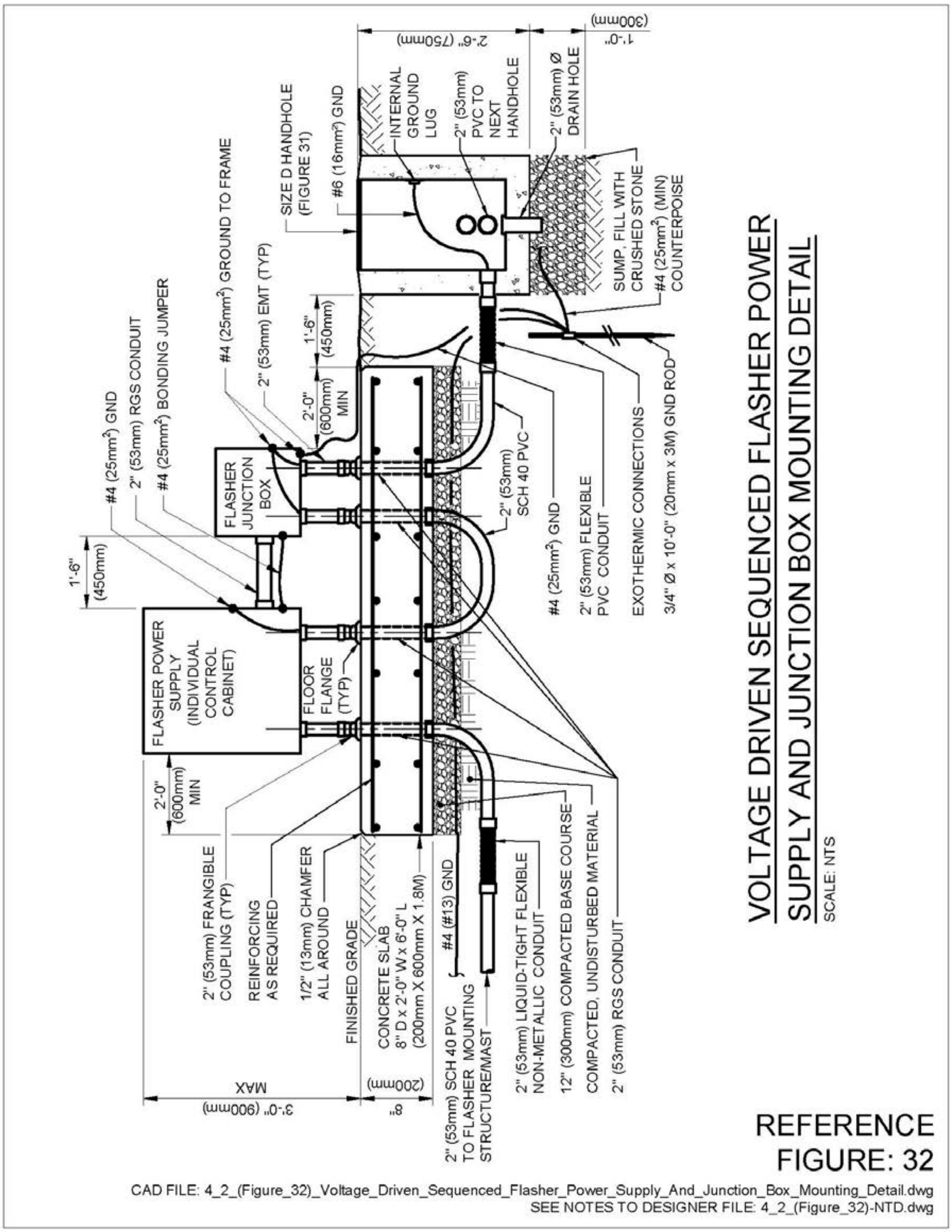
1. Each sequenced flasher requires its own power supply (individual control cabinet) and junction box. These are normally mounted as close to the flash head as possible. The standard manufacturer furnished cable between the flash head and the power supply is 60' (18m) maximum. The interconnecting wiring between the flasher junction box and the power supply is furnished by the contractor. If the flasher is mounted on a structure that is above 40' (12m), then the power supply is mounted up on the maintenance platform and the junction box is mounted at the base of the tower.

2. The flexible conduit allows for shifting due to freeze/thaw cycles in cold climates or to align conduits. If freeze/thaw cycles are not a problem, then the use of the flexible conduit is optional.

3. Recommend becoming familiar installation requirements from several different manufacturers.

4. The connection between the junction box and power supply is indicated below grade by a 2" (53mm) conduit. Some manufacturers connect the two directly with a short section of 2" (53mm) conduit.

Figure 32. Voltage Driven Sequenced Flasher Power Supply and Junction Box



Mounting Detail

5-3 Typical MG-20 L.I.R. Structure 6'-1" (1854mm) to 21'-1" (6.43m).

5-3.1 Figure 33.

5-3.1.1 Notes to Designer.

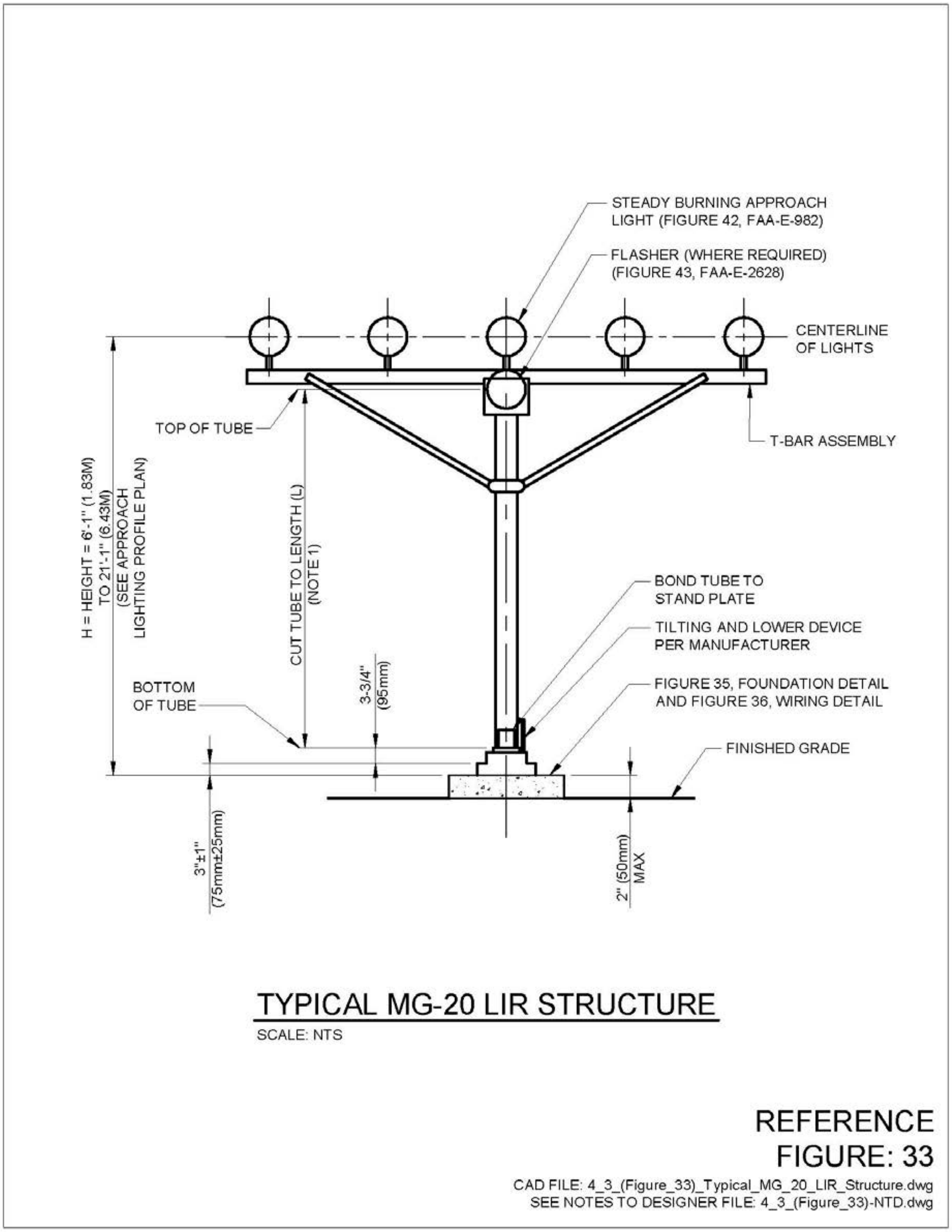
1. The contract documents should include an approach lighting profile plan that will state by station # the height above grade.

2. Refer to Chapter 3 in UFC 3-535-01 (Air Force/Army) or NAVAIR 51-50AAA-2 (Navy) for the spacing and number of the lights on the T-bar assembly. Specify the appropriate spacing (for the system being installed) in this detail and modify the detail to show the appropriate number of lights.

5-3.1.2 Drawing Notes for Figure 33.

1. Determine exact length of tube in accordance with manufacturer’s instructions.

Figure 33. Typical MG-20 L.I.R. Structure 6'-1" (1854mm) to 21'-1" (6.43m)



5-4 **Foundation for L.I.R. Structure MG-20 Plan View**

5-4.1 **Figure 34.**

5-4.1.1 **Notes to Designer.**

1. The female couplings are for mounting the 2" (53mm) frangible couplings and condulets for wiring to the tower. Two are required (one on each side) if both a sequenced flasher and steady burn lights are co-located on a tower.

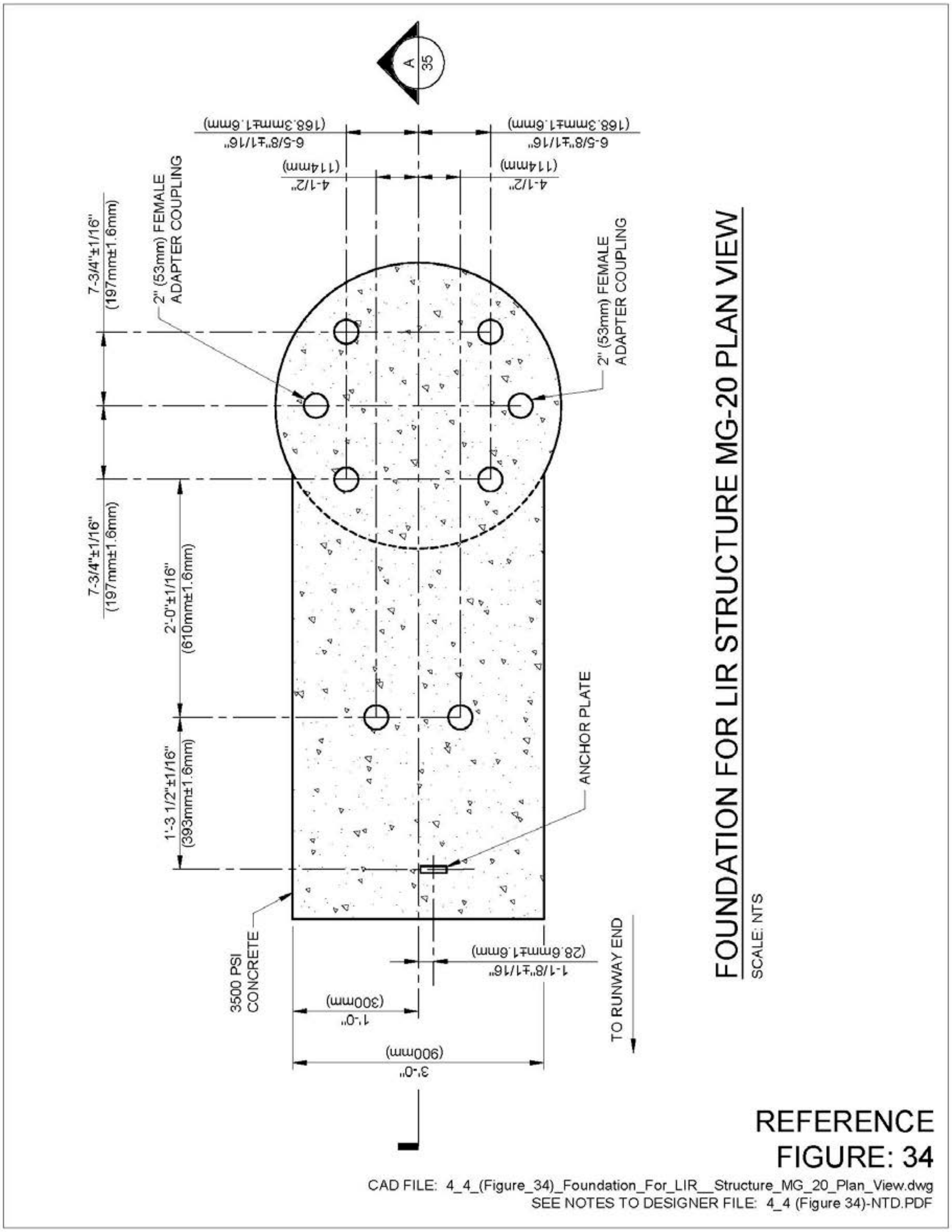
2. Foundation indicated is as recommended by tower manufacturer. However, rectangular foundations have been used in some installations. Consult with tower manufacturer for different options based on soil conditions, bearing capacity, etc.

5-4.1.2 **Drawing Notes for Figure 34.**

1. Refer to Figure 35, Section A.

2. Actual dimensions may vary. Coordinate with manufacturer prior to construction and construct per manufacturer's requirements.

Figure 34. Foundation for L.I.R. Structure MG-20 Plan View



5-5 Foundation for L.I.R. Structure MG-20 Sections A and B.

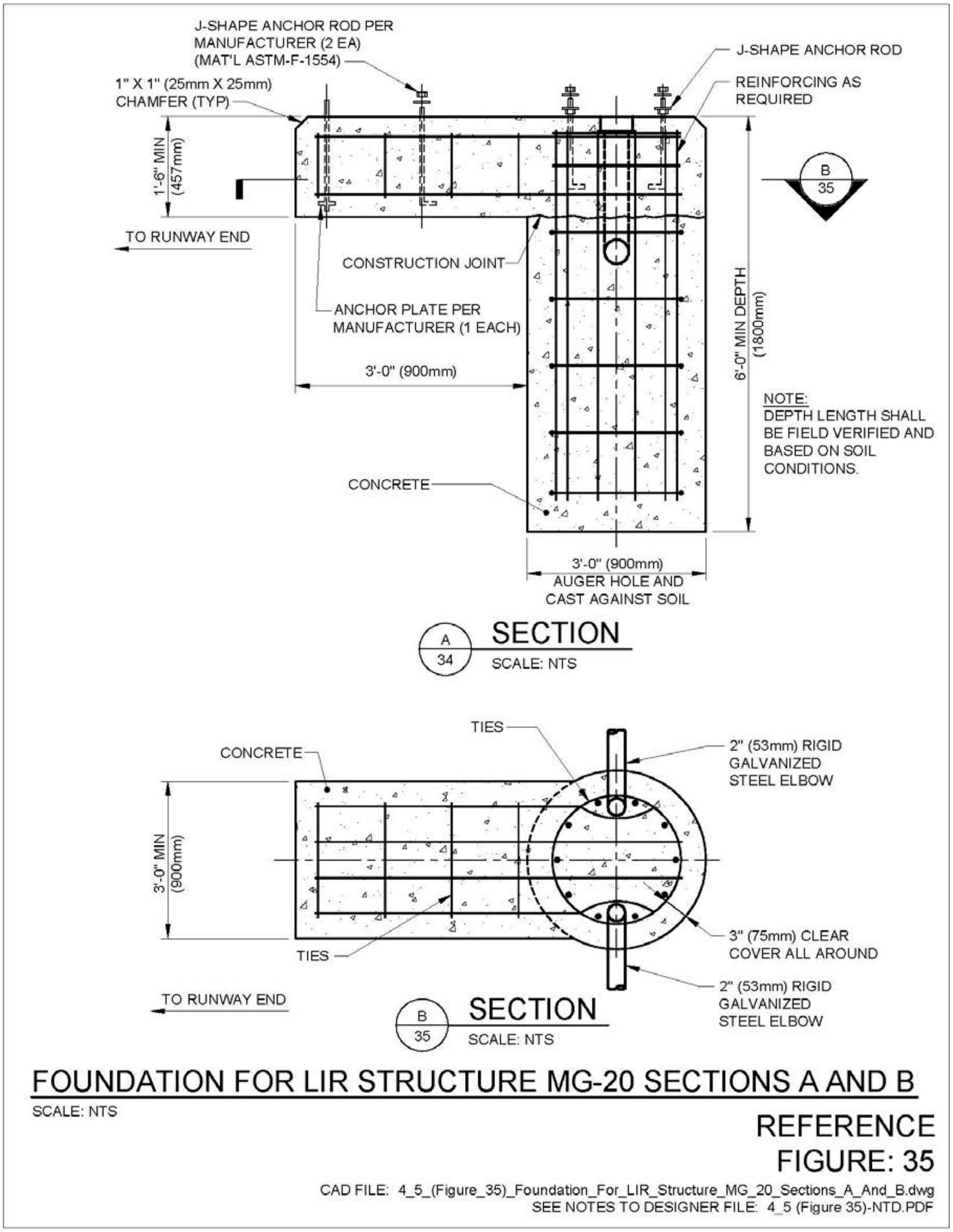
5-5.1 Figure 35.

5-5.1.1 Notes to Designer.

1. The foundation indicated is a suggested foundation from one tower manufacturer. The diameter was increased to allow the installation of the conduits in the foundation and still allow clearance for the tilt base on the tower.

2. Prior to designing the foundation for the tower, borings should be taken in the field for soil analysis. Many factors will affect the type and size of foundation to be installed (i.e. type of soil, existence of rock or ledge, soil bearing capacity, frost depth, etc.). The designer should base the foundation design on these factors and consult with the tower manufacturer regarding EPA (Effective Projected Area) for wind loading. The wind loading must include the proposed fixtures and hardware to be installed on the tower.

Figure 35. Foundation for L.I.R. Structure MG-20 Sections A and B



5-6 **Typical MG-20 L.I.R. Structure Tower Wiring Detail.**

5-6.1 **Figure 36.**

5-6.1.1 **Notes to Designer.**

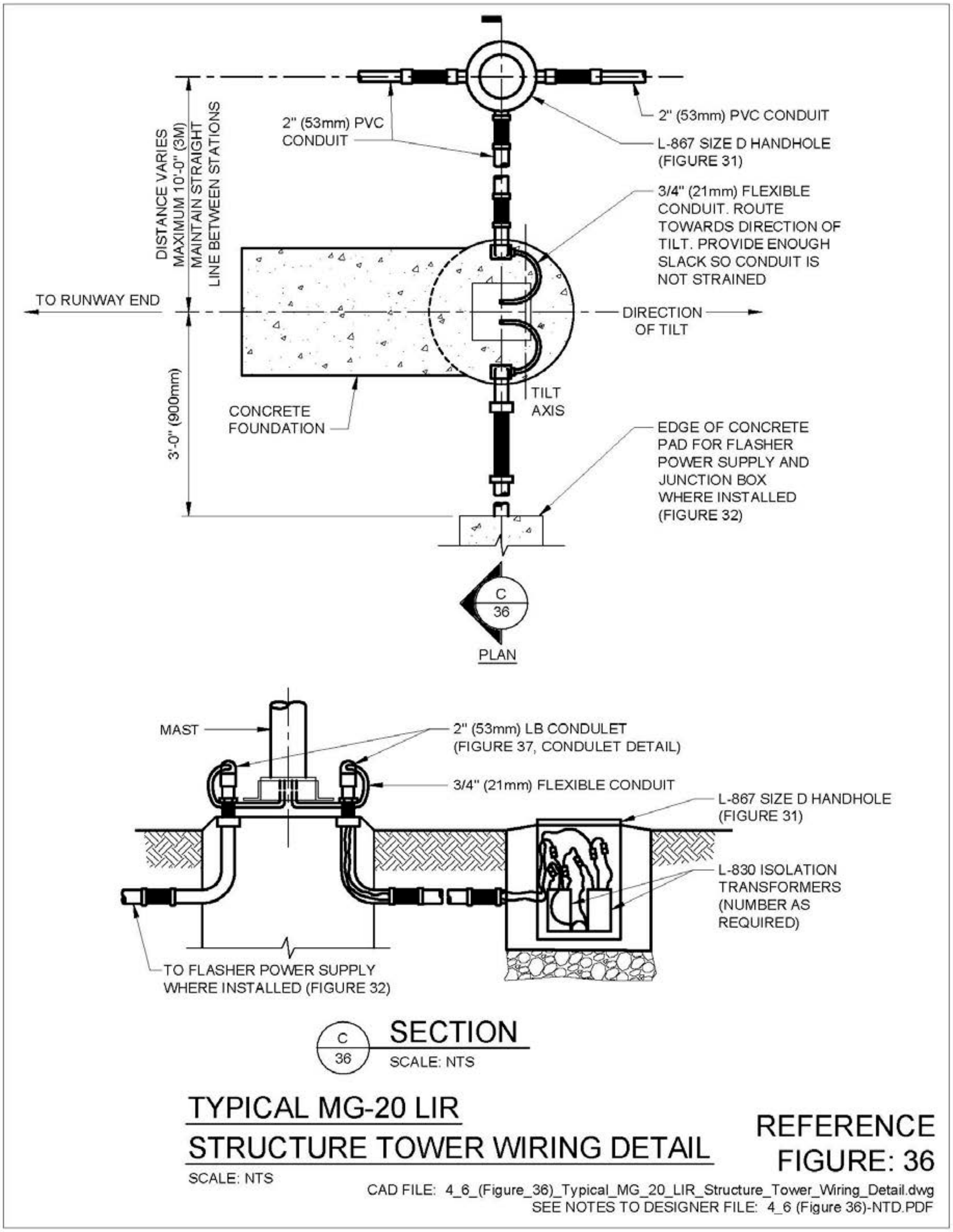
1. Location of the handhole with respect to the tower foundation will depend on system layout. Recommend keeping same distance from each tower foundation throughout system thereby allowing a straight run between handholes.

2. The tower tilts away from the end of runway and towards the approach. Routing the conduit towards the direction of the tilt and maintaining slack will prevent putting strain on the conduit while the tower is raised and lowered.

3. The number of isolation transformers will depend on the wattage and number of lamps to be installed. If more than one lamp is installed per isolation transformer, then the steady burn approach light must be specified with a lamp shorting device so the other lamps will remain on if one lamp burns out.

4. Number of conductors will vary depending on number of isolation transformers used, requirements of sequenced flashers, etc. Verify requirements with system wiring diagrams and provide (furnish and install) necessary conductors.

Figure 36. Typical MG-20 L.I.R. Structure Tower Wiring Detail



5-7 2" (53mm) LB Conduit Detail.

5-7.1 Figure 37.

5-7.1.1 Notes to Designer:

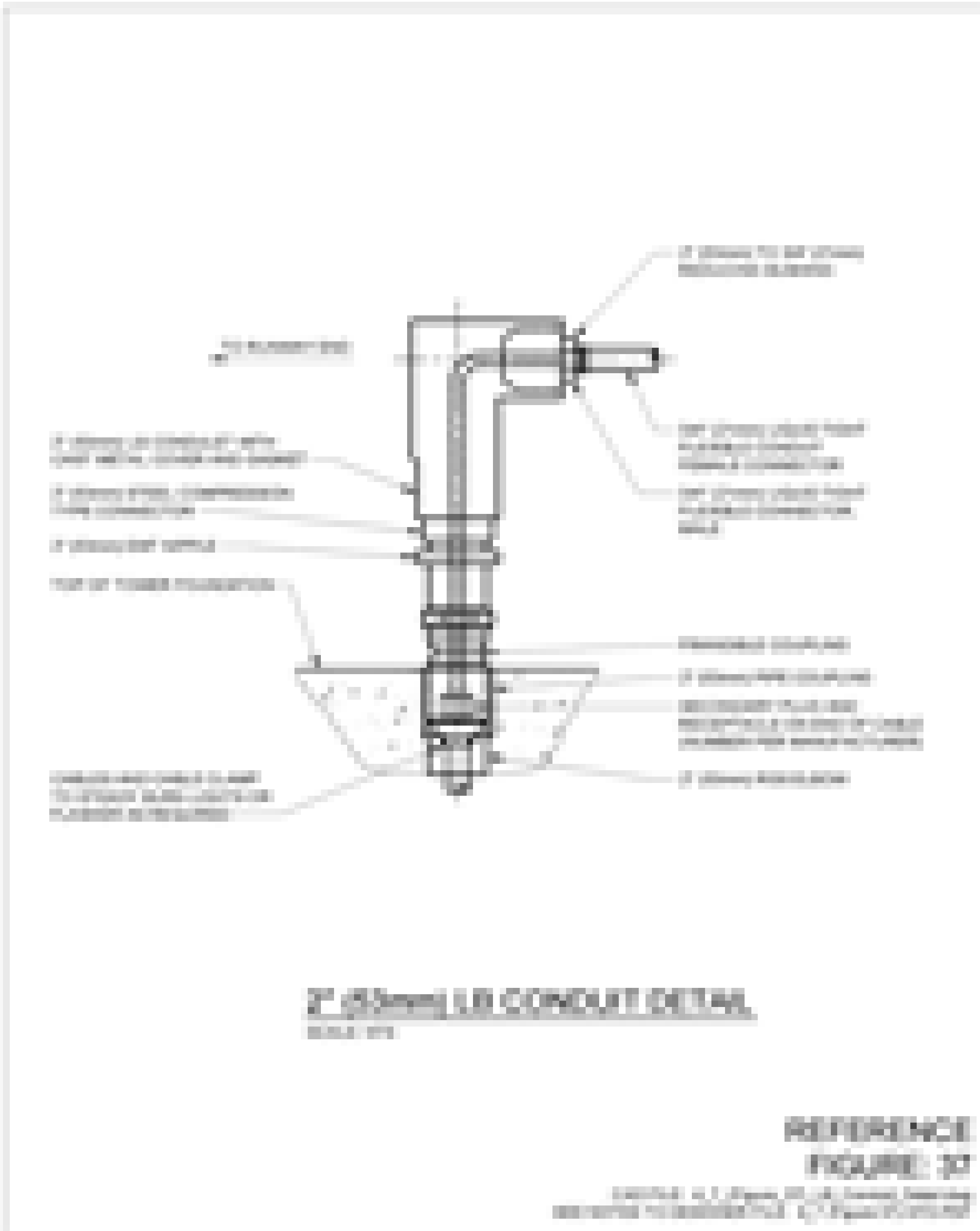
1. Figure is self-explanatory.

5-7.1.2 Drawing Notes for Figure 37.

1. Provide number of cables as required. Refer to system wiring diagrams.

2. Face conduit away from runway end and toward approach.

Figure 37. 2" (53mm) LB Conduit Detail



5-8 Typical MG-30 L.I.R. Structure 21'-2" (6.45m) to 30'-0" (9.14m).

5-8.1 Figure 38.

5-8.1.1 Notes to Designer.

1. The contract documents should include an approach lighting profile plan that will state by station # the height above grade.

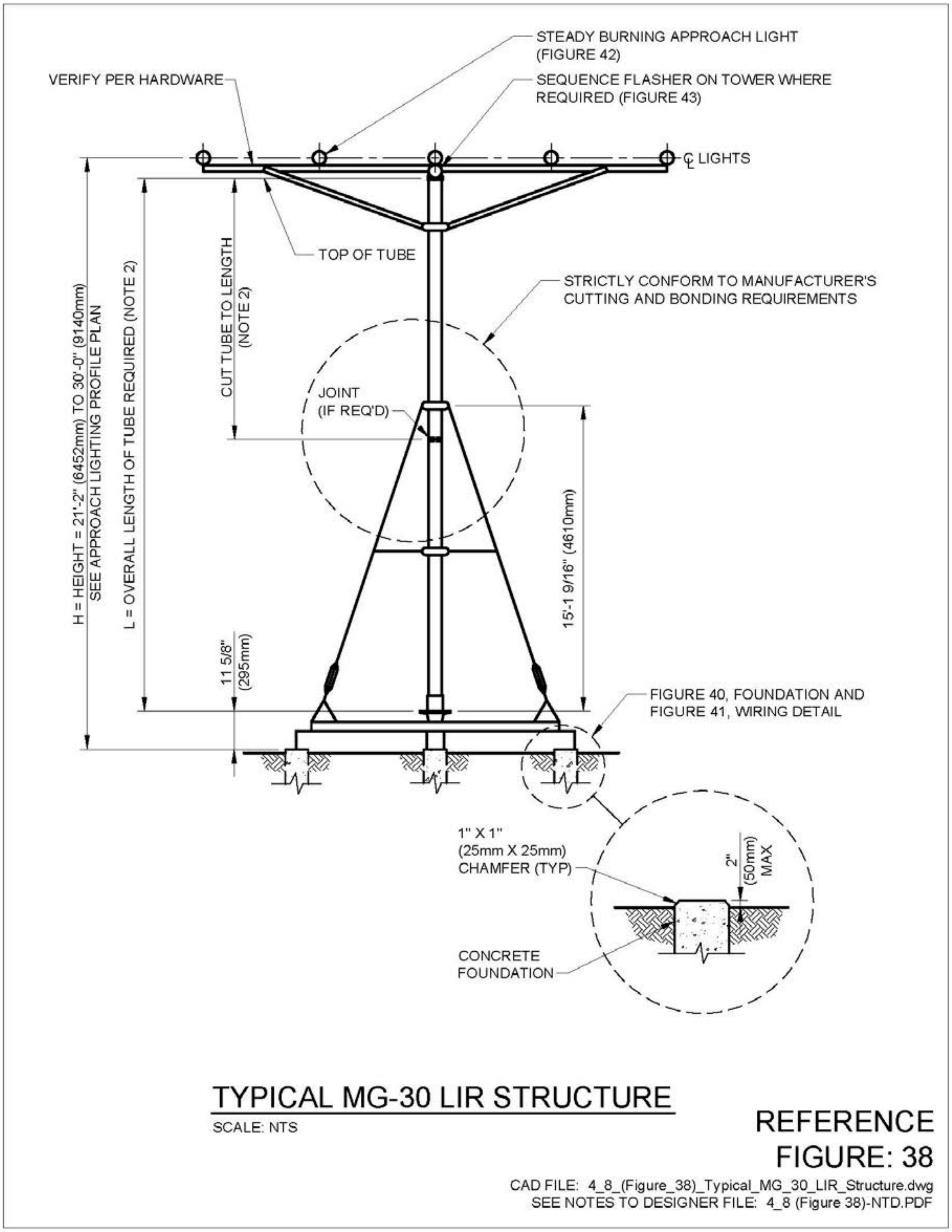
2. Refer to Chapter 3 in UFC 3-535-01 for spacing and number of lights on the T-bar assembly. Specify the appropriate spacing (for the system being installed) in this detail and modify the detail to show the appropriate number of lights.

5-8.1.2 Drawing Notes for Figure 38.

1. Foundations, connections, stabilizers, tilt devices, and associated components must be per manufacturer’s written specifications.

2. Determine length of tube per manufacturer’s requirements.

Figure 38. Typical MG-30 L.I.R. Structure 21'-2" (6.45m) to 30'-0" (9.14m)



5-9 Typical MG-40 L.I.R. Structure 30'-0" (9.14m) to 40'-0" (12.19m).

5-9.1 Figure 39.

5-9.1.1 Notes to Designer.

1. The contract documents should include an approach lighting profile plan that will state by station # the height above grade.

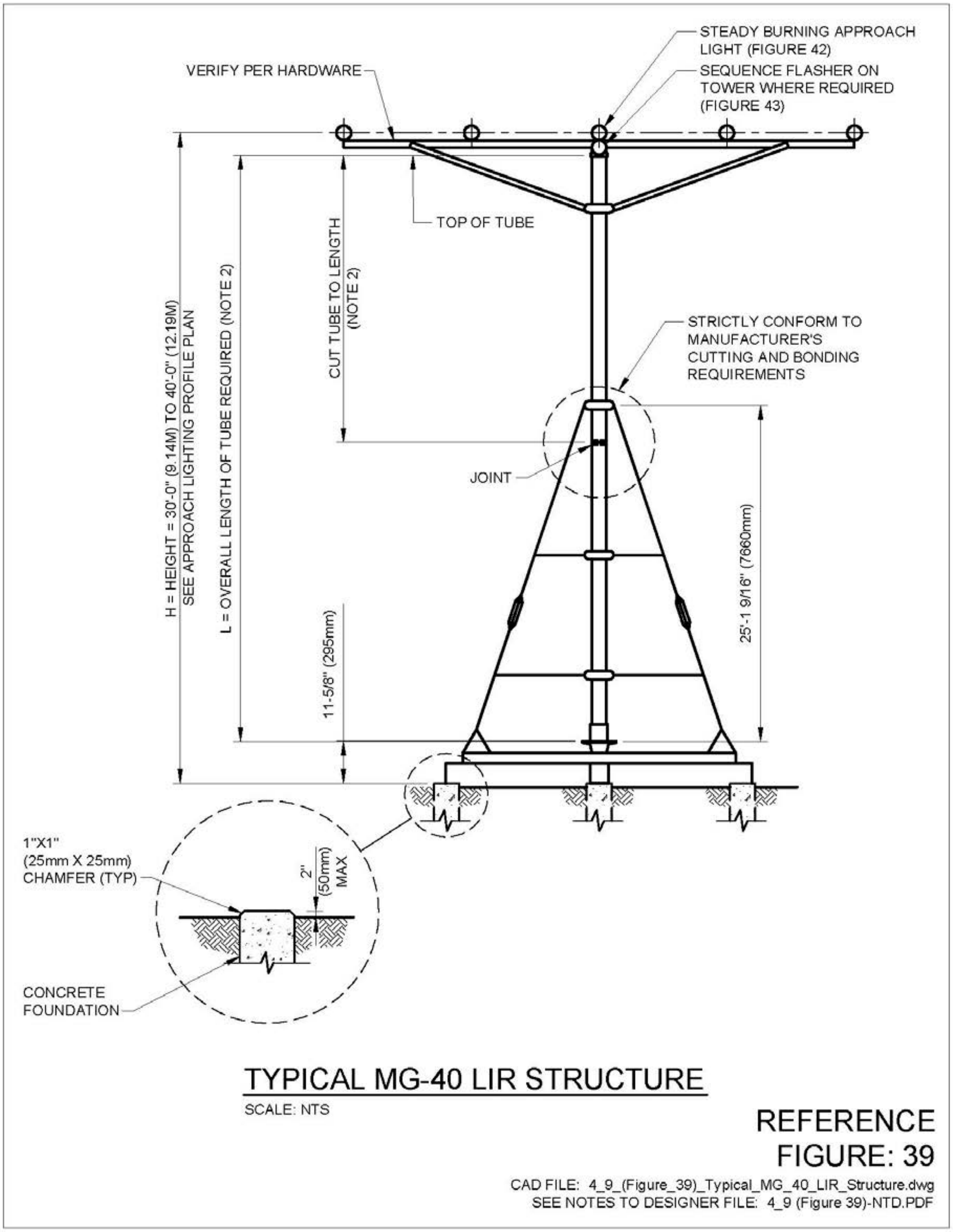
2. Refer to Chapter 3 in UFC 3-535-01 for spacing and number of lights on the T-bar assembly. Specify the appropriate spacing (for the system being installed) in this detail and modify the detail to show the appropriate number of lights.

5-9.1.2 Drawing Notes for Figure 39.

1. Foundations, connections, stabilizers, tilt devices, and associated components must be per manufacturer's written specifications.

2. Determine length of tube per manufacturer's requirements.

Figure 39. Typical MG-40 L.I.R. Structure 30'-0" (9.14m) to 40'-0" (12.19m)



5-10 Foundation for MG-30/40 L.I.R. Structures.

5-10.1 Figure 40.

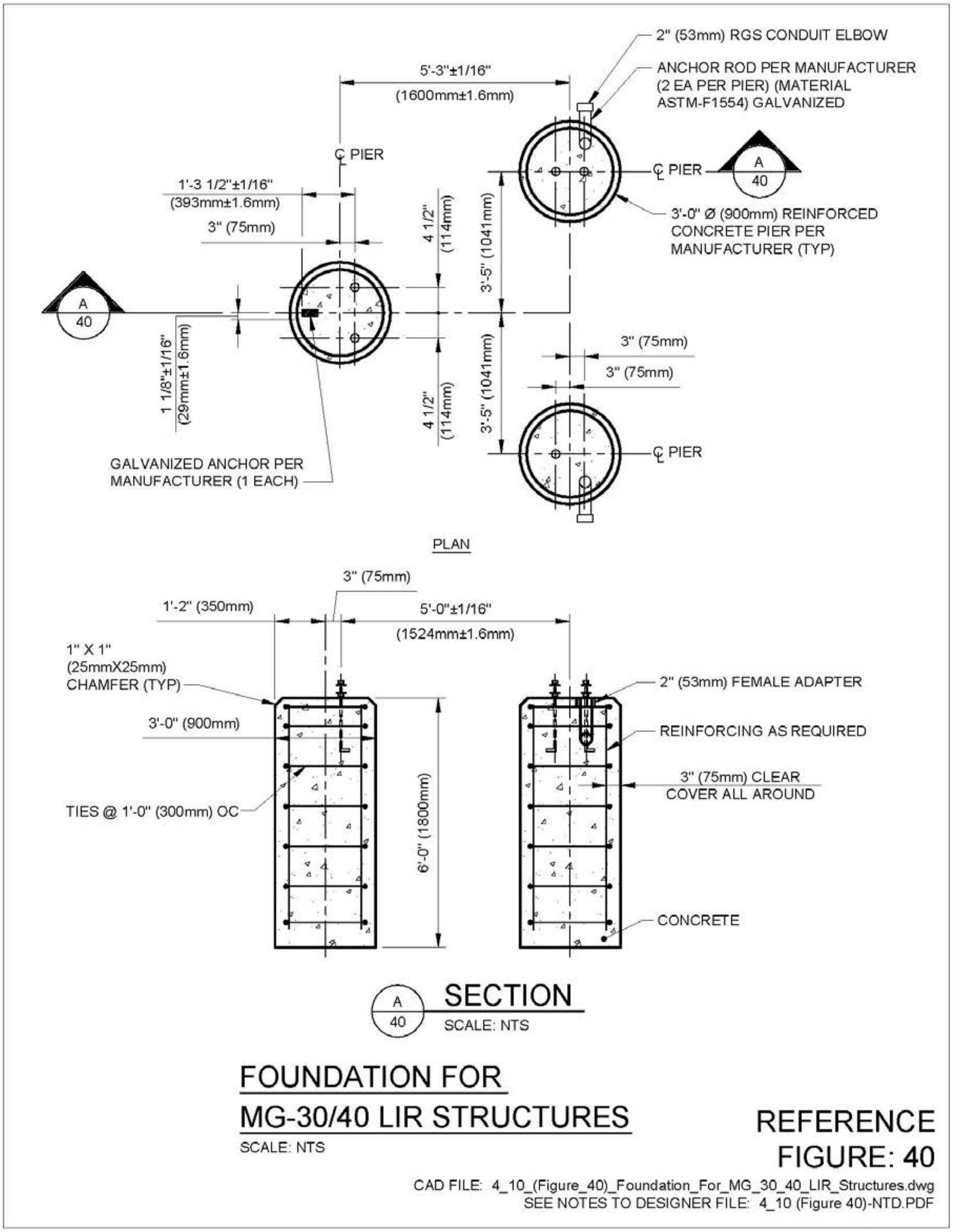
5-10.1.1 Notes to Designer.

1. The foundation indicated is a suggested foundation from one tower manufacturer. The diameter was increased to allow the installation of the conduits in the foundation and still allow clearance for the tilt base on the tower.

2. Prior to designing the foundation for the tower, borings should be taken in the field for soil analysis. Many factors will affect the type and size of foundation to be installed (i.e. type of soil, existence of rock or ledge, soil bearing capacity, frost depth, etc.). The designer should base the foundation design on these factors and consult with the tower manufacturer regarding EPA (Effective Projected Area) for wind loading. The wind loading must include the proposed fixtures and hardware to be installed on the tower.

3. Reinforce per the manufacturer’s written requirements.

Figure 40. Foundation for MG-30/40 L.I.R. Structures



5-11 Typical MG-30/40 L.I.R. Structure Tower Wiring Detail.

5-11.1 Figure 41.

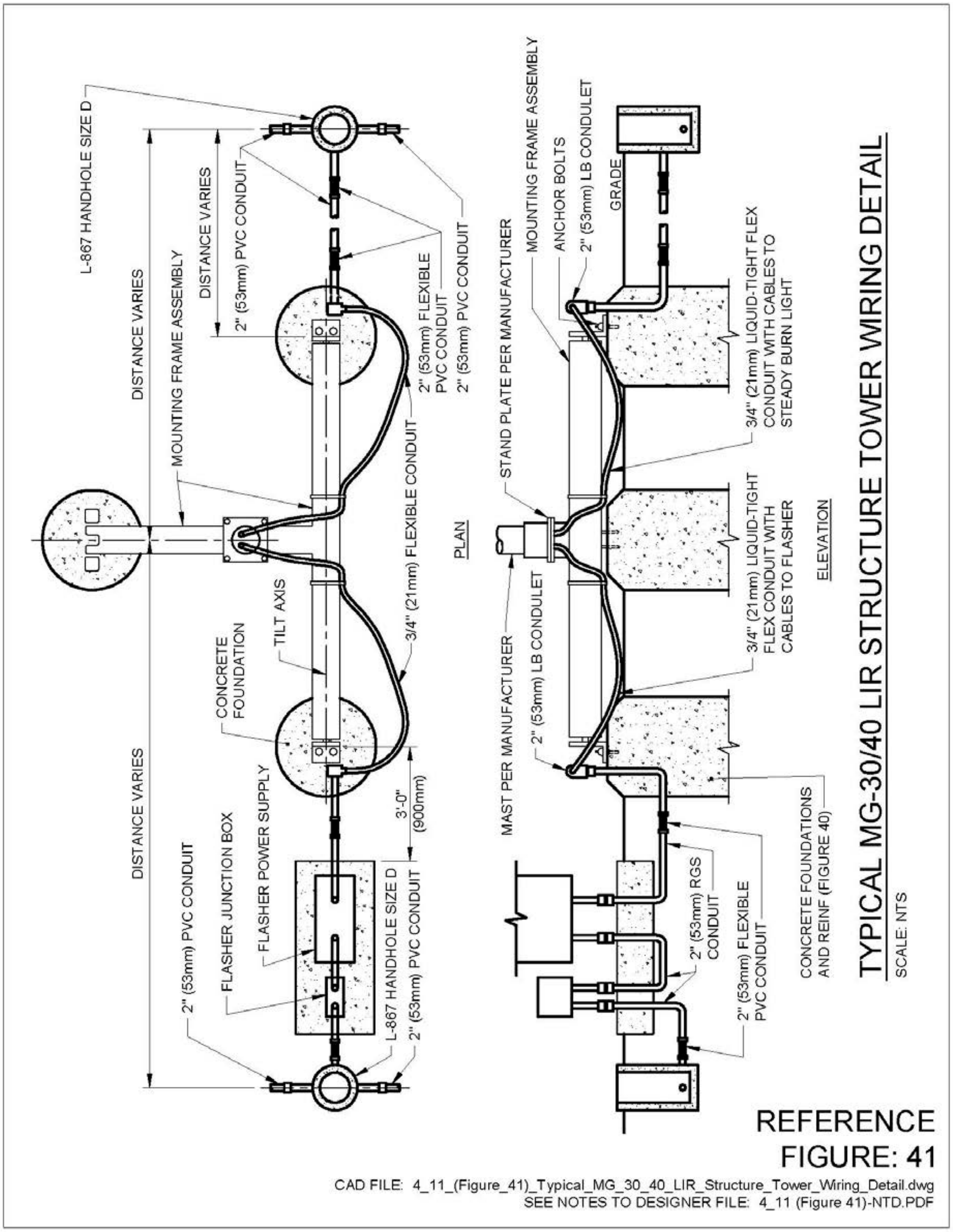
5-11.1.1 Notes to Designer.

1. Location of the handhole with respect to the tower foundation will depend on system layout. Recommend keeping same distance from each tower foundation throughout system thereby allowing a straight run between handholes.

2. The tower tilts away from the end of runway and towards the approach. Routing the conduit towards the direction of the tilt and maintaining slack will prevent putting strain on the conduit while the tower is raised and lowered.

3. The number of isolation transformers will depend on the wattage and number of lamps to be installed. If more than one lamp is installed per isolation transformer, then the steady burn approach light must be specified with a lamp shorting device so the other lamps will remain on if one lamp burns out.

Figure 41. Typical MG-30/40 L.I.R. Structure Tower Wiring Detail



5-12 Tower Mounted Steady Burning Approach Light Detail.

5-12.1 Figure 42.

5-12.1.1 Notes to Designer.

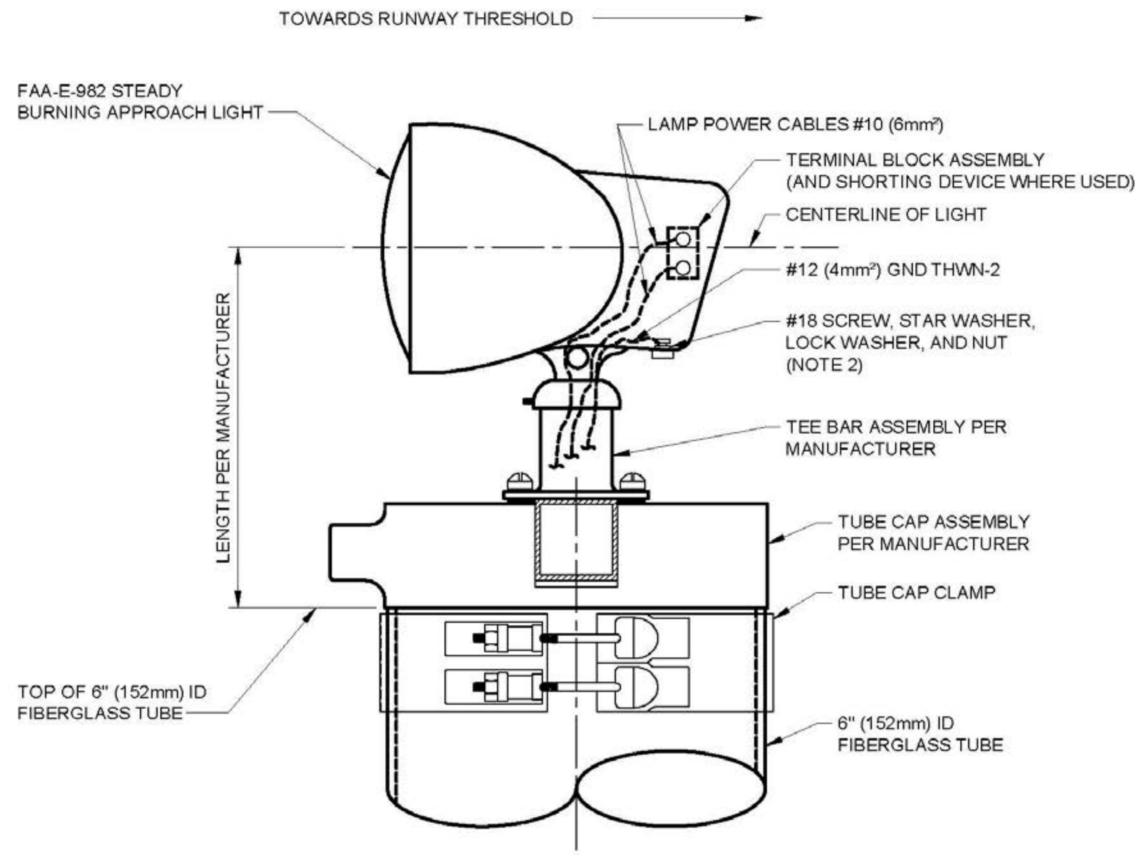
1. The FAA does not require a grounding terminal in the lamp holder. However, more recent installations have installed an equipment ground to the lamp holder. The ground conductor is routed with the circuit conductors and is bonded to the steel base plate and mounting assembly. This in turn is bonded to a ground.

5-12.1.2 Drawing Notes for Figure 42.

1. Measure distance between center of light and top of tube using actual equipment installed.

2. Attach #12 (4 square mm) ground to fixture housing by installing a #8 screw through hole provided in bottom of housing. Sand away paint and anodizing around hole on inside of housing to bare metal. Push screw up through hole and install star washer over screw on interior of housing. Crimp an insulated ring terminal on the end of the ground wire and install on screw. Place lock washer and nut on screw and tighten. Verify with manufacturer length and size of screw, star washer, lock washer, and nut to be utilized to maintain clearance from terminal block assembly.

Figure 42. Tower Mounted Approach Light Detail



TOWER MOUNTED STEADY BURNING APPROACH LIGHT DETAIL

SCALE: NTS

REFERENCE
FIGURE: 42

CAD FILE: 4_12_(Figure_42)_Tower_Mounted_Steady_Burning_Approach_Light_Detail.dwg
SEE NOTES TO DESIGNER FILE: 4_12 (Figure 42)-NTD.PDF

5-13 Tower Mounted SFL and Approach Light Detail.

5-13.1 Figure 43.

5-13.1.1 Notes to Designer.

1. The flasher equipment ground conductor may be bonded to the ground conductor for the steady burn lights inside the tube cap assembly.

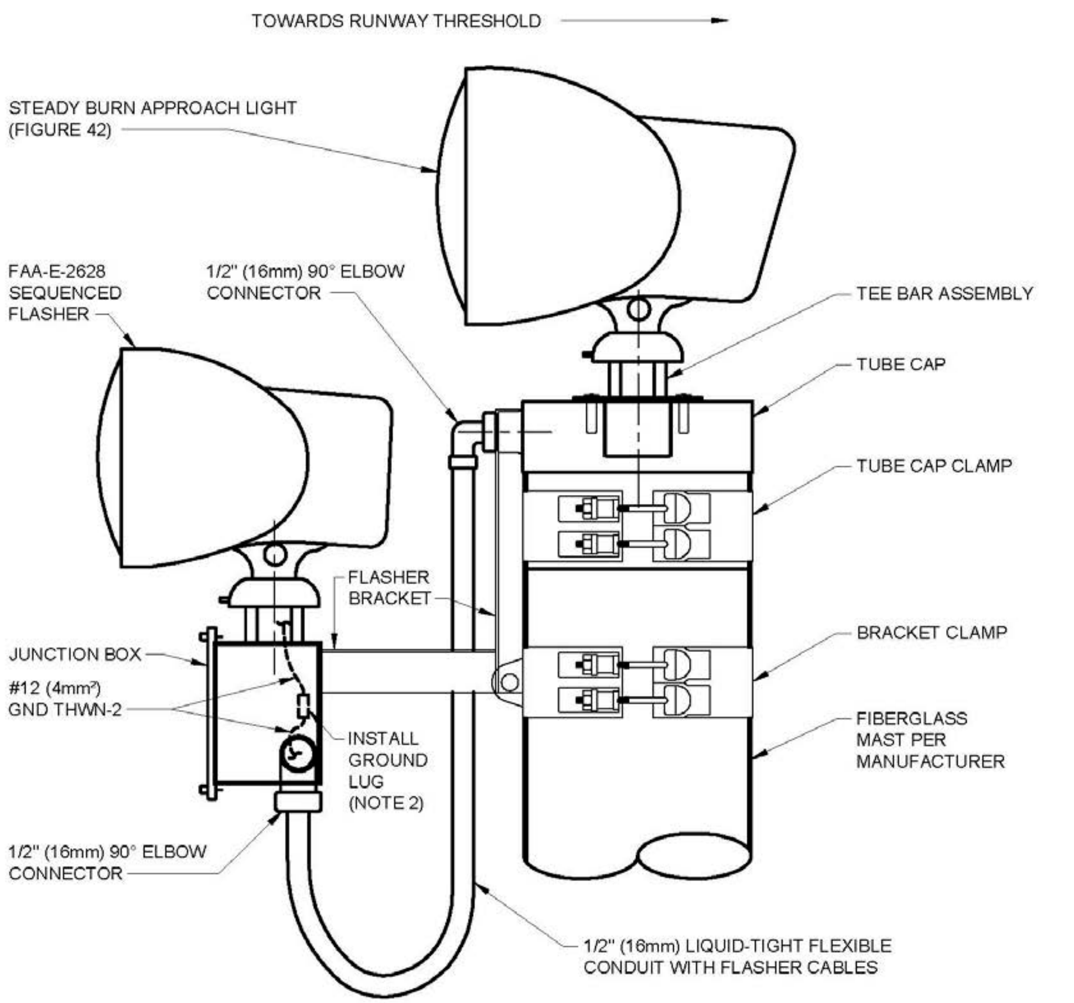
2. The number of conductors to the flasher must be verified. Typically, 2 #12 (4 square mm) and 3 #16 (1.5 square mm), 3kV, are used and are provided by the manufacturer. Ensure size of flexible conduit is adequate for these cables.

5-13.1.2 Drawing Notes for Figure 43.

1. Flasher junction box/bracket and bracket clamp furnished as an assembly. Install on mast per manufacturer’s requirements.

2. Install ground lug on one of the 2 aluminum angles inside the junction box and route a #12 (4 square mm) THWN-2 from flasher and fiberglass mast to lug. Terminate ground wire on lug.

Figure 43. Tower Mounted SFL and Approach Light Detail



TOWER MOUNTED SFL AND APPROACH LIGHT DETAIL

SCALE: NTS

REFERENCE
FIGURE: 43

CAD FILE: 4_13_(Figure_43)_Tower_Mounted_SFL_And_Approach_Light_Detail.dwg
SEE NOTES TO DESIGNER FILE: 4_13 (Figure 43)-NTD.PDF

5-14 **MALSR and SSALR Approach Light System Configuration.**

5-14.1 **Figure 44A, 44B.**

5-14.1.1 **Notes to Designer.**

1. Recommend including the system layout as part of the contract documents.

2. The SSALR configuration may be achieved with a dual mode ALSF/SSALR system and is used when Category I weather conditions exist thereby allowing an energy savings without having to use the full ALSF-2 system.

Figure 44A. MALSR Approach Light System Configuration

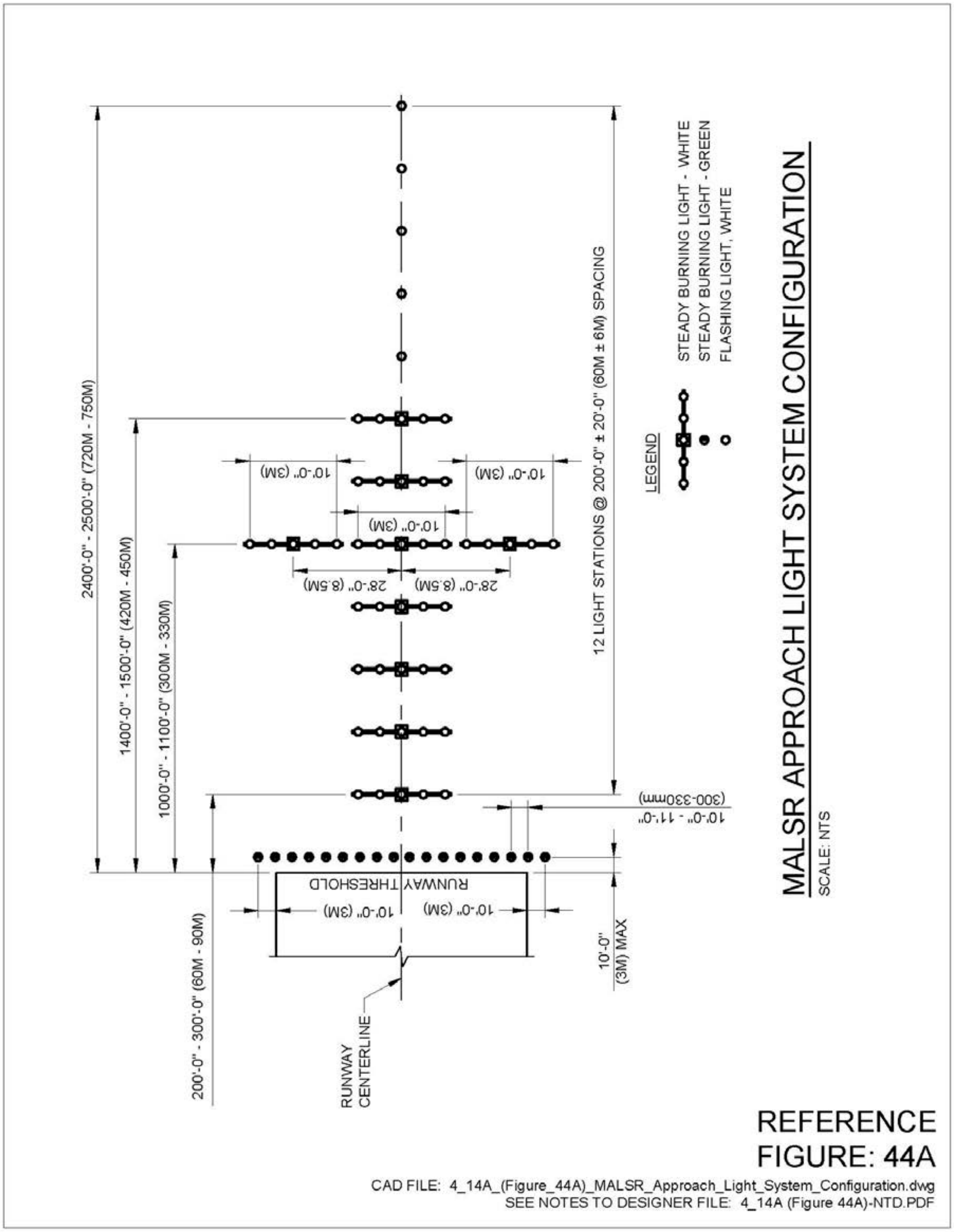
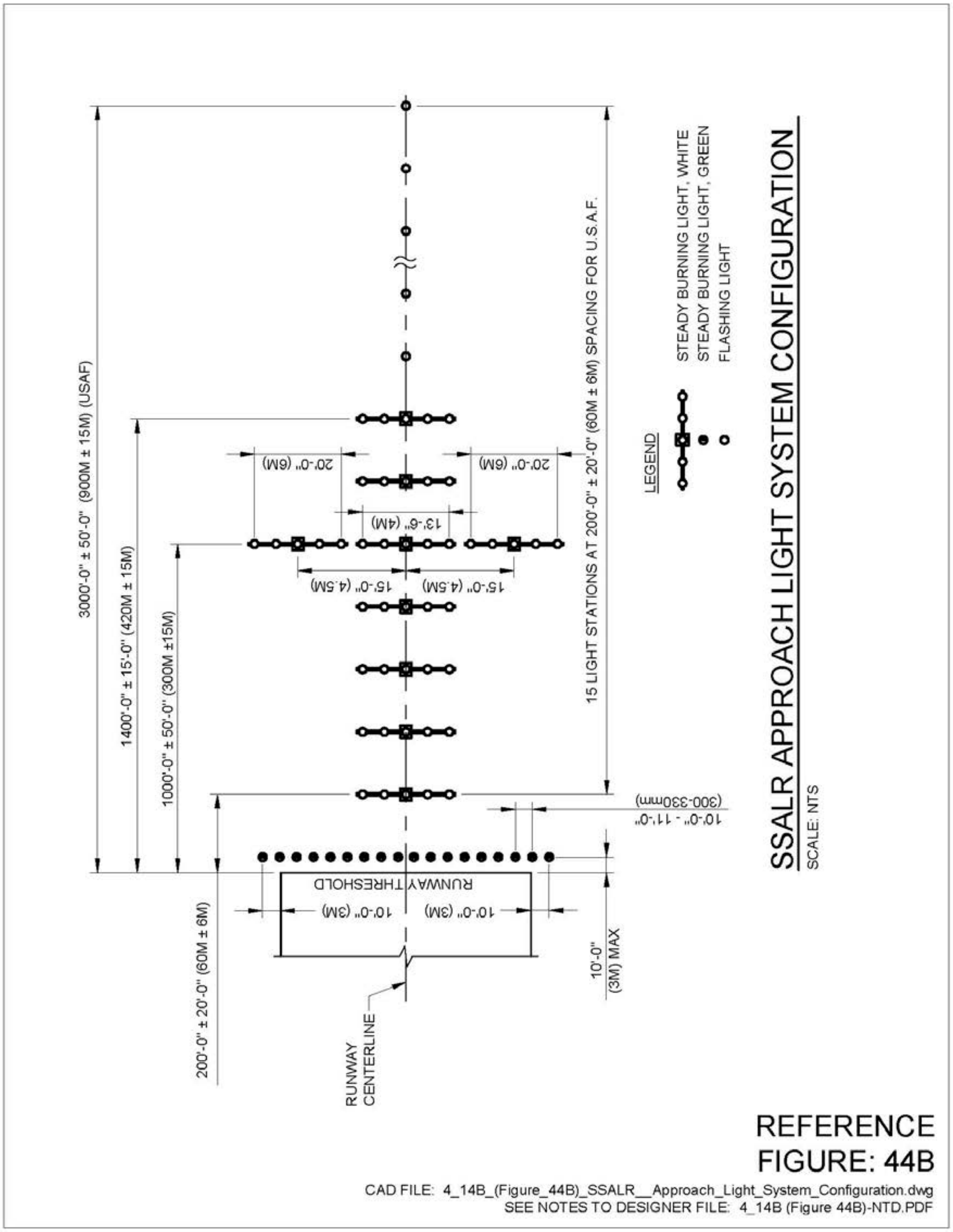


Figure 44B. SSALR Approach Light System Configuration



5-15 emote Flasher Installation 6' 0" (1800mm) Maximum.

5-15.1 Figure 45.

5-15.1.1 Notes to Designer.

1. This detail shows a remote flasher installation. The high voltage cable is normally supplied with the flasher and about 50' (15m) in length. Locate the flasher power supply within this distance.

2. Where the flasher is co-located with an approach light bar; the flasher may be mounted a maximum 5' (1.5m) in front of light bar and a maximum of 4' (1.2m) below the centerline of the approach light plane. When the flashers are mounted below the centerline, they must be uniformly mounted throughout the system.

5-15.1.2 Drawing Notes for Figure 45.

1. Maximum mounting height of configuration indicated is 5'-11" (1.775m) for mounting installation of more than 6'-0" (1800mm) see tower installation details.

2. Terminate all conduits with a standard grounding bushing.

3. Connection must be clean and dry with a light coating of silicone grease only.

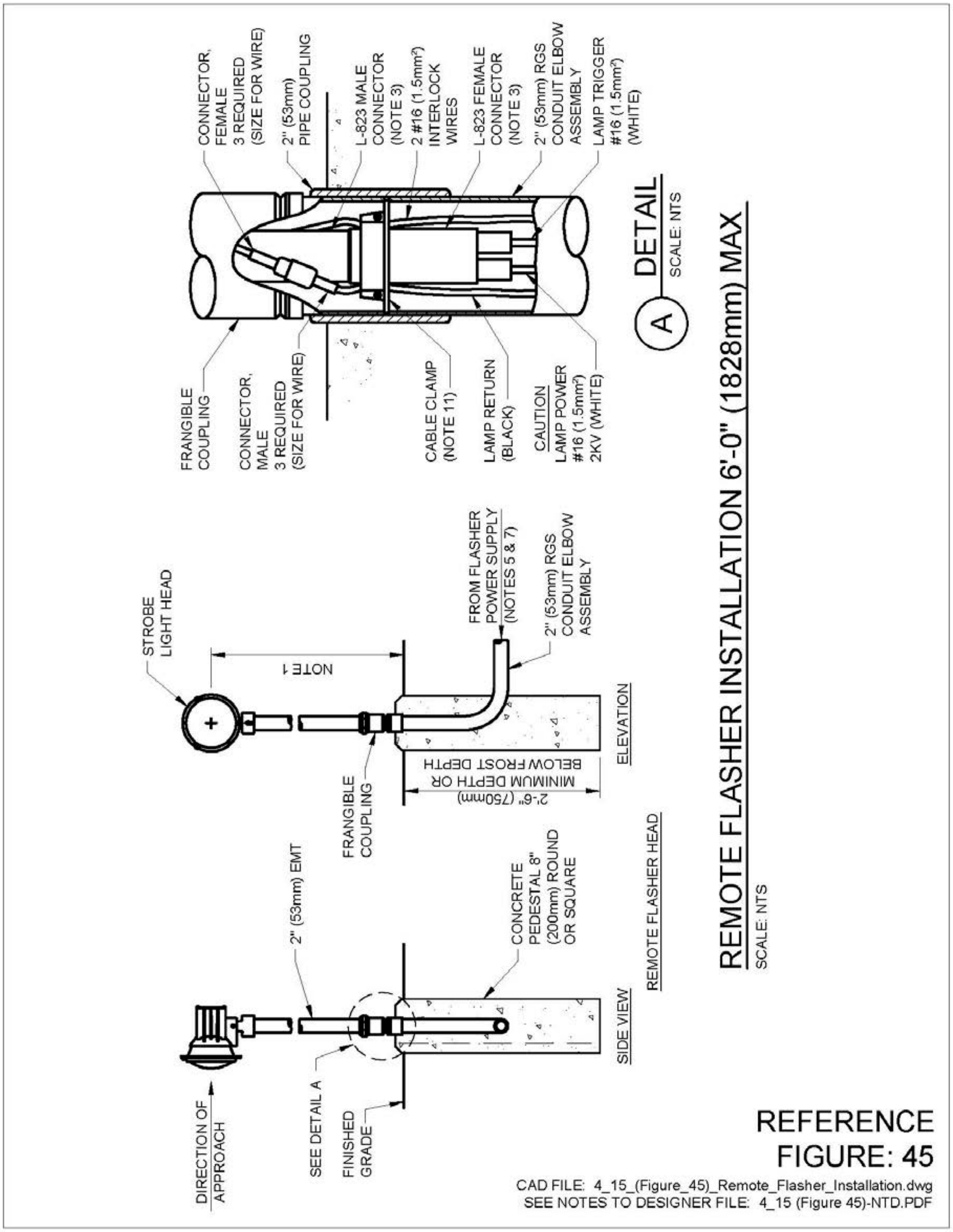
4. Continuity of power cables must be maintained between flasher stations. Where splices are required, they must be epoxy resin type with plastic shell. Equip conductors with mechanical wire clamps.

5. Ground clearance of electrical boxes must be determined in field, and must be 8" (200mm) minimum.

6. Flasher power supply/junction box unit must be located 35' (10.5m) from extended centerline of runway.

7. Insert lamp return wire into cable clamp prior to final assembly/tightening.

Figure 45. Remote Flasher Installation 6' 0" (1828mm) Maximum



5-16 Typical High Intensity Approach Light Bar.

5-16.1 Figures 46A, 46B, 46C, 46D, 46E, 46F, 46G.

5-16.1.1 Notes to Designer.

1. Figures 46A, 46B, 46C, 46D, 46E and 46F show the installation of an approach light bar in a concrete monolith. The pavement is excavated at the location where the bar will be installed. Depth and width of the excavation must be enough to allow setting the base cans, installing reinforcement and backfill with concrete.

2. Figures 46E and 46F show setting the base cans with the support brace spanning the excavated area. Sandbags are used on top of the bracing to prevent the base from floating during concrete installation.

3. The thickness of the snow plow ring is crucial in setting the base at the correct height. The plywood cover must match the diameter and thickness of the snowplow ring so that when removed the ring will fit properly and the outside edge of the ring is flush with the existing top of pavement.

5-16.1.2 Drawing Notes for Figure 46D.

1. Set the light base that mimic exact diameter and thickness of snow ring. Completely wrap plywood cover in roofing paper. See Figures 46E and 46F.

2. Light bases must meet or exceed to AC 150/5345-42, Specification for Airport Light Bases and Transformer Housing, Type L-868.

3. The contractor must provide 3/8" (10mm) -16 × 1-1/4" (30mm) long stainless steel bolts and stainless steel split lock-washers for bolting snow plow ring to L-868 base can.

4. Fill space with sealing compound P-606 for concrete or flexible pavement. Provide certification that sealer is compatible with pavement type.

5. Seal unused hole in light bases with pipe plugs.

5-16.1.3 Drawing Notes for Figures 46E, 46F and 46G.

1. Details for high intensity approach in-pavement light fixture/base can only. Installation methodology indicated for contractor information only. The methodology indicated on this sheet is general in nature. Final installation methodology must be determined by the contractor.

2. See civil plans for typical pavement section.

Figure 46A. In-Pavement High Intensity Approach Light Bar – Section View Materials

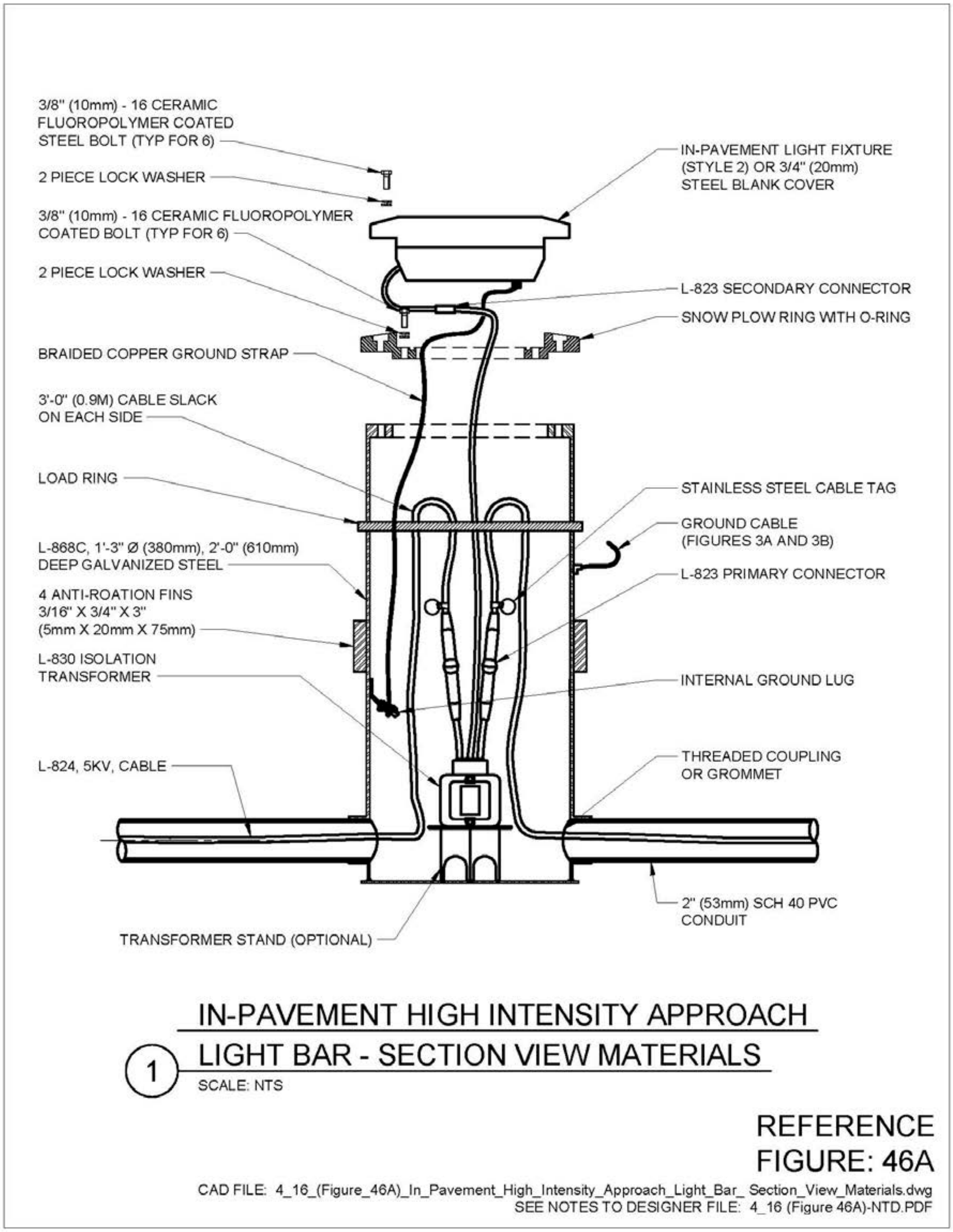


Figure 46B. Grounding Connections Air Force, Army, Navy Projects

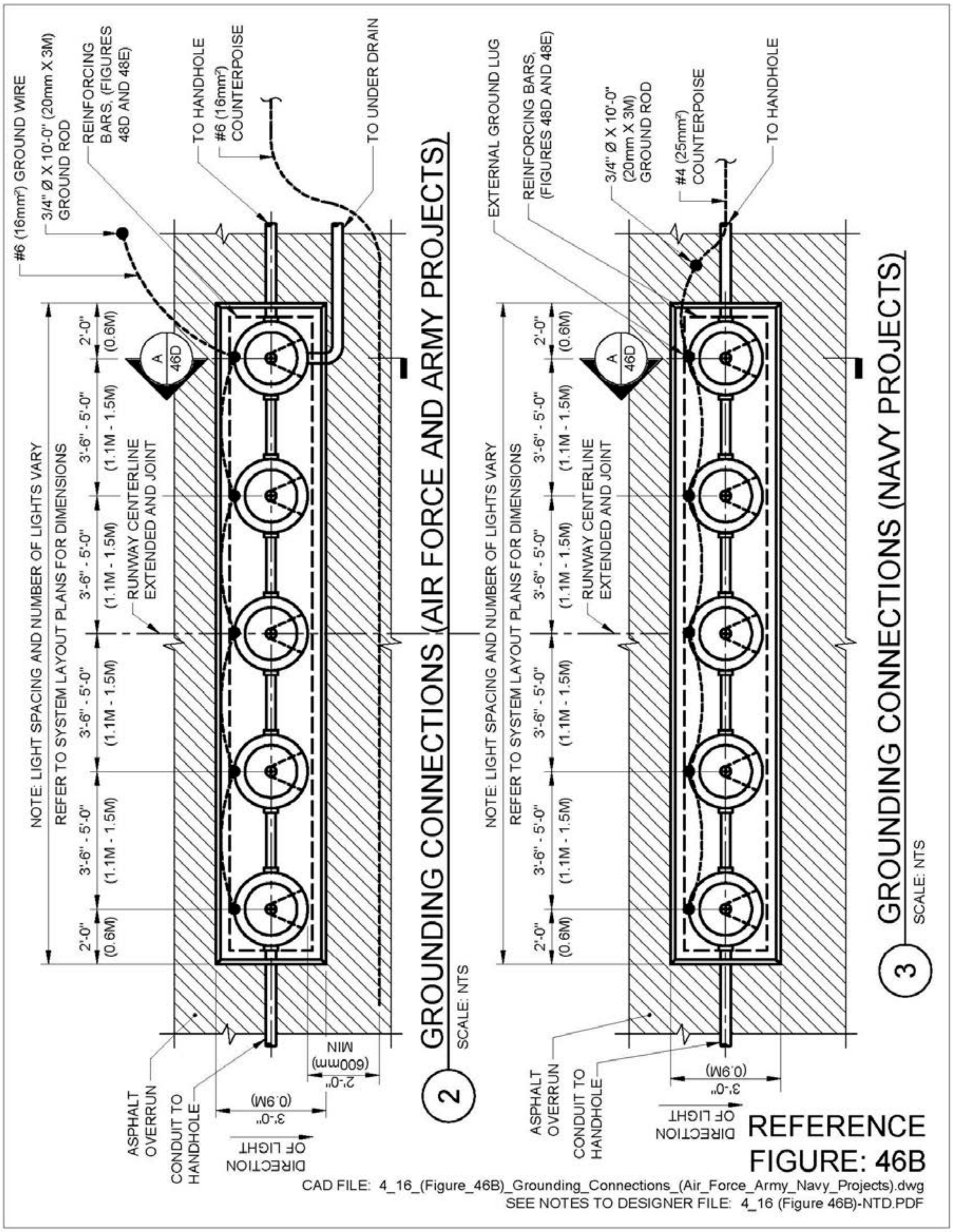


Figure 46C. Typical High Intensity Approach Light Bar (Air Force/Army)

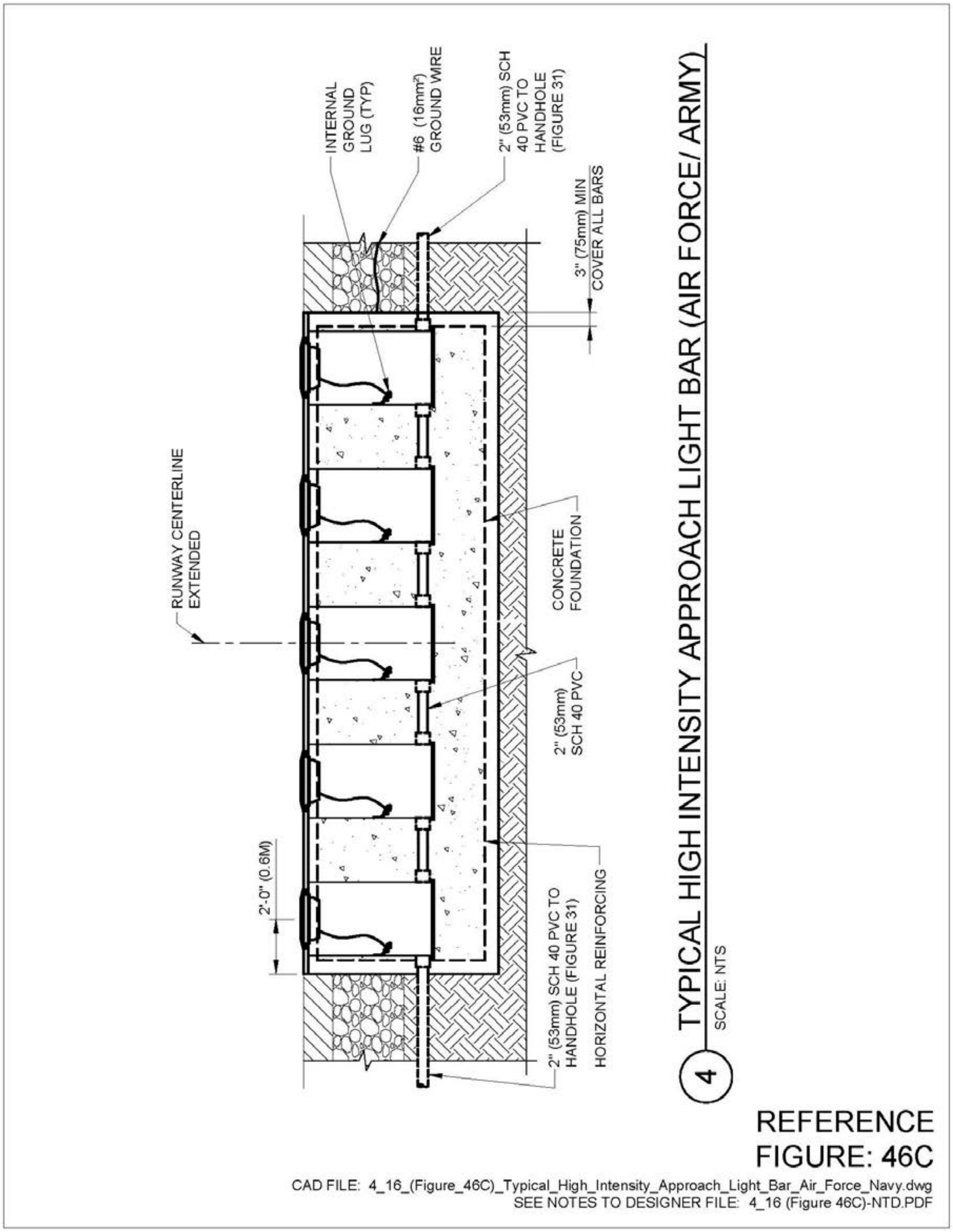
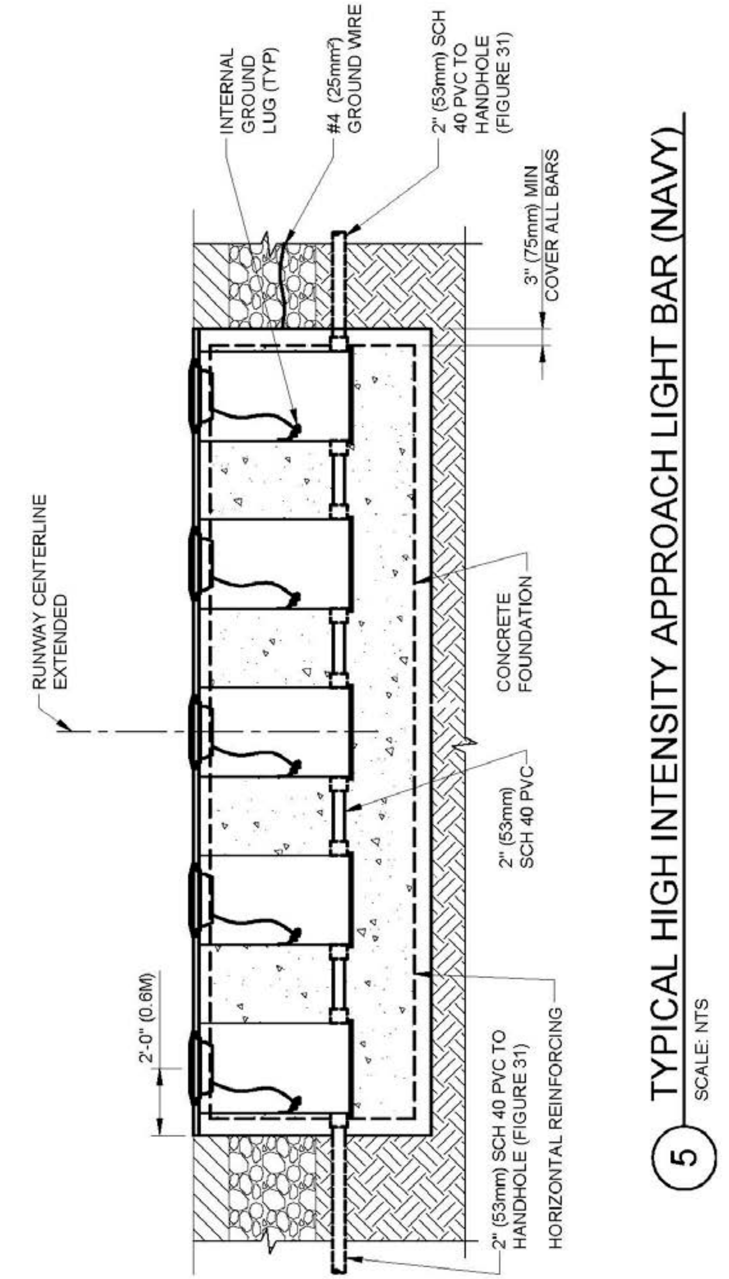


Figure 46D. Typical High Intensity Approach Light Bar (Navy)



REFERENCE
FIGURE: 46D

CAD FILE: 4_16_(Figure_46D)_Typical_High_Intensity_Approach_Light_Bar_Navy.dwg
SEE NOTES TO DESIGNER FILE: 4_16 (Figure 46D)-NTD.PDF

Figure 46E. In-Pavement High Intensity Approach Light Base – Section View and Conduit Installation

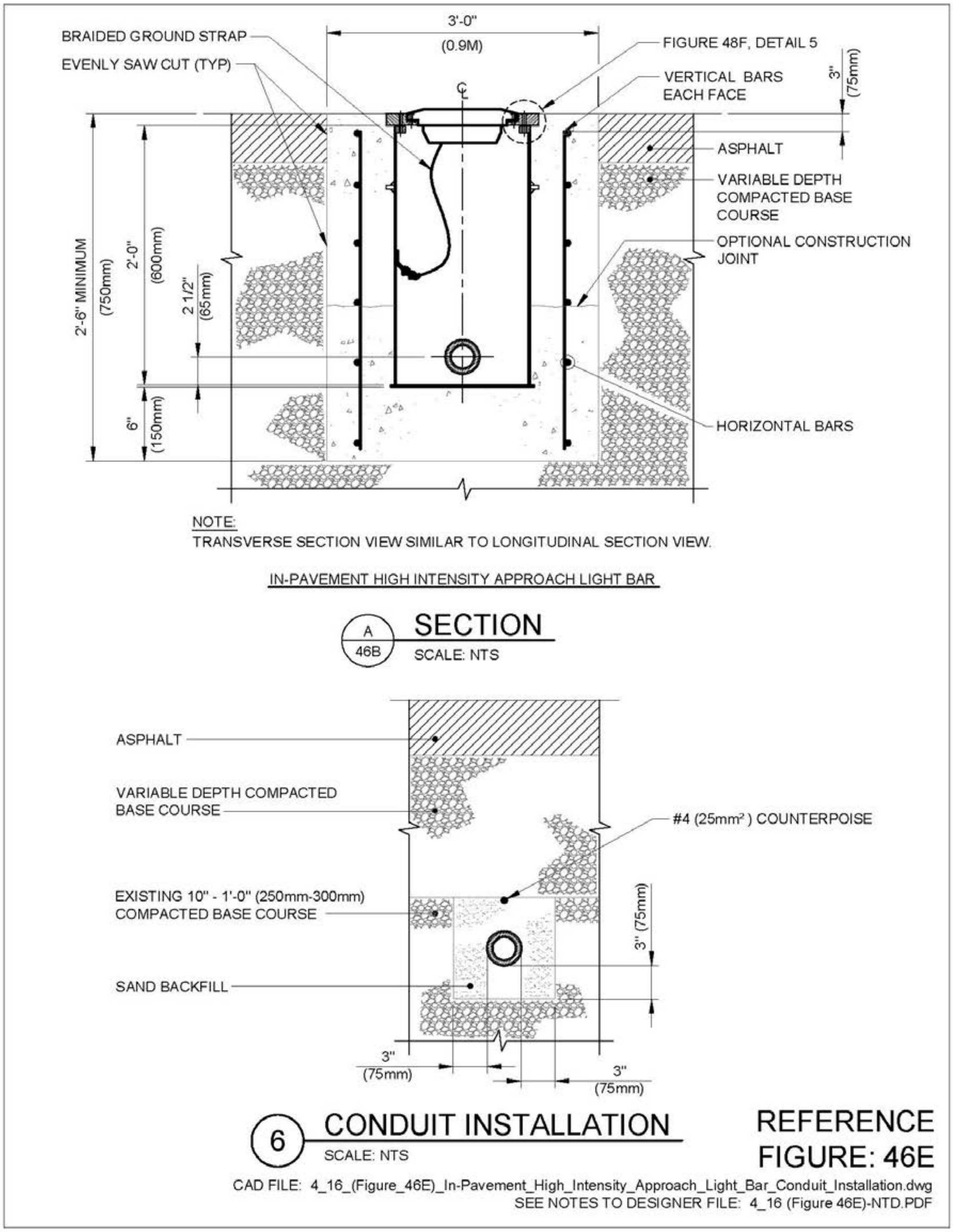


Figure 46F. Existing Trenching, Sawcut Asphalt and Trench, Set L-868 Base Can and Framework

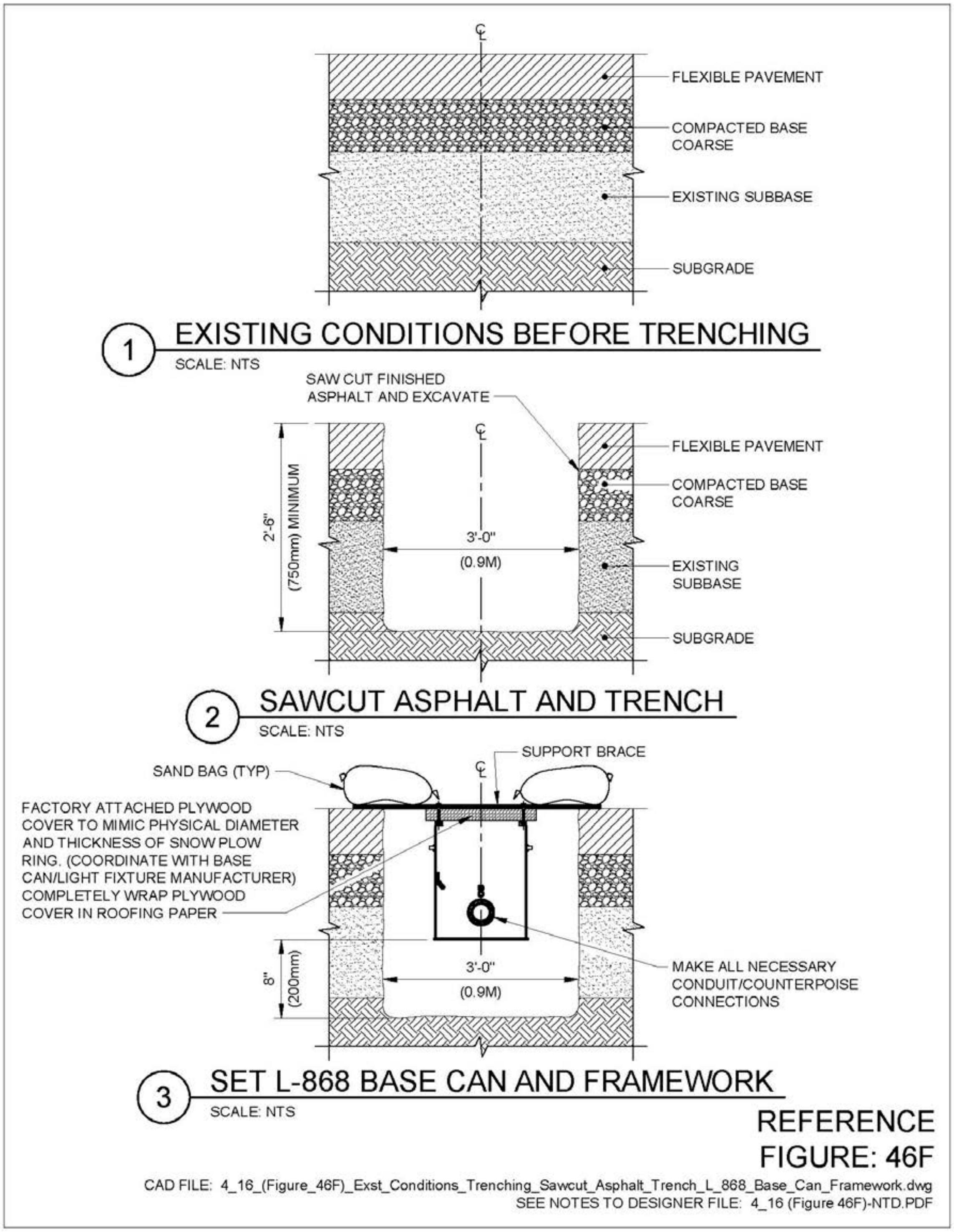
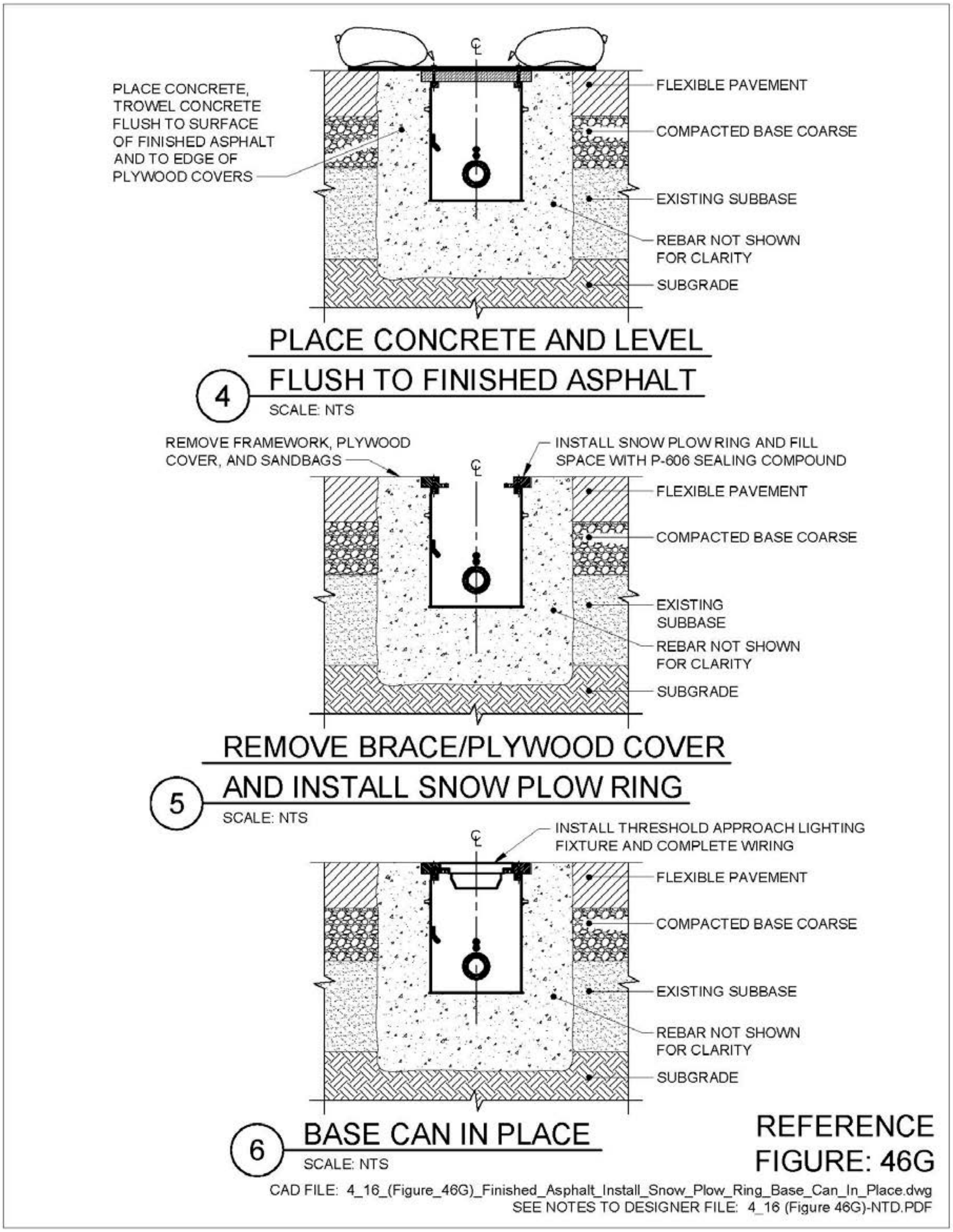


Figure 46G. Place Concrete, Remove Brace/Plywood Cover, Base Can in Place



5-17 Typical Elevated High Intensity Approach Light Bar 0' to 6'0" (0mm to 1800mm) Maximum.

5-17.1 Figure 47.

5-17.1.1 Notes to Designer.

1. This detail shows the elevated approach light bar. Spacing between the lights will depend on which system is installed.

2. The contract documents should contain an overall layout plan showing the spacing of the lights. Refer to UFC 3-535-01 for the spacing requirements for each system.

3. The flexible conduit allows for shifting due to freeze/thaw cycles in cold climates. If freeze/thaw cycles are not a problem, then the use of the flexible conduit is optional.

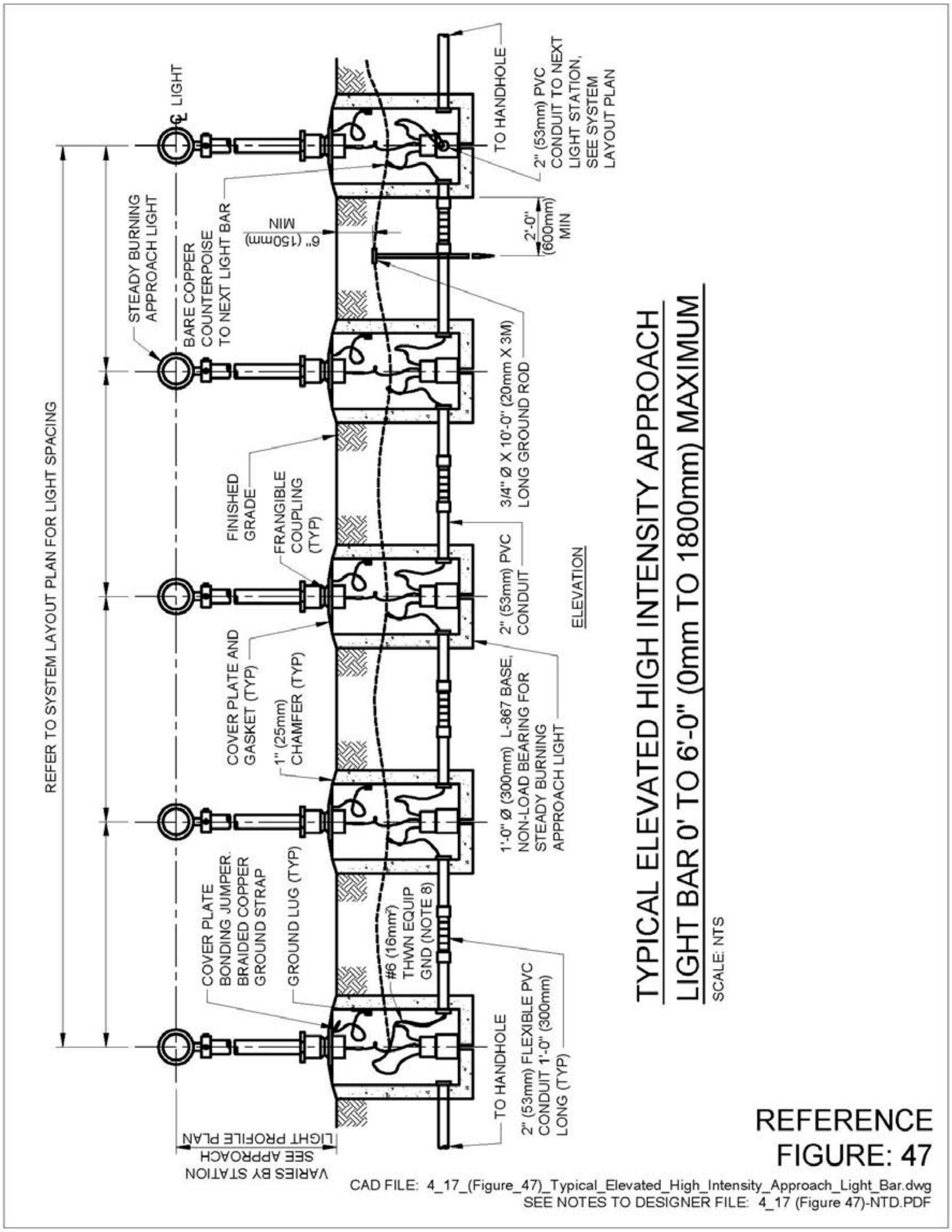
4. In some instances, the light bar may be installed in a reinforced concrete foundation similar to an in-pavement light bar as indicated in Figures 46A, 46B, 46C, 46D, 46E and 46F. The installation of the foundation would be the same except the light fixtures would be elevated. Typically, L-867 (non-loadbearing) base cans are used when the lights are located in turf areas. However, some commands require L-868 (load-bearing) base cans. Attention should be paid to the difference in the bolt circles for the two cans and providing the correct cover plate for the can being installed. L-867 cans utilize a 10 ½" (265mm) B.C. and L-868 utilize an 11 ¼" (285mm) B.C. Also, in some instances, a 15" (380mm) diameter can is required rather than 12" (305mm) diameter. The designer should consult with the Major Command for which the project is being designed for their requirements.

5-17.1.2 Drawing Notes for Figure 47.

1. Place all elevated light fixtures on 12" (305mm)∅ L-867, non-load bearing bases.

2. Maximum mounting height of configuration indicated is 6'-0" (1800mm). For mounting installation of more than 6'-0" (1800mm), see tower installation details.

Figure 47. Typical Elevated High Intensity Approach Light Bar 0' to 6'0" (0mm to 1800mm) Maximum



5-18 Typical In-Pavement High Intensity Threshold Light Foundation with Interleaved Edge Light Circuits.

5-18.1 Figures 48A, 48B, 48C, 48D, 48E.

5-18.1.1 Notes to Designer.

1. These figures show a typical foundation for a threshold light bar with interleaved edge light circuits.

2. No more than five lights should be in a bar before an expansion joint is installed.

3. Ensure photometric requirements are specified. Threshold lights must meet 10,000 CD min. average in green for a high intensity system.

4. The use of high-density polyethylene (HDPE) conduit allows the flexibility required of routing the conduit around cans. Two edge light and one threshold circuit feed the lights in the threshold bar. Refer to Figure 56 for high intensity threshold bar wiring diagram.

5-18.1.2 Drawing Notes for Figures 48A and 48B.

1. Not all fixtures in threshold bar are indicated for clarity. Threshold bar continues across runway and is symmetrical about runway centerline.

2. Interweave conduits as indicated.

3. Refer to Figure 56 for typical wiring diagram.

5-18.1.3 Drawing Notes for Flush Fixtures, Figure 48E.

1. Install corner edge of snow plow ring flush with pavement surface with a tolerance of +0", -1/16" (1.6mm). Check tolerance with straight edge. See Figure 19B.

2. Submit all base can installation techniques, methods, materials, etc., to the government for review and approval prior to the start of work.

3. Before backfilling around the base cans, the contractor must demonstrate to the government that the base cans are at the correct location, elevation, azimuth, and rotation.

4. Protect the finished pavement surface from foreign substances which could cause staining, i.e., concrete, oil, etc. The contractor must immediately clean all spills and correct/clean any stained surfaces at no additional cost to the government.

5. The base can cover mounting bolts must extend thru the base can mounting flange into the base can a minimum of 0.5" (13mm). The bolts must be threaded the full length of the bolt.

6. Concrete around base cans and duct/conduit must be completely consolidated by mechanical means and free of any voids.

7. For blank base cans, delete light fixture and install 3/4" (19mm) steel blank cover.

8. Air Force / Army Airfields: Connect local ground rod to base cans. Route counterpoise around base cans. Navy Airfields: Connect counterpoise to base cans.

9. Install top of edge of snow plow ring flush with pavement surface with a tolerance of +0", -1/16" (1.6mm).

10. If the distance between the edge of the snow ring and concrete is 1/8" (3mm) or less, seal top of opening with P-605 sealant and delete the P-606 compound.

11. The top of fixture must not exceed the top of the snow plow ring (+0, -1/8" (3mm)).

12. Install finished surface of concrete beam flush with adjacent pavement (+0, -1/16" (1.6mm))

Figure 48A. Runway Threshold Wing Bar Light Foundation – Plan View

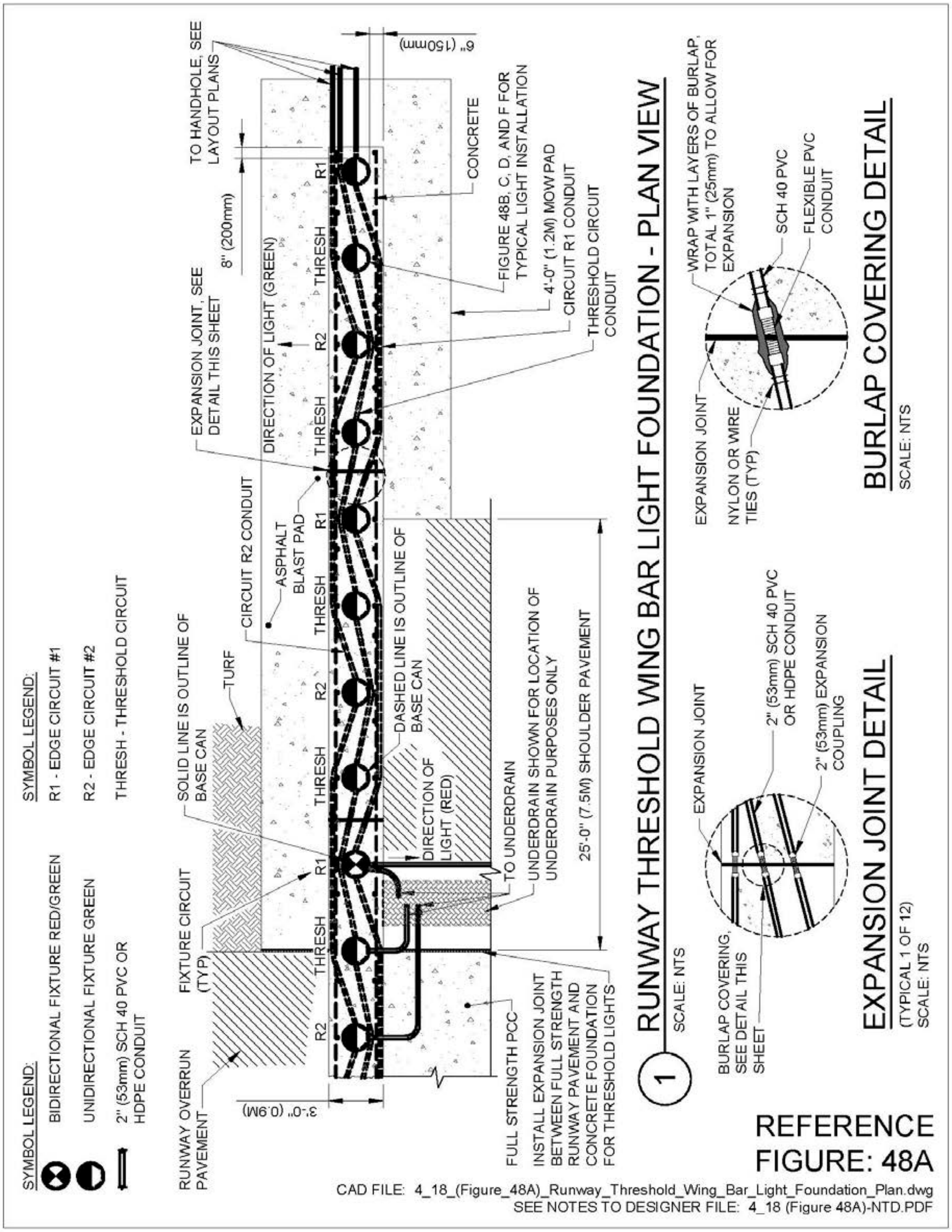


Figure 48B. Runway Threshold Wing Bar Light Foundation – Elevation View

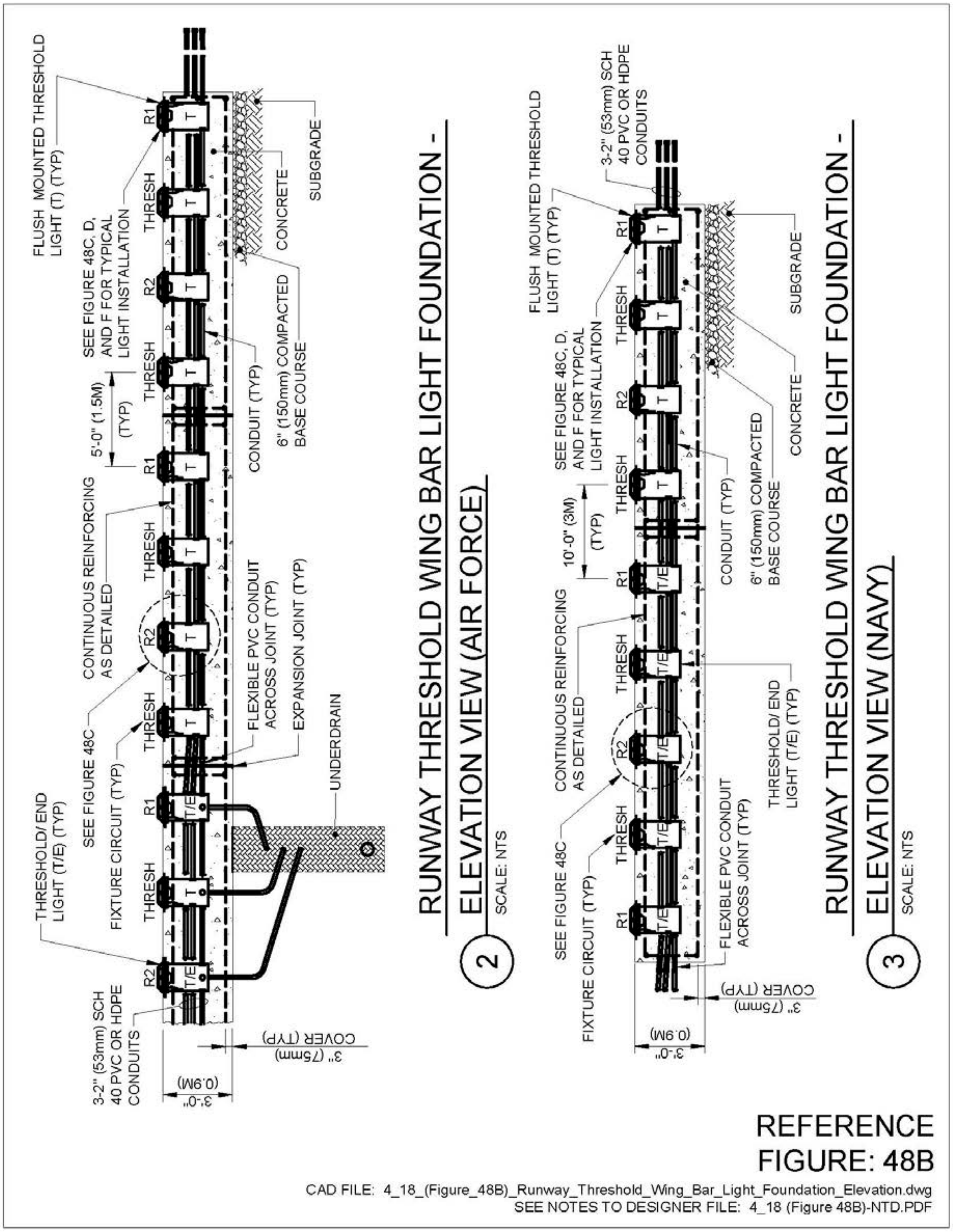


Figure 48C. Threshold Light in Concrete Beam

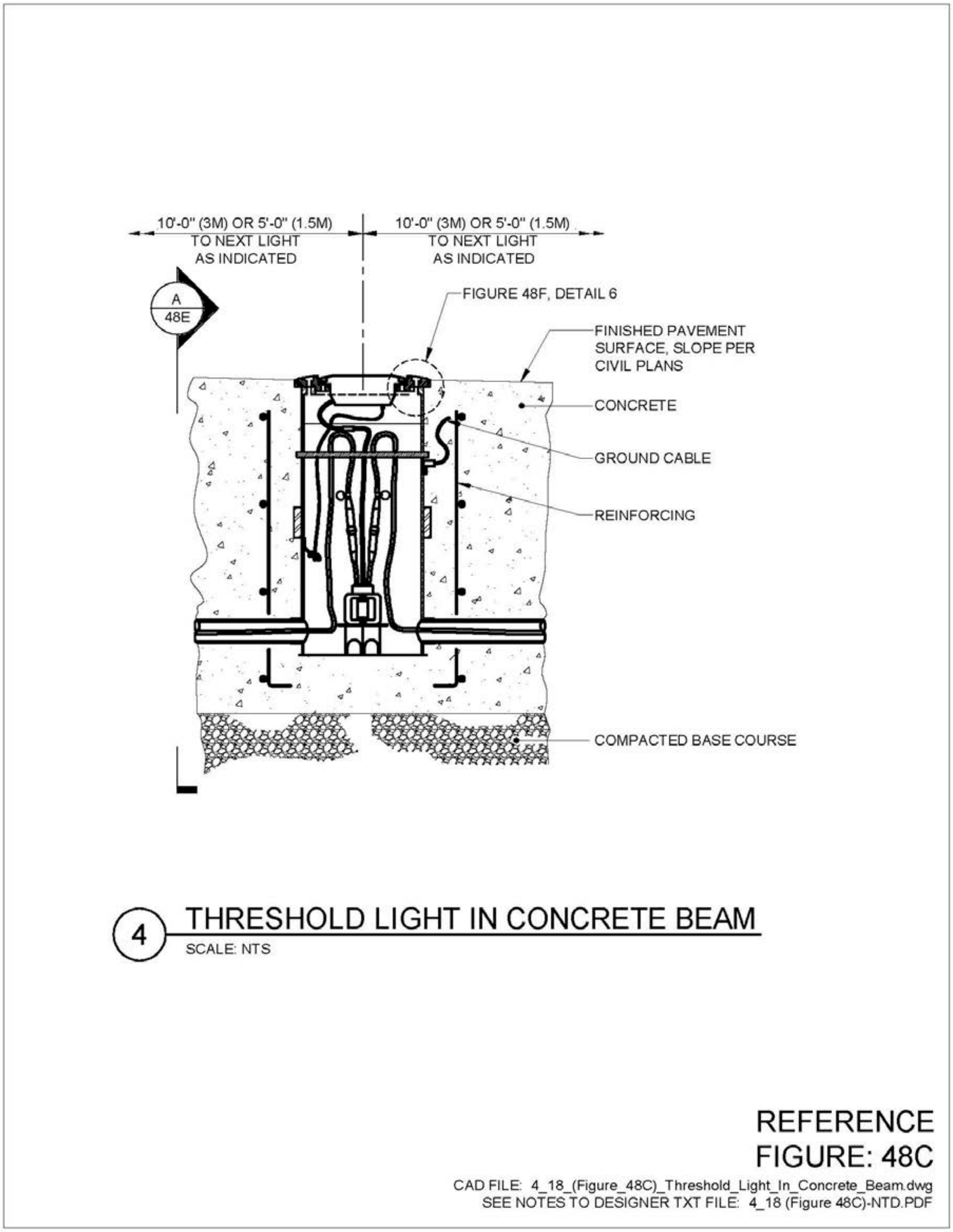


Figure 48D. Threshold Light Beam

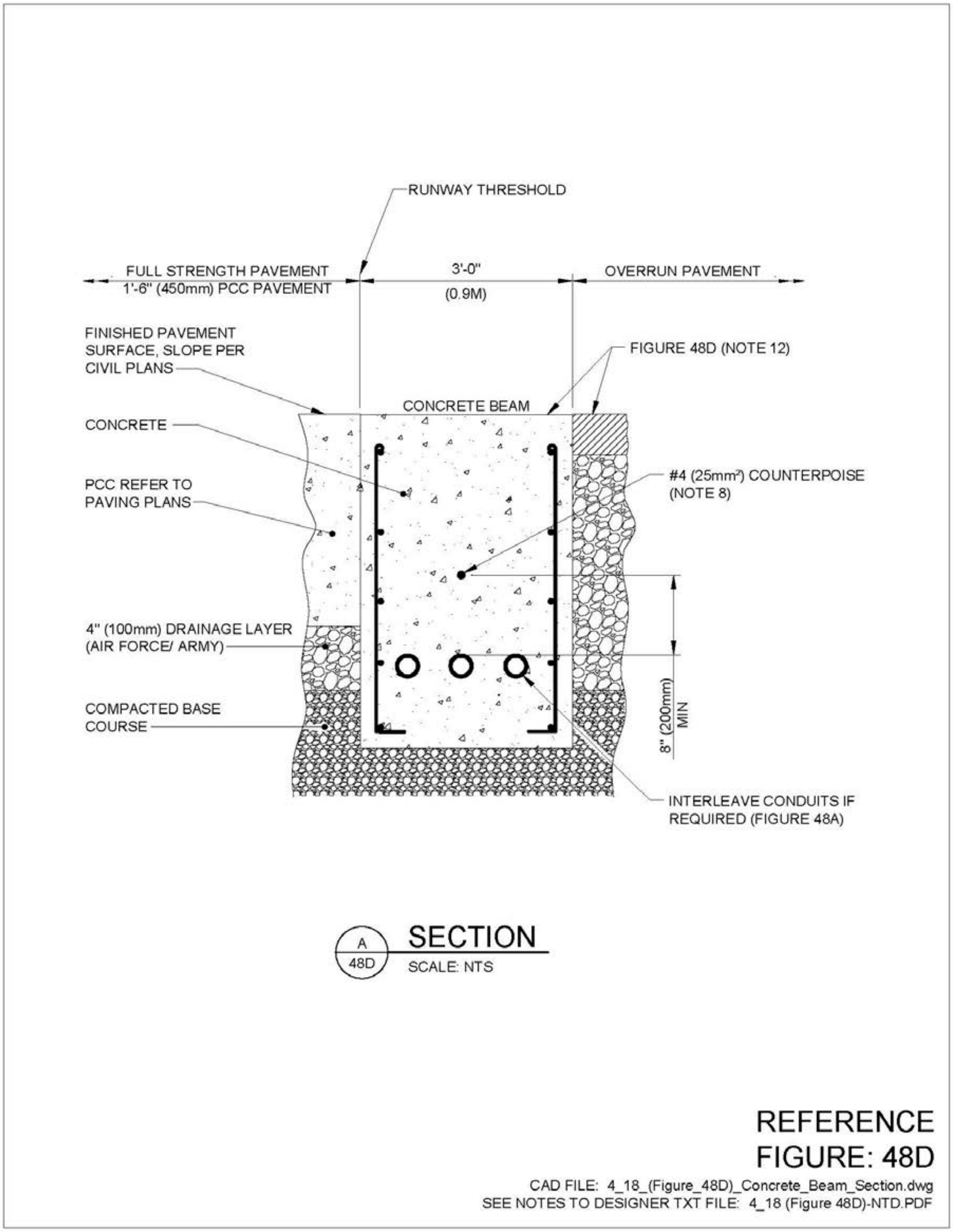
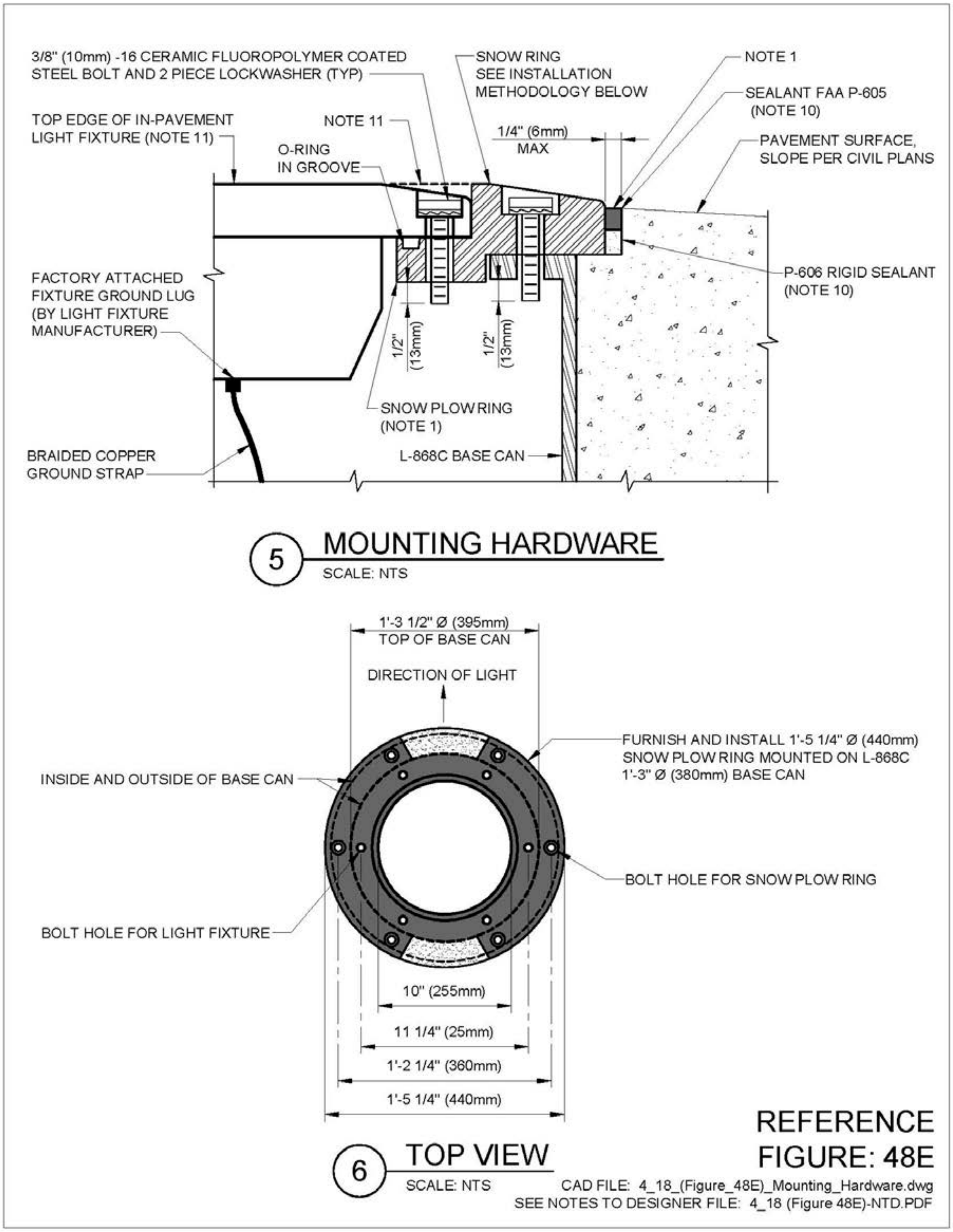


Figure 48E. Mounting Hardware



5-19 **Typical Elevated High Intensity Approach/ Threshold Light 6'0" (1800mm) Maximum.**

5-19.1 **Figure 49.**

5-19.1.1 **Notes to Designer.**

1. The color filter used is dictated by the system.

2. Ensure proper lamp wattage is utilized to meet the photometric requirements specified in UFC 3-535-01. Recommend specifying photometric requirements in the contract documents.

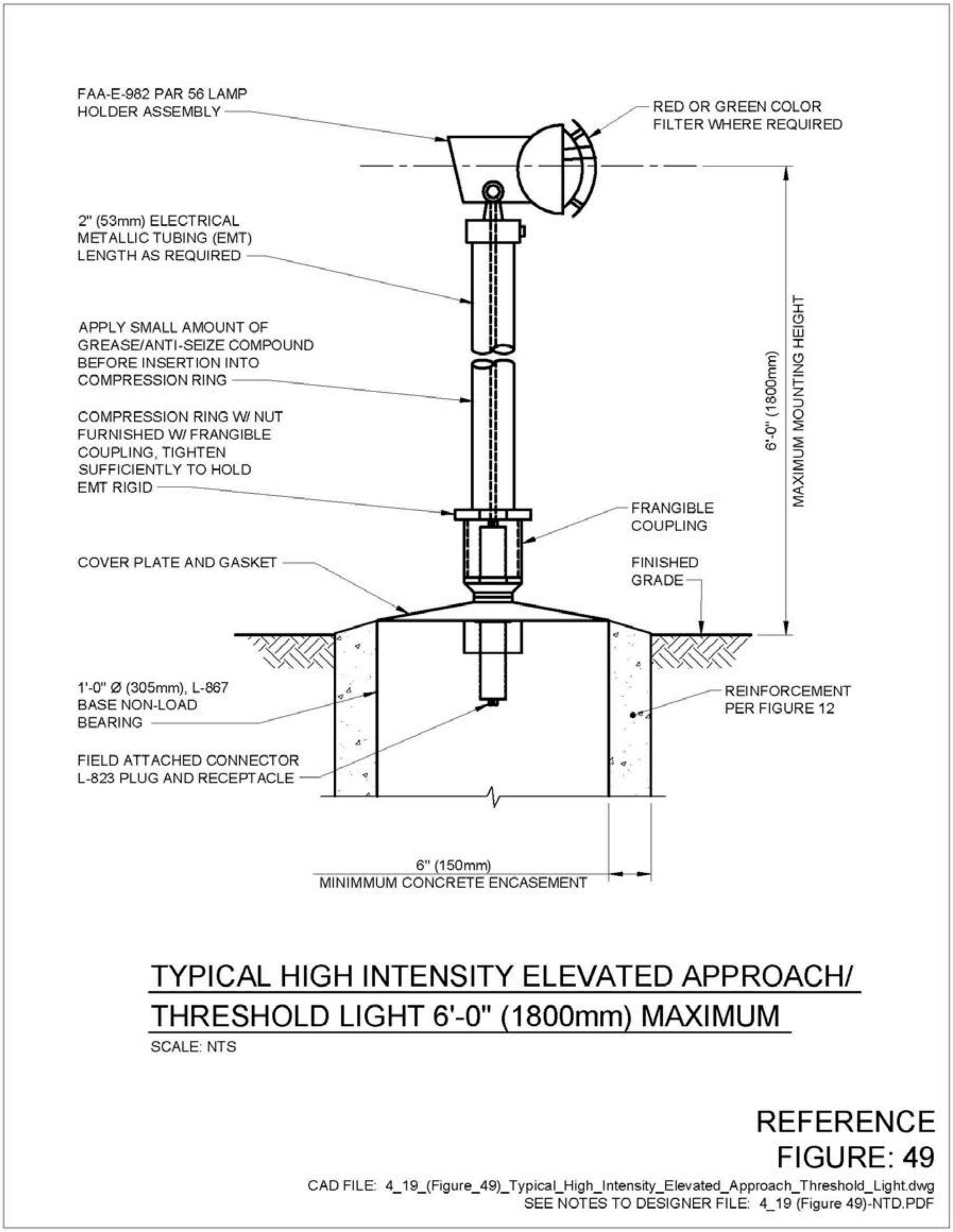
5-19.1.2 **Drawing Notes for Figure 49.**

1. Green color filter for threshold bar.

2. Red color filter for side row barrettes (ALSF-2); pre-threshold and terminating bars (ALSF-1, SALS).

3. No color filter for centerline bars; 500' (150m) bar (ALSF-2); 1000' (300m) bar (ALSF-1, ALSF-2, SALS, SSALR).

Figure 49. Typical High Intensity Elevated Approach/Threshold Light 6'0"



(1800mm) Maximum

5-20 **ALSF-1 Approach Light System Configuration.**

5-20.1 **Figures 50A, 50B, 50C.**

5-20.1.1 **Notes to Designer.**

1. Recommend including the system layout as part of the contract documents.

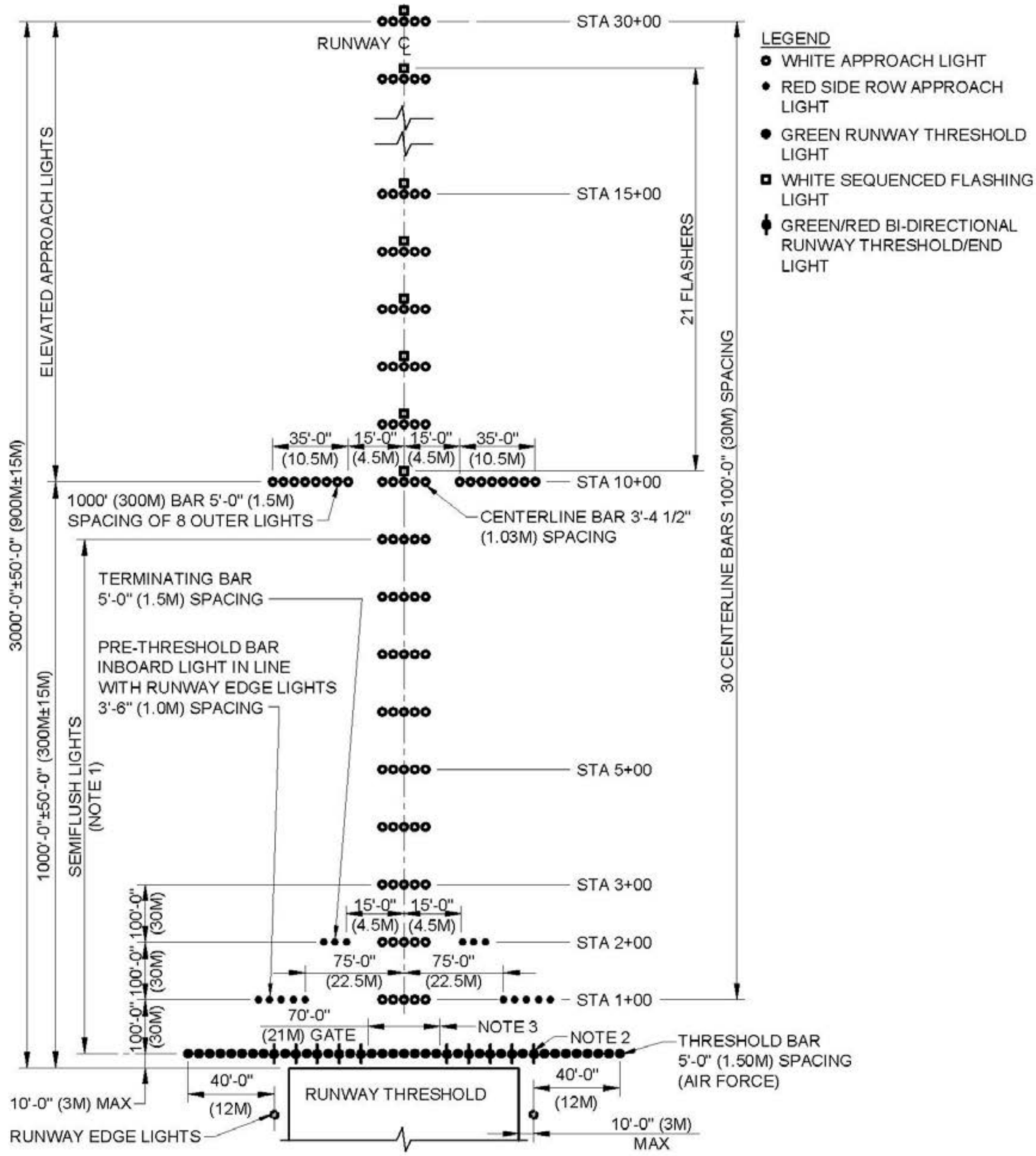
5-20.1.2 **Drawing Notes for Figures 50A, 50B, 50C.**

1. The threshold and the approach light system up to and including station 9+00 are in-pavement in paved overruns, and elevated in non-paved overruns.

2. For reference only, runway end lights consist of 10 red lights arranged in two groups of 5 lights. The lights in each group must have a uniform spacing of 10' (3m). The outboard most light in each group must be in line with the line of the runway edge lights on that side of the runway. The groups must be located symmetrically about, and on a line perpendicular to, the runway centerline within 10' (3m) of the end of the usable runway surface. Where they are collocated, runway end lights may be incorporated into the opposite end threshold fixtures.

3. The threshold bar may be “gated” to alleviate the problem of tail hook bounce. The threshold gate is accomplished by eliminating those lights in the center 70' (21m) portion centered about the runway centerline.

Figure 50A. ALSF-1 Approach Light System Configuration (Air Force)



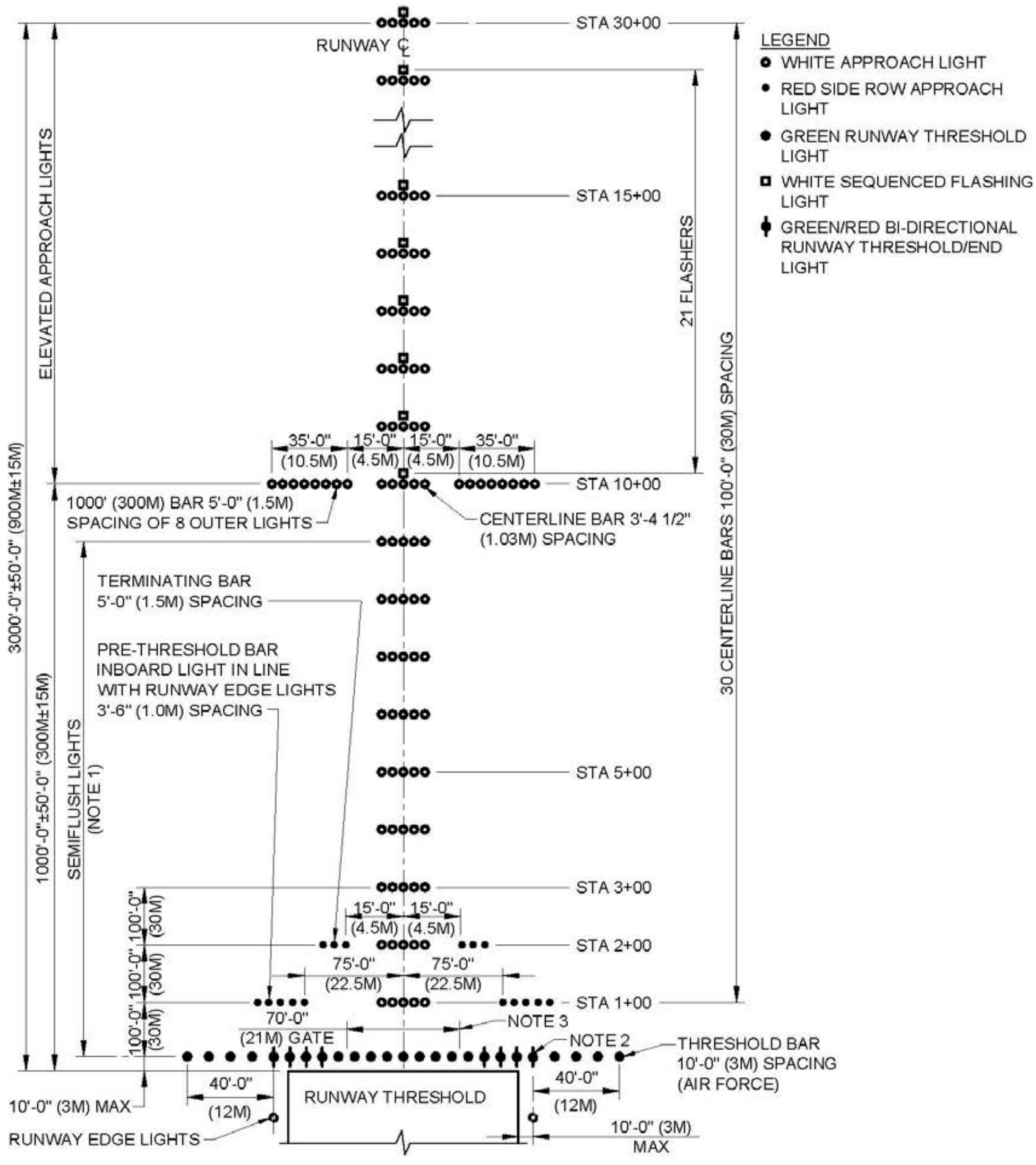
ALSF-1 APPROACH LIGHT SYSTEM CONFIGURATION (AIR FORCE)

SCALE: NTS

REFERENCE FIGURE: 50A

CAD FILE: 4_20_(Figure_50A)_ALSF_1_Approach_Light_System_Configuration_Air_Force.dwg
SEE NOTES TO DESIGNER FILE: 4_20 (Figure 50A)-NTD.PDF

Figure 50B. ALSF-1 Approach Light System Configuration (Army)



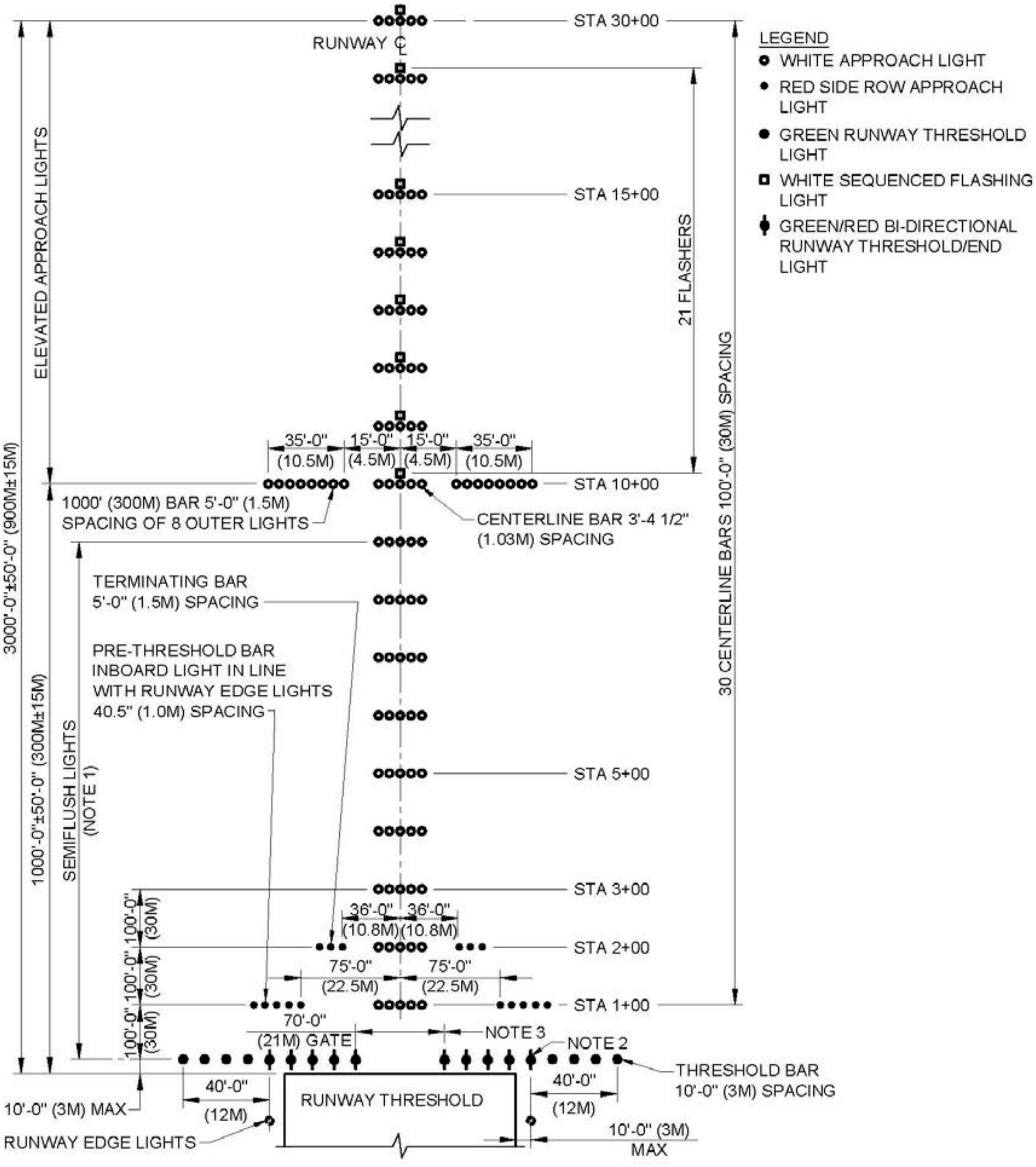
ALSF-1 APPROACH LIGHT SYSTEM CONFIGURATION (ARMY)

SCALE: NTS

REFERENCE FIGURE: 50B

CAD FILE: 4_20_(Figure_50B)_ALSF_1_Approach_Light_System_Configuration_Army.dwg
SEE NOTES TO DESIGNER FILE: 4_20 (Figure 50B)-NTD.PDF

Figure 50C. ALSF-1 Approach Light System Configuration (Navy)



ALSF-1 APPROACH LIGHT SYSTEM CONFIGURATION (NAVY)

SCALE: NTS

REFERENCE
FIGURE: 50C

CAD FILE: 4_20_(Figure_50C)_ALSF_1_Approach_Light_System_Configuration_Navy.dwg
SEE NOTES TO DESIGNER FILE: 4_20 (Figure 50C)-NTD.PDF

5-21 ALSF-2 Approach Light System Configuration (Air Force).

5-21.1 Figure 51.

5-21.1.1 Notes to Designer.

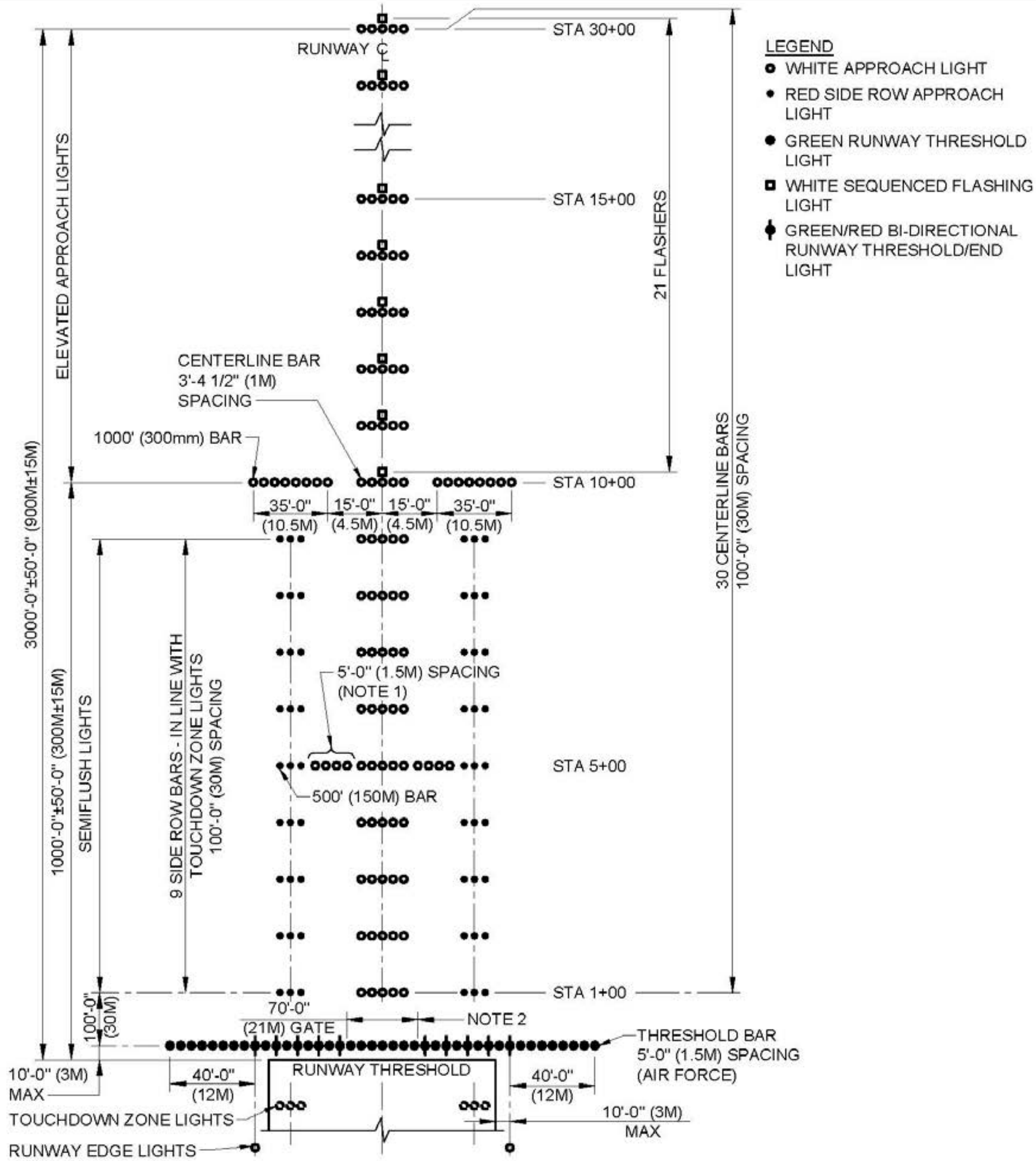
1. Recommend including the system layout as part of the contract documents.

5-21.1.2 Drawing Notes for Figure 51.

1. Locate 4-light barrettes equidistant between side row bars and centerline bars

2. The threshold bar may be “gated” to alleviate the problem of tail hook bounce. The threshold gate is accomplished by eliminating those lights in the center 70' (21m) portion centered about the runway centerline.

Figure 51. ALSF-2 Approach Light System Configuration (Air Force)



ALSF-2 APPROACH LIGHT SYSTEM CONFIGURATION

SCALE: NTS

REFERENCE FIGURE: 51

CAD FILE: 4_21_(Figure_51)_ALFS_2_Approach_Light_System_Configuration.dwg
SEE NOTES TO DESIGNER FILE: 4_21 (Figure 51)-NTD.PDF

5-22 MALSR Wiring Diagram.

5-22.1 Figure 52.

5-22.1.1 Notes to Designer.

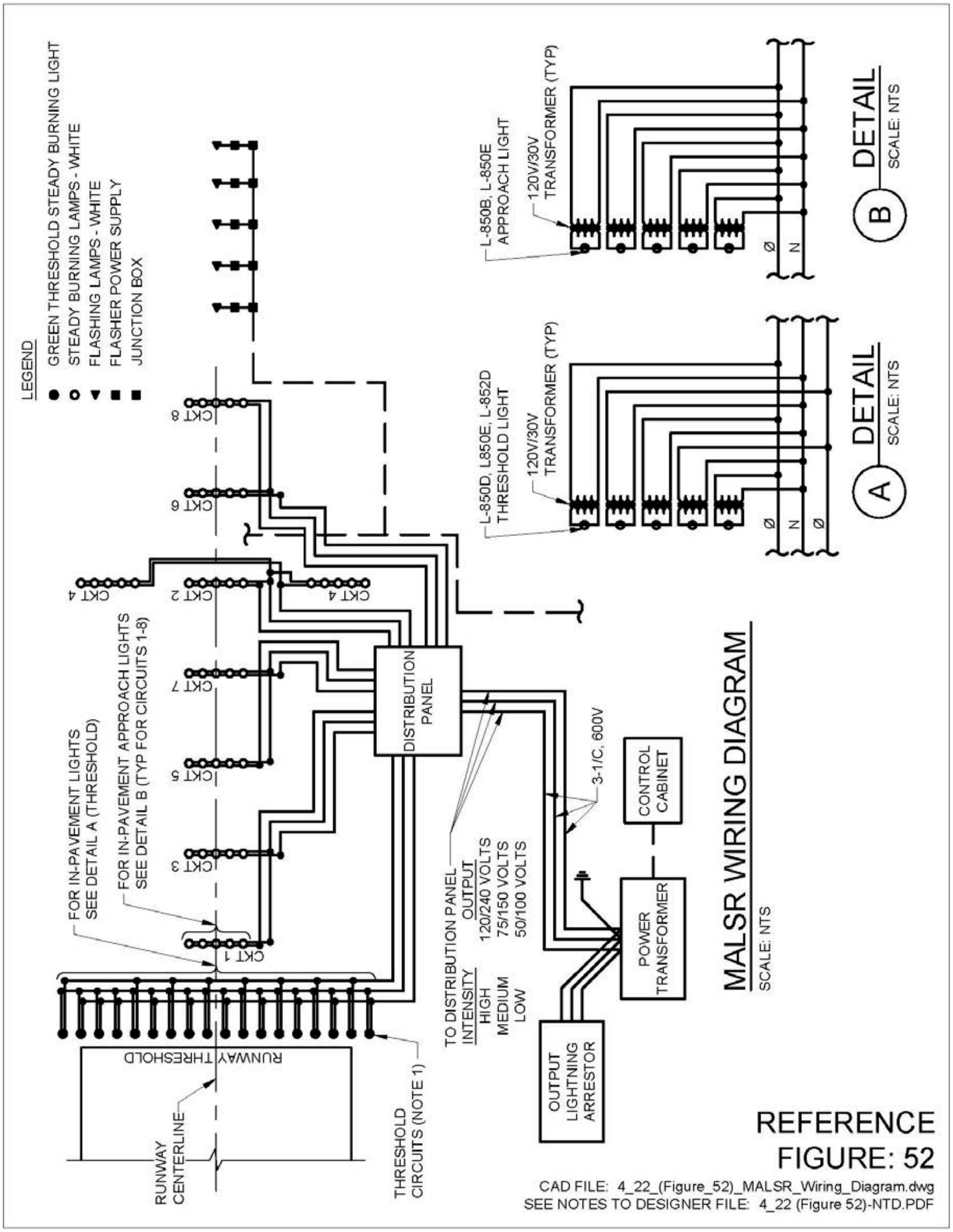
1. The MALSR system is a constant voltage (parallel) system. When designing system close attention must be given to voltage drop.

2. The MALSR system utilizes the same type of LIR structures as the high intensity ALSF systems. The light spacing on the T-bar assembly is different, however, and the lamp holder is for a PAR 38 in lieu of a PAR 56 as used on a high intensity system.

5-22.1.2 Drawing Notes for Figure 52.

1. Threshold lights are wired alternately between phases and are fed by a 2-pole breaker.

Figure 52. MALSR Wiring Diagram



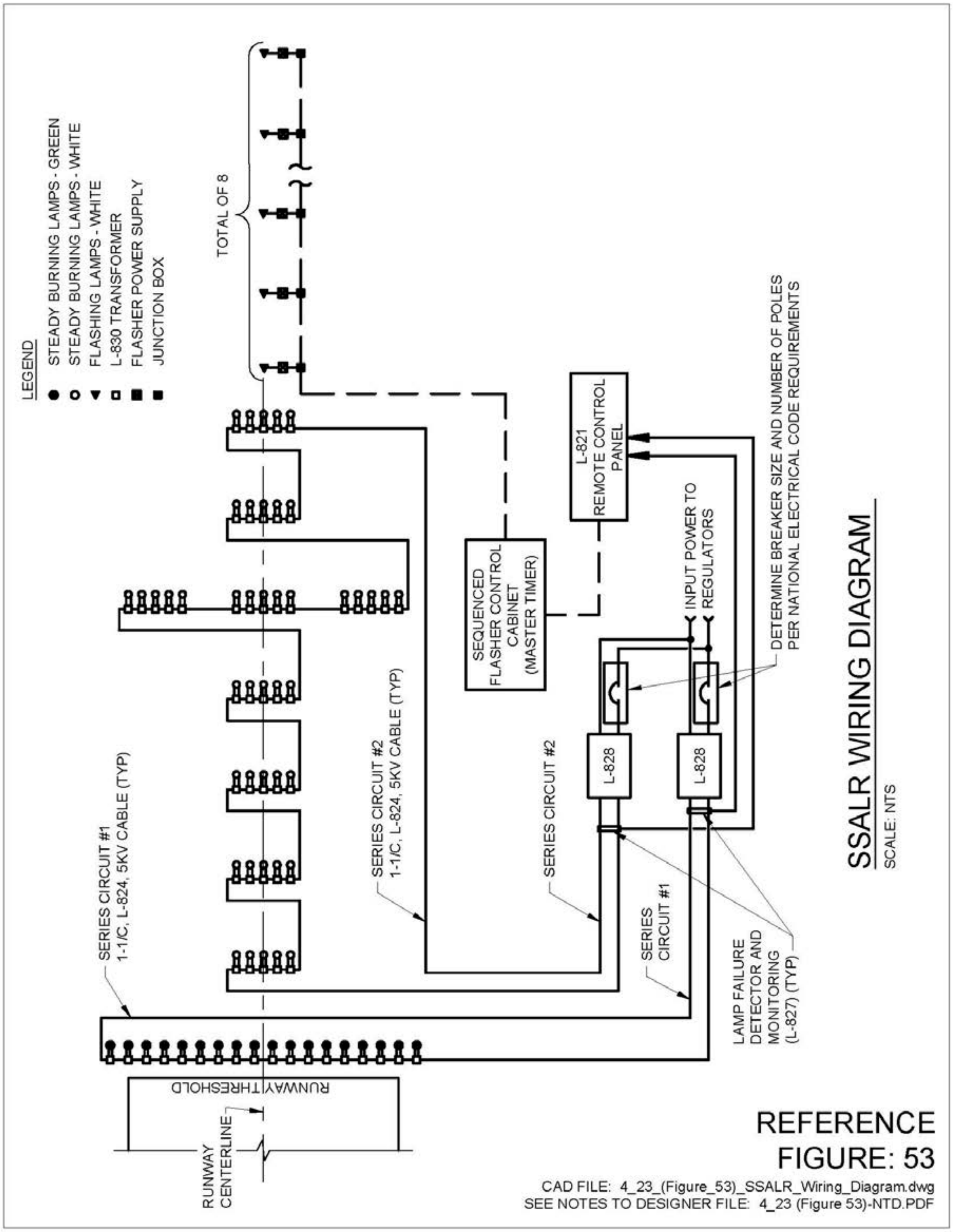
5-23 SSALR Wiring Diagram.

5-23.1 Figure 53.

5-23.1.1 Notes to Designer.

1. Typically high intensity approach light systems are 20 amp circuits. The size of the regulators depends on the fixtures to be used. On major upgrades or new installations recommend researching the use of most recent 200 watt 6.6 amp lamp that meets the photometric requirements for the steady burn lamp. An energy savings and smaller regulator size may result. Refer to UFC 3-535-01 for more information.

Figure 53. SSALR Wiring Diagram



5-24 L.I.R. Structure MS-20.

5-24.1 Figure 54.

5-24.1.1 Notes to Designer.

1. The MS-20 structure includes the crossbar and lowering device. The manufacturer provides standard details for mounting the MS-20 structure onto the tower platform. These details should be given to the proposed tower manufacturer.

2. Conduit and wiring details for the structure should be included in the contract documents. Conduit size and number of conductors will depend on the number and types of lights installed. Approved manufacturers of approach light systems should be consulted.

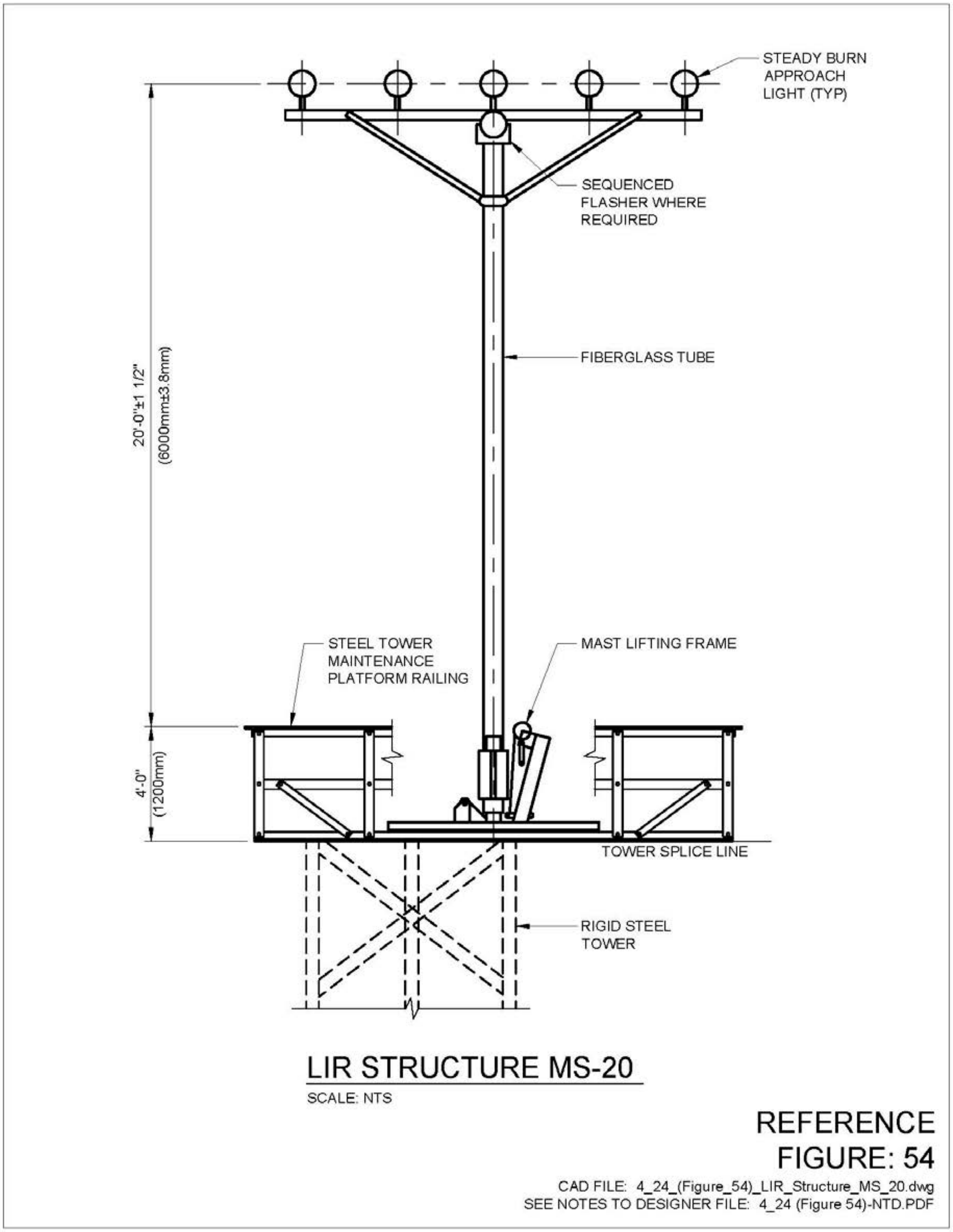
3. If a sequenced flasher is to be installed, the flasher power supply should be installed on the maintenance platform and the flasher junction box should be installed at grade. However, if installation is in a flood plain or wet area both flasher power supply and junction box should be installed on the maintenance platform. Cables may then be routed underground or aerially.

5-24.1.2 Drawing Notes for Figure 54.

1. Install mast lifting frame, fiberglass tube, and lights per manufacturer’s requirements.

2. Install maintenance platform on steel tower per manufacturer’s requirements.

Figure 54. L.I.R. Structure MS-20



5-25 **Approach Light Structure 40' to 128' (12m to 38.4m).**

5-25.1 **Figure 55.**

5-25.1.1 **Notes to Designer.**

1. The top 20' (6m) of the structure is the low impact resistant portion of the overall structure. The height of the required rigid steel tower is determined by subtracting 20' (6m) for the L.I.R. structure and 4'-0" (1.2m) for the maintenance platform and railing from the overall height as indicated in the approach light system profile plan.

2. Prior to designing the foundation for the tower, borings should be taken in the field for soil analysis. Many factors will affect the type and size of foundation to be installed (i.e. type of soil, existence of rock or ledge, soil bearing capacity, frost depth, etc.). The designer should base the foundation design on these factors and consult with the tower manufacturer regarding EPA (Effective Projected Area) for wind loading. The wind loading must include the proposed fixtures and hardware to be installed on the tower.

5-25.1.2 **Drawing Notes for Figure 55.**

1. Design tower for appropriate loads based on ANSI/TIA-222, or on stricter local codes if required at site.

2. Base foundation design on local terrain and subsurface conditions, and tower loads.

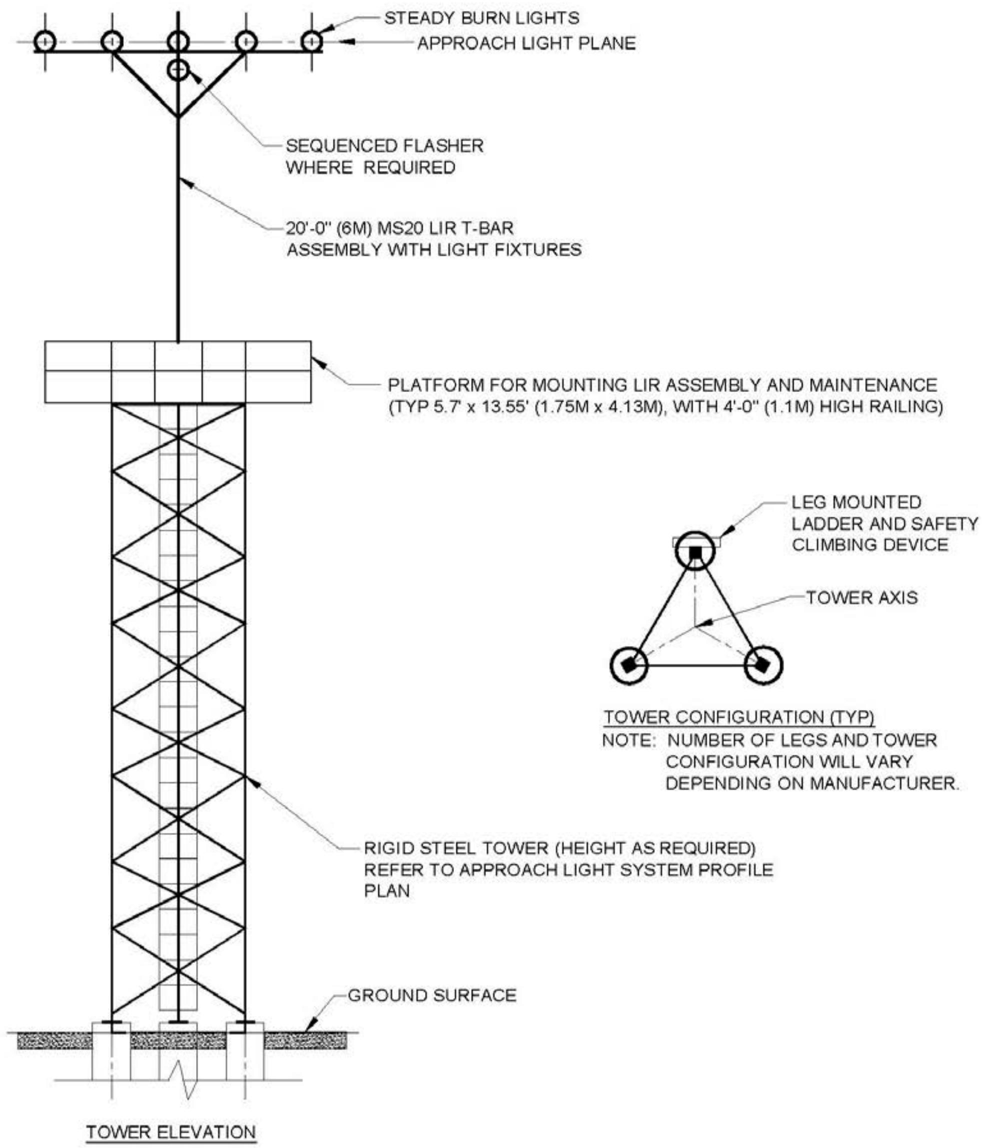
3. Provide ladder for climbing entire height of rigid tower, with safety climbing device, meeting ANSI/TIA-222.

4. Provide suitable locking device for nuts on all tower and anchor bolts.

5. Tower manufacturer should provide detail fabrication drawings based on furnished height and load requirements.

6. Provide grounding for the steel tower and platform per ANSI/TIA-222.

Figure 55. Approach Light Structure 40' to 128' (12m to 38.4m)



APPROACH LIGHT STRUCTURE 40'-128' (12M-38.4M)

SCALE: NTS

REFERENCE
FIGURE: 55

CAD FILE: 4_25_(Figure_55)_Approach_Light_Structure.dwg
SEE NOTES TO DESIGNER FILE: 4_25 (Figure 55)-NTD.PDF

5-26 **High Intensity Threshold Bar Wiring Diagram (Air Force).**

5-26.1 **Figure 56.**

5-26.1.1 **Notes to Designer.**

1. Figure is self-explanatory.

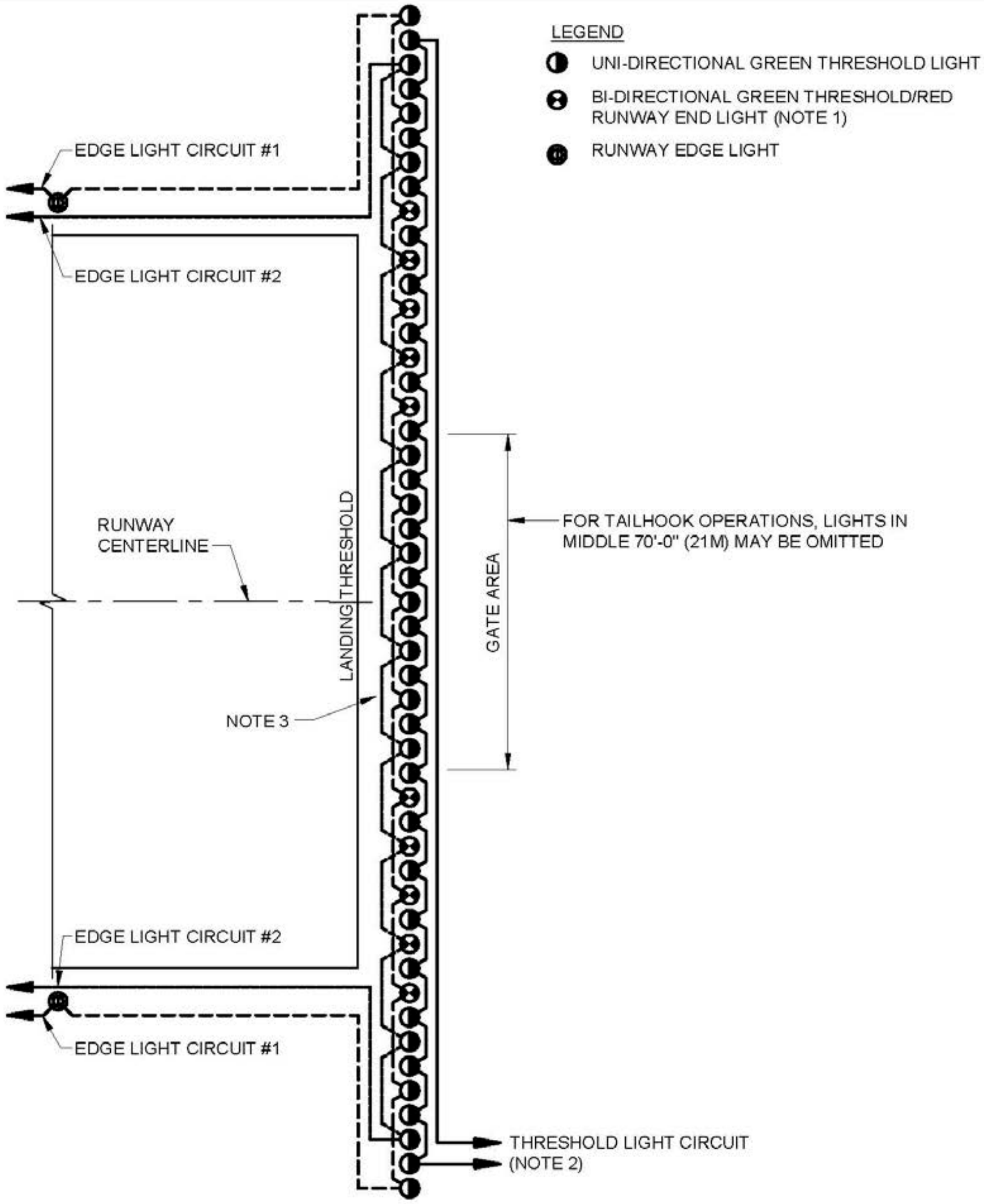
5-26.1.2 **Drawing Notes for Figure 56.**

1. The bi-directional runway end/threshold light may be installed as separate uni-directional fixtures. The bi-directional fixture must meet the photometrics for threshold and end lights as indicated in UFC 3-535-01.

2. Control circuits for threshold regulator must be wired in parallel with edge lighting control circuits. For runway edge light regulator(s) such that threshold lights are energized and at same intensity as runway edge lights.

3. Where there are an even number of threshold bar lights, the two adjacent lights about the runway centerline must be connected to the same circuit to provide a symmetrical lighting pattern on each side of the runway centerline.

Figure 56. High Intensity Threshold Bar Interleaved Wiring Diagram (Air Force)



HIGH INTENSITY THRESHOLD BAR INTERLEAVED WIRING DIAGRAM (AIR FORCE)

SCALE: NTS

REFERENCE FIGURE: 56

CAD FILE: 4_26_(Figure_56)_High_Intensity_Threshold_Bar_Interleaved_Wiring_Diagram_(Air_Force).dwg
SEE NOTES TO DESIGNER FILE: 4_26 (Figure 56)-NTD.PDF

5-27 **Threshold Bar Wiring Diagram (Army).**

5-27.1 **Figure 57.**

5-27.1.1 **Notes to Designer.**

Figure is self-explanatory.

5-27.1.2 **Drawing Note for Figure 57.**

Where there are an even number of threshold bar lights, the two adjacent lights about the runway centerline must be connected to the same circuit to provide a symmetrical lighting pattern on each side of the runway centerline.

Figure 57. Threshold Bar Wiring Diagram (Army)

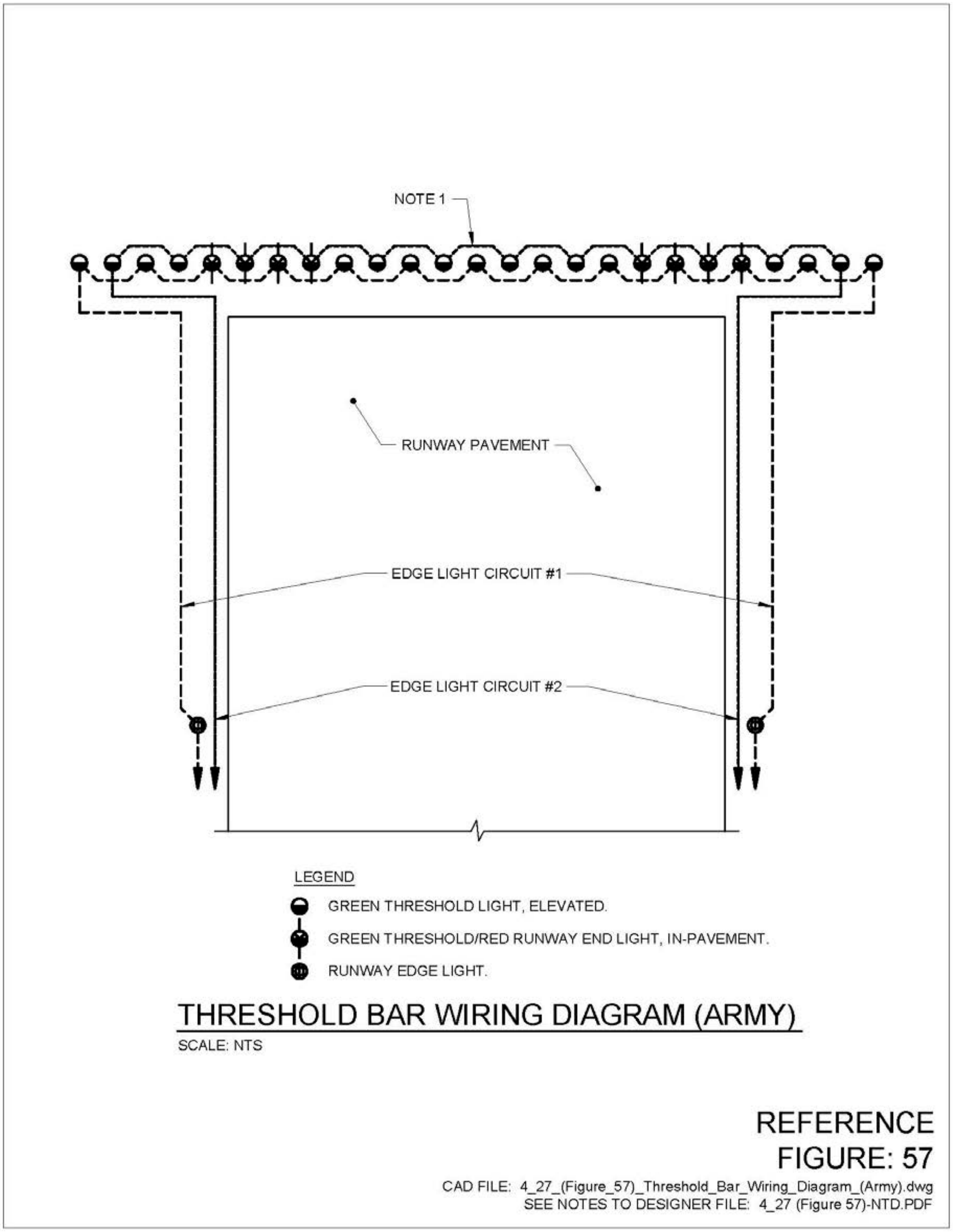


Figure 58. Reserved.

5-28 High Intensity ALSF-1/SSALR Wiring Diagram.

5-28.1 Figure 59.

5-28.1.1 Notes to Designer.

1. When designing the approach light system, several factors must be taken into account:

    a. Each regulator should be equal in kw capacity,

    b. No two adjacent light bars should be on the same circuit.

    c. Circuiting should be symmetrical about the runway centerline.

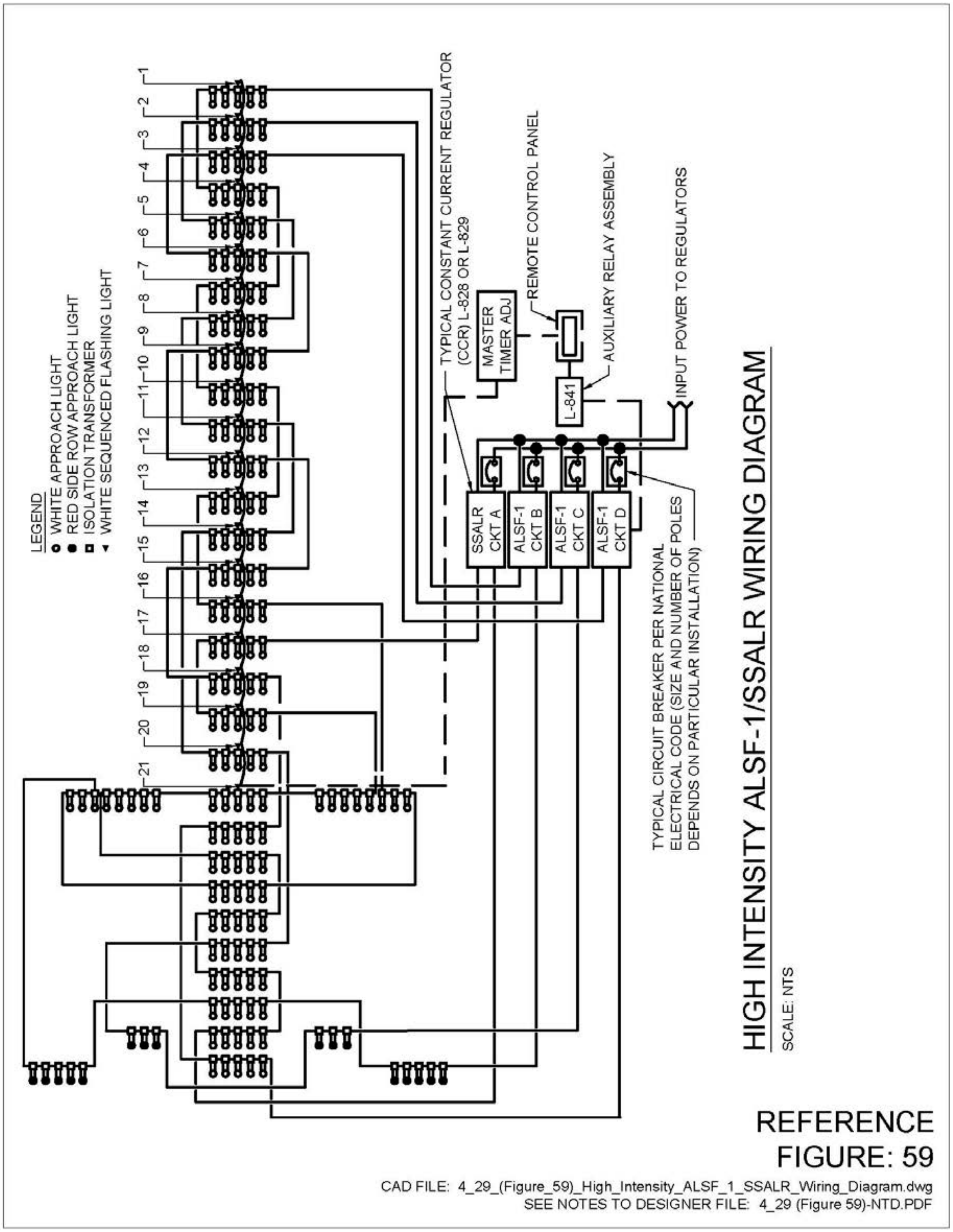
2. Some locations may use a single 1500 watt isolation transformer to feed five 300 watt tower mounted lights.

3. The present trend is to limit the regulator size to 30kw, 20 amp. This is being done to lower the available voltage throughout the system for safety reasons. Also, the trend may be to utilize 6.6 amps rather than 20 amps and newly developed light sources.

4. 50kw and 70kw regulators and 2400V input are not approved by FAA for new installations, only for replacement of existing units.

5. In SSALR mode, only flashers #1, 3, 5, 7, 9, 11, 13 and 15 operate. All 21 flashers operate in full ALSF mode.

Figure 59. High Intensity ALSF-1/SSALR Wiring Diagram



5-29 High Intensity ALSF-2/SSALR Wiring Diagram.

5-29.1 Figure 60A.

5-29.1.1 Notes to Designer.

1. When designing the approach light system, several factors must be taken into account:

    a. Each regulator should be equal in kw capacity,

    b. No two adjacent light bars should be on the same circuit, and

    c. Circuiting should be symmetrical about the runway centerline.

2. Some locations may use a single 1500 watt isolation transformer to feed (5) 300 watt tower mounted lights.

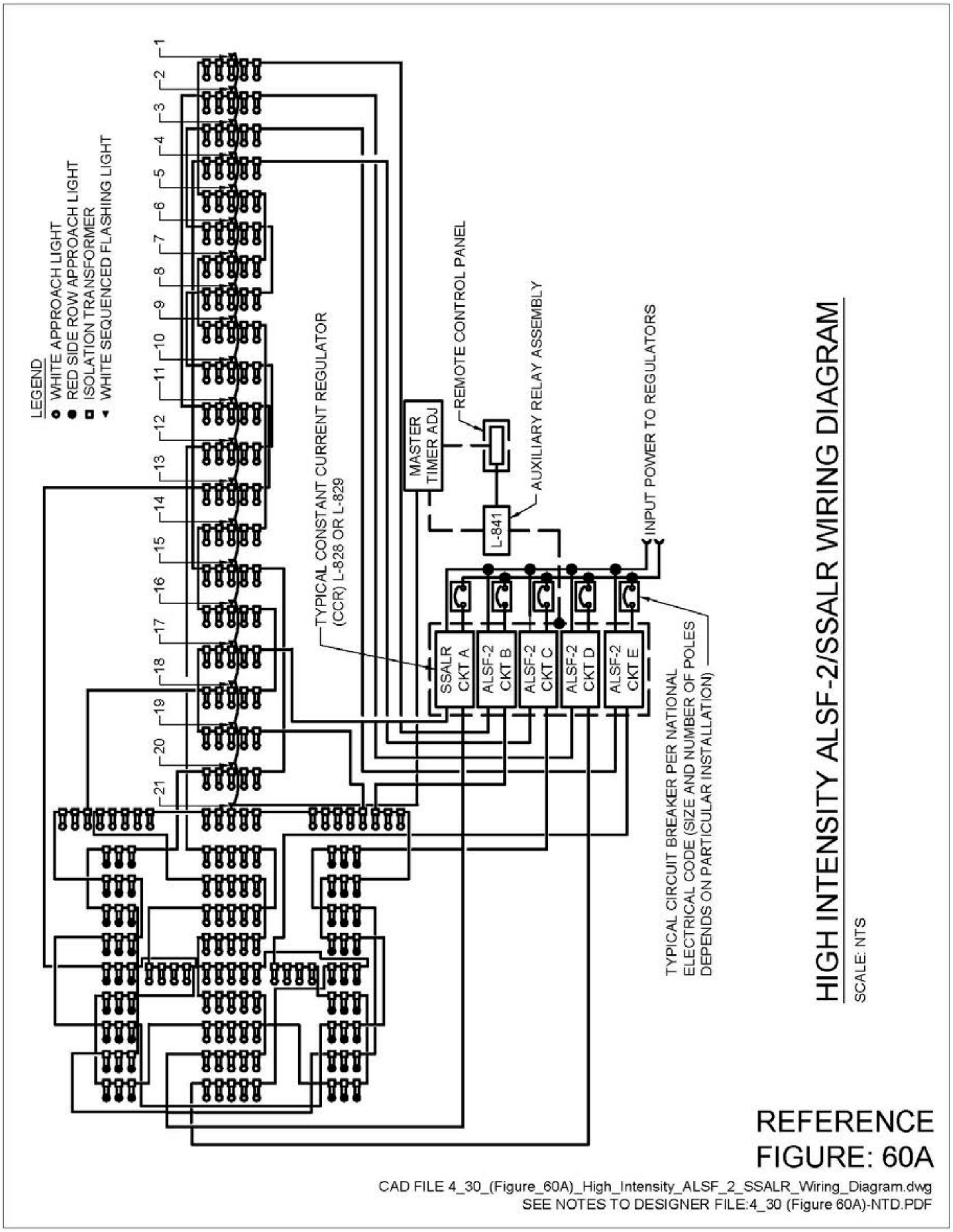
3. The present trend is to limit the regulator size to 30kw, 20 amp. This is being done to lower the available voltage throughout the system for safety reasons. Also, the trend may be to utilize 6.6 amps rather than 20 amps and newly developed light sources.

4. This wiring diagram depicts the latest circuiting from the FAA utilizing (5) 30kw regulators in lieu of (3) 50kw regulators used in older systems.

5. 50 kw and 70 kw regulators and 2400V input is not approved by FAA for new installations, only for replacement of existing units.

6. In SSALR mode, only flashers #1, 3, 5, 7, 9, 11, 13 and 15 operate. All 21 flashers operate in full ALSF mode.

Figure 60A. High Intensity ALSF-2/SSALR Wiring Diagram



5-30 ALSF-2/SSALR Wiring Diagram Modification.

5-30.1 Figures 60A, 60B, 60C.

5-30.1.1 Notes to Designer.

1. Figure 60A depicts a wiring diagram for an ALSF-2/SSALR system using more efficient lamps. Older FAA systems utilized 300-watt lamps for elevated lights and 500-watt lamps for in-pavement lights.

2. The isolation transformer must be sized by the fixture manufacturer and the photometric requirements of the fixture must conform to UFC 3-535-01.

3. This wiring diagram depicts four circuit loops for the ALSF-2/SSALR system and one circuit loop for the threshold.

4. Similarly, an ALSF-1/SSALR system could be reduced to three circuit loops for the system and one circuit loop for the threshold

5. The contract documents for the installation of an approach light system should include a plan and profile of the complete system showing stationing and light plane slopes.

Figure 60B. ALSF-2/SSALR Wiring Diagram Modification – Sheet 1

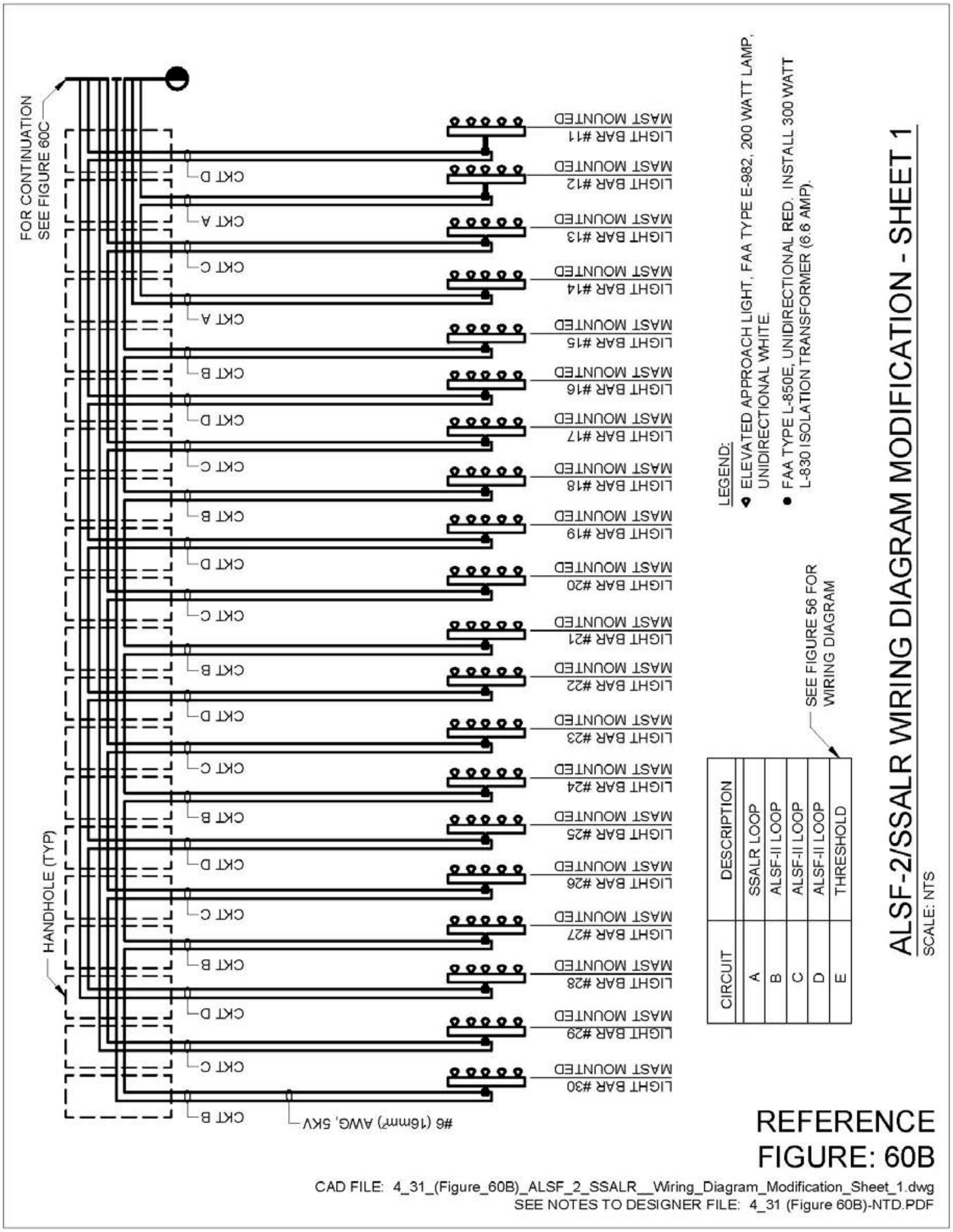
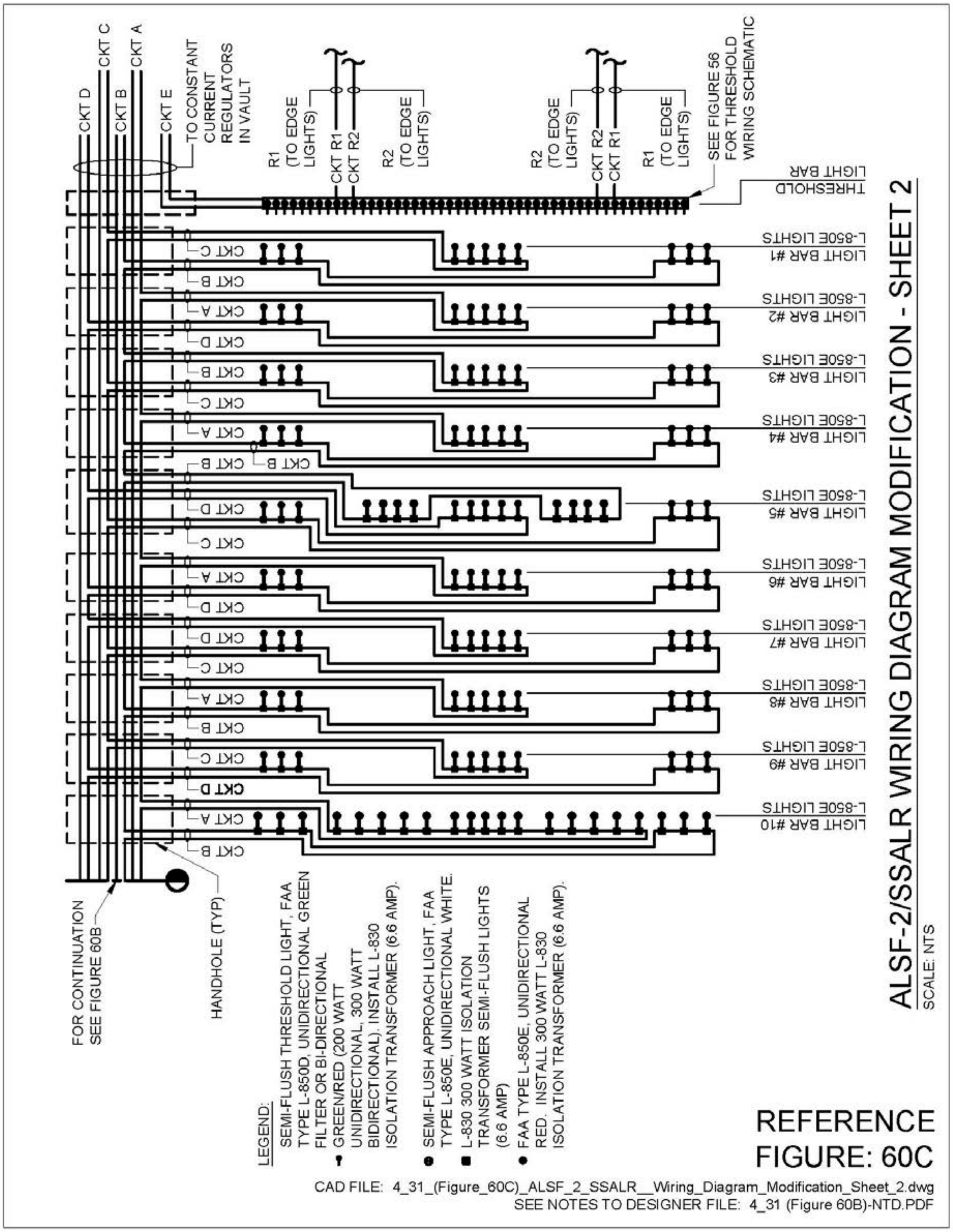


Figure 60C. ALSF-2/SSALR Wiring Diagram Modification – Sheet 2



CHAPTER 6 PAPI and REIL Systems

6-1 FAA L-880 Style A (Constant Voltage) PCU Mounting Details.

6-1.1 Figure 61.

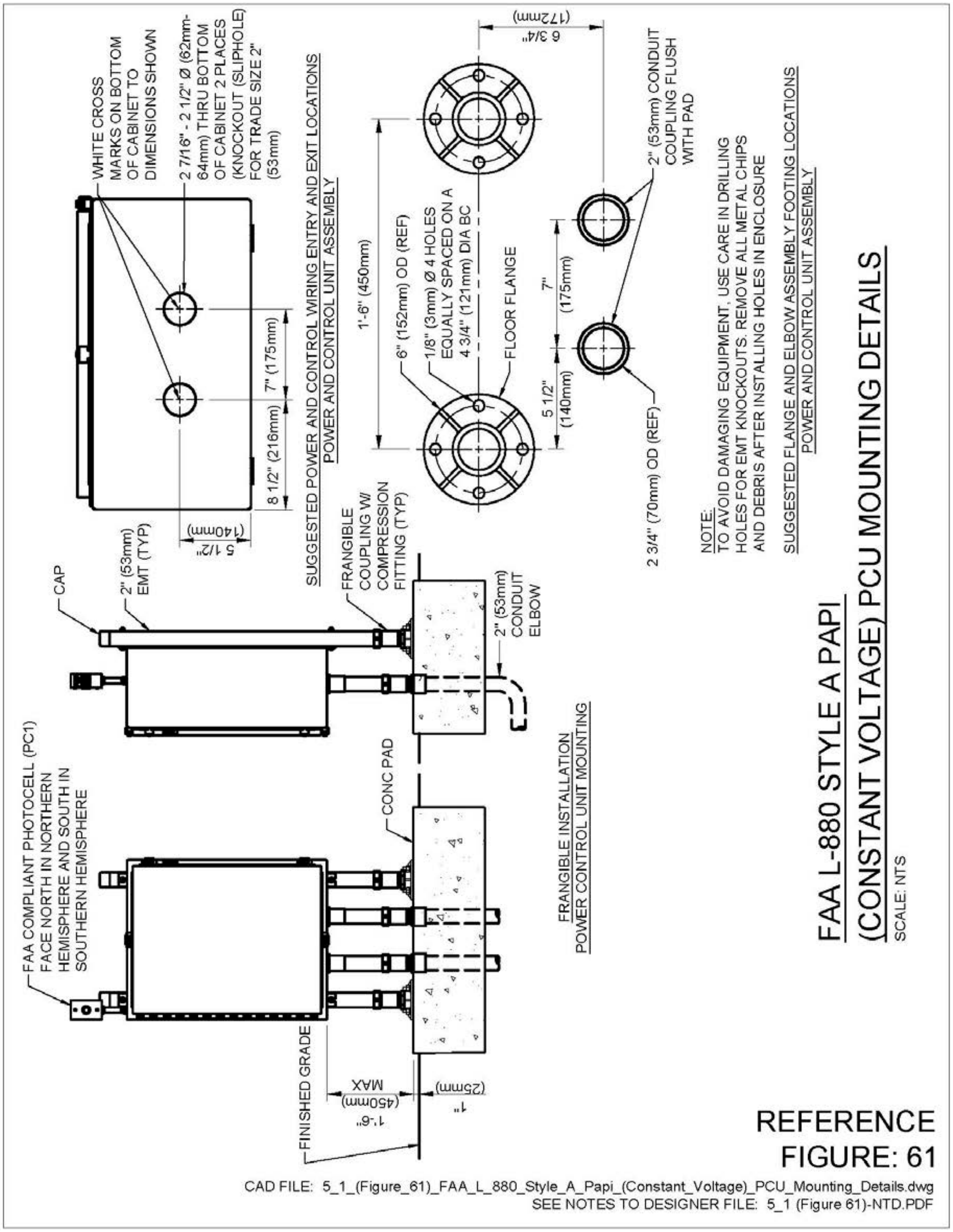
6-1.1.1 Notes to Designer.

1. Verify with manufacturer mounting dimensions and hardware.
2. Pad size indicated is minimum for this particular unit. Pad must be designed by a Registered Structural Engineer.

6-1.1.2 Drawing Notes for Figure 61.

1. Verify dimensions with equipment manufacturer.
2. Concrete pad must be minimum 30" × 18" × 12" (750mm × 450mm × 300mm).
3. Mounting hardware must be stainless steel sized per manufacturer’s requirements.
4. Installation must be per manufacturer’s requirements.

Figure 61. FAA L-880 Style A (Constant Voltage) PCU Mounting Details



6-2 **FAA L-880 Style A (Constant Voltage) System Wiring Diagram.**

6-2.1 **Figures 62A, 62B.**

6-2.1.1 **Notes to Designer.**

1. The L-880 Style A uses a constant voltage to power the system. Intensity control is accomplished automatically by an integral photocell. The system is at maximum brightness during the daytime and lower brightness ≈ 20% during hours of darkness.

2. A constant voltage source must be available within the vicinity of the system. Design must take into account voltage drop back to the supply.

3. The three-lamp version is preferred. However, newer units utilizing two lamps that meet the photometric requirements have been developed.

4. Consult with manufacturer for power requirements.

Figure 62A. FAA L-880 Style A (Constant Voltage) System Wiring Diagram

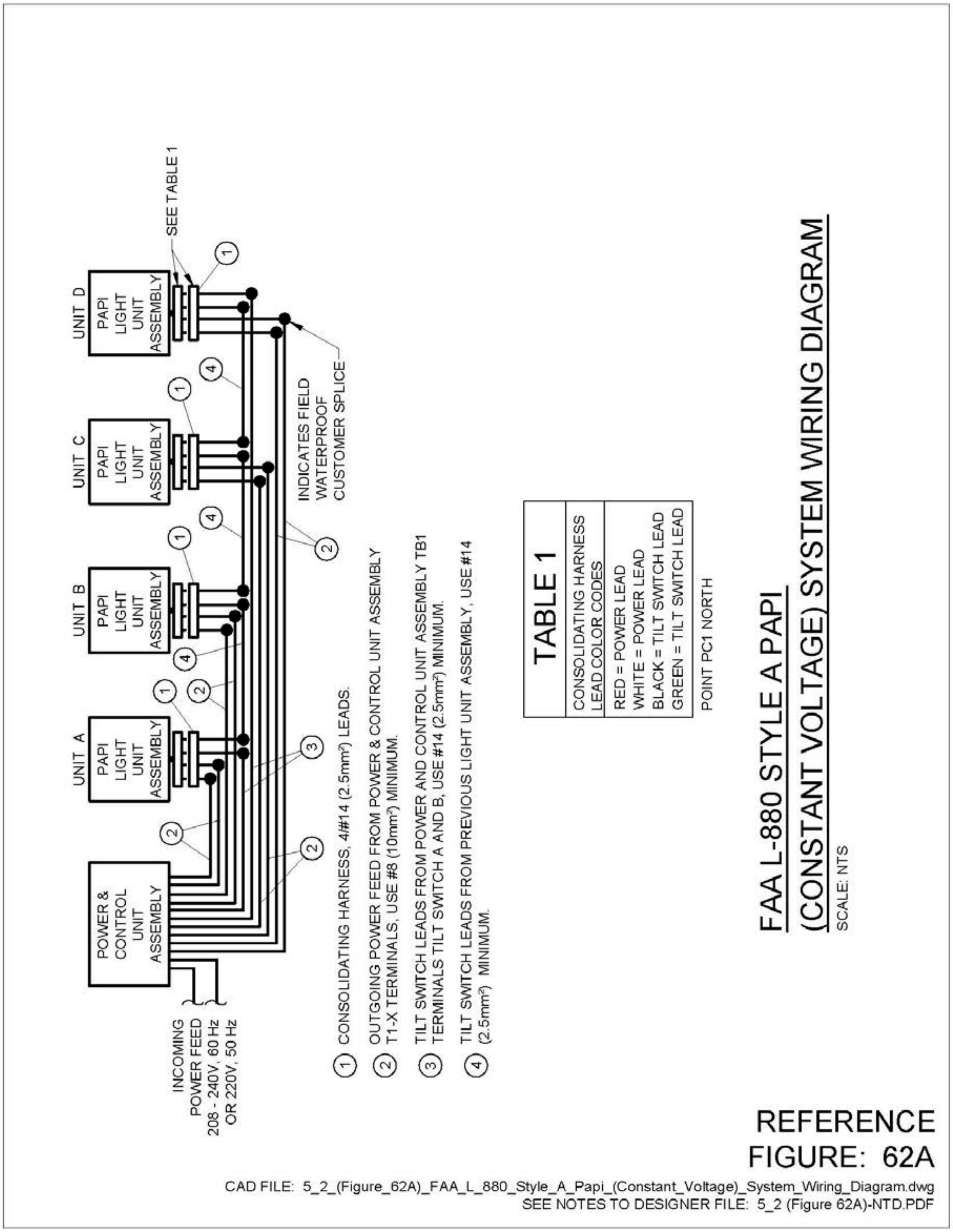
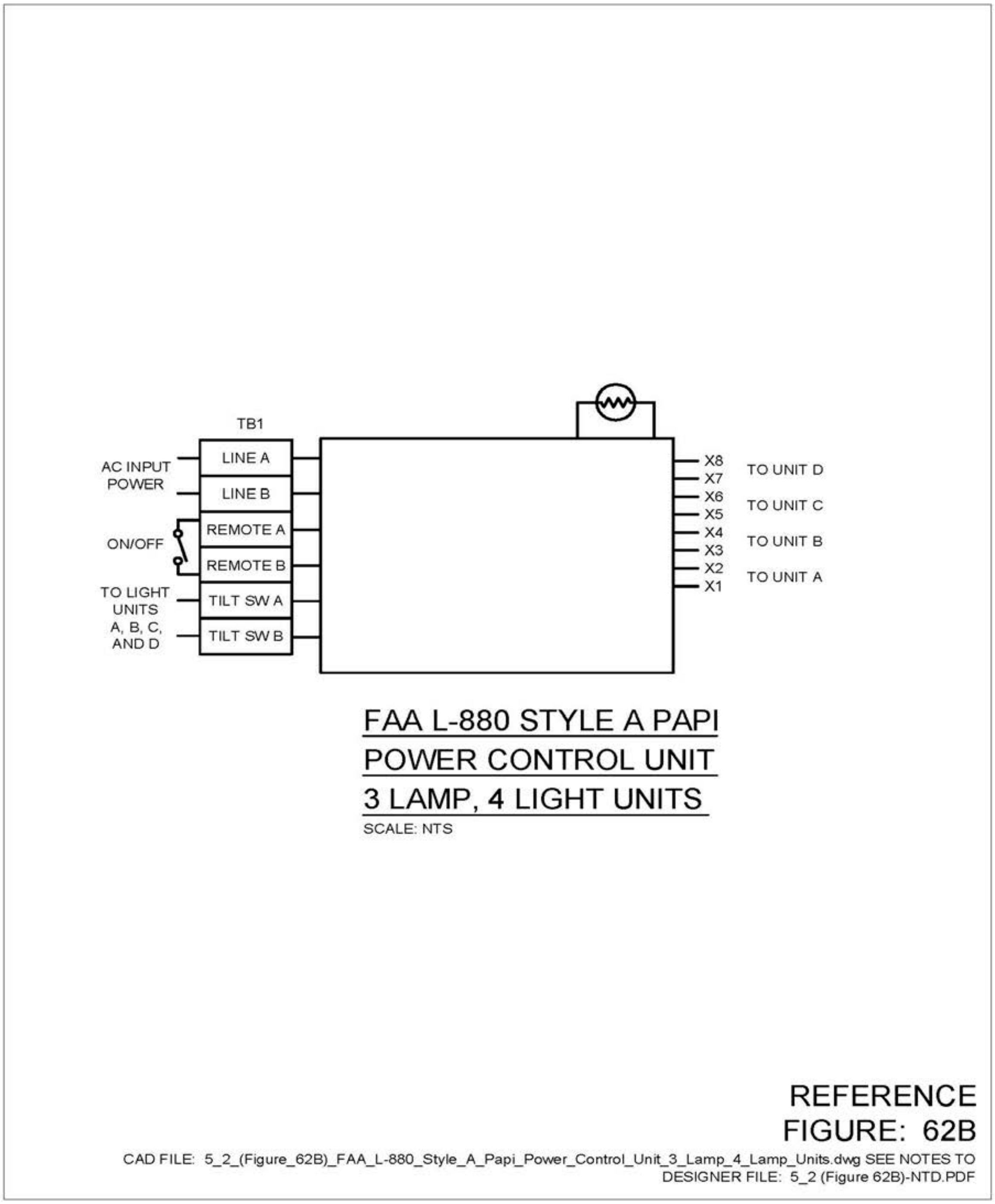


Figure 62B. Power Control Unit 3 Lamp, 4 Projector

FAA L-880 Style B (Constant Current) System Wiring Diagram.



6-2.2 **Figure 63.**

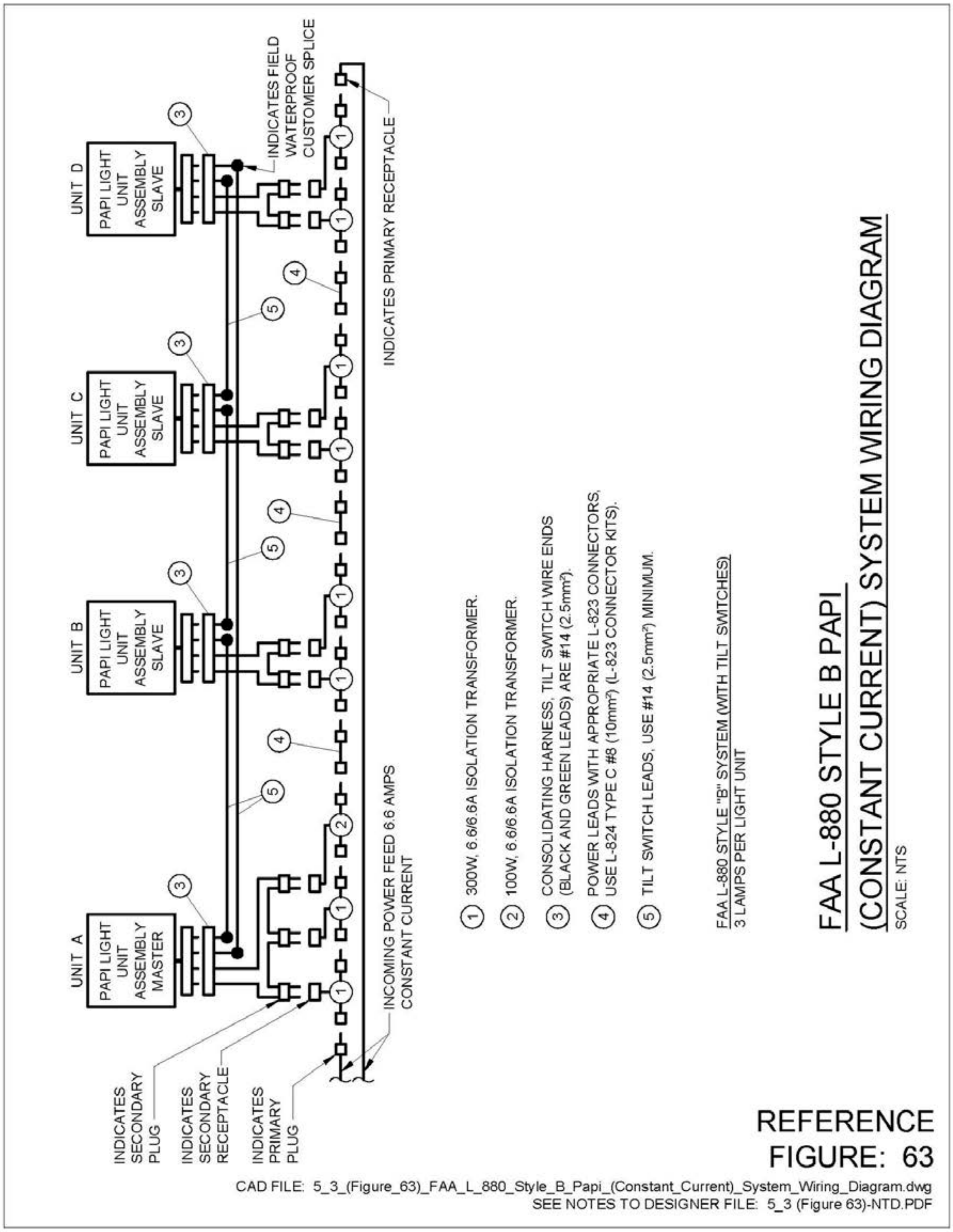
6-2.2.1 **Notes to Designer.**

1. The L-880 Style B uses a constant current source to power the system. This is typically done using a 4kw constant current regulator with 5 brightness steps. Intensity is selected manually at the control panel in the tower or vault at airfields that have 24-hour tower control. A different control scheme is used at part time or unmanned tower airfields.

2. The three-lamp version is preferred. However, newer units utilizing two lamps that meet the photometric requirements have been developed.

3. Consult with manufacturer for power requirements.

Figure 63. FAA L-880 Style B (Constant Current) System Wiring Diagram



6-3 FAA L-880 Style B (Constant Current) PAPI Power and Control Schematic Diagram.

6-3.1 Figure 64.

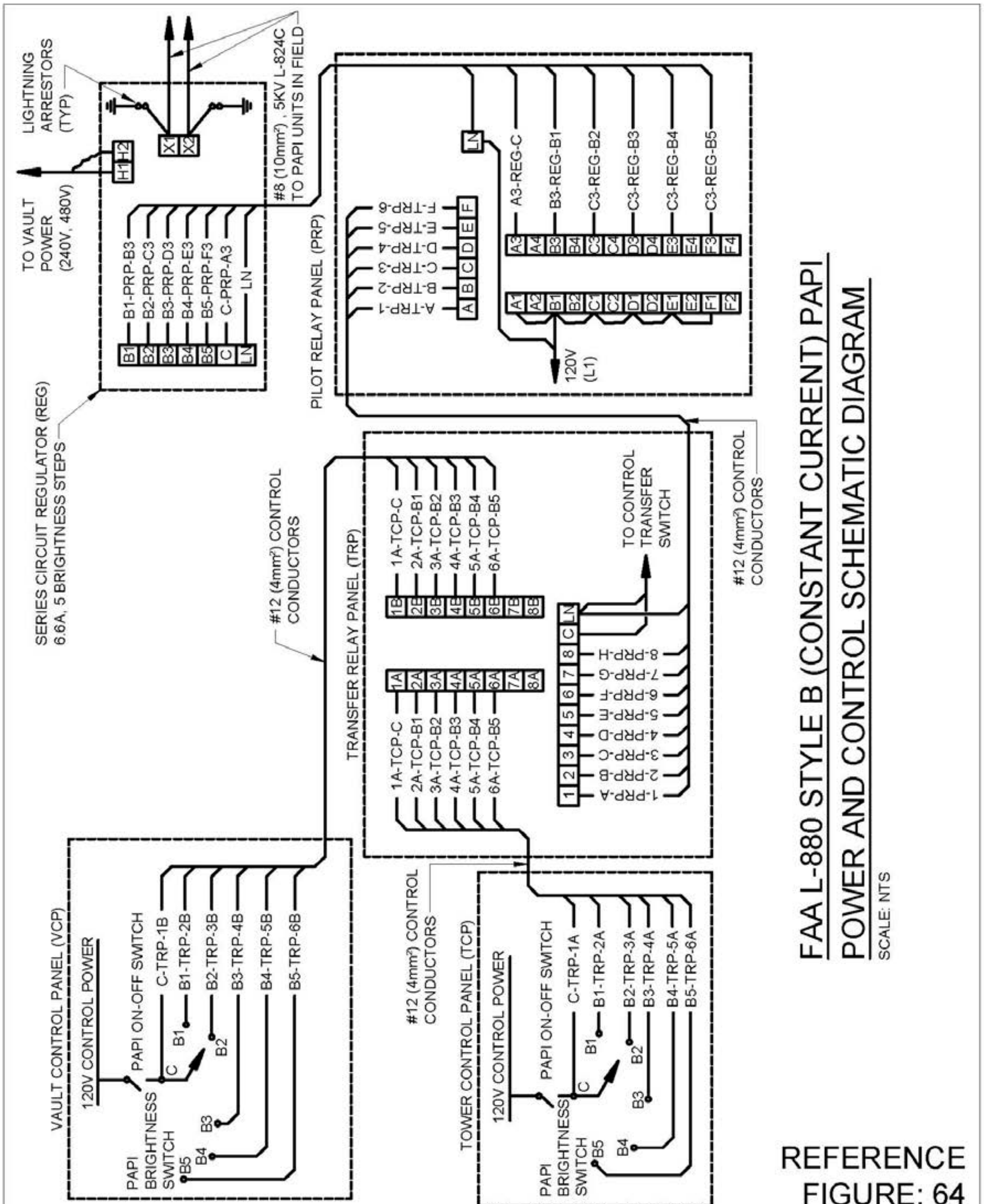
6-3.1.1 Notes to Designer.

1. This detail shows a typical schematic diagram of a Style B system. The actual control diagram used will depend on site specific requirements.

2. Newer installations may use computer control systems with touch-screen monitors for the control panels.

3. Although this diagram is provided for a constant current powered PAPI system served by 5-step constant current regulator, it can be used for any 5-step regulator powered system with control panels in two locations.

Figure 64. FAA L-880 Style B (Constant Current) PAPI Power and Control Schematic Diagram



CAD FILE: 5_4_(Figure_64)_FAA_L_880_Style_B_(Constant_Current)_Papi_Power_And_Control_Schematic_Diagram.dwg
SEE NOTES TO DESIGNER FILE: 5_4 (Figure 64)-NTD.PDF

6-4 PAPI Light Housing Unit (LHU) Installation Detail.

6-4.1 Figures 65A, 65B.

6-4.1.1 Notes to Designer.

1. The contract documents should show location of PAPI units and aiming angles. Refer to UFC 3-535-01 for siting requirements.

2. Verify with manufacturer pad dimensions and number of openings in cover of L-867 can.

3. The detail shows a 4" (100mm) thick concrete mow pad around the housing unit. The mow pad acts as a weed barrier 10' (3m) in front of the unit and 5' (1.5m) behind the unit. Some installations continue the weed barrier between the units. Recommend the weed barrier is extended at least 5' (1.5m) on each side of concrete foundation for the light housing unit.

4. Concrete foundation must be designed by a Registered Structural Engineer.

6-4.1.2 Drawing Notes for Figures 65A and 65B.

1. Each light unit must be aimed outward into the approach zone on a line parallel to the runway centerline within ±1/2 degree.

2. The beam centers of all light units must be within ±1" (25mm) of horizontal plane.

3. The front face of each light unit in a bar must be located on a line perpendicular to the runway centerline within a tolerance of ±1" (25mm).

4. Dimensions are approximate and must be coordinated with PAPI manufacturer.

5. Aiming angle and location of units must be indicated on contract documents.

Figure 65A. PAPI Light Housing Unit (LHU) Installation Detail

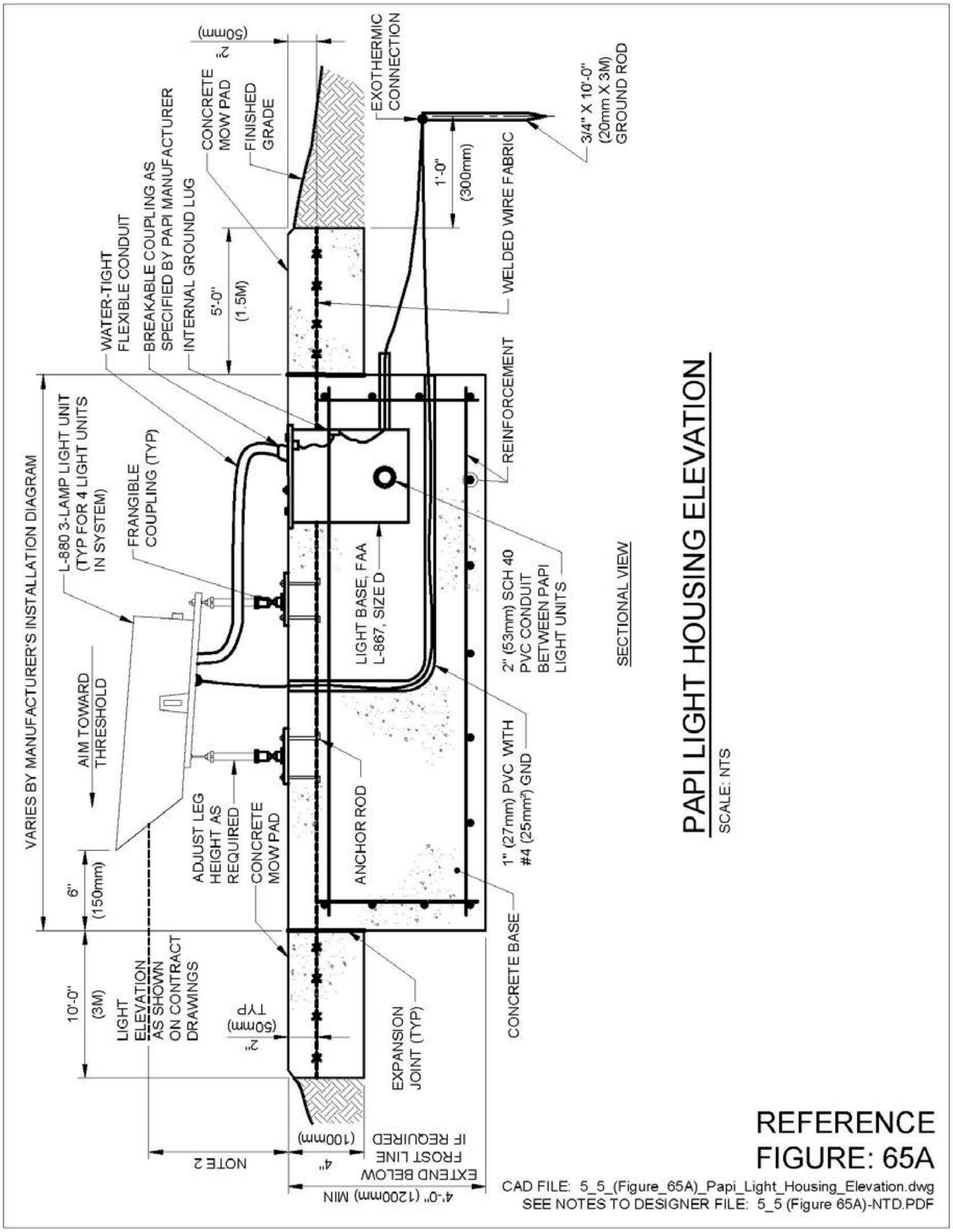
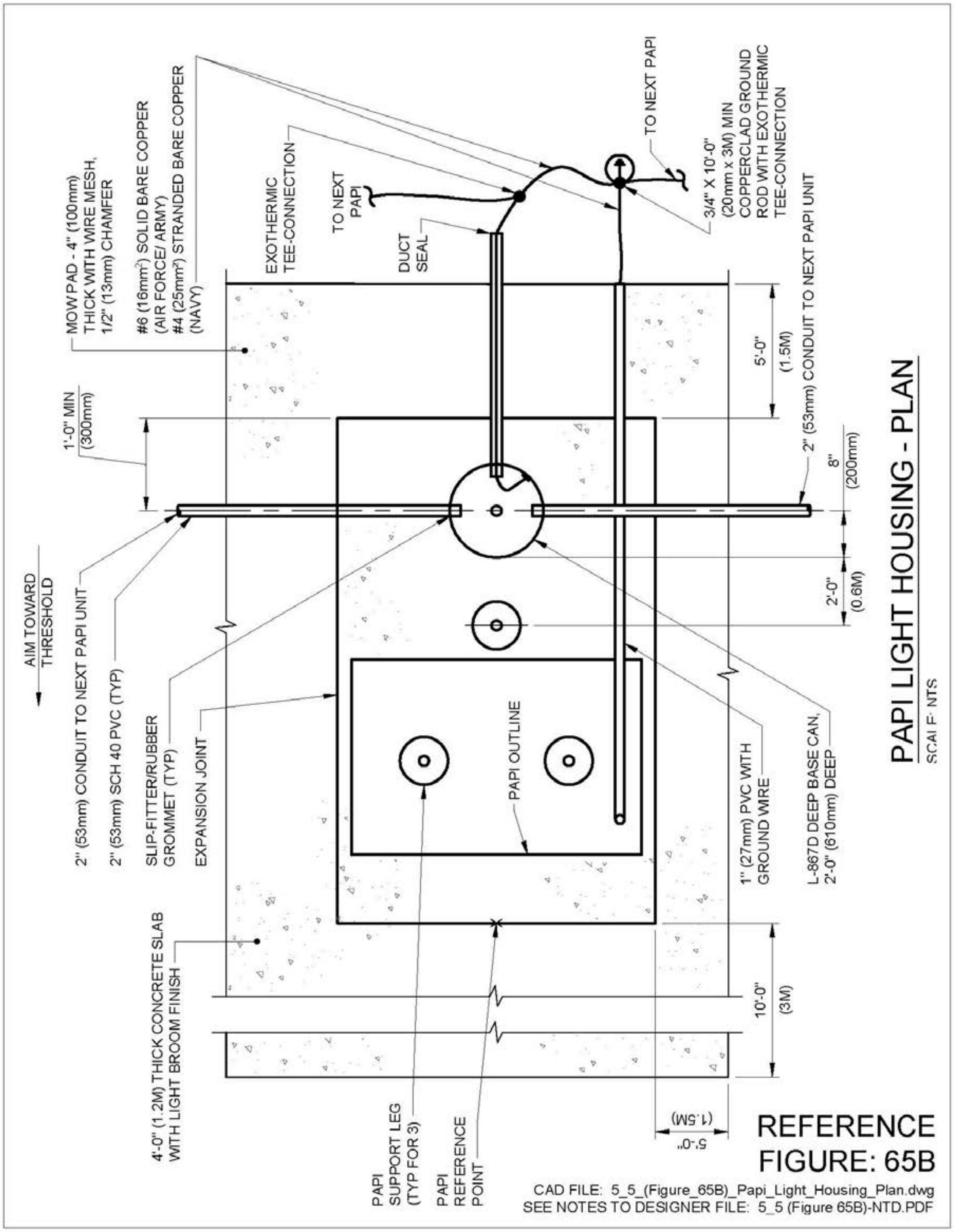


Figure 65B. PAPI Light Housing Unit (LHU) Installation Detail (continued)



6-5 PAPI Sighting Calculations and Obstacle Clearance Surfaces.

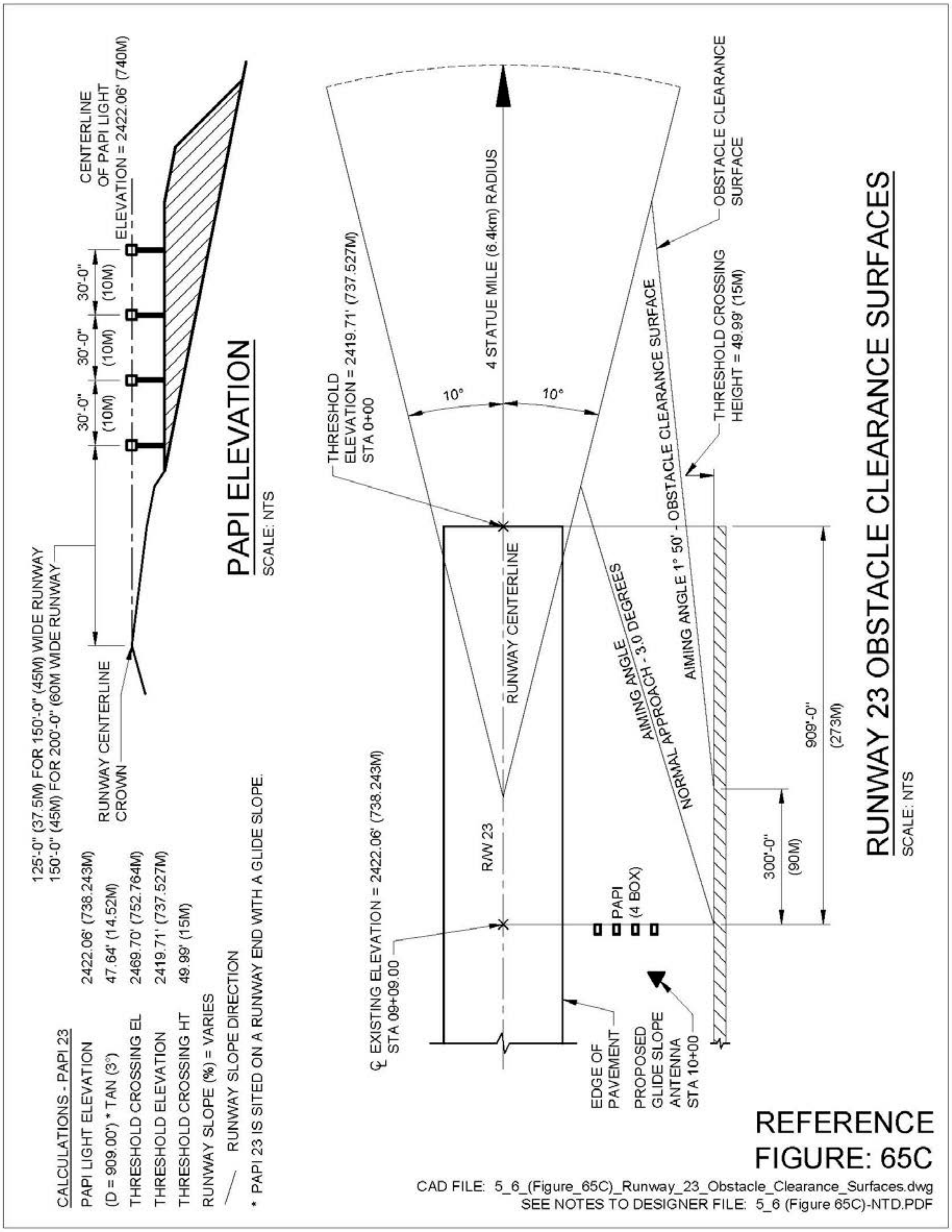
6-5.1 Figure 65C.

6-5.1.1 Notes to Designer.

1. Figure 65C shows examples of PAPI siting calculations (in accordance with UFC 3-535-01) and obstacle clearance surfaces. This information should be included on the contract documents for the project.

2. TCH is based on aiming angle (3 degrees), the same as the glideslope angle.

Figure 65C. Obstacle Clearance Surfaces



6-6 L-880 Signal Presentation and Installation Tolerances.

6-6.1 Figure 65D.

6-6.1.1 Notes to Designer.

1. Figure 65D shows the light signal presentation of a 4-box PAPI (L-880) installation as seen from an approaching aircraft. Also indicated are the installation tolerances and aiming angles of the light units. This information should be included on the contract documents for the project.

6-6.1.2 Drawing Notes for Figure 65D.

1. Aiming Parameter table:

Aiming of PAPI relative to pre-selected glide path

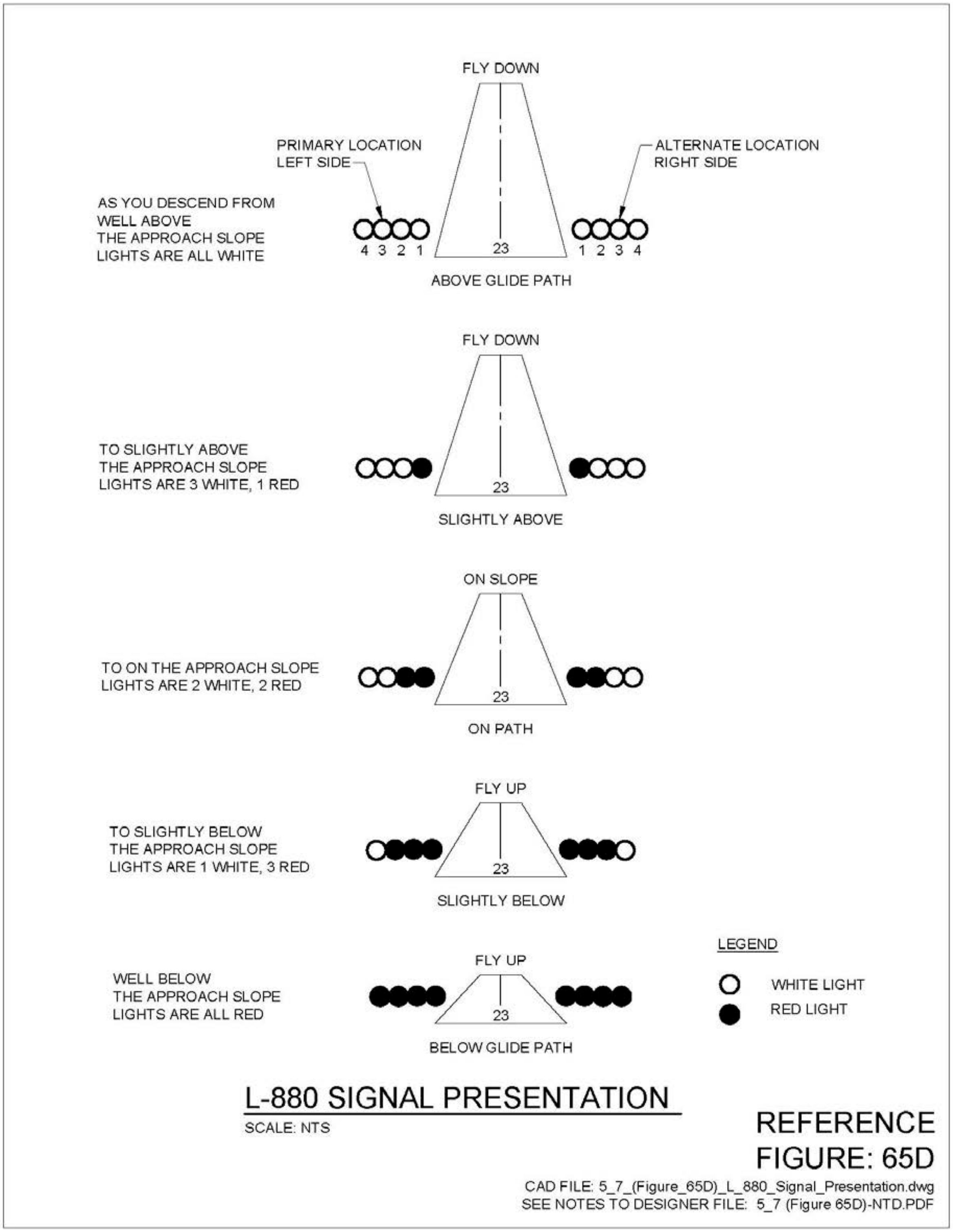
Light unit	Aiming angle (in minutes of arc)
Unit nearest runway	30' (minutes) above glide path
Next adjacent unit	10' (minutes) above glide path
Next adjacent unit	10' (minutes) below glide path
Next adjacent unit	30' (minutes) below glide path

2. Installation Tolerance table:

Installation Tolerance

Item	Tolerance
Azimuthal aiming	±1/2 degrees
Mounting height tolerance (from horizontal planes)	±1" (25mm)
Tolerance along line perpendicular to runway	±1" (25mm)
Horizontal plane through beam center to elevation of runway centerline at intercept point	±12" (305mm)

Figure 65D. L-880 Signal Presentation



6-7 REIL Systems Schematic Wiring Diagrams.

6-7.1 Figure 66.

6-7.1.1 Notes to Designer.

1. The most common system presently in use is depicted in Detail 1. This system uses a separate 120/240 volt source for the incoming power. When designing this system ensure the separate power source is available near the master unit.

2. Detail 2 uses a power adapter that is installed in series with the series runway lighting circuit. The power adapter converts the constant current from the lighting circuit to a 120/240 volt output. This output is used as the 120/240 volt source to power the system.

3. Some special precautions should be taken when designing this type of system:

    a. Power adapters often have varied performance. Variations in brightness levels selected, load, and regulators will produce variations in voltage output.

    b. System may add up to an additional 4kw to runway lighting system.

    c. System may not work well with certain types of regulators.

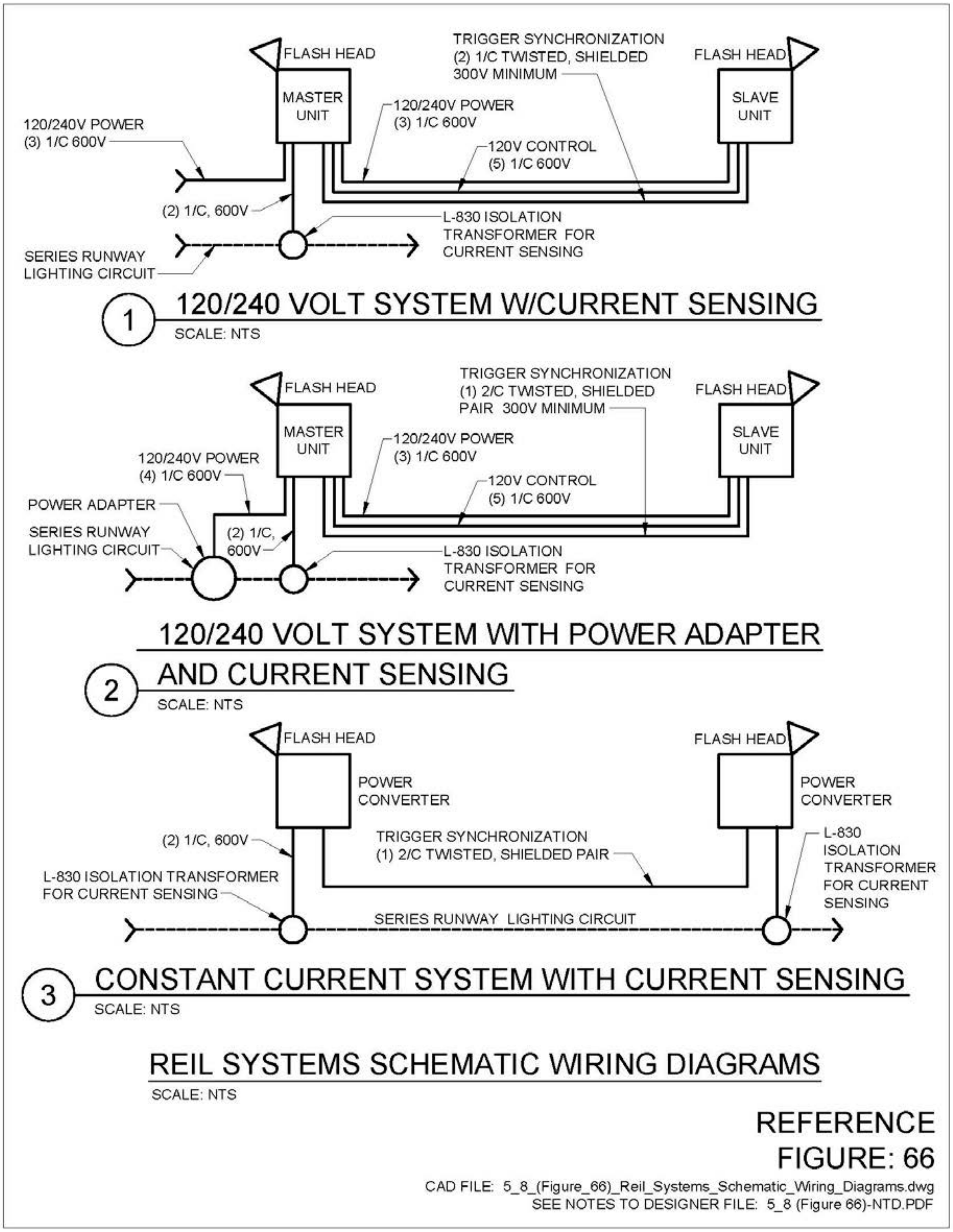
4. Recommend coordinating with manufacturer prior to designing this type of system.

5. The system in Detail 3 uses the constant current as the power feed to each unit via an L-830 isolation transformer. The flash heads are synchronized via the twisted pair between the two units. Load on the runway lighting circuit is about 150 watts per flash head or 300 watts for the system.

6. The contract documents should only show the schematic wiring diagram of the actual system to be utilized. Designer should delete the other diagrams.

7. Size and number of conductors must be verified with manufacturer.

Figure 66. REIL Systems Schematic Wiring Diagrams



6-8 Master and Slave REIL Unit Installation.

6-8.1 Figure 67.

6-8.1.1 Notes to Designer.

1. This detail shows a typical 120/240 volt system installation. All manufacturers are similar but arrangements of conduit entrances and support legs may be different. Recommend verifying requirements with several different manufacturers.

2. Foundations will vary with manufacturer.

3. Ensure contract documents show location of REILs and power source. Locations will be as specified in UFC 3-535-01.

6-8.1.2 Drawing Notes for Figure 67.

1. Dimensions and layout vary with manufacturer. Install per manufacturer's requirements.

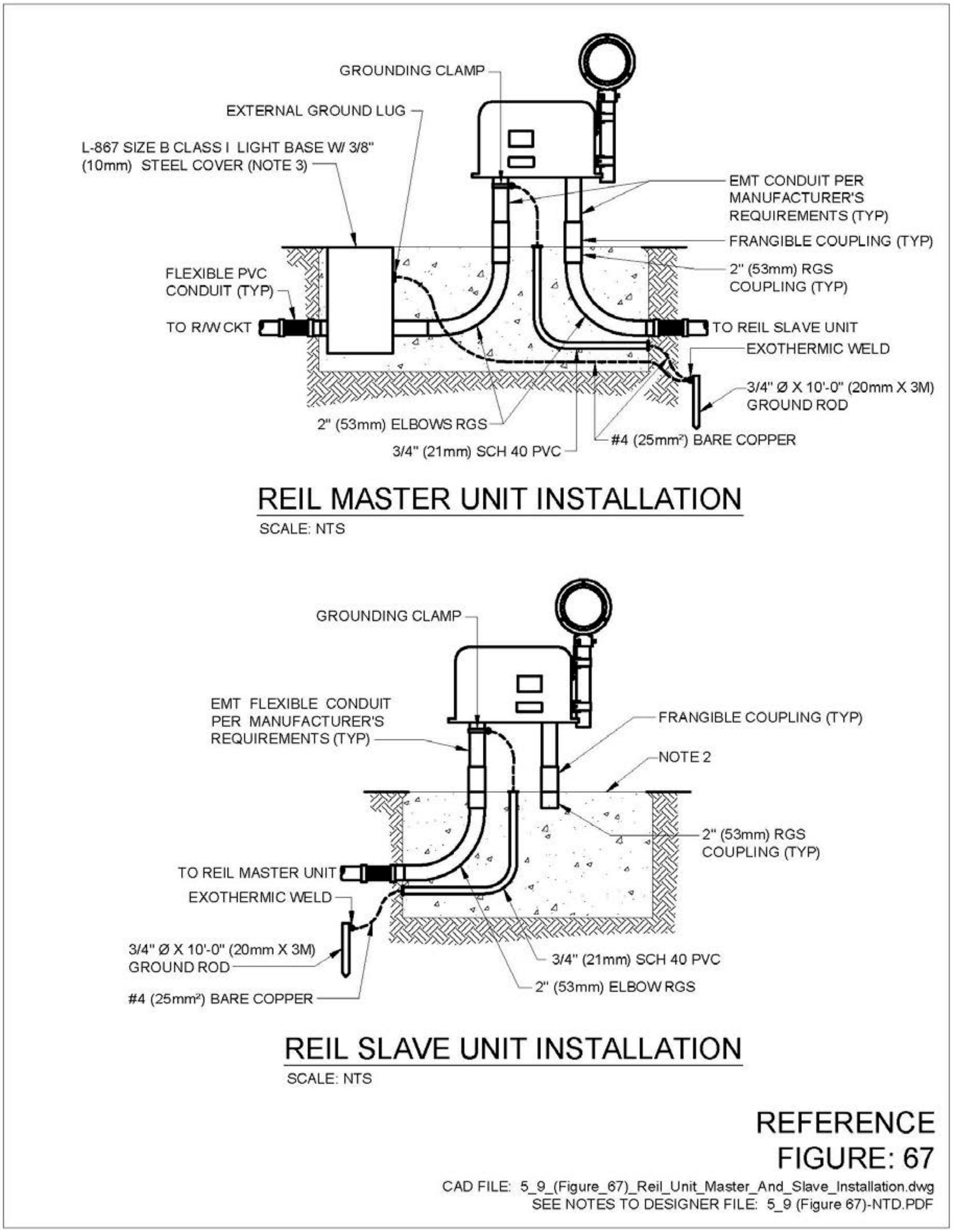
2. Dimension of concrete foundation varies with equipment supplied. Depth must be 36" (900mm) or 6" (150mm) below frost line whichever is greater.

3. L-867 base for mounting L-830 isolation transformer may be part of foundation or mounted separately.

4. Wire per manufacturer's requirements.

5. Incoming power wiring and conduit not indicated for clarity. Power wiring may enter L-867 light base in a separate conduit from the series circuit lighting cables.

Figure 67. Master and Slave REIL Unit Installation



CHAPTER 7 Miscellaneous (Rotating Beacons, Wind Cones, Can Plazas, Manholes, and High Mast Lighting)

7-1 51' (15.5m) Pre-Fabricated Beacon Tower.

7-1.1 Figure 68.

7-1.1.1 Notes to Designer.

1. This diagram shows a typical self-supporting 51' (15.5m) tower. Actual height of tower will depend on site conditions. Refer to UFC 3-535-01 for additional information.

2. Tower is designed by manufacturer. Recommend furnishing manufacturer with following data based on actual site:

   a. Weight and Effective Projected Area (EPA) of proposed beacon

   b. Beacon mounting footprint

   c. Overall height of tower

   d. Soil bearing capacity and analysis based on borings taken at site.

7-1.1.2 Drawing Notes for Figure 68.

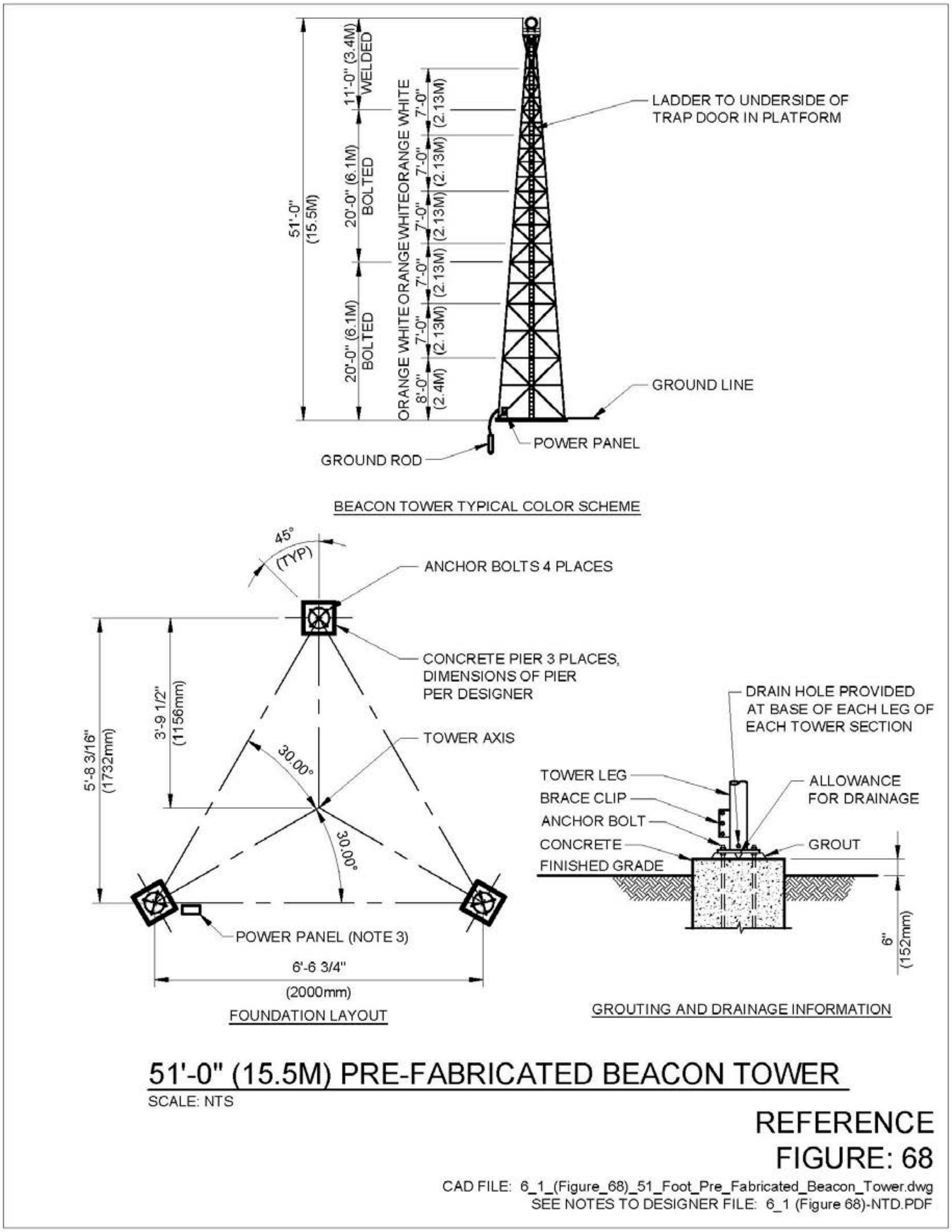
1. Ladder must be furnished with OSHA approved safety climbing tower.

2. Size of piers per Registered Structural Engineer.

3. Install power panel with top at 5'-0" (1.5m) above finished grade.

4. Provide circuits to top of tower for beacon, motor, heater, and obstruction light. Provide disconnect switch for each circuit at top of tower.

Figure 68. 51' (15.5m) Pre-Fabricated Beacon Tower



7-2 Beacon Dimensions and Wiring Diagram.

7-2.1 Figure 69.

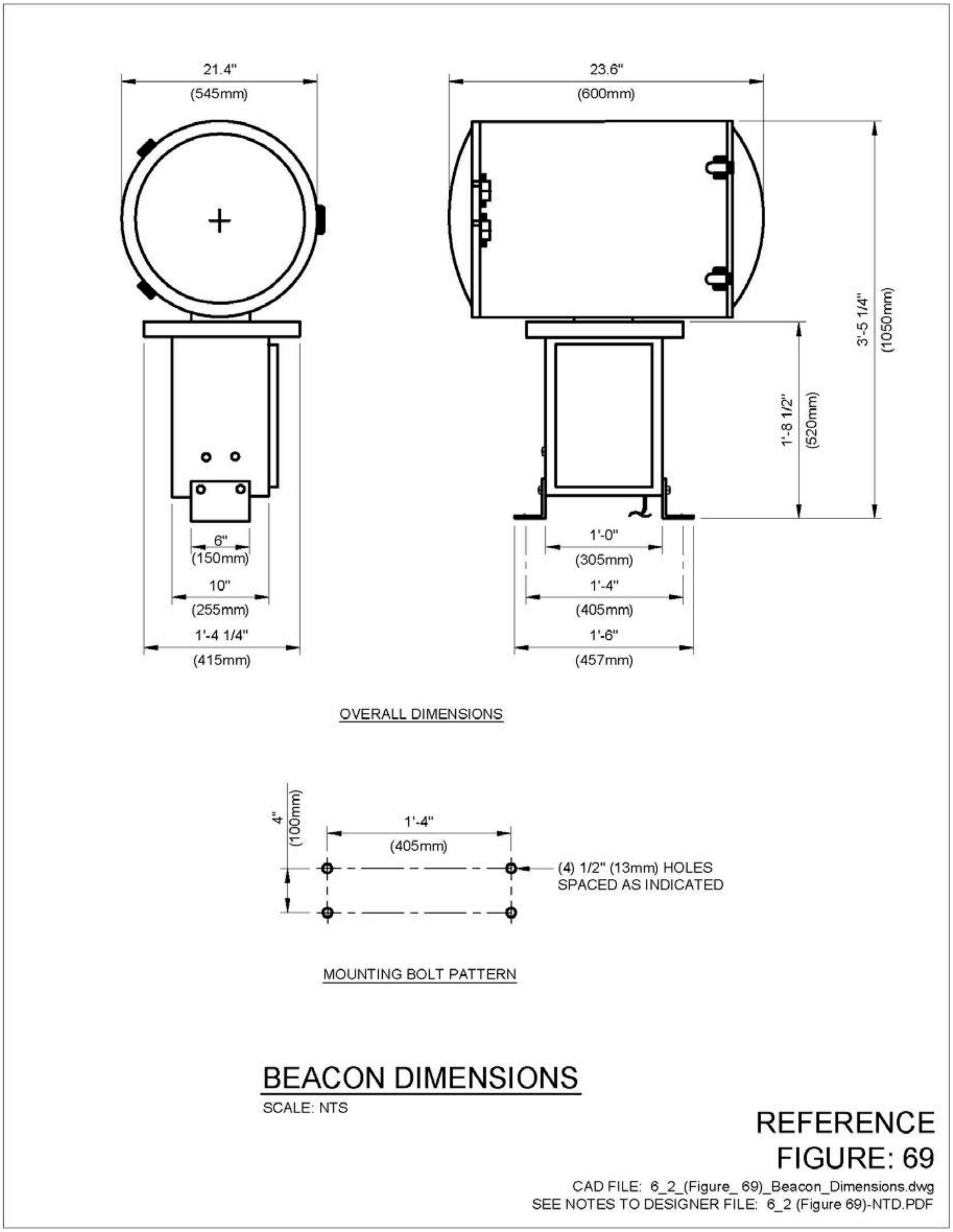
7-2.1.1 Notes to Designer.

1. The dimensions may vary between manufacturers.

2. Control of the beacon is typically automatic by a photocell or timeclock. Means should be provided in the control tower for overriding the photocell or timeclock. The beacon could be located up to 5000' (1500m) from the nearest runway and power wiring will come from the closest source. The control feed from the tower override could be by radio link, telephone switching relay, etc. Recommend during design that control route and available power be verified.

3. Verify dimensions and wiring with manufacturer.

Figure 69. Beacon Dimensions



7-3 Beacon Tower Platform Details.

7-3.1 Figure 70.

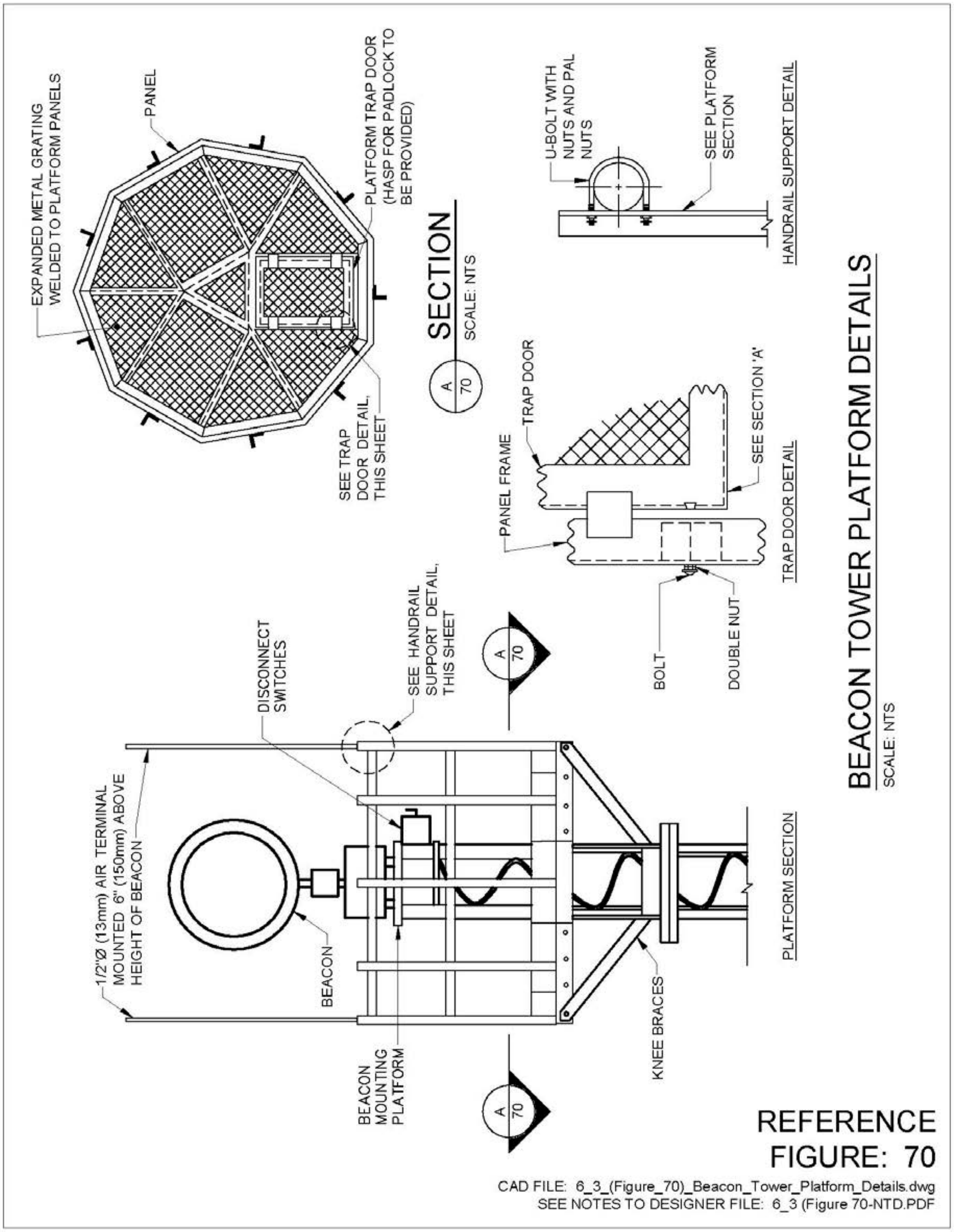
7-3.1.1 Notes to Designer.

1. Figure is self-explanatory.

7-3.1.2 Drawing Notes for all Tower Components, Figure 70.

1. All tower components must be hot dipped galvanized after fabrication.
2. Install per manufacturer’s requirements.
3. Locate disconnect switches on walkway handrail or center structure.

Figure 70. Beacon Tower Platform Details



7-4 Tower Safety Climbing Device.

7-4.1 Figure 71.

7-4.1.1 Notes to Designer.

1. Figure is self-explanatory.

7-4.1.2 Drawing Notes for Figure 71.

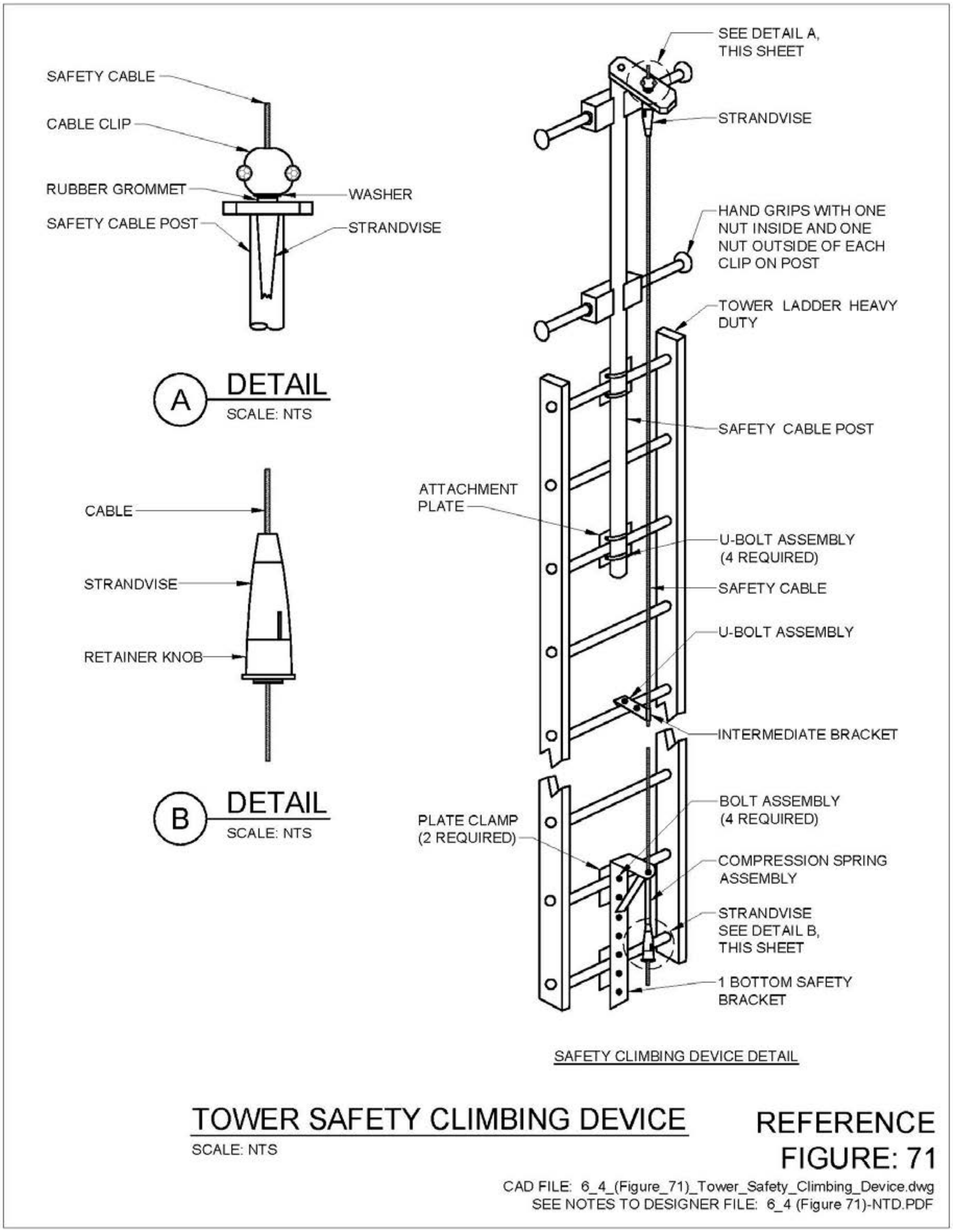
1. Installation per manufacturer’s requirements.

2. Contractor must provide two full body harnesses equipped with d-rings at front, back and both sides. Harness must be fully compatible for use with safety climbing device.

3. Contractor must provide two 6' (1829mm) shock absorbing lanyards, nylon/dacron construction.

4. Climbing device must meet latest OSHA and ANSI standards.

Figure 71. Tower Safety Climbing Device



7-5 **L-806 Windcone Assembly (Frangible).**

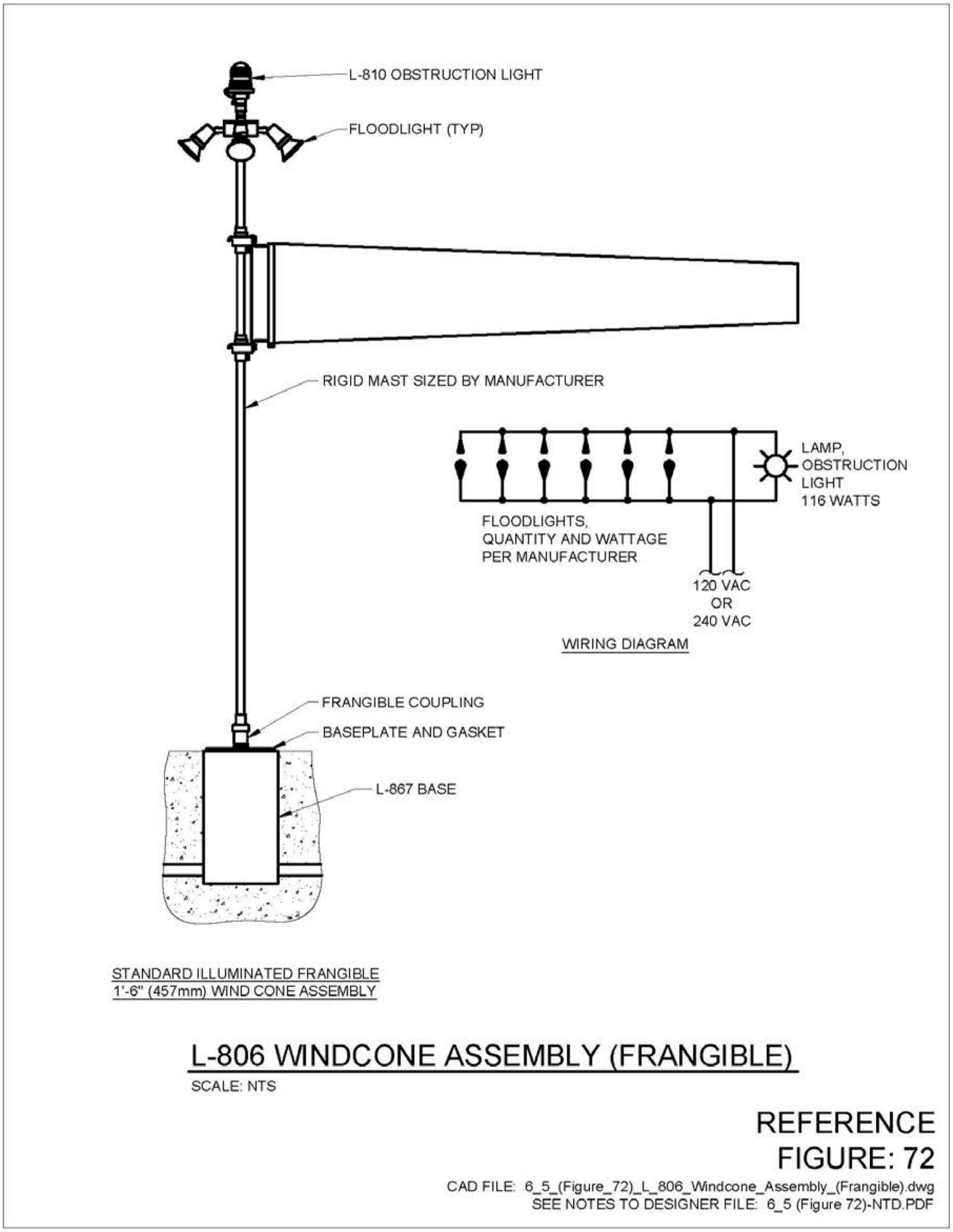
7-5.1 **Figure 72.**

7-5.1.1 **Notes to Designer.**

1. Typically, windcones are powered from a 120 or 240 volt ac source. Voltage drop must be analyzed. Depending on the length of run, a boosting transformer may have to be added.

2. The windcone should be powered and controlled from a separate circuit independent of runway edge lights.

Figure 72. L-806 Windcone Assembly (Frangible)



7-6 L-807 Windcone Assembly (Rigid Installation).

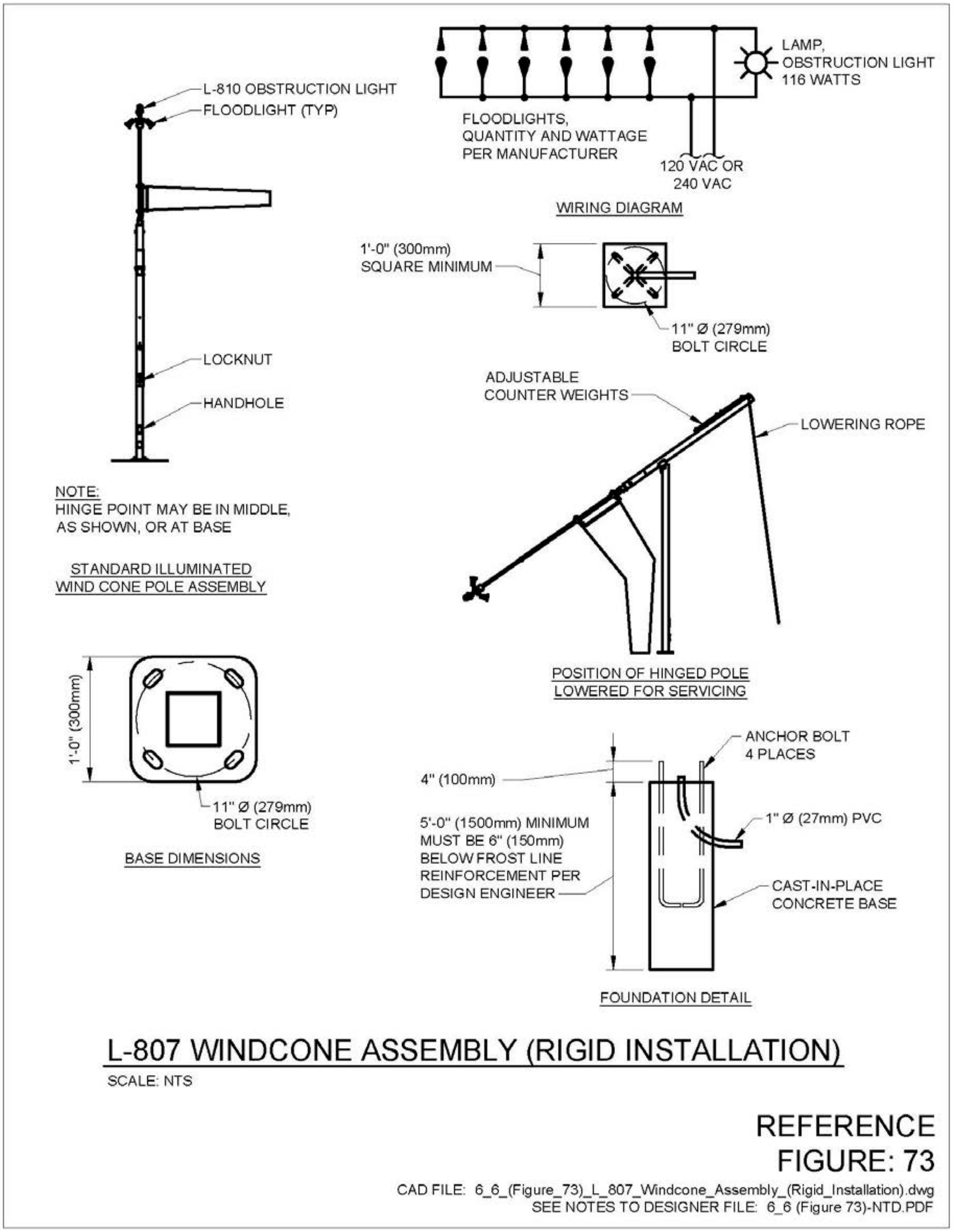
7-6.1 Figure 73.

7-6.1.1 Notes to Designer.

1. Typically, windcones are powered from a 120 or 240 volt source. Voltage drop must be analyzed. Depending on the length of run, a boosting transformer may have to be added.

2. The windcone should be powered and controlled from a separate circuit independent of runway edge lights.

Figure 73. L-807 Windcone Assembly (Rigid Installation)



7-7 Junction Can Plaza, Type A.

7-7.1 Figure 74.

7-7.1.1 Notes to Designer.

1. The purpose of individual base cans is to segregate the field circuits into separate conduit runs and provide access to each circuit. The advantages are:
    a. A fault in one circuit will not affect the others.
    b. Maintenance personnel do not have to be confined space trained (presently required by OSHA to enter manholes).
    c. Access time is considerably less than manholes.

2. Circuit and junction can plaza IDs should be indicated on the layout plans. The designer should coordinate with maintenance and operations personnel during the design review process to ensure each circuit and junction can is identified correctly for the specific installation.

7-7.1.2 Drawing Notes for Figure 74.

1. Number of junction cans and conduit configurations vary. See layout plan sheets for orientation.

2. Conduits which are not used in the project must be capped 12" (300mm) outside of plaza concrete.

3. Orient plaza as indicated on layout plan sheets.

4. Contractor must provide a 2" (50mm) diameter domed bronze marker at each junction can as indicated. Marker must be stamped with circuit identification as indicated on layout plan sheets.

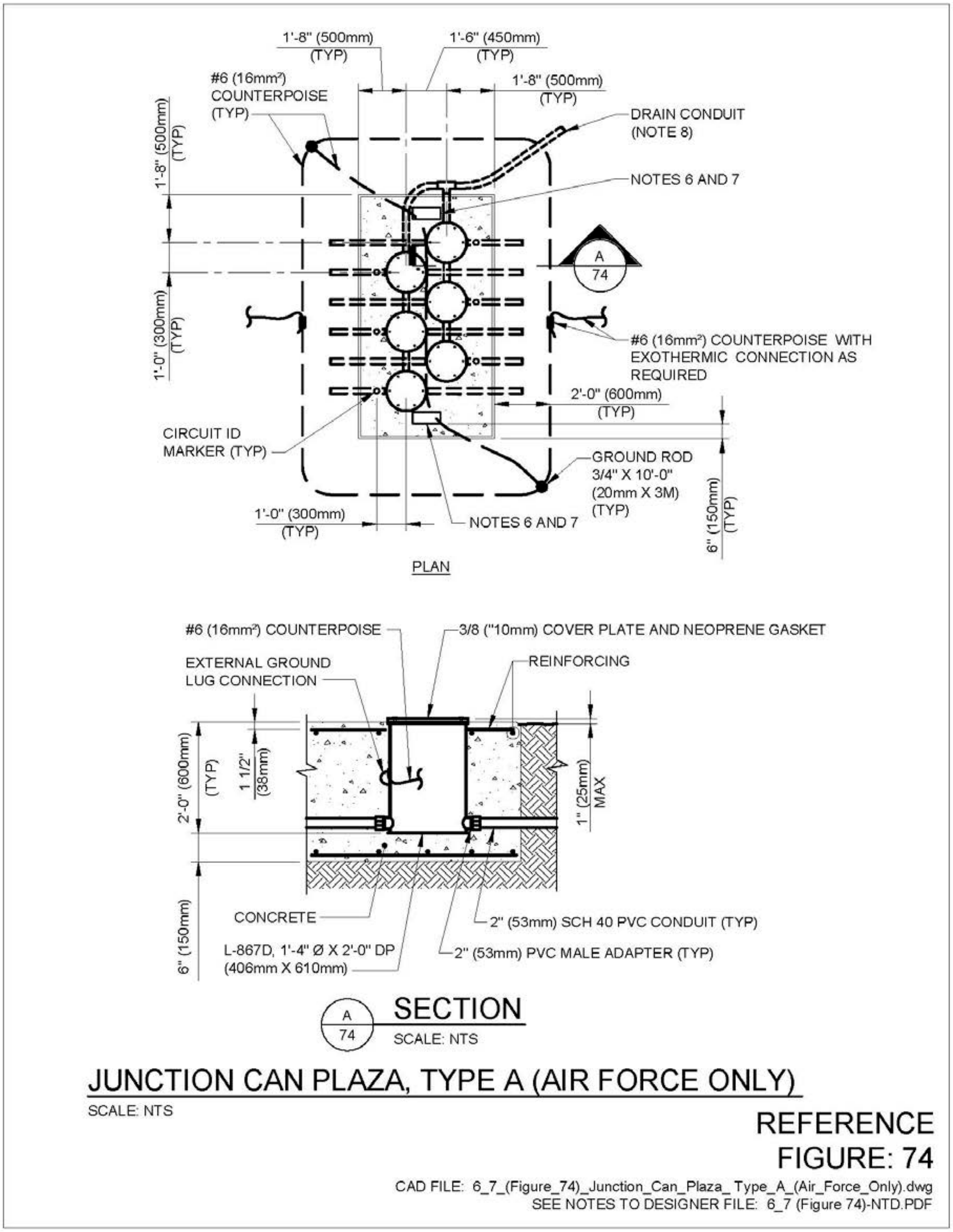
5. Install ground rods and ground loop at all junction can plazas as indicated. Two ground rods per plaza located at opposite corners must be provided. Counterpoise must be located nominally 12" (300mm) below existing grade.

6. Contractor must label 2 ends of each junction can plaza (JCP) by impressing the JCP identification number into the concrete foundation during placement. Letters and numbers must be 4" (100mm) in height, proportional in width, and have a stroke width of 1/2" (13mm) and 1/4" (6mm) depth.

7. See layout plan sheets for JCP identification numbers.

8. Drain conduits must be provided where indicated on the lighting and signage layout sheets. See Figure 76 for connection to junction cans.

Figure 74. Junction Can Plaza, Type A



7-8 **Junction Can Plaza, Type B.**

7-8.1 **Figure 75.**

7-8.1.1 **Notes to Designer.**

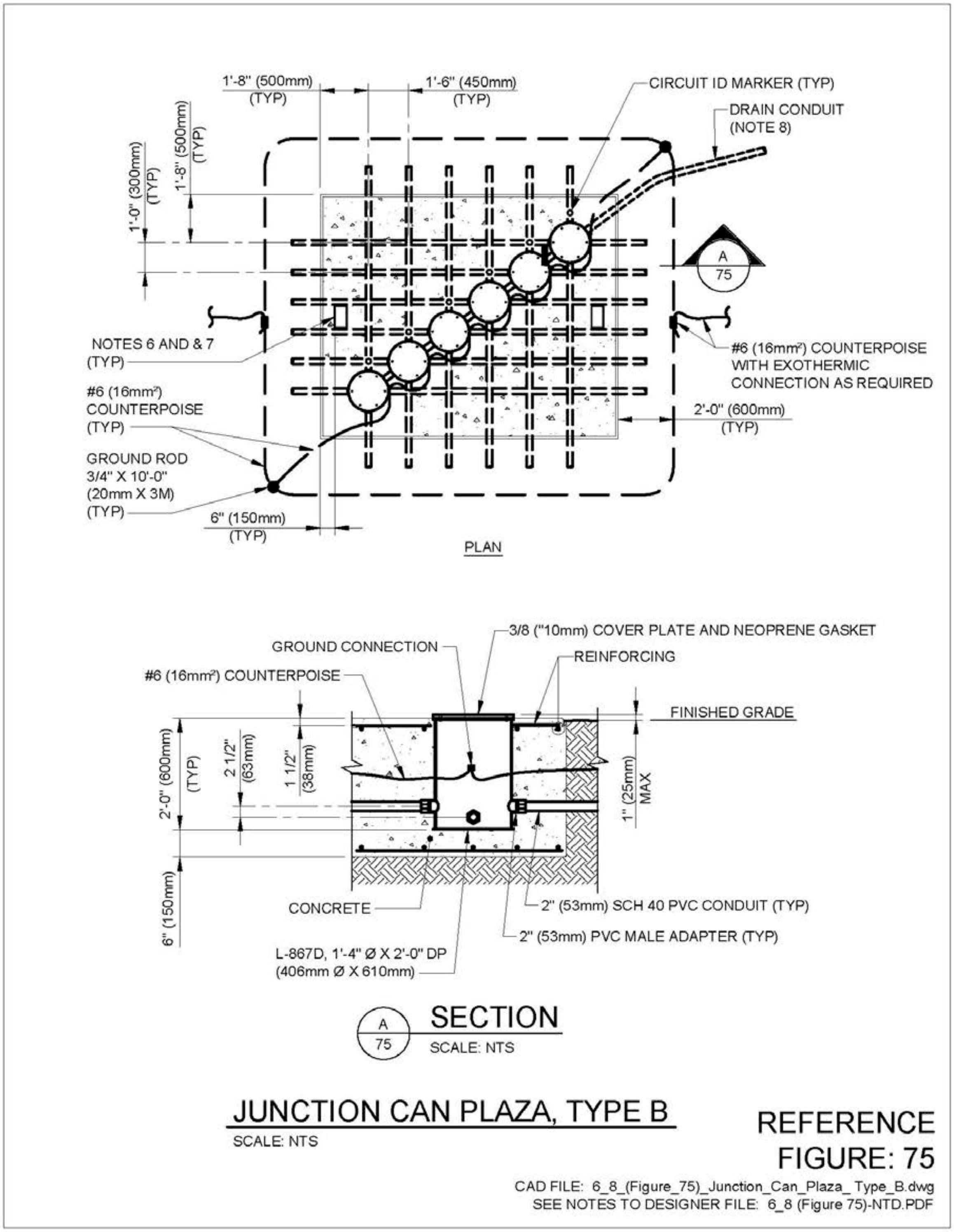
1. The purpose of the base cans is to segregate the field circuits into separate conduit runs and provide access to each circuit. The advantages are:
   a. A fault in one circuit will not affect the others.
   b. Maintenance personnel do not have to be confined space trained (presently required by OSHA to enter manholes).
   c. Access time is considerably less than for manholes.
2. Circuit and junction can plaza IDs should be indicated on the layout plans. The designer should coordinate with maintenance and operations personnel during the design review process to ensure each circuit and junction can is identified correctly for the specific installation.

7-8.1.2 **Drawing Notes for Figure 75.**

1. Number of junction cans and conduit configurations vary. See layout plan sheets for orientation.
2. Conduits which are not used in the project must be capped 12" (300mm) outside of plaza concrete.
3. Orient plaza as indicated on layout plan sheets.
4. Contractor must provide a 2" (50mm) diameter domed bronze marker at each junction can as indicated. Marker must be stamped with circuit identification as indicated on layout plan sheets.
5. Install ground rods and ground loop at all junction can plazas as indicated. Two ground rods per plaza located at opposite corners must be provided. Counterpoise must be located nominally 12" (300mm) below existing grade.
6. Contractor must label 2 ends of each junction can plaza (JCP) by impressing the JCP identification number into the concrete foundation during placement. Letters and numbers must be 4" (100mm) in height, proportional in width, and have a stroke width of 1/2" (13mm) and 1/4" (6mm) depth.
7. See layout plan sheets for JCP identification numbers.

8. Provide drain conduits where indicated on the lighting and signage layout sheets. See Figure 76 for connection to junction cans.

Figure 75. Junction Can Plaza, Type B



7-9 Drain for Junction Cans (Air Force Only).

7-9.1 Figure 76.

7-9.1.1 Notes to Designer.

1. The junction can plaza is for Air Force installations only.

2. The purpose is to segregate the field circuits into separate conduit runs and provide access to each circuit. The advantages are:

   a. A fault in one circuit will not affect the others.

   b. Maintenance personnel do not have to be confined space trained (presently required by OSHA to enter manholes).

   c. Access time is considerably less than manholes.

7-9.1.2 Drawing Notes for Figure 76.

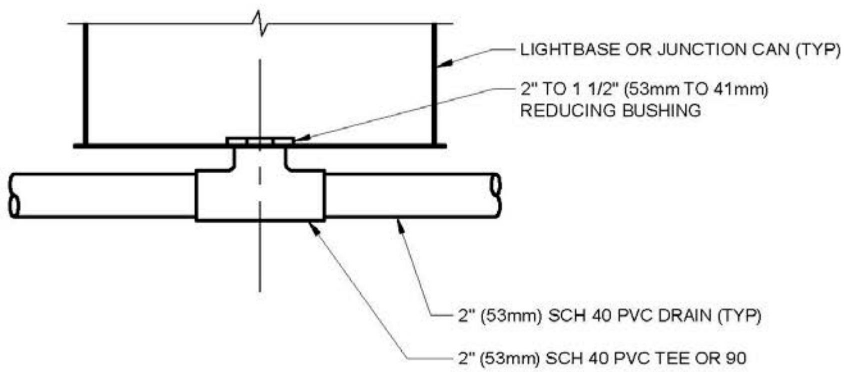
1. See layout plan sheets for location of drain conduits.

2. Slope drain conduits 1/8" per foot (3mm per 300mm) minimum toward drainage structures.

3. Penetrate inlet/manhole with drain conduit above storm sewer pipes where possible while maintaining slope requirement.

4. Seal entry around drain conduit at the inlet/manhole with compatible non-shrink grout.

Figure 76. Drains for Junction Cans (Air Force Only)



DRAINS FOR JUNCTION CANS (AIR FORCE ONLY)

SCALE: NTS

REFERENCE
FIGURE: 76

CAD FILE: 6_9_(Figure_76)_Drains_For_Junction_Cans_(Air_Force_Only).dwg
SEE NOTES TO DESIGNER FILE: 6_9 (Figure 76)-NTD.PDF

7-10 Manhole Grounding, Optional Cable Rack and Marker Details.

Figure 77. Reserved

Figure 78. Reserved

7-10.1 Figure 80A.

7-10.1.1 Notes to Designer.

1. Manhole grounding must be installed in all manholes and handholes. Typically, the metal frame of the access cover is grounded by a #4 (25 square mm) solid bare copper conductor connected to a ground lug on the frame and the ground rod. If the cover is removable grounding is also required, utilize flexible cable such as welding cable and connect to the frame and cover. The length of flexible cable should be long enough to allow removal of the cover away from the frame to allow access into the manhole.

2. The length of the cable rack arm is indicated at 14" (355 mm). There are smaller arms available as well as “U” shaped saddle rack that meet the minimum 300 lb loading. In 3' (0.9m) × 3' (0.9m) handholes, the 14" (355mm) arm may hinder access. Recommend using an 8" (200mm) arm or saddle rack.

3. The brass survey marker is used to identify the handhole or manhole for circuit routing and duct bank layouts as well as maintenance schedules. The actual identification number to be used should be coordinated with the facility maintenance personnel.

7-10.1.2 Drawing Notes for Figure 80A.

1. All conduits that contain copper cables for constant voltage circuits must be equipped with a minimum #6 (16 square mm), TW green ground wire. All conduits that are empty must not contain a ground wire.

2. Ground all metallic parts of the manhole with a #4 (25 square mm) bare stranded ground wire.

3. The contractor must install a 200 lb polypropylene pull rope/string in each duct and conduit installed and plug or cap the duct. The rope must be securely attached to the pull iron in each manhole, or a stake where the duct terminates underground.

4. All manholes must be installed as indicated on the plans. Coordinate final location with grading and drainage plans. When extending existing duct to new manhole, put manhole in line with existing duct when possible. Manholes must not be installed in ditches, drainage swales or where water will pond on top of the manhole.

5. All PVC conduit and fittings must be Schedule 40 and must be U.L. listed.

6. PVC plugs must be installed in each empty sleeve and duct.

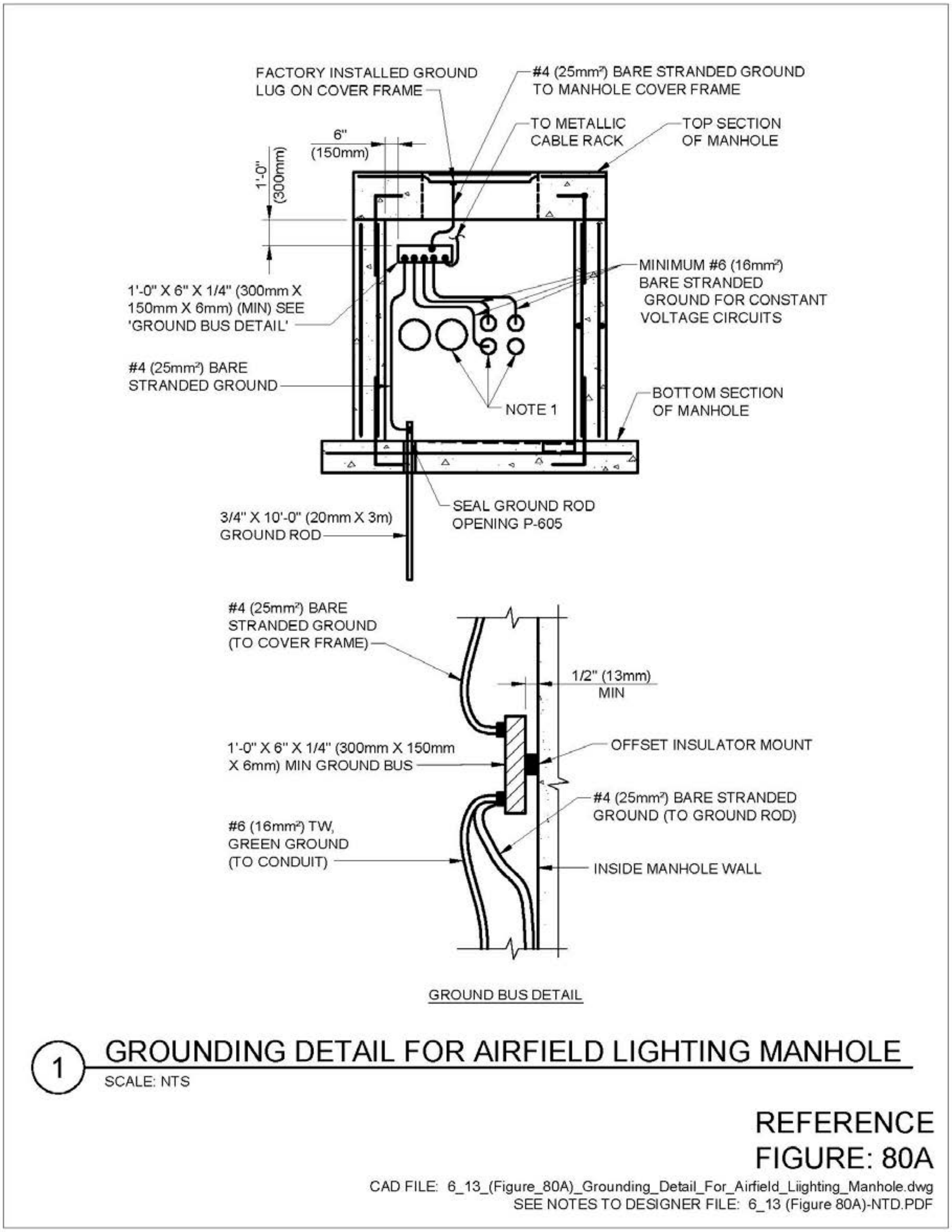
7. Provide pulling irons on all walls opposite conduit entry points.

8. All wall reinforcement (loop and vertical) affected by ductwork must be relocated on either side of the duct and detailed in the submittal.

9. The contractor must submit shop drawings showing all reinforcing steel and other construction details (ship-lap joint, etc.) prior to fabrication.

10. Each duct crossing under pavement must be located and dimensioned on the record drawings, accurate to 0.5' (150mm). The entrance and exit from under the pavement must be marked with an embedded id marker and stamped with the duct bank number.

igure 80A. Grounding Detail for Airfield Lighting Manhole



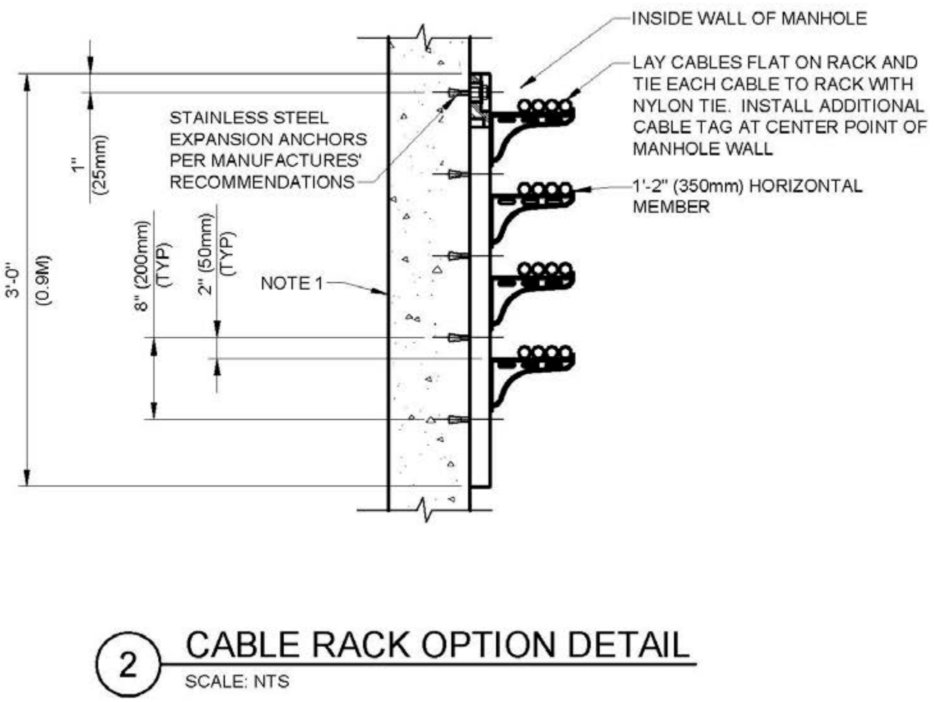
7-10.2 **Figure 80B.**

7-10.2.1 **Drawing Notes for Figure 80B.**

1. The cable racking system must be rated for 300 lbs. Cable racks must be placed on all manhole walls whether currently used or not. Cables must be tied to racks using cable ties.

2. Ground all metallic parts of the manhole with a #4 bare stranded ground wire.

Figure 80B. Cable Rack Option Detail



REFERENCE
FIGURE: 80B

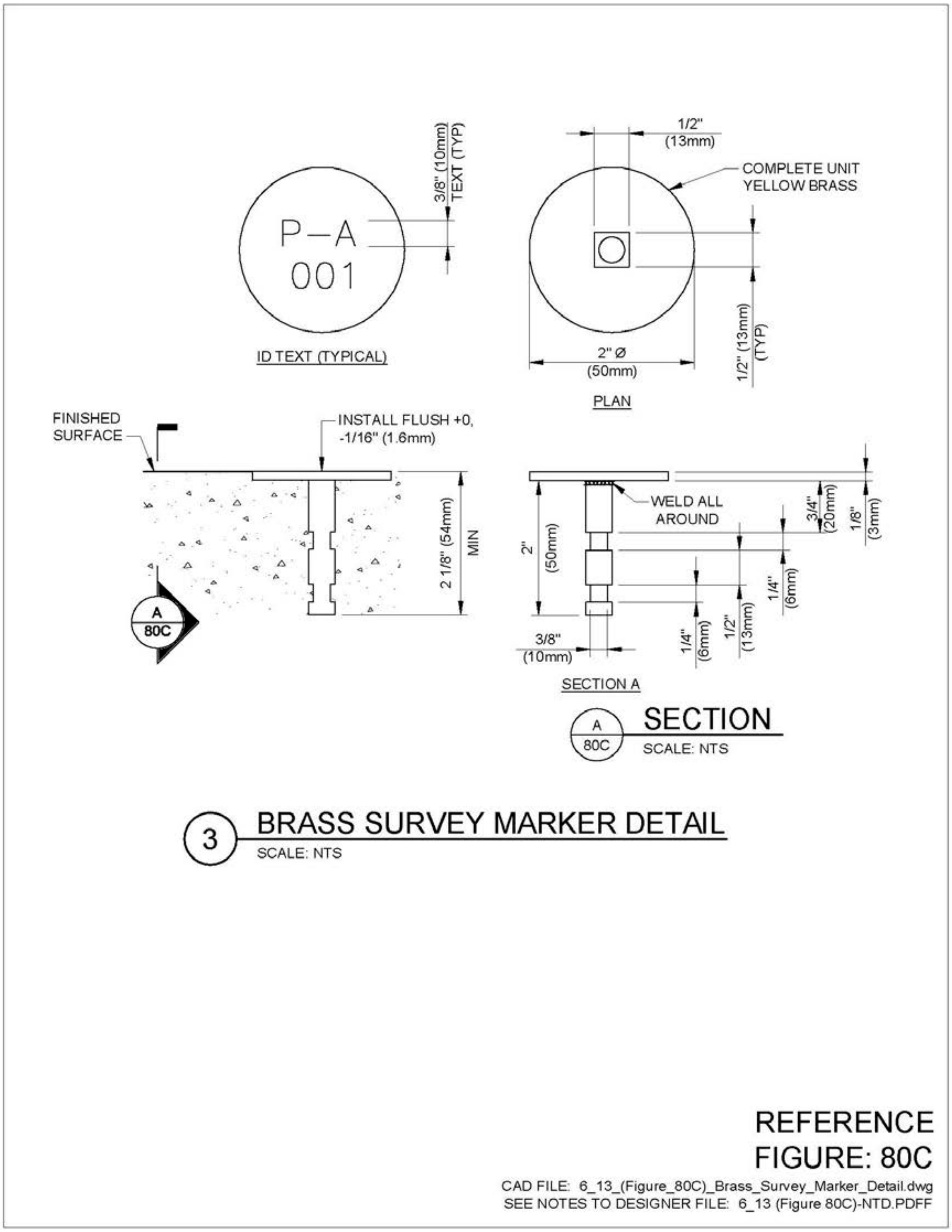
CAD FILE: 6_13_(Figure_80B)_Cable_Rack_Option_Detail.dwg
SEE NOTES TO DESIGNER FILE: 6_13 (Figure 80B)-NTD.PDFF

7-10.3 **Figure 80C.**

7-10.3.1 **Drawing Notes for Figure 80C.**

1. Provide a brass survey marker with ID text stamped into it for each airfield lighting manhole.

Figure 80C. Brass Survey Marker Detail



Manhole Foldout Diagrams and Circuit Schedule.

7-10.4 **Figures 80D, 80E.**

7-10.4.1 **Notes to Designer.**

1. The Manhole Foldout Diagram indicates the number and size of duct/conduit entering each wall of a manhole or handhole. For each wall, identify the duct/conduit and the circuits contained within the duct/conduit.

2. A foldout diagram should be provided for each manhole or handhole that a circuit(s) enters from the source, through the duct bank system and to the last manhole or handhole for that circuit.

3. The circuit schedule tabulates the manholes and ducts/conduits within the manholes a specific enters. The manholes are listed in succession and are coordinated with the manhole foldout diagrams.

Example Circuit Schedule Table:

Markings	Circuit Description	Manhole and Duct Identifier						
		(NOTE 1) P-T-025		(NOTE 1) P-T-025		P-A-027		
		SEE SHEET EF-316		SEE SHEET EF-316 (NOTE 2)		SEE SHEET EF-316		
		W	E	W	E	S	W	E (NOTE 3)
05SSALR-17	Runway 05 ALSF No. 1	C	G	C	C	B		C
05ALSF-16	Runway 05 ALSF No. 2	D	H	D	D	C		D
05ALSF-15	Runway 05 ALSF No. 3	E	I	E	E	D		E
05ALSF-14	Runway 05 ALSF No. 4	F	J	F	F	E		F

05ALSF-13 (NOTE 5)	Runway 05 ALSF No. 4 (NOTE 5)	G	K	G	G	F (NOTE 4)	G

Example Circuit Schedule Notes:

1. Denotes manhole identification number (typ).

2. Denotes contract drawing where foldout diagram is indicated (typ).

3. Denotes wall (north, south, east, west) that ducts containing indicated circuits penetrate (typ).

4. Denotes duct designation containing indicated circuit (typ).

5. Denotes cable marking and circuit designation (typ).

Figure 80D. Example Manhole Cable Foldout Diagram

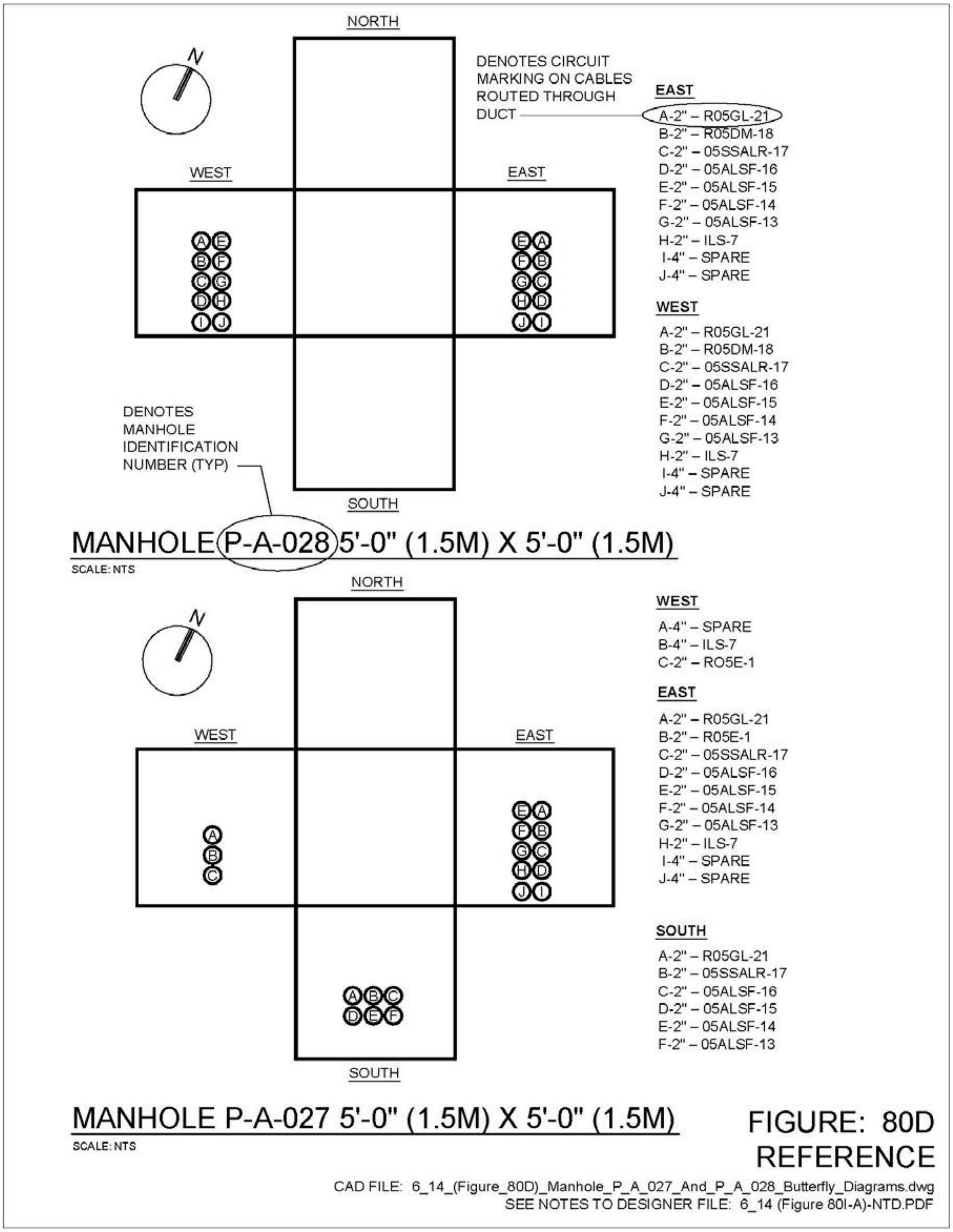


Figure 80E. Markings, Circuit Description, Manhole and Duct Identifier

MARKINGS	CIRCUIT DESCRIPTION	MANHOLE AND DUCT IDENTIFIER						
		P-T-025 (NOTE 1)		P-A-026		P-A-027		
		SEE SHEET EF-316		SEE SHEET EF-316 (NOTE 2)		SEE SHEET EF-316		
		W	E	W	E	S	W	E (NOTE 3)
05SSALR-17	RUNWAY 05 ALSF NO. 1	C	G	C	C	B		C
05ALSF-16	RUNWAY 05 ALSF NO. 2	D	H	D	D	C		D
05ALSF-15	RUNWAY 05 ALSF NO. 3	E	I	E	E	D		E
05ALSF-14	RUNWAY 05 ALSF NO. 4	F	J	F	F	E		F
05ALSF-13 (NOTE 5)	RUNWAY 05 ALSF NO. 4 (NOTE 5)	G	K	G	G	F (NOTE 4)		G

NOTES:

1. DENOTES MANHOLE IDENTIFICATION NUMBER (TYP).
2. DENOTES CONTRACT DRAWING WHERE FOLDOUT DIAGRAM IS SHOWN (TYP).
3. DENOTES WALL (NORTH, SOUTH, EAST, WEST) THAT DUCTS CONTAINING INDICATED CIRCUITS PENETRATE (TYP).
4. DENOTES DUCT DESIGNATION CONTAINING INDICATED CIRCUIT (TYP).
5. DENOTES CABLE MARKING AND CIRCUIT DESIGNATION (TYP).

REFERENCE
FIGURE: 80E

CAD FILE: 6_14_(Figure_80E)_Manhole_And_Duct_Identifier_Schedule.dwg
SEE NOTES TO DESIGNER FILE: 6_14 (Figure 80D-B)-NTD.PDF

Figure 81. Reserved

Figure 82. Reserved

Figure 82. Reserved.

Figure 83. Reserved.

7-11 **Traffic Signs and Signals Installation.**

7-11.1 **Figures 84A, 84B, 84C, 84D.**

7-11.1.1 **Notes to Designer.**

1. Figures 84A, 84B, 84C and 84D show the installation of traffic signs and signals installed on a roadway that crosses the approach end of a runway. The purpose is to provide visual warning to vehicle traffic that they are near low flying aircraft.

2. Control of the flashing signals is initiated by air traffic control by transmission over a fiber optic cable to the master controller. Ground-to-ground radio transmission might also be used.

3. Figure 84A shows a plan view of master and slave flashers and sign locations. Figures 84B, 84C, and 84D show details of the roadway sign and signal assembly.

7-11.1.2 **Drawing Notes for Figure 84C.**

1. Install signal controller with 8-position M49 cabinet.

2. Integrate signal controller and cabinet into proposed fiber optic system with single mode data transceiver and interconnect center compatible with other fiber optic equipment provided.

3. Signal rests in “dark” mode. Air traffic control will activate signal. Upon activation, display a flashing yellow signal indication, for 5.0 seconds, followed by a 5.0 second solid yellow change interval. Follow change interval with two alternating red signals (i.e. wig-wag). Air traffic control will terminate flashing red. Upon termination of red signal will revert to “dark” mode.

Figure 84A. Plan View of Traffic Sign/Signal Installation

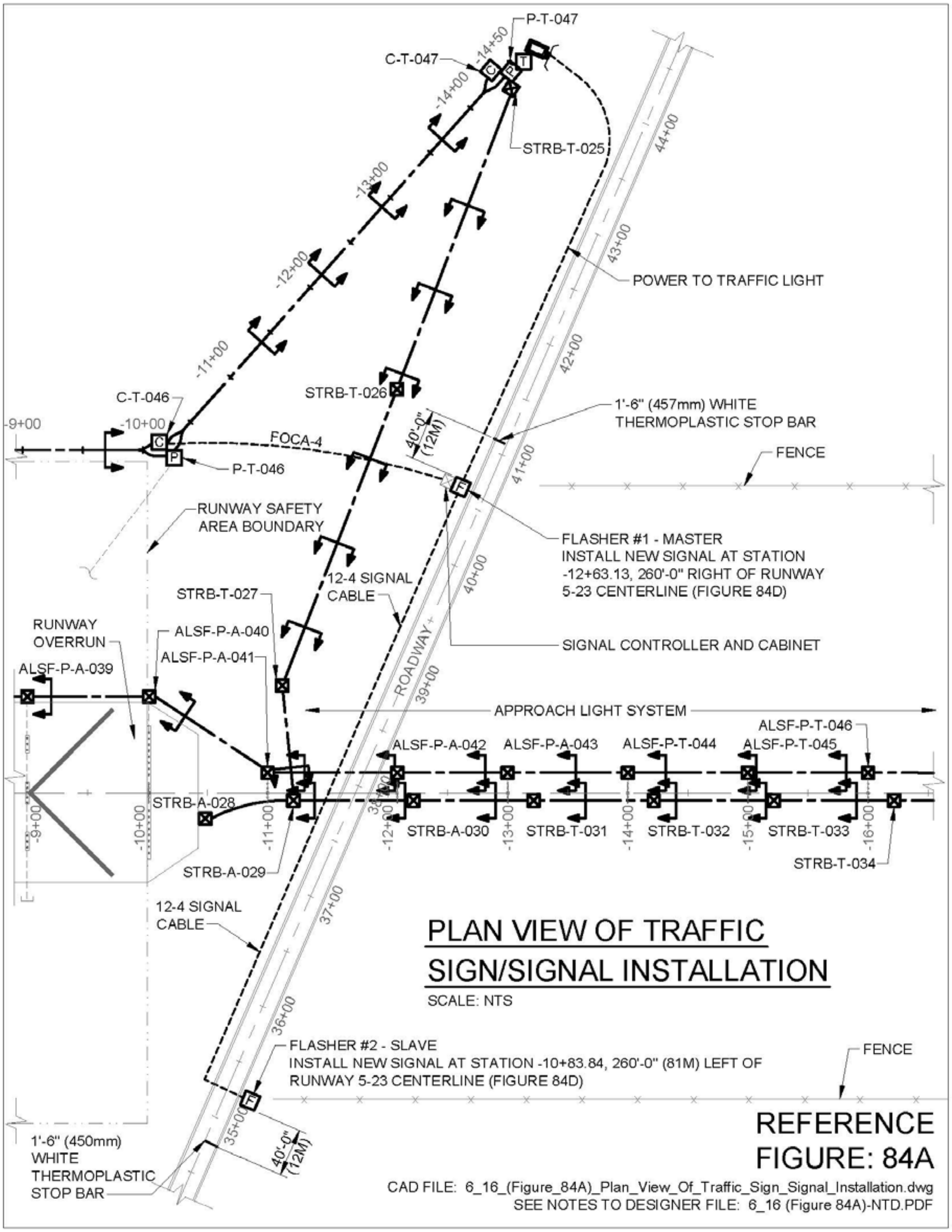


Figure 84B. Roadway Sign Detail

BACKGROUND COLOR: WHITE/YELLOW

SIGN NUMBER: SIGNAL SIGN COPY COLOR: BLACK

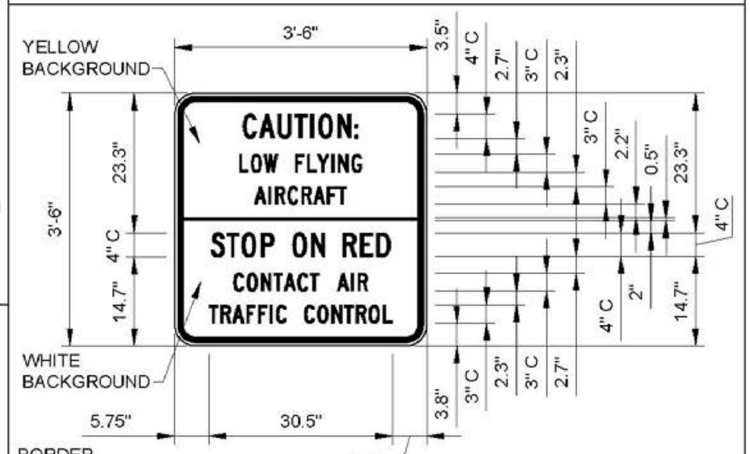
TYPE: D
QUANTITY: 2
SIGN WIDTH: 3'-6"
HEIGHT: 3'-6"
TOTAL AREA: 12.3 SQ FT
BORDER TYPE: RECESSED
RECESS: 0.5"
WIDTH: 1"
RADII: 3"
NO. Z BARS: **
LENGTH: **

SYMBOL	X	Y	WID	HT

MATERIAL: 0.080" (2.0 mm) ALUMINUM

NOTES:
1. LEGEND AND BORDER SHALL BE DIRECT APPLIED BLACK, NON-REFLECTIVE SHEETING.
2. BACKGROUND SHALL BE REGULAR GRADE REFLECTIVE SHEETING.
3. TOP PANEL SHALL BE YELLOW REGULAR GRADE SHEETING.

DESIGN BY: CHECKED BY:
PROJECT ID: DATE:



BORDER
R = 3"
TH = 1"
IN = 0.5"

SPACING FACTOR IS 1 UNLESS SPECIFIED OTHERWISE

LETTER POSITIONS

LETTER SPACINGS ARE TO START OF NEXT LETTER

																	SERIES/SIZE TEXT LENGTH
	C	A	U	T	I	O	N	:									C 2000
11.4	2.7	3.1	2.8	2.6	1.4	3.2	2.8	0.6	11.4								19.2
	L	O	W		F	L	Y	I	N	G							C 2000
10.8	1.9	2.1	2.3	3	1.9	1.7	2.3	1.1	2.3	1.7	10.8						20.3
	A	I	R	C	R	A	F	T									C 2000
13.3	2.3	1.1	2.1	2.3	2	2.3	1.7	1.5	13.3								15.4
	S	T	O	P		O	N		R	E	D						C 2000
6.1	2.6	2.5	3.2	2.2	3	3.2	2.2	3	2.9	2.7	2.2	6.1					29.8
	C	O	N	T	A	C	T		A	I	R						C 2000
9.8	2.2	2.4	2.1	1.7	2.3	2	1.5	3	2.3	1.1	1.7	9.8					22.4
	T	R	A	F	F	I	C		C	O	N	T	R	O	L		C 2000
5.7	2	1.9	2.3	1.9	1.9	2a1	1.7	3	2.2	2.4	2.1	1.9	2.1	2.4	1.5	5.7	30.5

1 ROADWAY SIGN DETAIL
SCALE: NTS

REFERENCE
FIGURE: 84B

CAD FILE: 6_16_(Figure_84B)_Roadway_Sign_Detail.dwg
SEE NOTES TO DESIGNER FILE: 6_16 (Figure 84B)-NTD.PDF

Figure 84C. Pedestal Foundation – Top View, In Earth

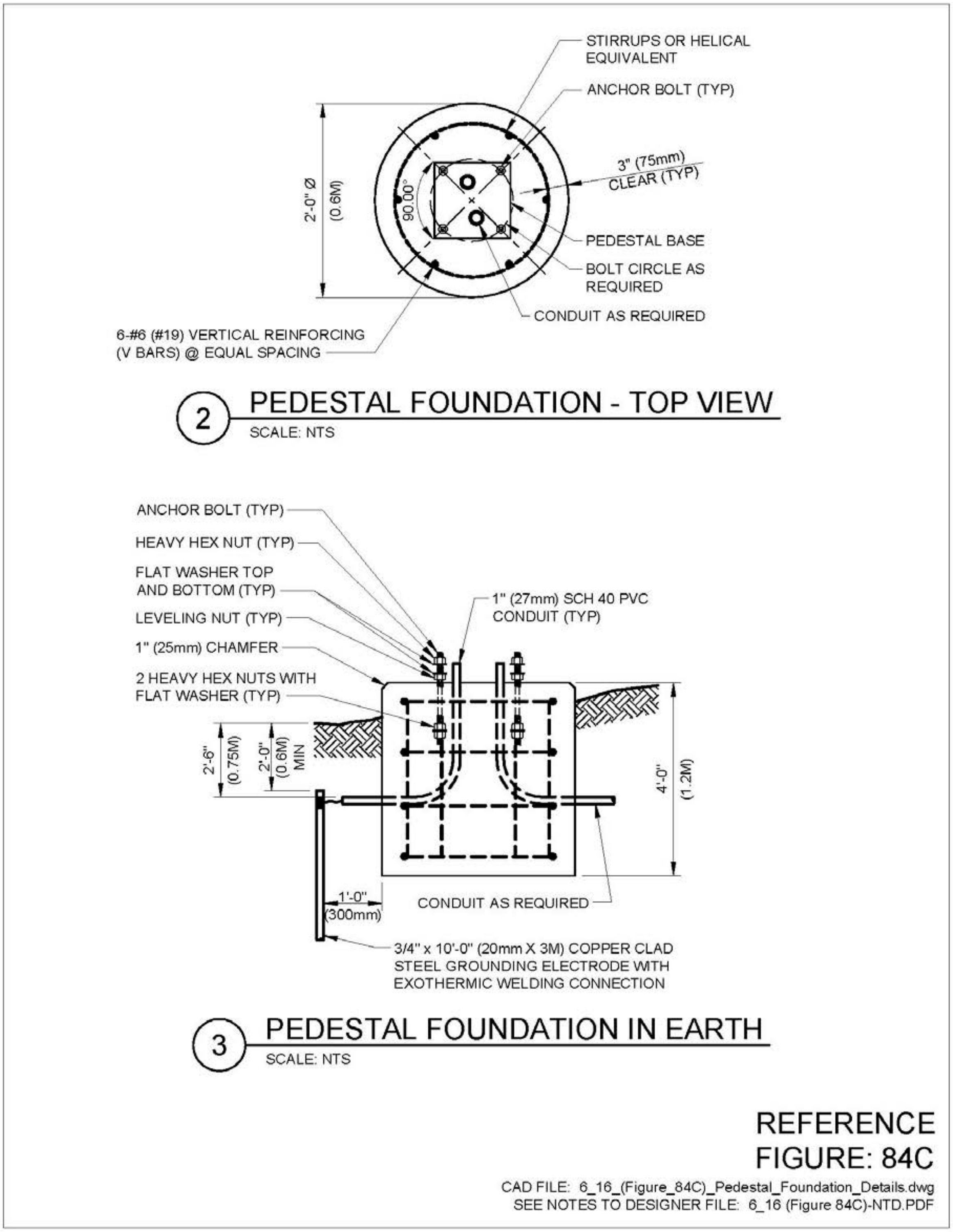
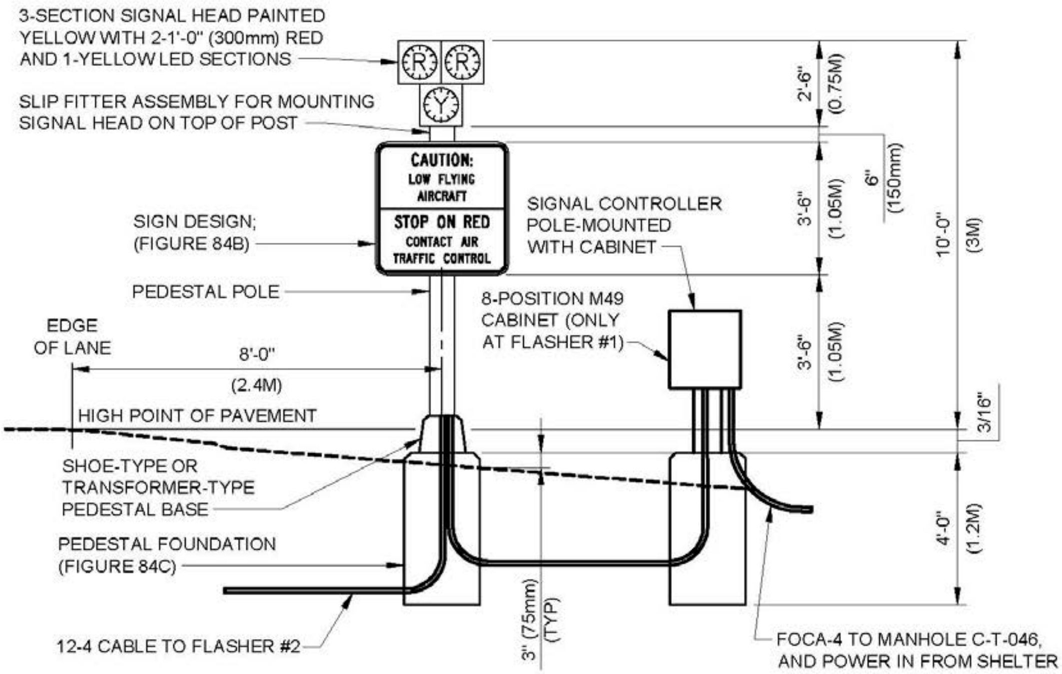


Figure 84D. Roadway Signal Assembly Detail



4 ROADWAY SIGNAL ASSEMBLY DETAIL
SCALE: NTS

REFERENCE
FIGURE: 84D

CAD FILE: 6_16_(Figure_84D)_Roadway_Signal_Assembly_Detail.dwg
SEE NOTES TO DESIGNER FILE: 6_16 (Figure 84D)-NTD.PDF

CHAPTER 8 Helicopter Pad Systems

8-1 Helipad Perimeter Lighting.

8-1.1 Figure 85.

8-1.1.1 Notes to Designer.

1. The standard elevated fixture is an FAA type L-861 base mounted with 45 watt lamp. The maximum height is 14" (350mm) above grade except in areas where snow accumulations of 12" (300mm) or more are frequent, the mounting height may be increased to 24" (600mm) above grade.

2. In areas that are paved and used by wheeled helicopters or vehicles, in-pavement fixtures are used and are FAA type L-852E base mounted fixtures.

3. The perimeter lights are normally powered from a constant current regulator with a minimum of 3 brightness steps. However, some installations may utilize constant voltage circuits (120/240V) such as helipads on rooftops and/or hospitals.

4. The series circuit cable is FAA type L-824C #8 5 kV for 6.6 amp circuits.

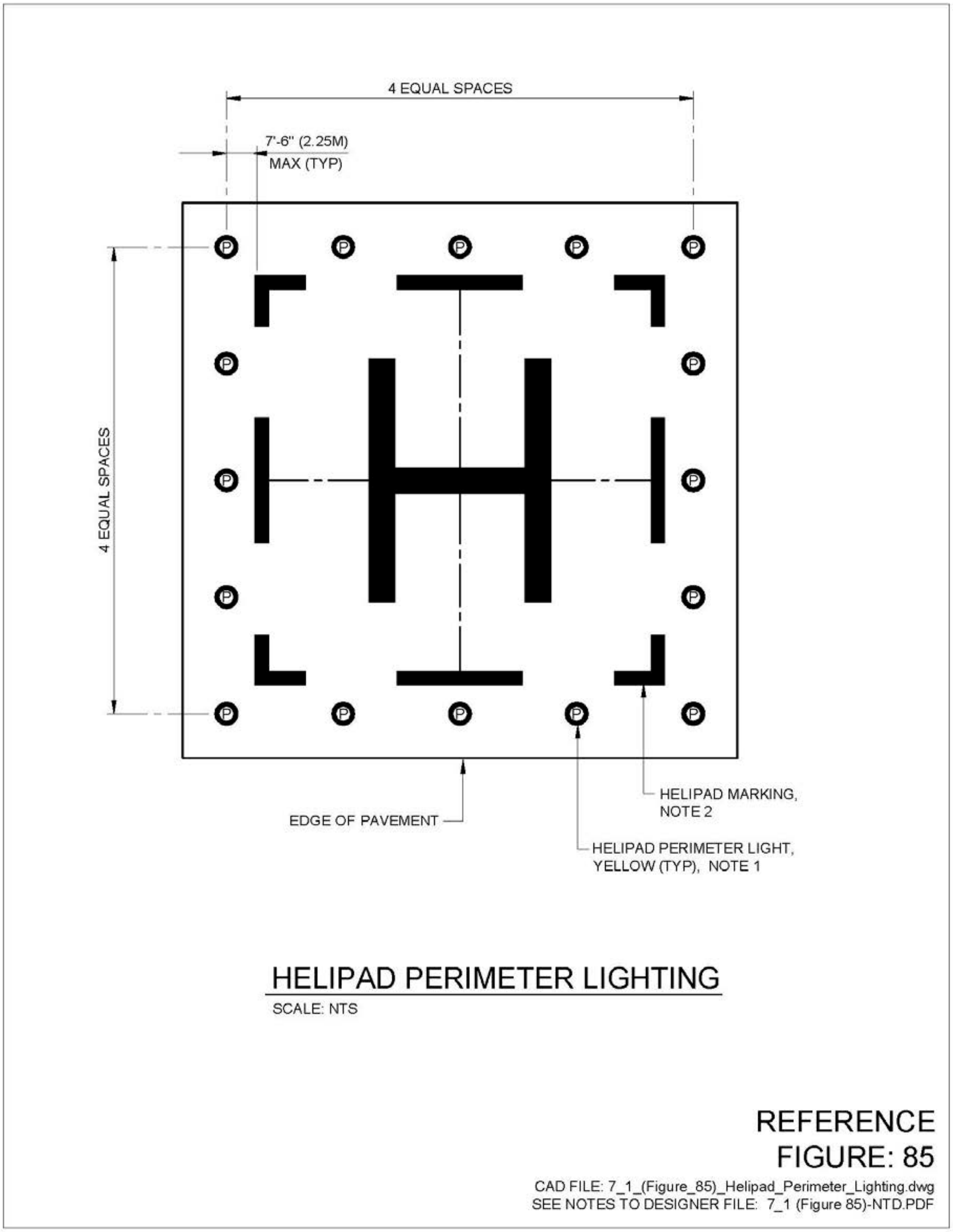
5. See ETL 04-2 for Air Force / Army marking standards and NAVAIR 51-50AAA-2 for Navy marking standards.

8-1.1.2 Drawing Notes for Figure 85.

1. Elevated lights must be base mounted FAA type L-861. In-pavement lights must be base mounted FAA type L-852E.

2. Markings based on 100' (30m) x 100' (30m) helipad. For other pads, markings will appear different.

Figure 85. Helipad Perimeter Lighting



8-2 Hospital Helipad Perimeter Lighting.

8-2.1 Figure 86.

8-2.1.1 Notes to Designer.

1. The hospital helipad perimeter light configuration is similar to the standard helipad light configuration except 4 additional lights are added. These lights are located 25' (7.5m) from the middle light on each side of the helipad. These lights and the corresponding middle lights are green. The remaining perimeter lights are yellow.

2. The color of lights for the hospital helipad should be coordinated with the user prior to design.

3. In areas where vehicle traffic will be crossing or accessing the helipad use in-pavement fixtures.

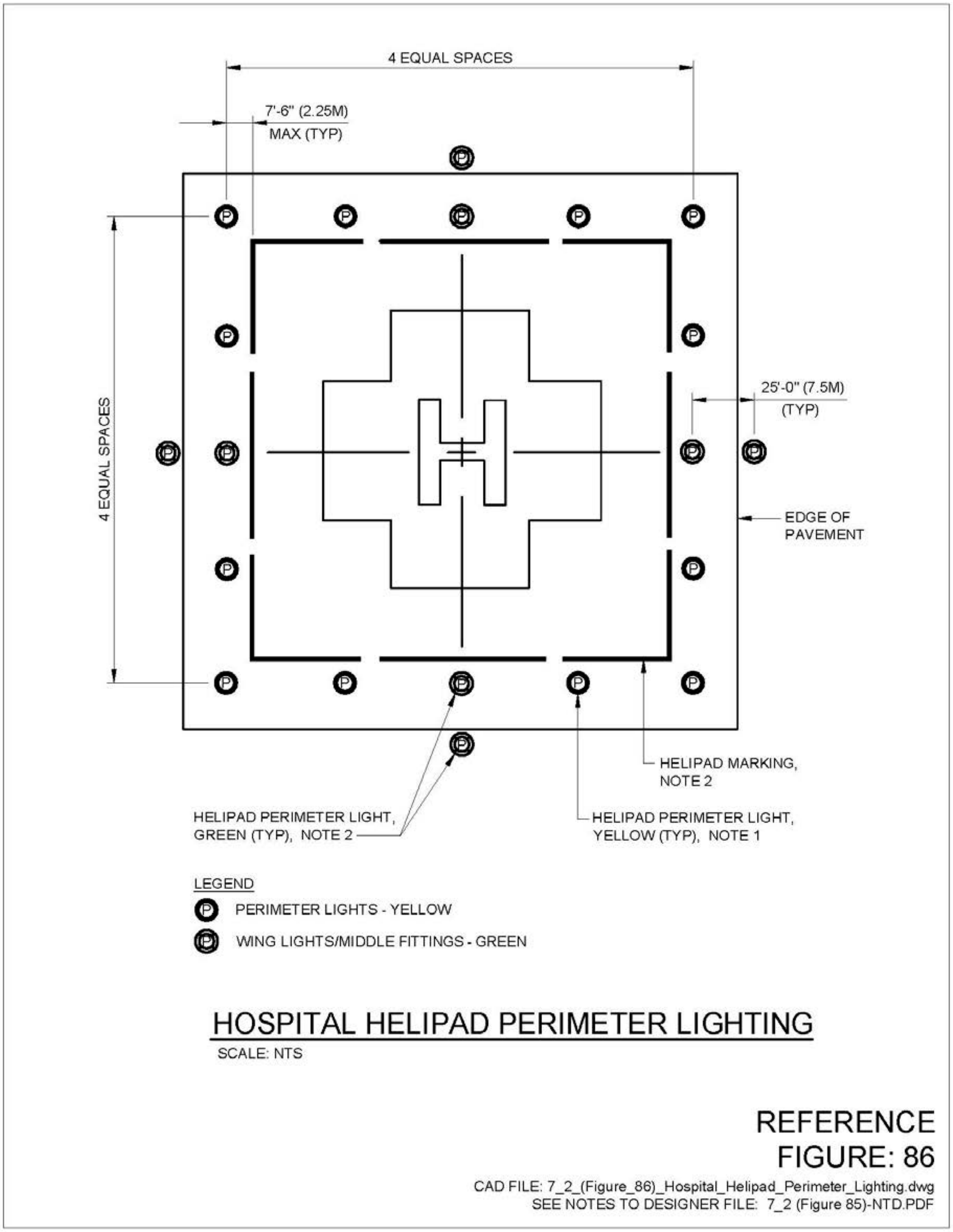
4. See ETL 04-2 for Air Force / Army marking standards and NAVAIR 51-50AAA-2 for Navy marking standards.

8-2.1.2 Drawing Notes for Figure 86.

1. Elevated lights must be base mounted FAA type L-861. In-pavement lights must be base mounted FAA TYPE L-852E.

2. Markings based on 100’ (30 m) x 100’ (30 m) helipad. For other pads, markings will appear different.

Figure 86. Hospital Helipad Perimeter Lighting



8-3 Helipad Landing Direction Lights.

8-3.1 Figure 87.

8-3.1.1 Notes to Designer.

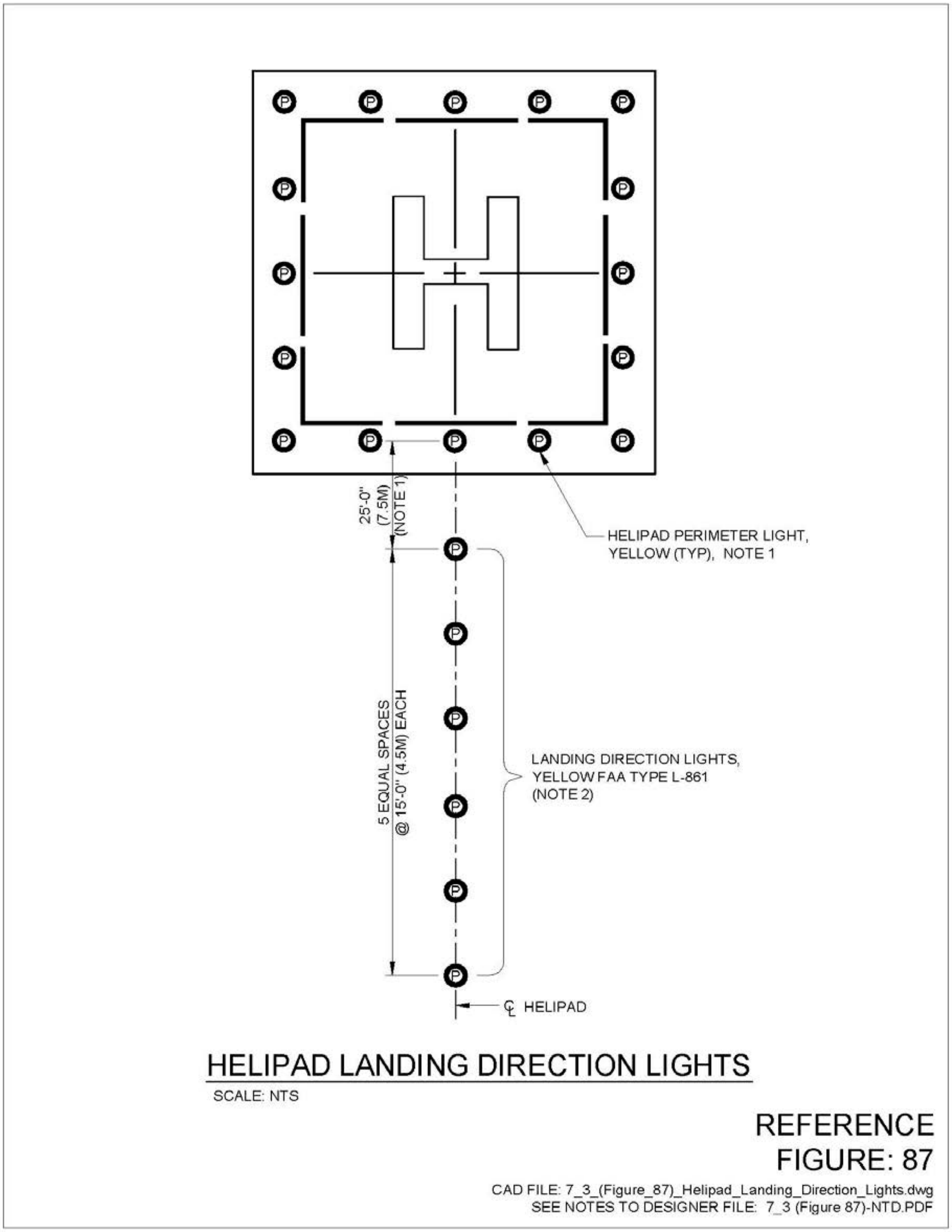
1. The landing direction lights may be powered from the regulator feeding the perimeter lights. The circuit may be separated by using an FAA type L-847 circuit selector switch, thereby allowing the direction lights to be switched off independently. The landing lights may not be switched on unless the perimeter lights are on.

8-3.1.2 Drawing Notes for Figure 87.

1. Landing direction light configuration for hospital helipad must start 25' (7.5m) from the outer perimeter light.

2. In-pavement fixtures must be used in areas of vehicle traffic and must be FAA type L-852E.

Figure 87. Helipad Landing Direction Lights



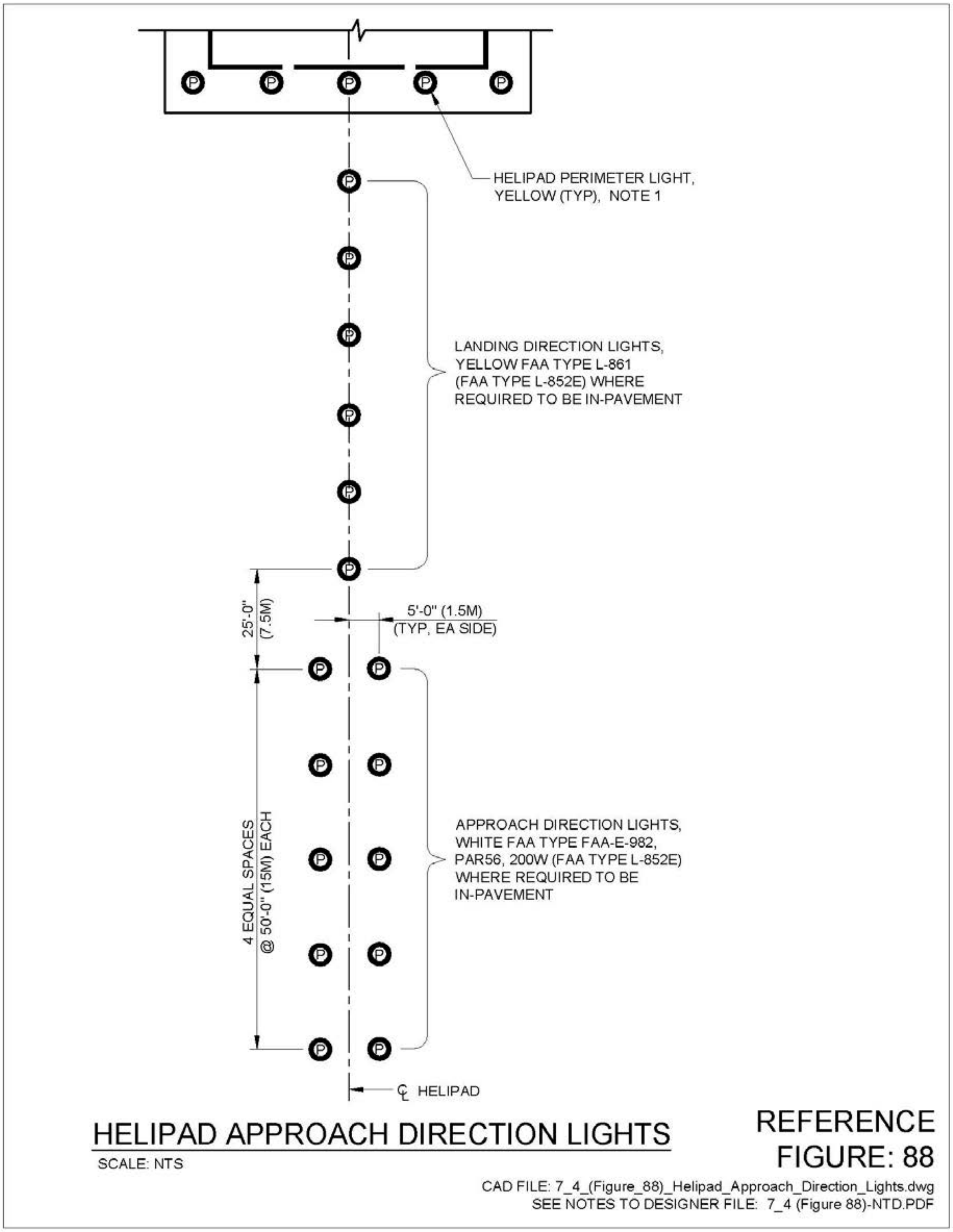
8-4 **Helipad Approach Direction Lights.**

8-4.1 **Figure 88.**

8-4.1.1 **Notes to Designer.**

1. The approach direction lights may be powered from the regulator feeding the perimeter and landing direction lights. The circuits may be separated by using an FAA type L-847 circuit selector switch, thereby allowing the approach direction lights to be switched off independently. The approach direction lights may not be switched on unless the perimeter and landing direction lights are on.

Figure 88. Helipad Approach Direction Lights



8-5 Helipad Lighting Wiring and Control Diagram.

8-5.1 Figure 89.

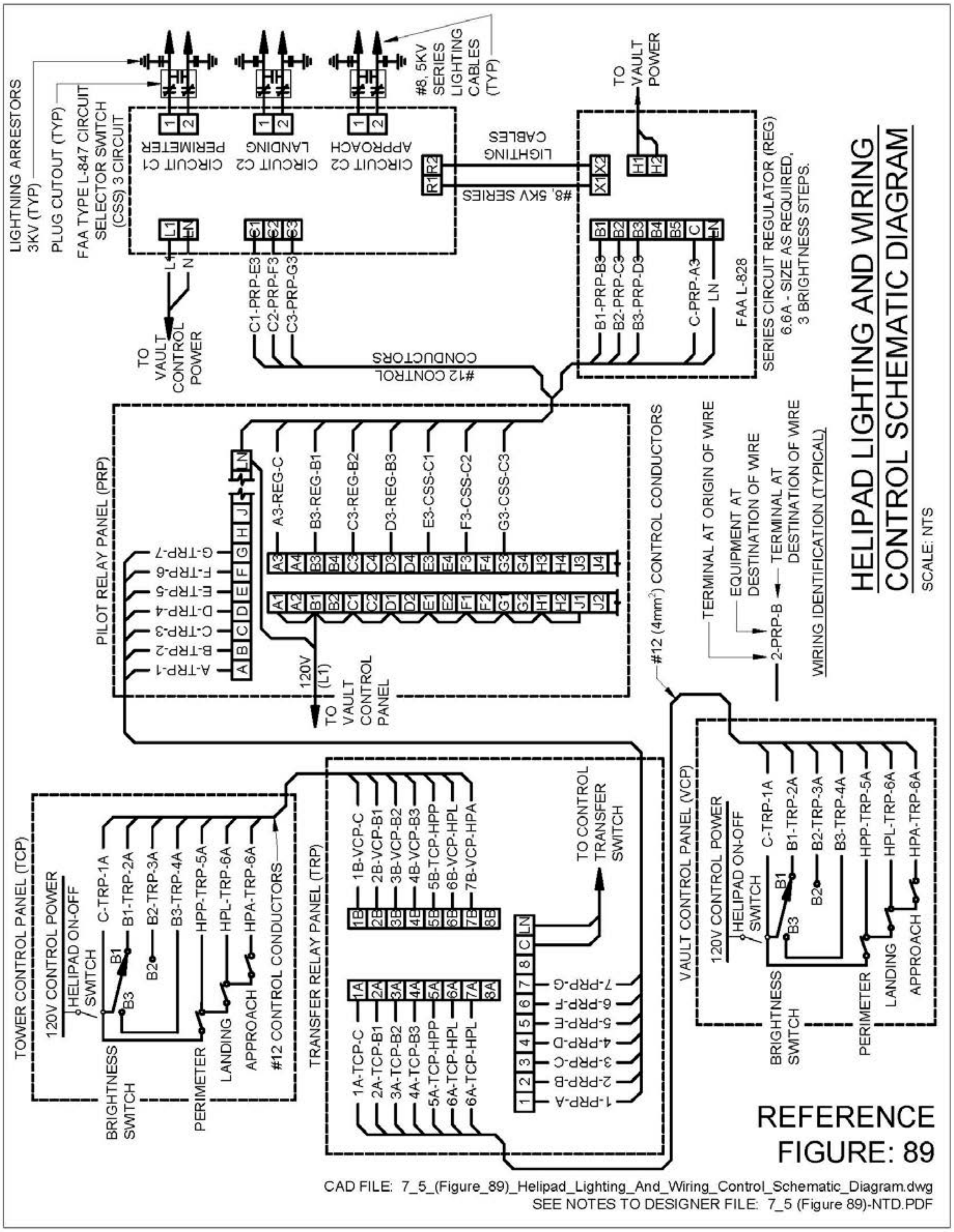
8-5.1.1 Notes to Designer.

1. Figure 89 shows a typical control diagram at a facility with an airfield lighting vault and control tower. A single constant current regulator with 3 brightness steps is used to power the system.

2. The helipad lights are separated into 3 circuits: C1 – perimeter, C2 – landing direction, and C3 – approach direction. Each circuit is operated by a SPST toggle switch that energizes the corresponding loop relay in the L-847 circuit selector switch. The 3 switches are connected such that the landing direction lights cannot be on unless the perimeter lights are on and the approach direction lights cannot be on unless the landing direction lights are on.

3. In some installations 120/240V is used to power the circuits in lieu of constant current regulators. In these cases separate branch circuits are used together with lighting contactors and interlock switches.

Figure 89. Helipad Lighting Wiring and Control Schematic Diagram



CHAPTER 9 Naval Facilities Specific Wave-Off & Wheels-Up Lighting Systems

9-1 Location Plans: Wave-Off & Wheels-Up Lighting Systems.

9-1.1 Figure 90.

Notes to Designer.

9-1.1.1 Wave-off Lighting System.

1. Description. The runway wave-off light system consists of sets of simultaneously flashing red lights installed adjacent to the runway which are aimed toward the threshold. They are intended to inform the pilot that an emergency wave-off or missed approach procedure is necessary. The runway wave-off must be activated from either the control tower, airfield lighting vault, or the wheels-watch station.

2. Power Requirements. Power for the wave-off power converter unit (PCU) must be from a 480 volt source. A single 10 kVA minimum 2400/480V pad mount (weatherproof) transformer may supply the power for the wave-off lights via the PCU.

3. Control Requirements. The wave-off lights must be controlled manually using momentary-contact type switches. The switches must be located only at the control tower, airfield lighting vault, and the wheels-watch station.

4. Control relay must be general purpose, hermetically sealed, 4pdt, 3 amp contacts with 120vac, 60hz coil.

5. Time delay relay must have 10 amp, 120vac contacts with 120vac 60hz coil relay must have one normally-open instantaneous contacts and one normally-closed time delay opening contact adjustable from 5 to 60 second delay on energizing but initially set for 15 seconds delay.

6. Contactor must have two normally-open 30 amp, 480vac contacts with 120vac, 60hz coil.

7. Wave-off pushbuttons must be normally-open momentary contacts. Locate pushbuttons within control tower as directed by the air traffic control officer.

8. If possible use spare conductors in the control tower that runs between the airfield lighting vault and the control panel within the control tower.

9. If available use spare pilot and transfer relays within the airfield lighting vault.

10. Provide 2 - 2" (53mm) conduits (1 - spare) between power converter units (PCU). Also provide 2 - 2" (53mm) conduits (1 - spare) between PCU and threshold.

11. Provide 1 - 2" (53mm) conduit between PCUs and optical assembly units.

9-1.1.2 **Wheels-up Lighting System.**

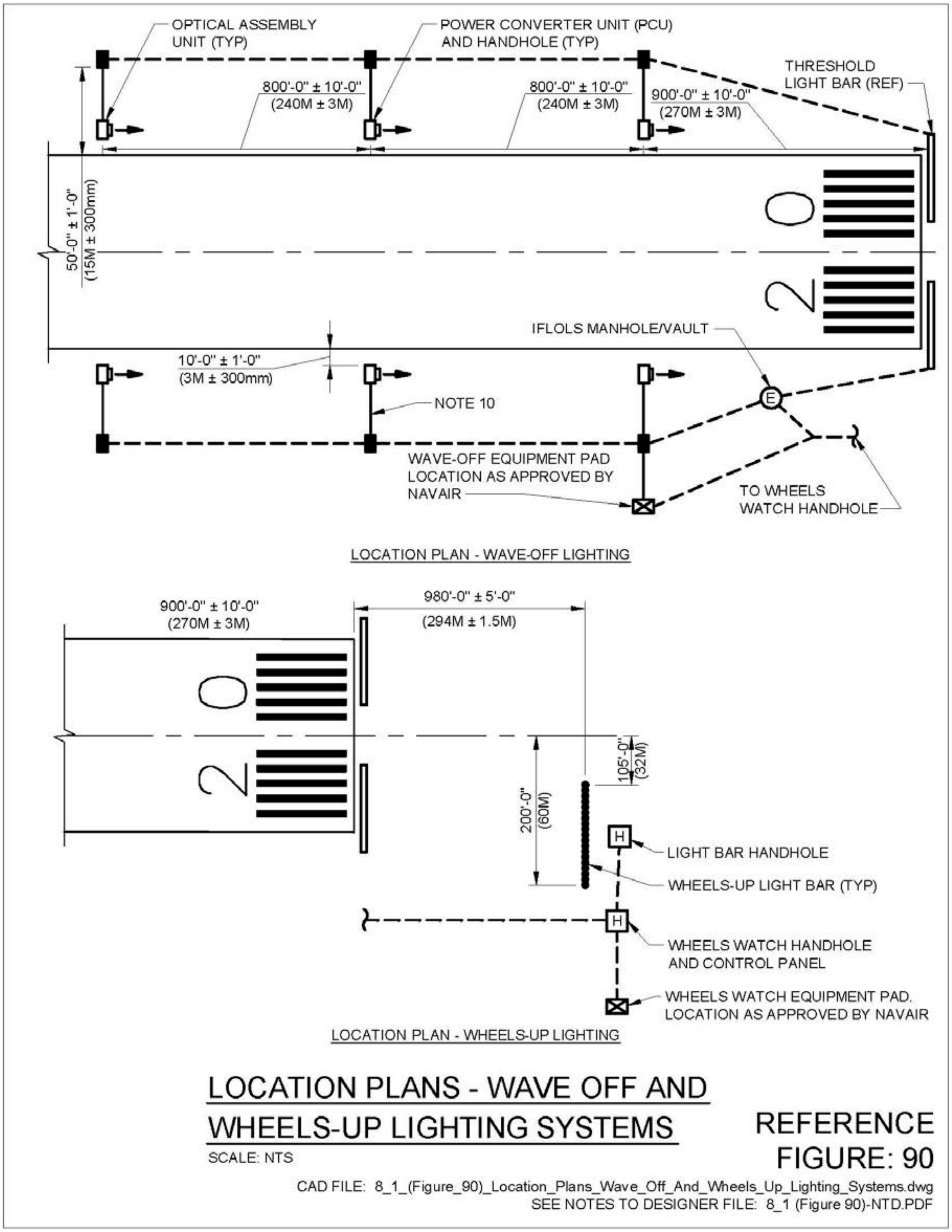
1. Description. Wheels-up lights are a bar of white lights installed under the approach which are aimed upward and toward the threshold. They are intended to illuminate the underside of landing aircraft to permit observers to determine that the landing gear is fully lowered. The system also includes a portable government furnished wheels-watch shelter which protects the observer from the weather and a wheels-watch control panel.

2. Power Requirements. Wheels-up lights are connected to 120 Vac multiple circuits requiring somewhat in excess of 10kW. A 15 kVA pad mount transformer (weatherproof) is recommended.

3. Control Requirements. Wheels-up lights require on/off control and continuous intensity control from 10 to 100 percent of intensity at the rated voltage. This control is required only at the wheels-watch control panel.

4. The wheels-watch control panel also contains a switch which is activated by the observer that energizes the wave-off lighting system.

Figure 90. Location Plans – Wave-Off & Wheels-Up Lighting Systems



9-2 Equipment Pad and Duct Details.

9-2.1 Figure 91.

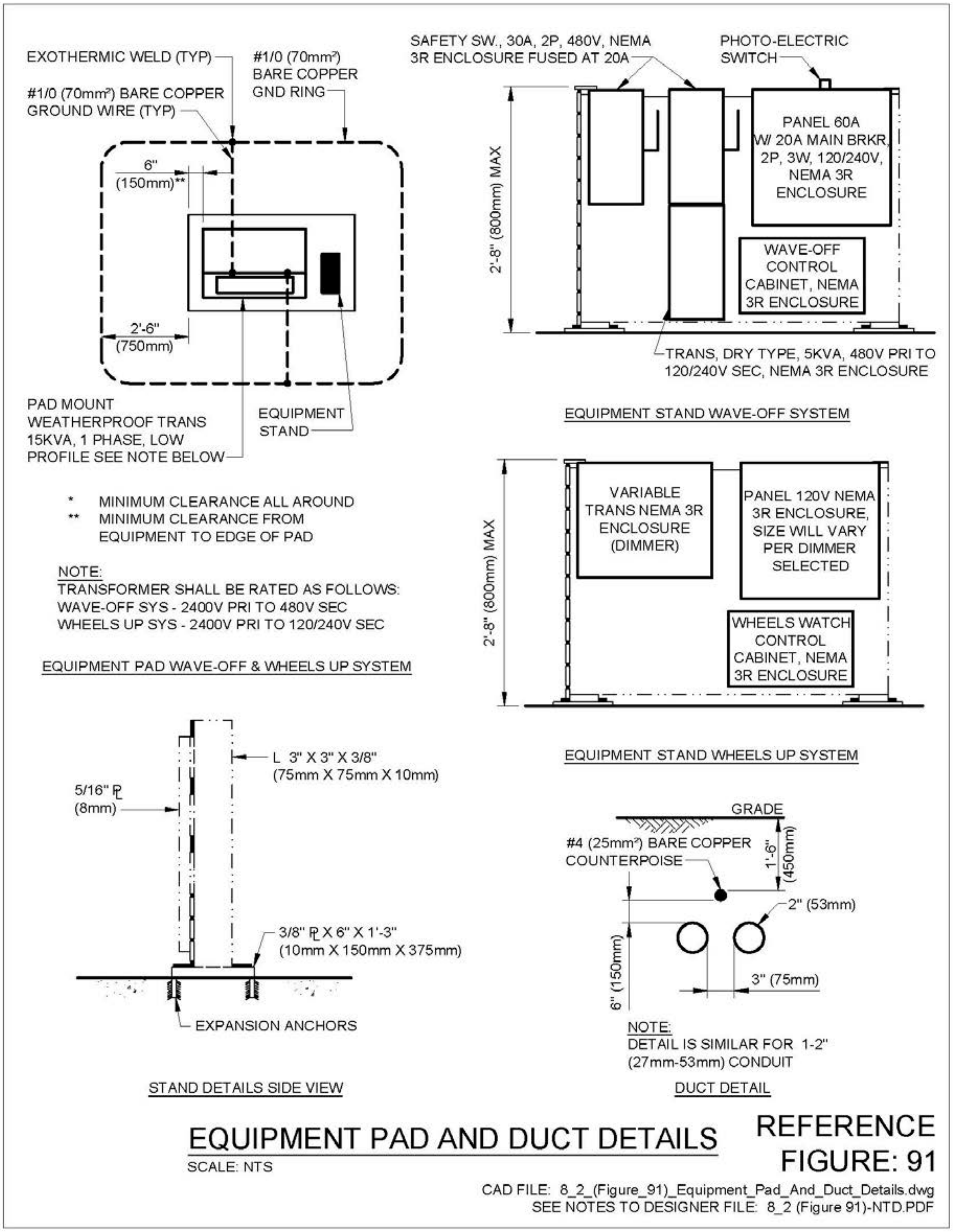
9-2.1.1 Notes to Designer.

1. The equipment stands for the wave-off and wheels-up lighting systems are freestanding and a maximum of 32" (800mm) above grade.

2. The equipment is rated NEMA 3R (weatherproof). In some areas where corrosion may be a problem (i.e. salt, sand, etc.); the use of NEMA 4X rated equipment may be justified.

3. The equipment pads should be located as close as possible to the lighting system (first power converter unit (PCU) of wave-off system and wheels-watch control panel) to limit the voltage drop to the system components. However, NAVFAC ENGCOM should be consulted before placement within the runway safety area or object free zone.

Figure 91. Equipment Pad and Duct Details



9-3 Wave-Off System Wiring Details.

9-3.1 Figure 92.

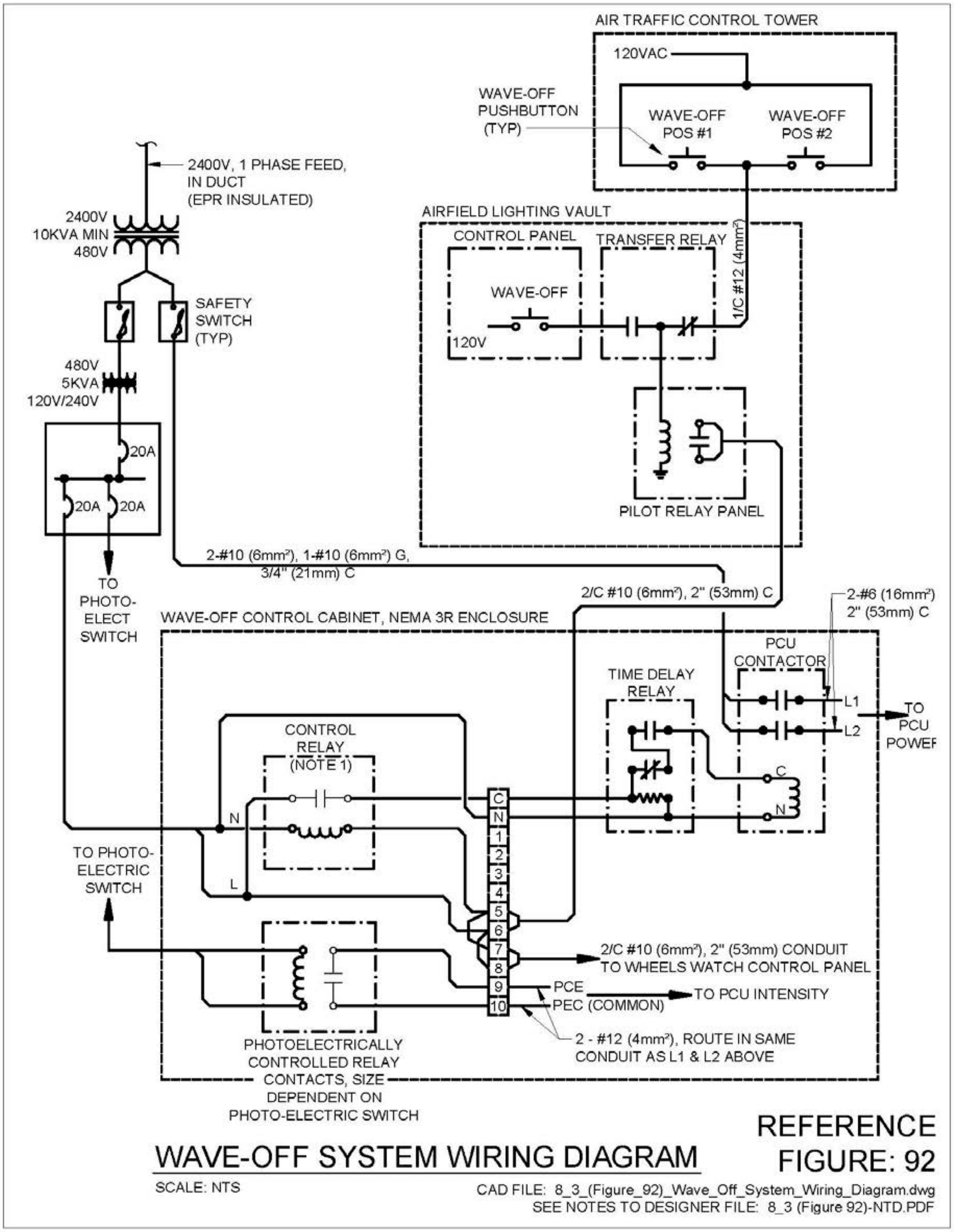
9-3.1.1 Notes to Designer.

1. The wave-off system may be activated by the air traffic controller in the control tower or by personnel in the airfield lighting vault via the transfer relay.

2. The system may also be activated by the observer at the wheels watch control panel.

3. The photoelectric switch controls the intensity of the wave-off system. The system operates at maximum intensity during daytime hours and reduced intensity during hours of darkness.

Figure 92. Wave-Off System Wiring Details



9-4 Flashhead and PCU Wiring Diagram.

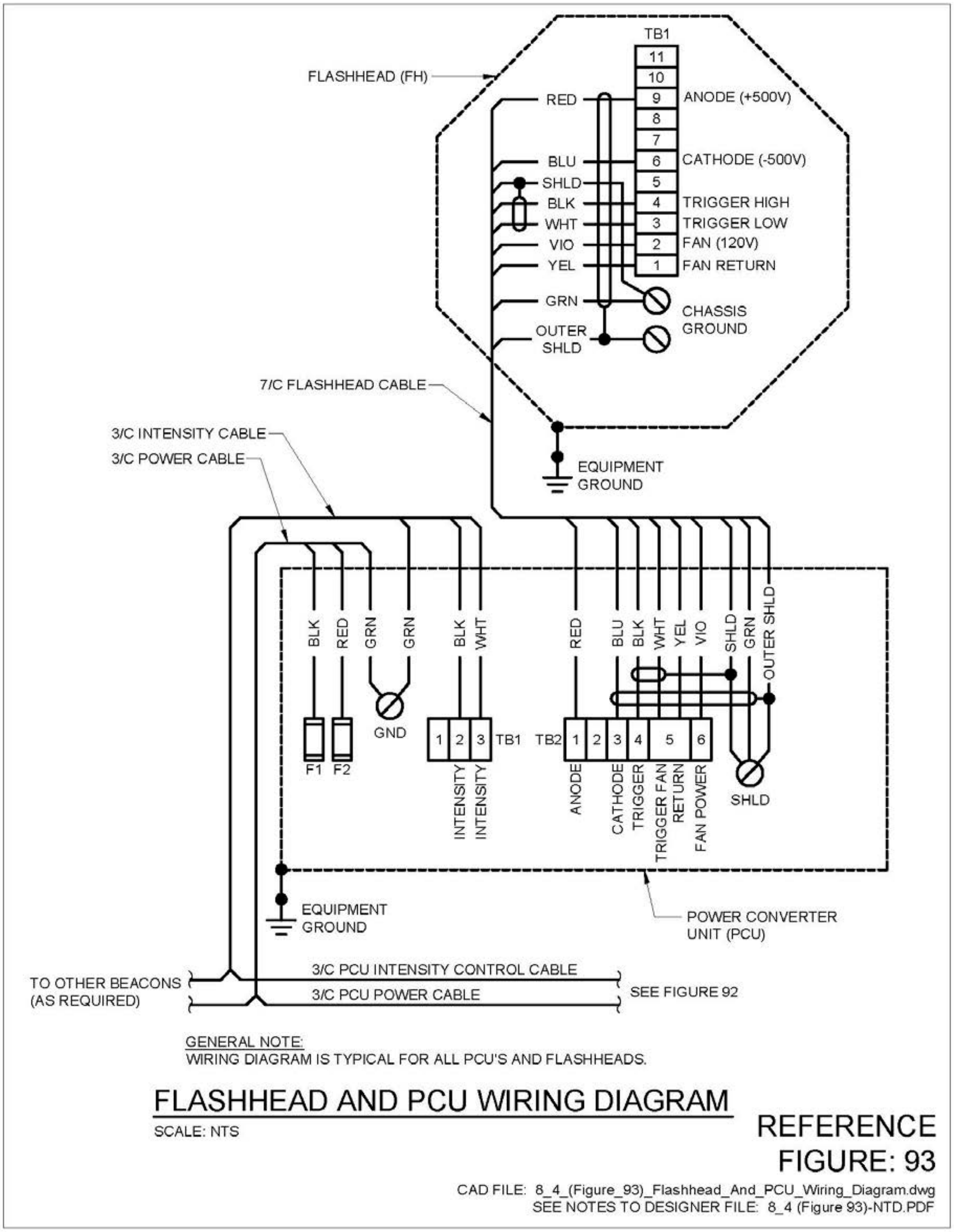
9-4.1 Figure 93.

9-4.1.1 Notes to Designer.

1. 480 Volts, single phase power is delivered to each power converter unit (PCU) from the PCU contactor located in the wave-off control cabinet.

2. Intensity control to each PCU is routed in the same conduit as the power conductors and originates at the photo-electrically controlled relay in the wave-off control cabinet.

Figure 93. Flashhead and PCU Wiring Diagram



9-5 **Wave-Off Fixture Mounting.**

9-5.1 **Figure 94.**

9-5.1.1 **Notes to Designer.**

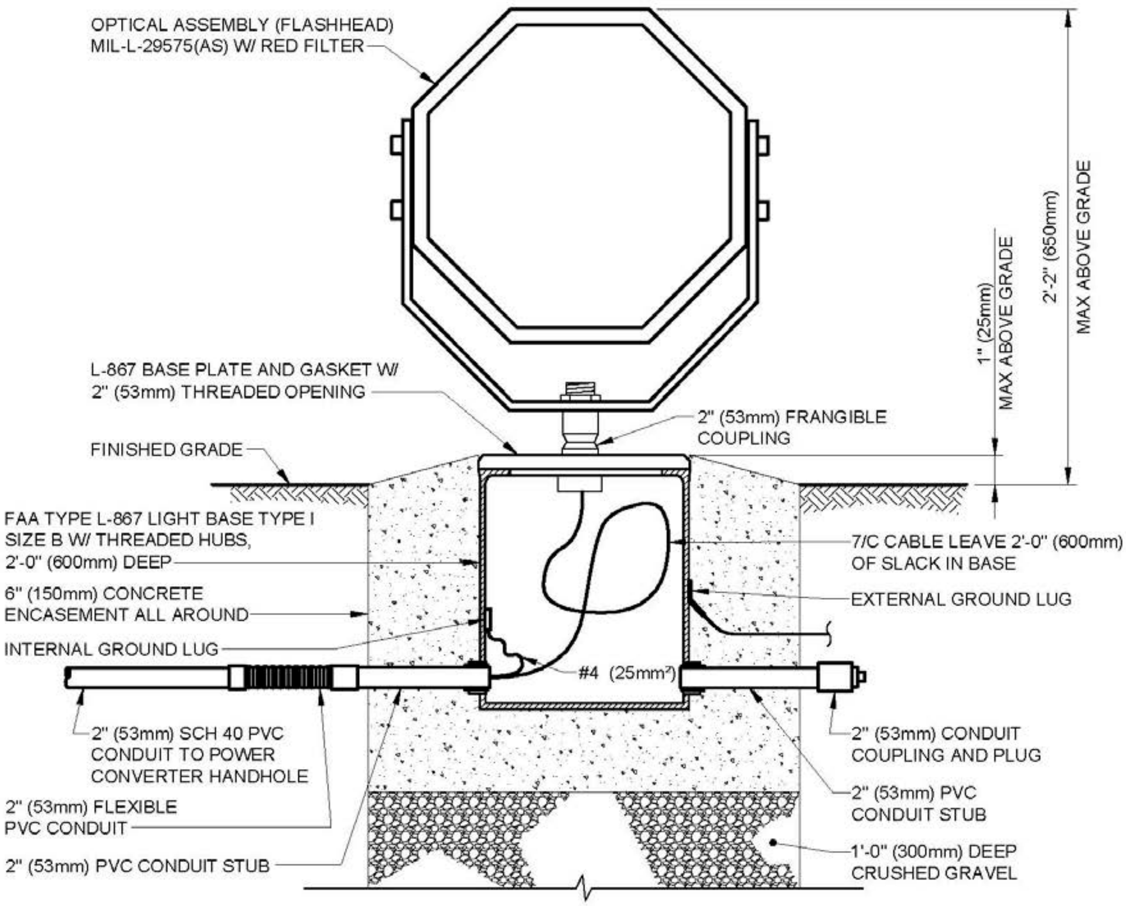
1. The optical assembly (flash head) is mounted on an FAA type L-867 concrete encased light base.

2. The flexible non-metallic conduit allows movement in the 2" (53mm) conduit due to freeze-thaw cycles in frost susceptible areas.

9-5.1.2 **Drawing Notes for Figure 94.**

1. Reinforcing cage indicated on Figure 12.

Figure 94. Wave-Off Fixture Mounting



WAVE-OFF FIXTURE MOUNTING

SCALE: NTS

REFERENCE
FIGURE: 94

CAD FILE: 8_5_(Figure_94)_Wave_Off_Fixture_Mounting.dwg
SEE NOTES TO DESIGNER FILE: 8_5 (Figure 94)-NTD.DOC

9-6 **Wave-Off Fixture Aiming.**

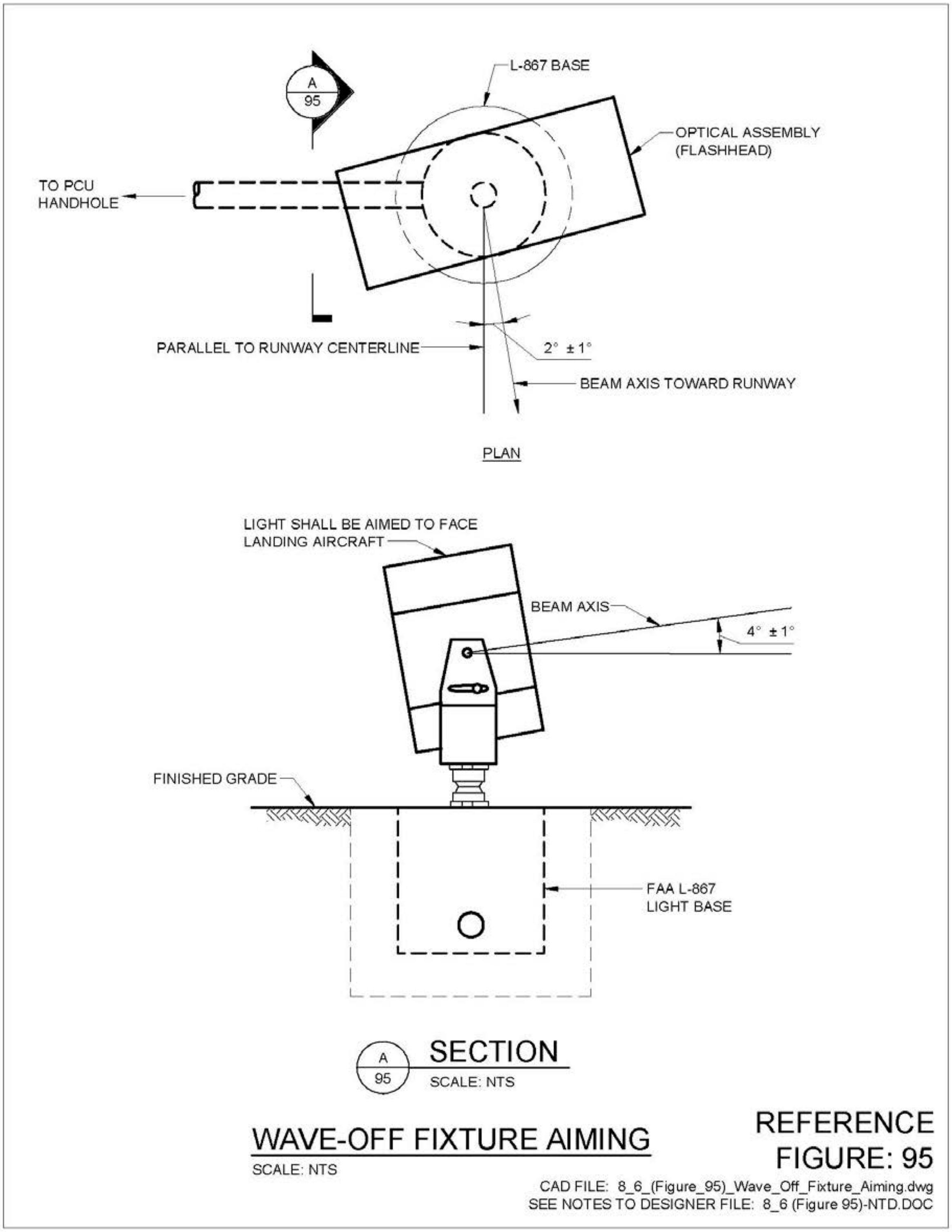
9-6.1 **Figure 95.**

9-6.1.1 **Notes to Designer.**

1. The wave-off fixture is aimed towards the landing aircraft as indicated.

2. Construction document should include the aiming requirements.

Figure 95. Wave-Off Fixture Aiming



9-7 Power Converter Unit.

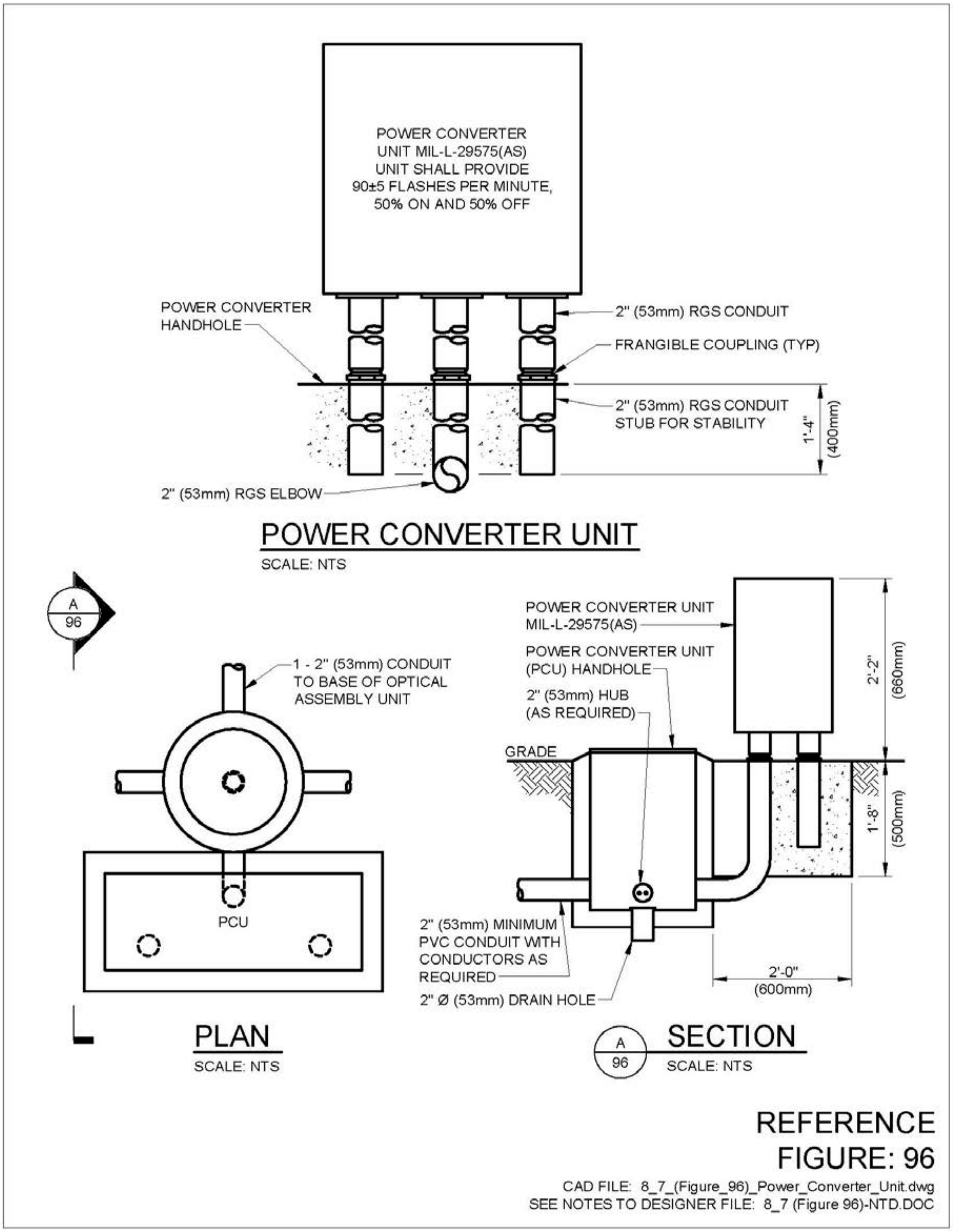
9-7.1 Figure 96.

9-7.1.1 Notes to Designer.

1. Use an FAA type L-867 Size D (16" ∅) light base concrete encased. Conduit openings are 2" thread hubs and must be specified ((2) 2" (53mm) one above the other at 0 degrees and 180 degrees, (1) 2" (53mm) at 90 degrees and 270 degrees).

2. Install 6" (150mm) long flexible non-metallic conduit (not indicated) on each conduit after leaving handhole.

Figure 96. Power Converter Unit



9-8 Wheels-Up Lighting System Layout.

Figure 97. Reserved

Figure 98. Reserved.

9-8.1 Figure 99.

9-8.1.1 Notes to Designer.

1. The wheels-up lights are located and aimed as indicated.

2. Coordinate with NAVAIR on location of the equipment pad. Design for a maximum voltage drop of ±4% total from the equipment pad to the farthest fixture in the system. #6 (16 square mm) must be the minimum wire size.

9-8.1.2 Drawing Notes for Figure 99.

1. Wheels up light bar must be located on same side of runway as the control tower.

2. Relocation or re-aiming of light bar requires approval of NAVFACENGCOM.

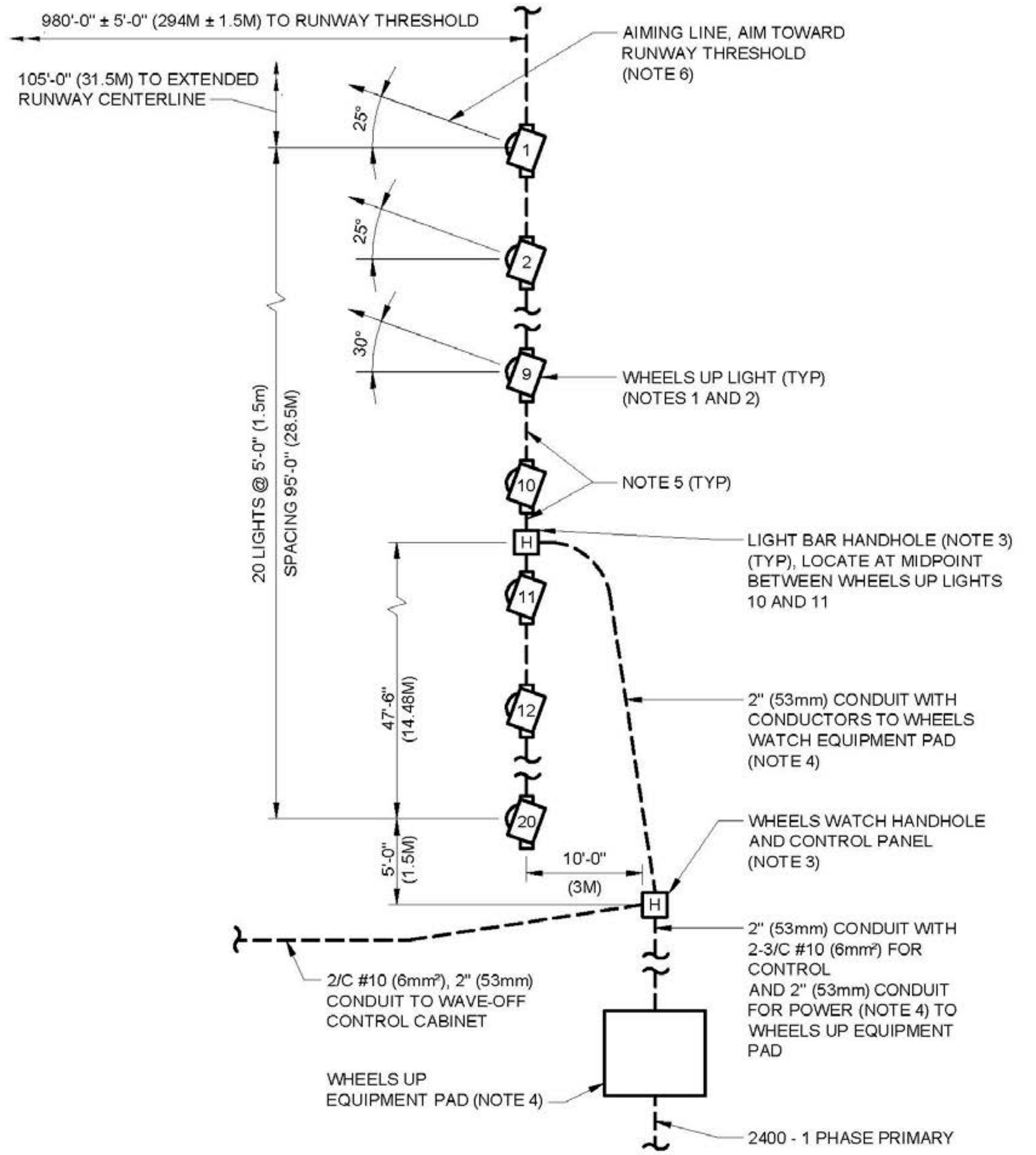
3. Provide L-867D handhole per Figure 31.

4. Conductor size between light bar handhole and wheels up equipment pad must be determined once location of equipment pad is approved by NAVAIR. The total voltage drop for the wheels-up lighting circuit must be maintained to ±4% or less.

5. Conductor size between light bar handhole and wheels-up lights must be 2 #6 (16 square mm), 1 #6 (16 square mm) ground in 2" (53mm) conduit.

6. The three (3) inner most lights are aimed toward the runway at an angle of 25 degrees.

Figure 99. Wheels – Watch System Layout



WHEELS - WATCH SYSTEM LAYOUT

SCALE: NTS

REFERENCE FIGURE: 99

CAD FILE: 8_10_(Figure_99)_Wheel_Watch_System_Layout.dwg
SEE NOTES TO DESIGNER FILE: 8_10 (Figure 99)-NTD.PDF

9-9 **Wheels-Up Lighting Wiring Diagram.**

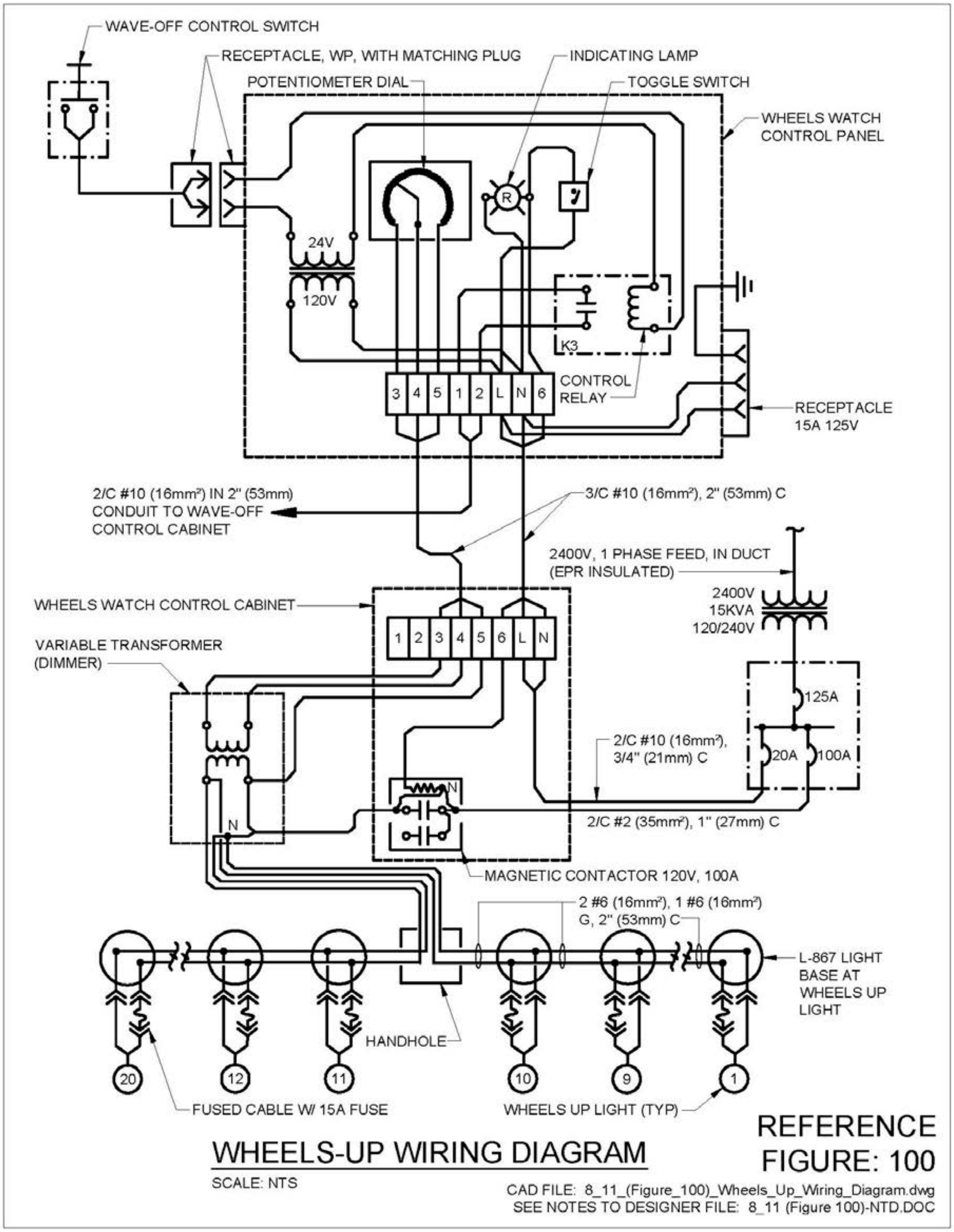
9-9.1 **Figure 100.**

9-9.1.1 **Notes to Designer.**

1. The observer varies the intensity of the lights by the potentiometer located in the control panel.

2. Activation of the wave-off system is accomplished by the wave-off control connected to the control panel by a flexible cord.

Figure 100. Wheels-Up Wiring Diagram



9-10 Wheels-Up Light Fixture.

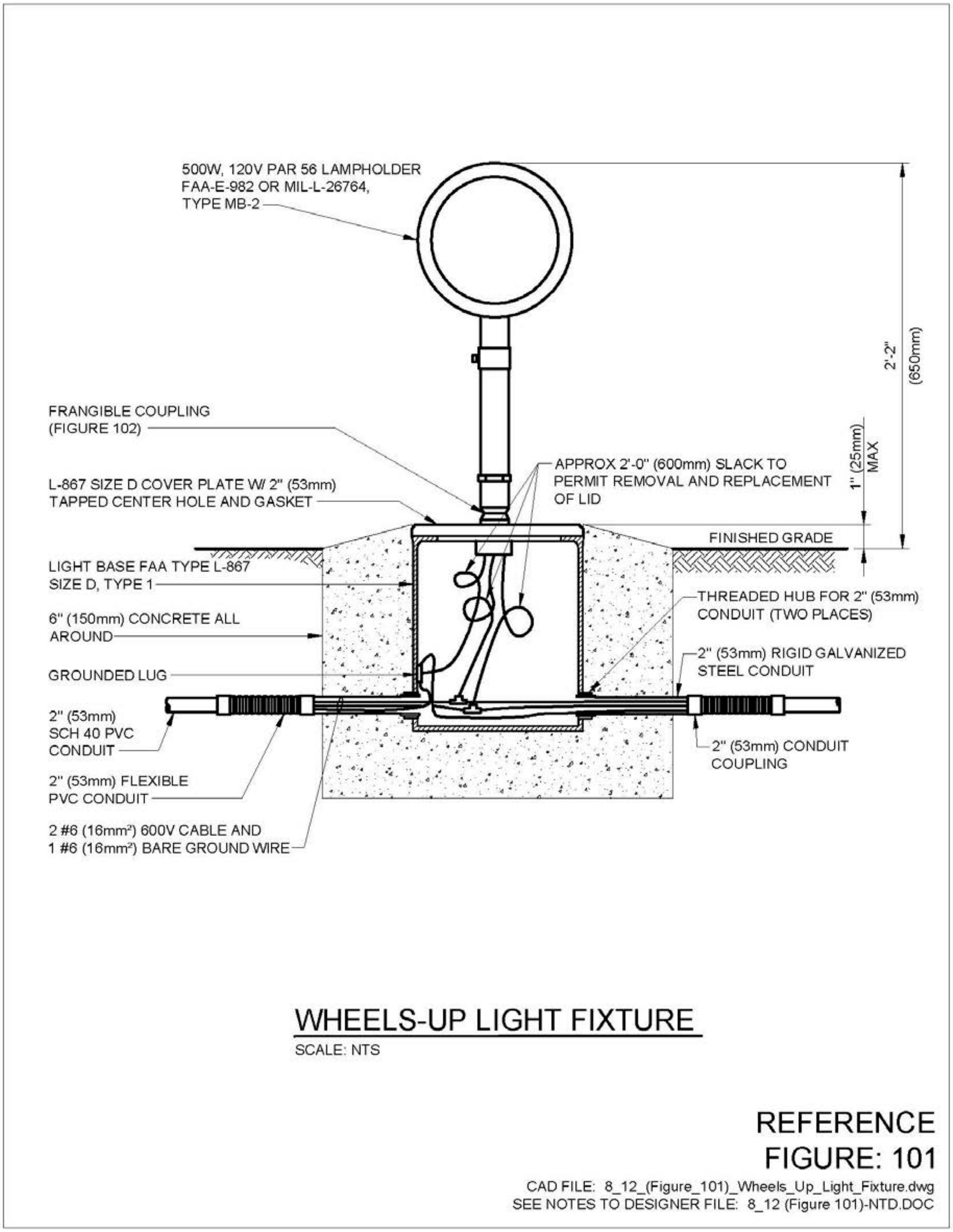
9-10.1 Figure 101.

9-10.1.1 Notes to Designer.

1. The wheels-up lighting system is a constant voltage system. The lamp shorting device which is part of an FAA-E-982 fixture is not used.

2. The flexible non-metallic conduit allows play in the conduit due to freeze-thaw cycles in areas susceptible to frost penetration or alignment with conduits.

Figure 101. Wheels-Up Light Fixture



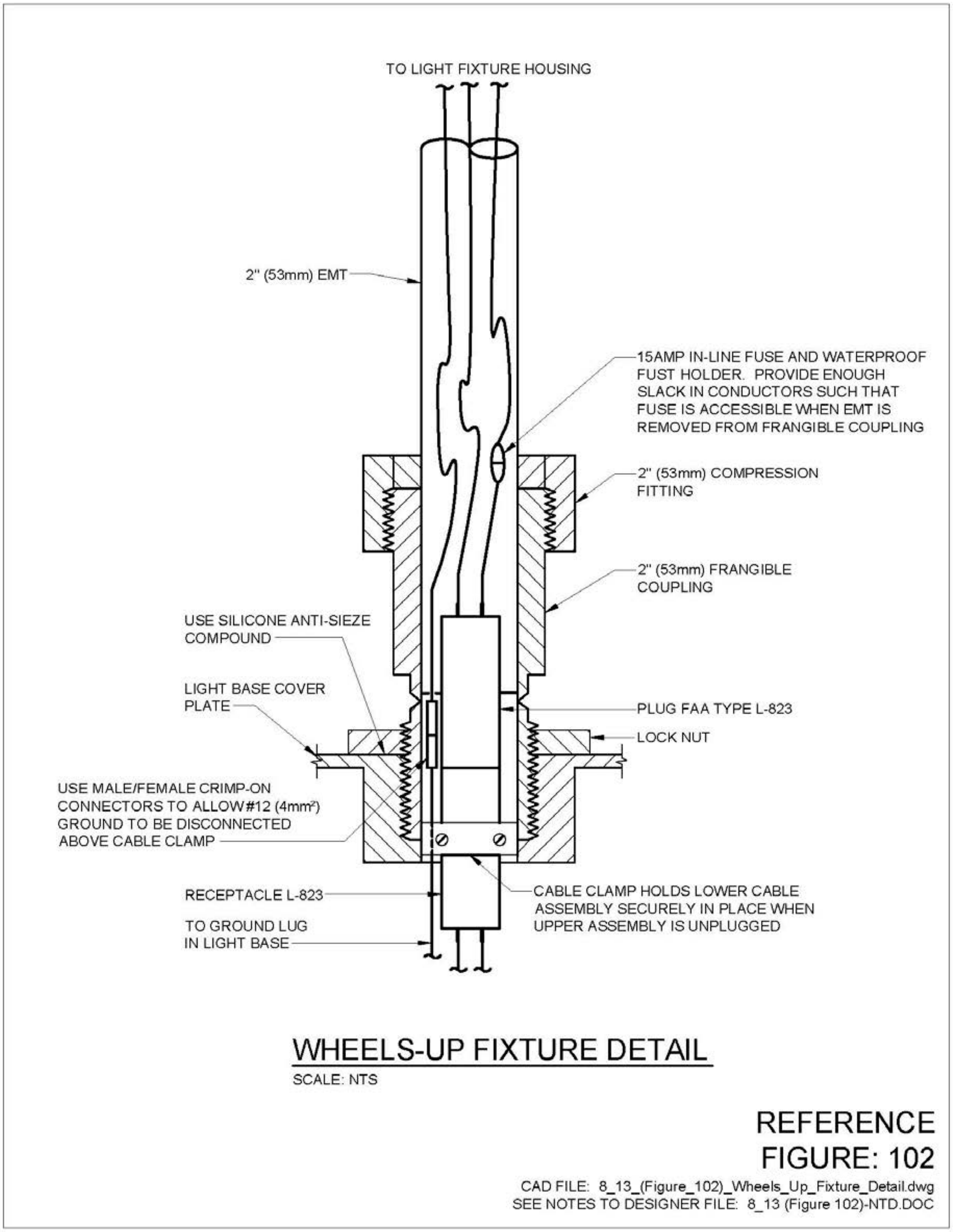
9-11 **Wheels-Up Light Fixture.**

9-11.1 **Figure 102.**

9-11.1.1 **Note to Designer.**

1. The in-line fuse sets inside the EMT conduit. Enough slack should be provided such that the fuse is accessible when the EMT is removed from the frangible coupling.

Figure 102. Wheels-Up Light Fixture



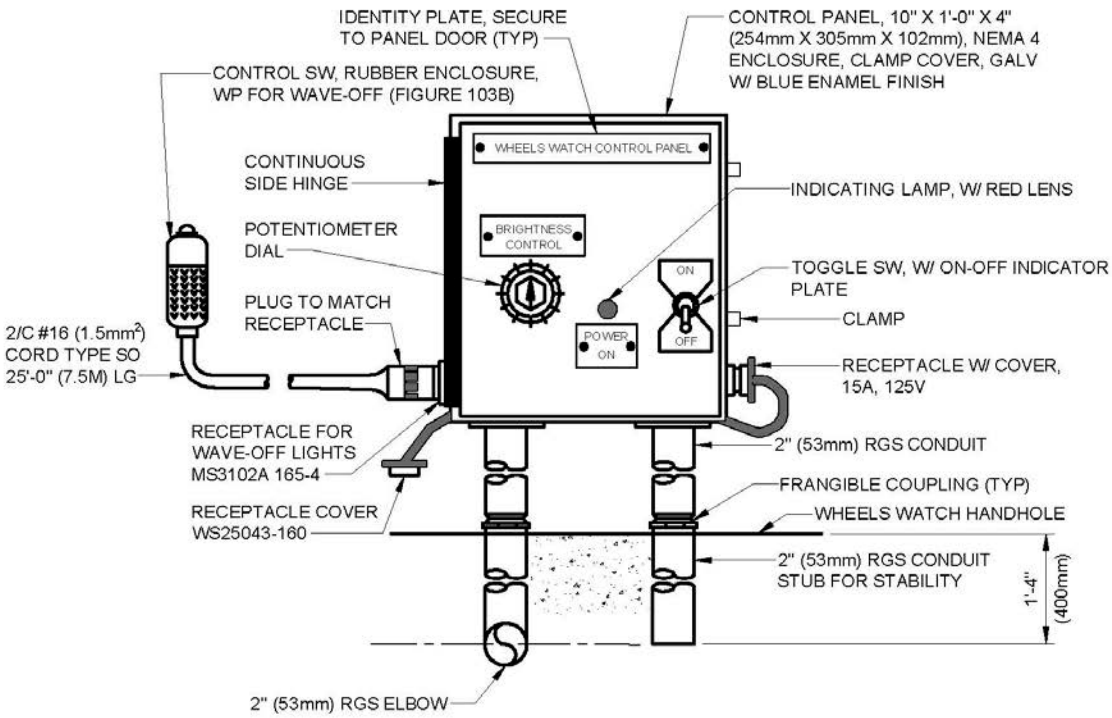
9-12 **Wheels-Watch Control Panel.**

9-12.1 **Figures 103A, 103B.**

9-12.1.1 **Note to Designer.**

1. Use an FAA type L-867 Size D (16" ∅) concrete encase light base with 2" (53mm) threaded hubs for conduit located at 0 degrees, 90 degrees, and 180 degrees.

Figure 103A. Wheels-Watch Control Panel



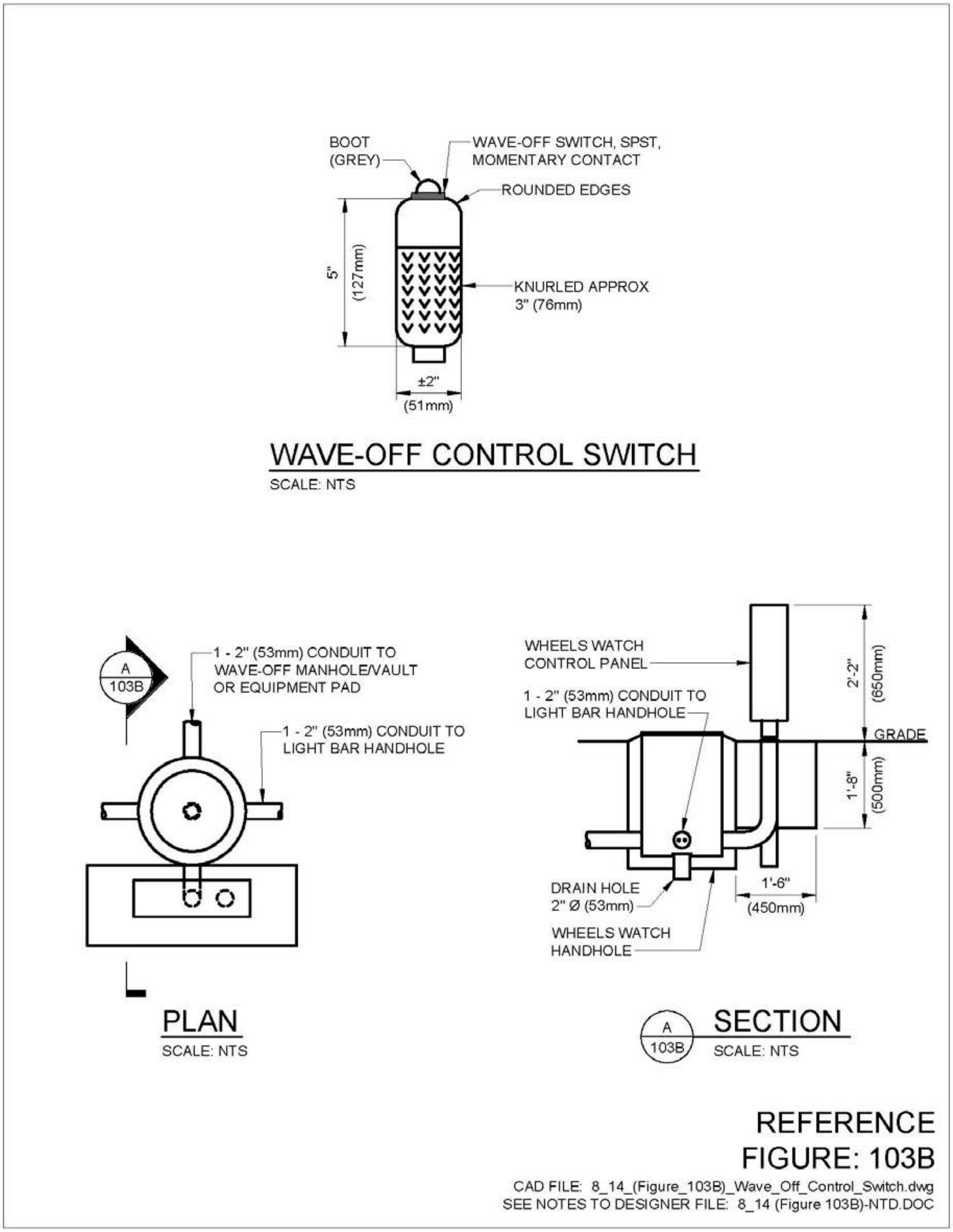
WHEELS-WATCH CONTROL PANEL

SCALE: NTS

REFERENCE
FIGURE: 103A

CAD FILE: 8_14_(Figure_103A)_Wheels_Watch_Control_Panel.dwg
SEE NOTES TO DESIGNER FILE: 8_14 (Figure 103A)-NTD.DOC

Figure 103B. Wave-Off Control SW



CHAPTER 10 Naval Facilities Specific Simulated Carrier Deck Systems

10-1 Simulated Carrier Deck Lighting System Layout Plan & Wiring Diagram.

10-1.1 Figures 104A, 104B, 104C.

10-1.1.1 Notes to Designer.

1. The simulated carrier deck lighting system is installed on a runway along with the associated carrier deck markings to provide a training and practice environment for carrier deck approaches and landings. The system is controlled by a landing signals officer (LSO) via a portable control panel and control switch. The panel and switch are connected to a submersible terminal box located in the LSO handhole.

2. Siting of simulated carrier deck lighting system must be in accordance with NAVAIR 51-50AAA-2.

3. Designer must lay out simulated carrier deck saw kerfs for minimal crossing of centerline lighting system saw kerfs.

4. All wiring installed in saw kerfs must be single conductor #10 (6 square mm), 600V, type THWN-2.

5. For new runway construction, the entire width of the deck lighting system must be Portland Cement Concrete (PCC). Airfield lighting designer must coordinate installation of FAA L-868 light bases and 2" (53mm) conduit with isolation transformers in each light base.

6. Where simulated carrier deck lighting systems are to be installed in existing runways having a flexible pavement surface, guidance must be received from COMNAVFACENGCOM.

7. Inset light fixtures must be a 45 watt, 6.6 amp, in-pavement, unidirectional inset light per FAA L-852N, type V or VI. Base mounted type must be either type VII or VIII. Fixture must have extra strength stainless steel housing and thickened, hardened top optical casting. Lamps must be provided with a shorting disc to allow operation of other lamps upon single lamp burnout.

8. Distance from runway to handhole varies up to 10 ft (3m) maximum. Designer will minimize offset distance to satisfy field conditions.

9. Marking of runway pavement for simulated carrier deck system must comply with NAVAIR 51-50AAA-2.

10. Lights are aimed parallel with the centerline and toward the runway threshold.

11. Outermost lights on ramp athwartship, and forward athwartship lights must be in line with the carrier deck edge lights; all lights are on 5’ (1.5m) spacing.

12. There are 17 centerline lights, 34 edge lights, 12 ramp athwartship lights, and 12 forward athwartship lights.

Figure 104A. Simulated Carrier Deck Lighting System – Layout Plan

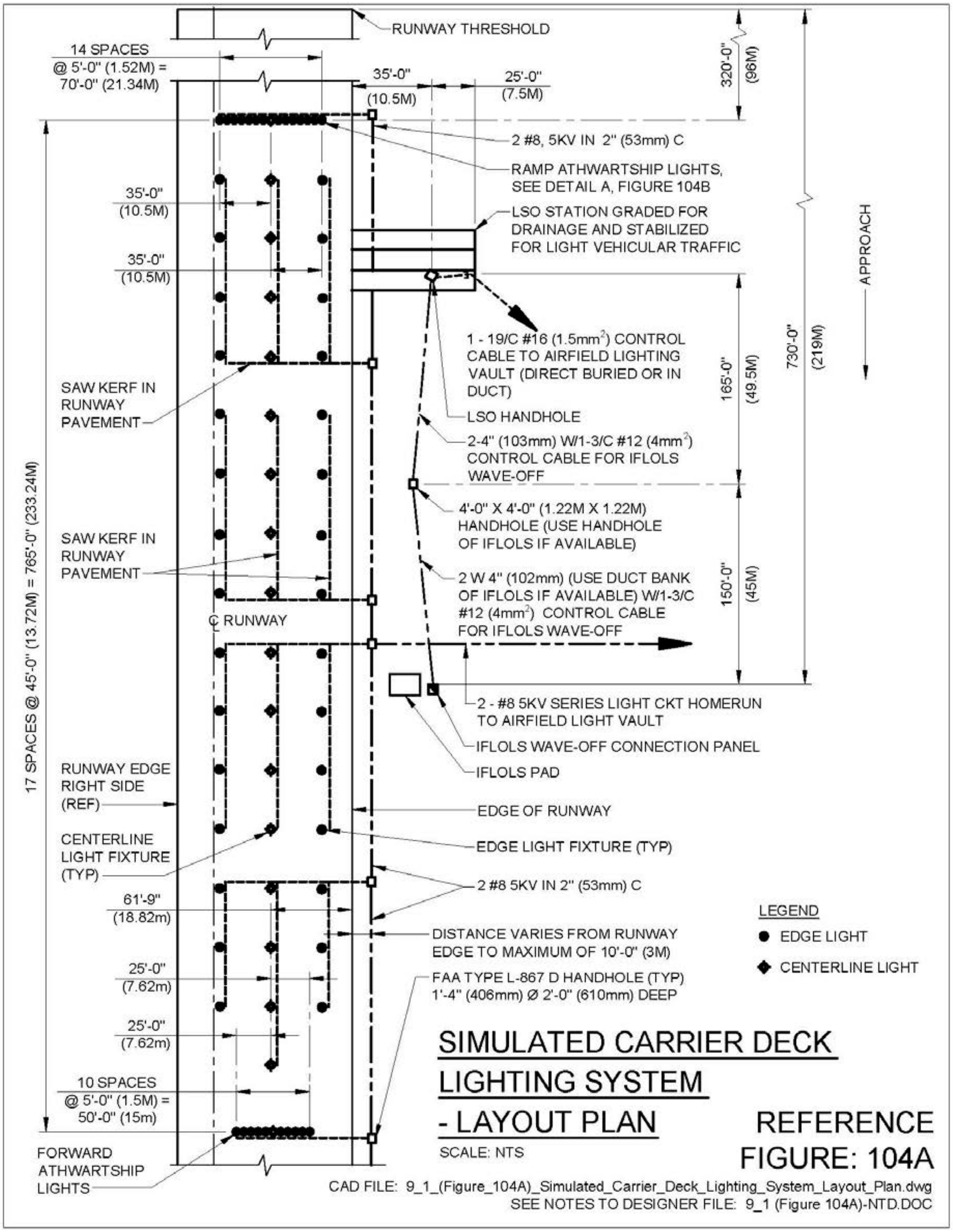


Figure 104B. Simulated Carrier Deck Lighting System – Detail

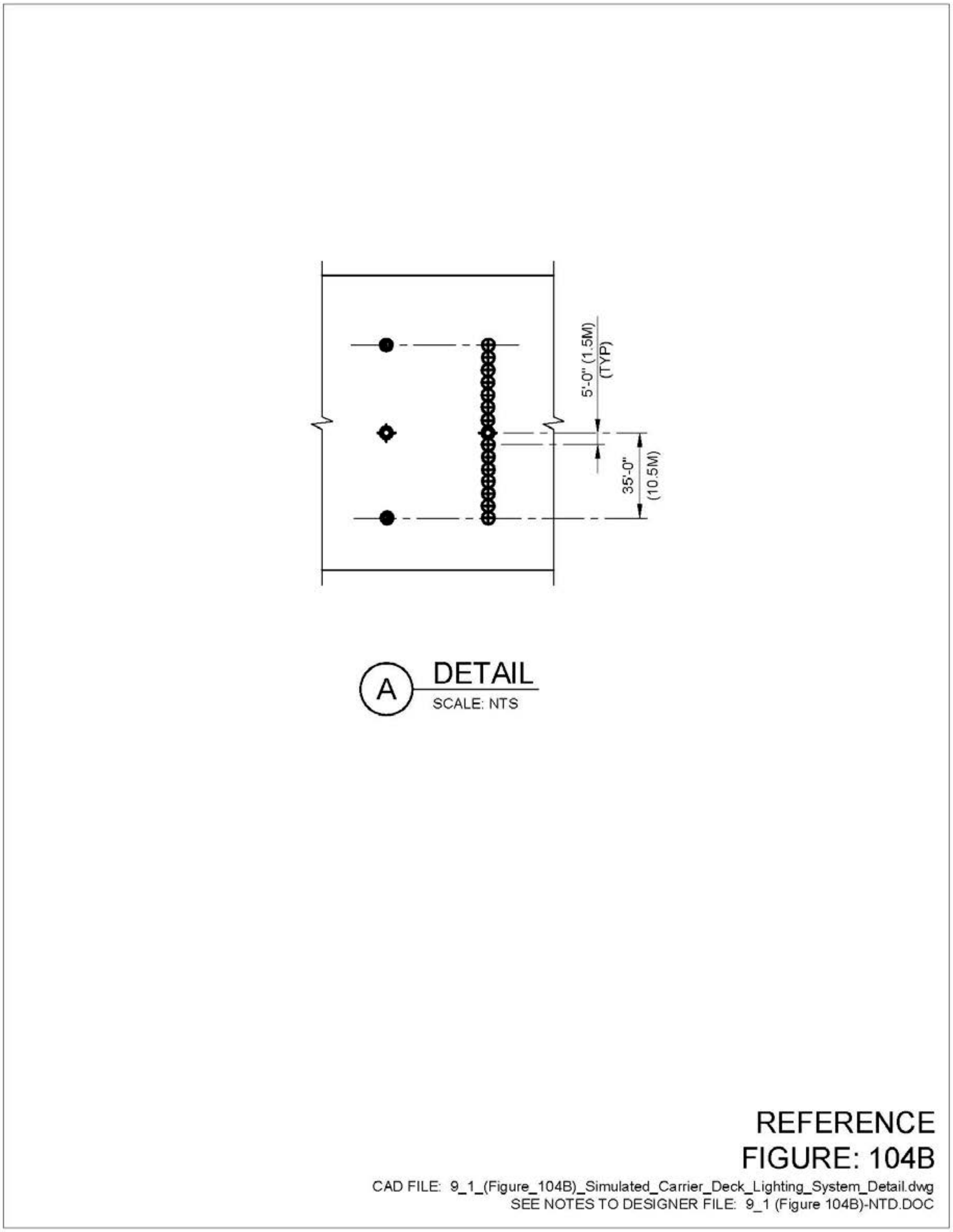
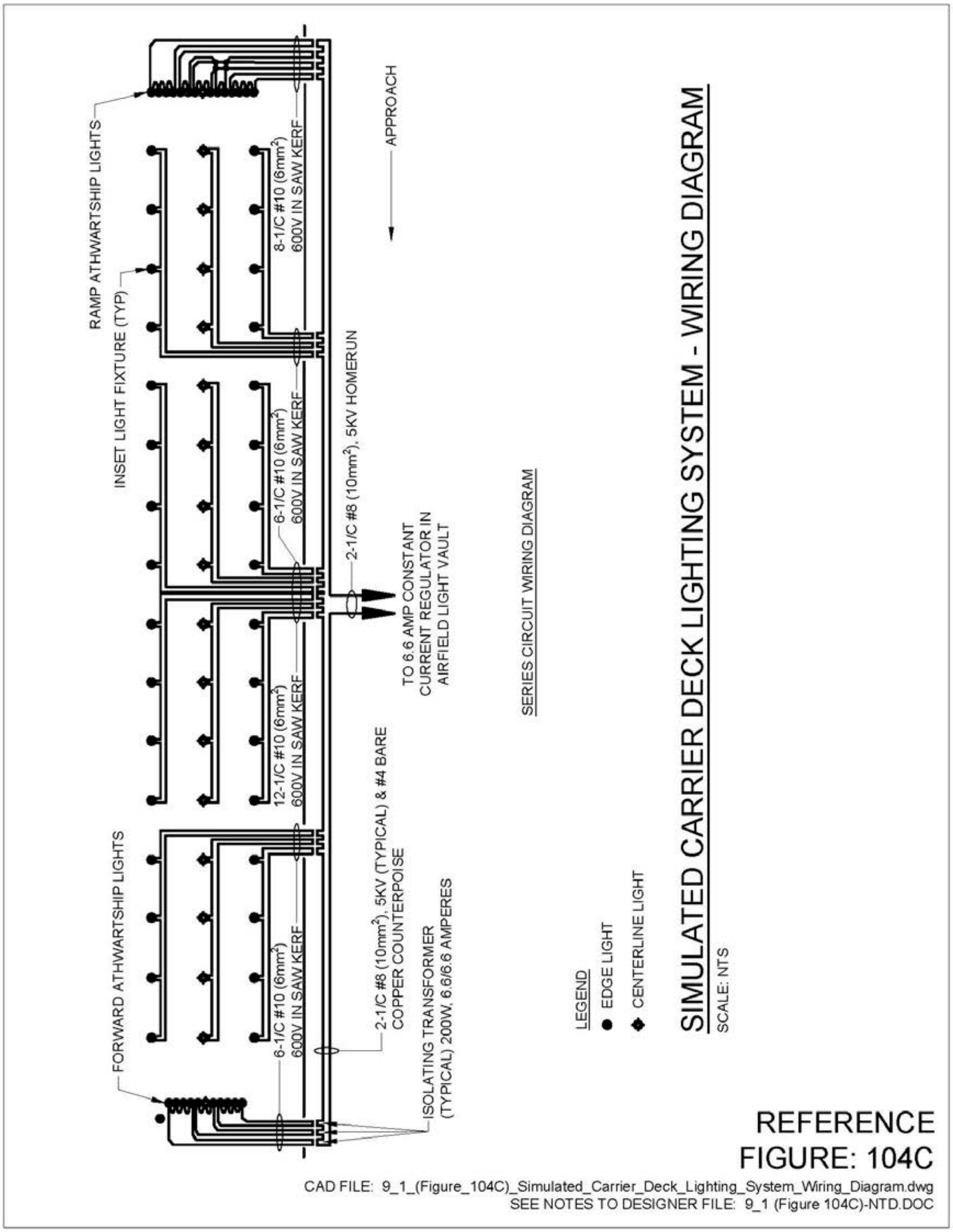


Figure 104C. Simulated Carrier Deck Lighting System – Wiring Diagram



10-2 **LSO Handhole Details.**

10-2.1 **Figure 105.**

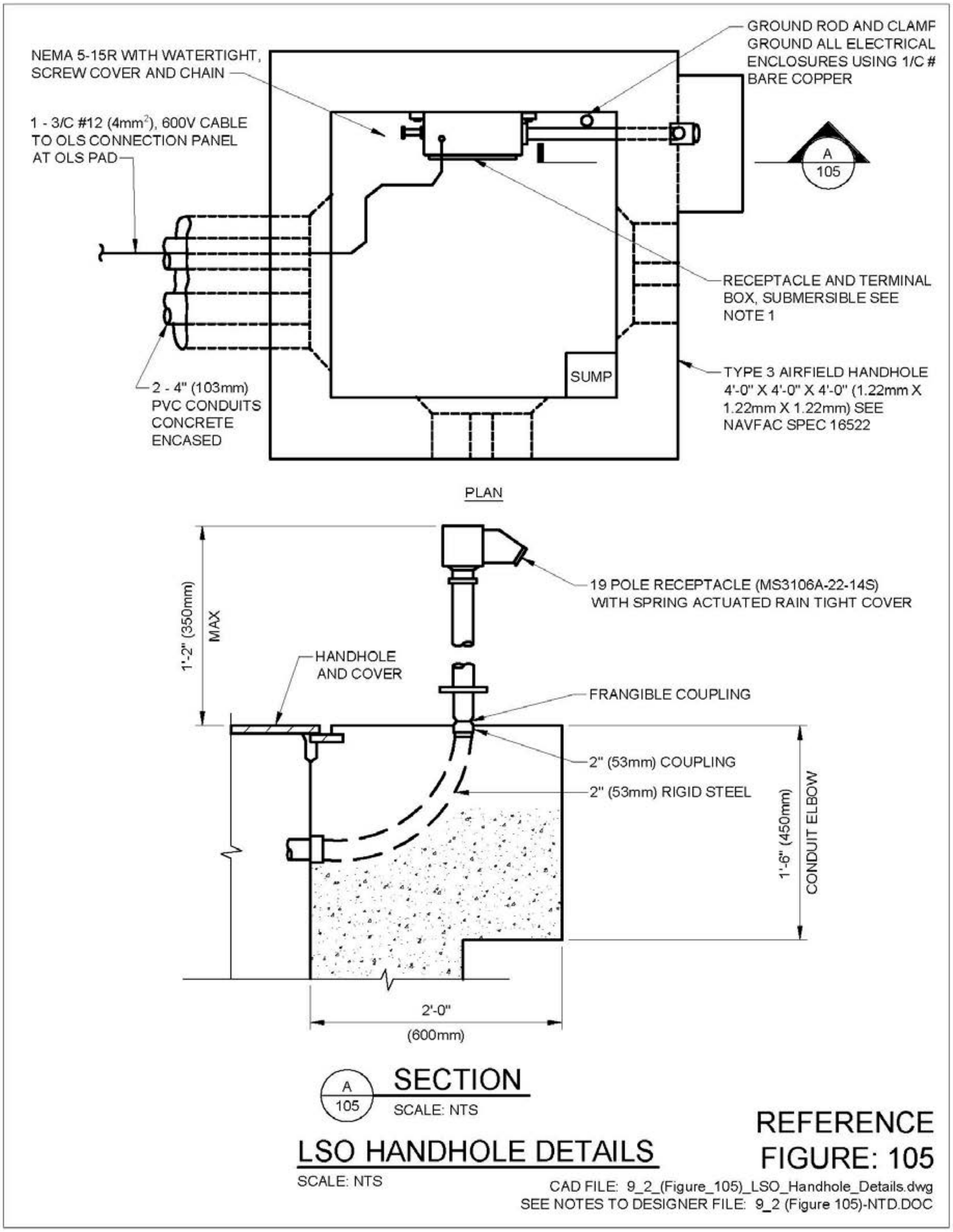
10-2.2 Notes to Designer.

1. The LSO handhole has an above-grade terminal box and receptacle. This serves as a junction point for connecting the multiconductor cables from the L.S.O. control panel, portable OLS (optical landing system), and the airfield lighting vault.

2. The handhole is located 115' (34.5m) upwind from the ramp athwartship lights and 62' (18.6m) outboard of the simulated carrier deck edge lights. A 44' (13.2m) wide area extending outboard 60' (18m) from the runway edge must be provided. This area must be graded for drainage and stabilized for light vehicular traffic.

3. Receptacle and terminal box must be rated NEMA 4 and must have threaded hubs.

Figure 105. LSO Handhole Details



10-3 Handhole and Transformer Housing.

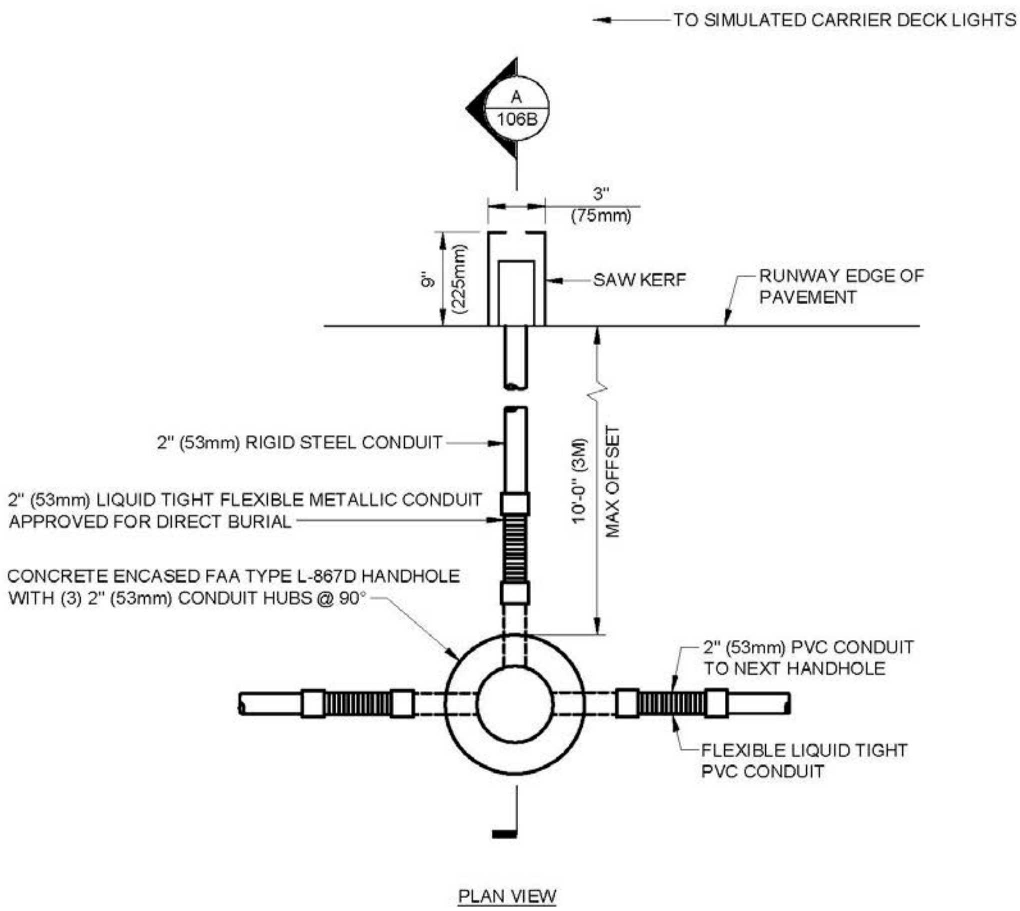
10-3.1 Figures 106A, 106B.

10-3.1.1 Notes to Designer.

1. The flexible conduit allows for flexibility of the conduit runs during freeze/thaw cycles in cold climates and should be at least 12" (300mm) long.

2. The handhole should be specified with both an internal and external ground lug. The entire handhole is then bonded to a ground rod by a #6 (16 square mm) bare copper pigtail.

Figure 106A. Handhole and Transformer Housing



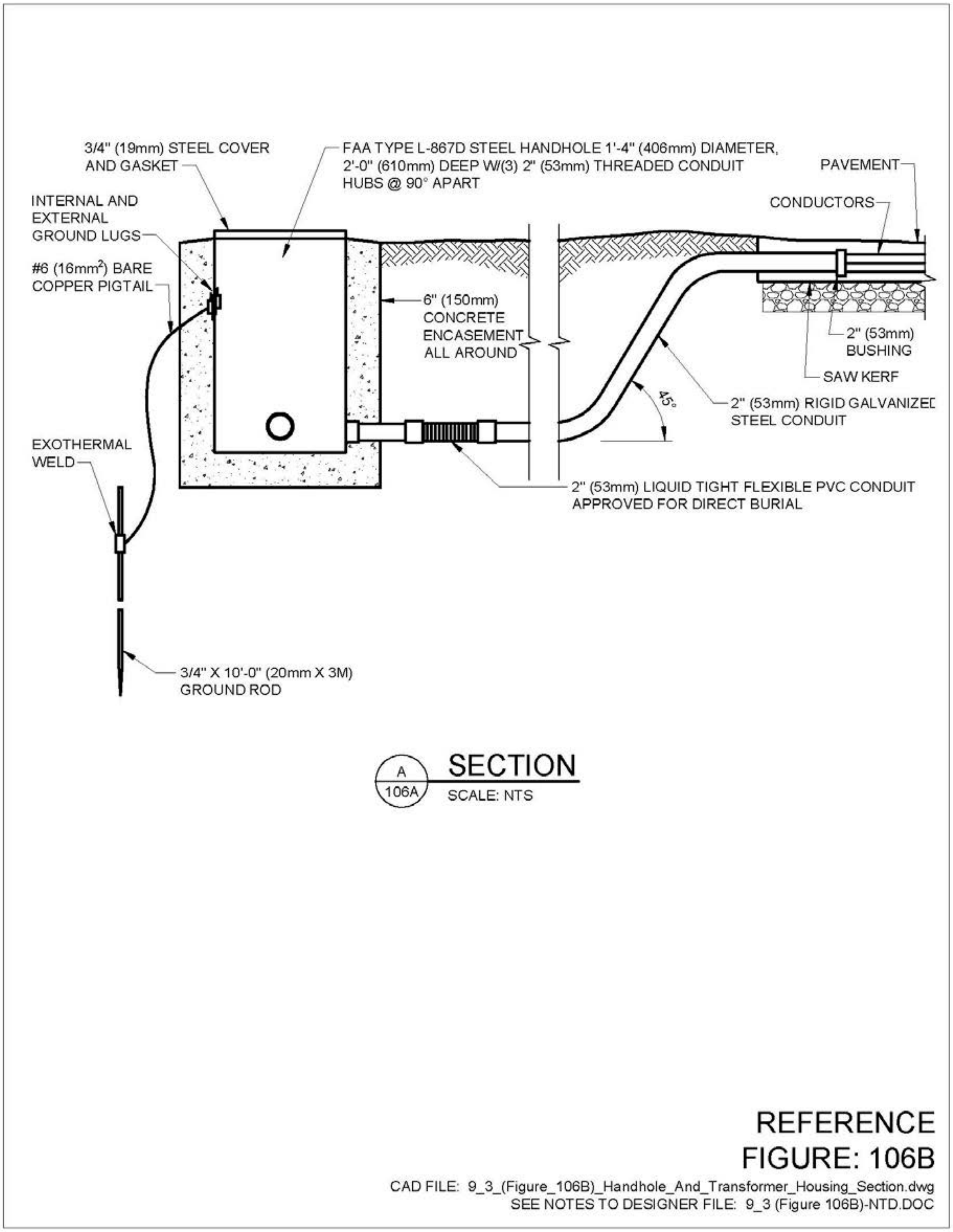
HANDHOLE AND TRANSFORMER HOUSING

SCALE: NTS

REFERENCE
FIGURE: 106A

CAD FILE: 9_3_(Figure_106A)_Handhole_And_Transformer_Housing.dwg
SEE NOTES TO DESIGNER FILE: 9_3 (Figure 106A)-NTD.DOC

Figure 106B. Handhole and Transformer Section



10-4 Simulated Carrier Deck Lighting Control Wiring Diagram.

10-4.1 Figure 107A, 107B.

10-4.1.1 Notes to Designer.

1. The control wiring diagram indicated is for two carrier deck lighting systems at opposite ends of the runway. Where a single system is installed and/or a 5 step regulator is used, modify the wiring diagram as required to show the type system installed.

2. When the carrier deck system is using an optical landing system (OLS), the runway wave-off system must not be used.

3. Contact NAVAIR NAWC for Lighting Control.

Figure 107A. Simulated Carrier Deck Lighting – Control Wiring Diagram – Sheet 1

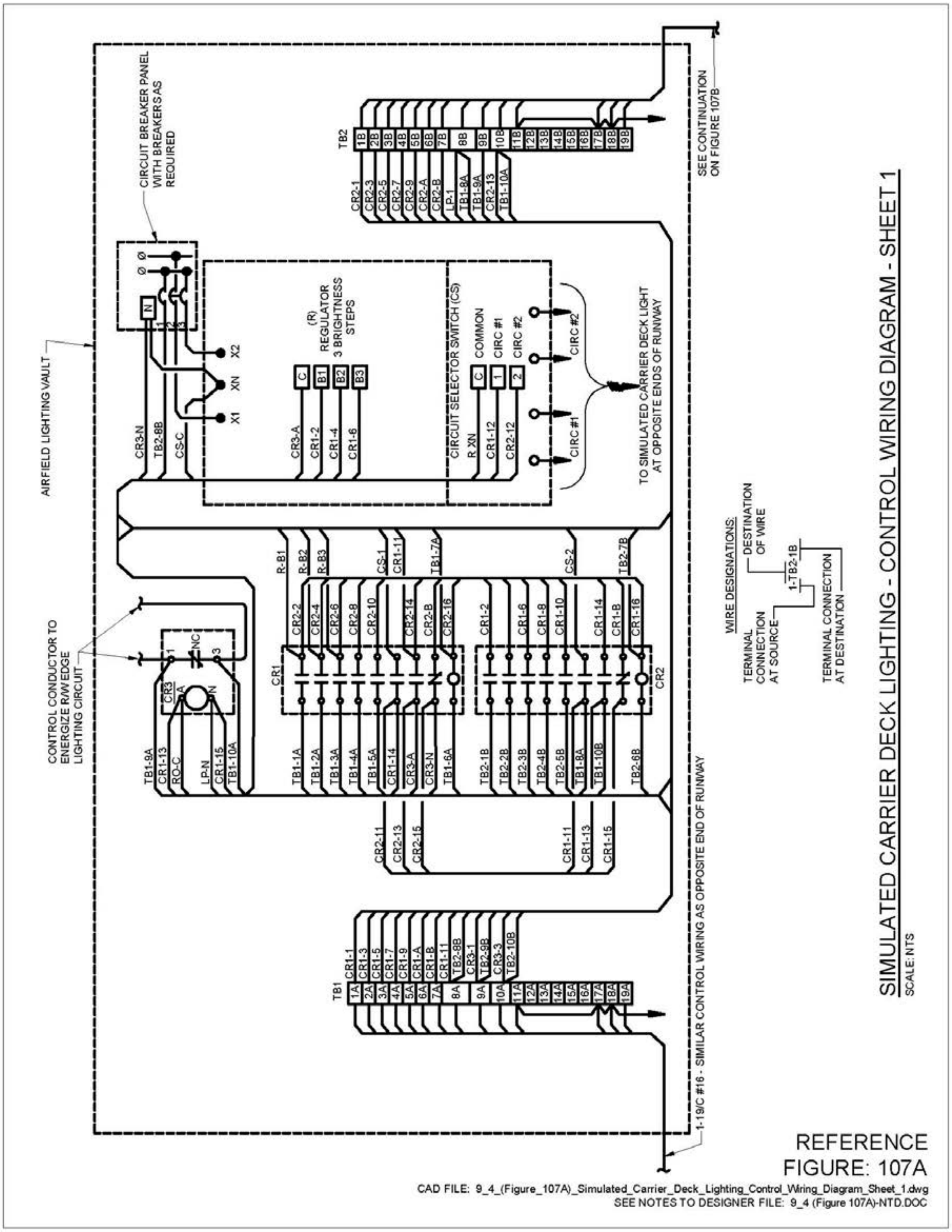
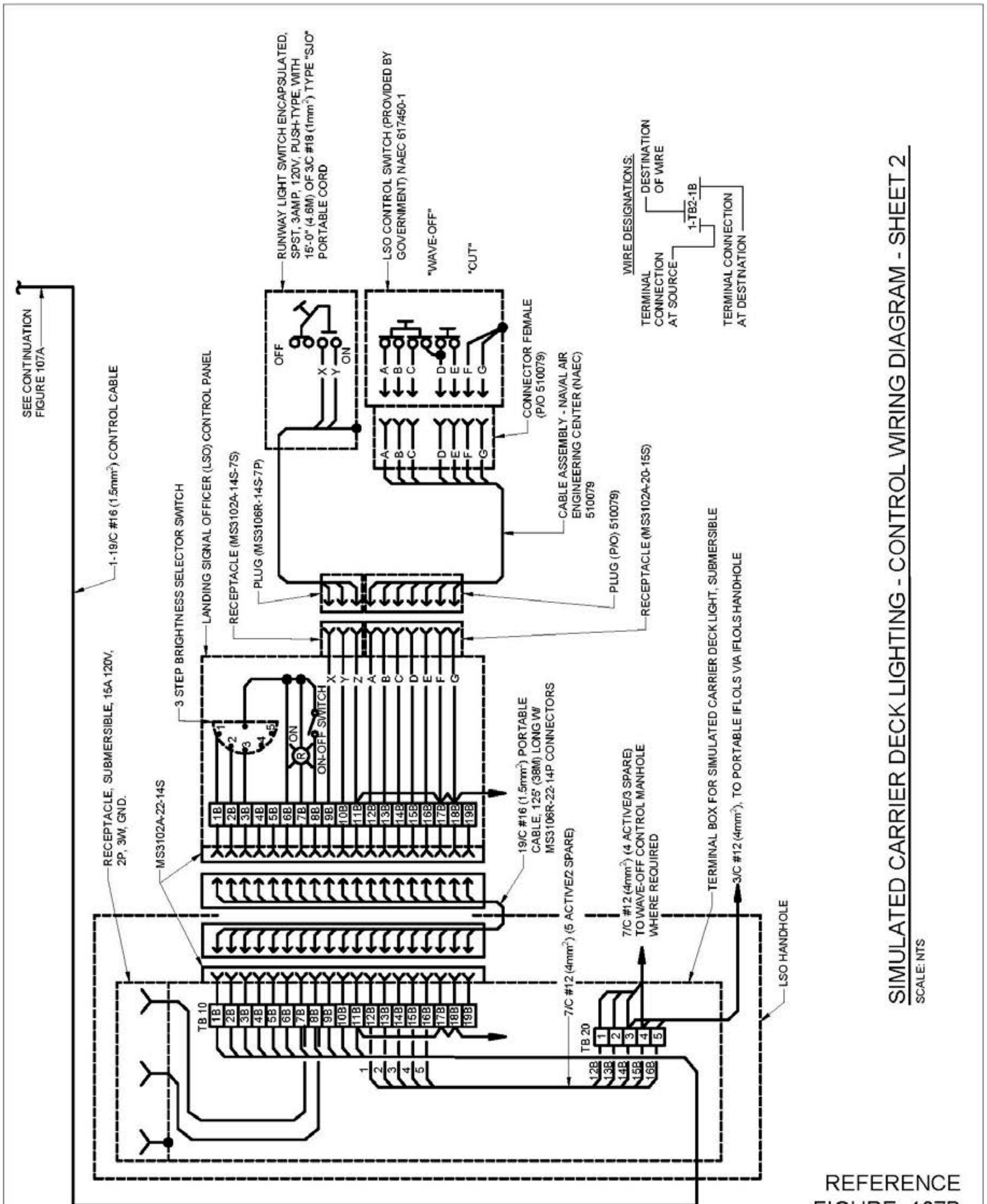


Figure 107B. Simulated Carrier Deck Lighting – Control Wiring Diagram – Sheet 2



REFERENCE
FIGURE: 107B

CAD FILE: 9_4_(Figure_107B)_Simulated_Carrier_Deck_Lighting_Control_Wiring_Diagram_Sheet_2.dwg
SEE NOTES TO DESIGNER FILE: 9_4 (Figure 107B)-NTD.DOC

10-5 **LSO Control Panel and Portable Control Switch.**

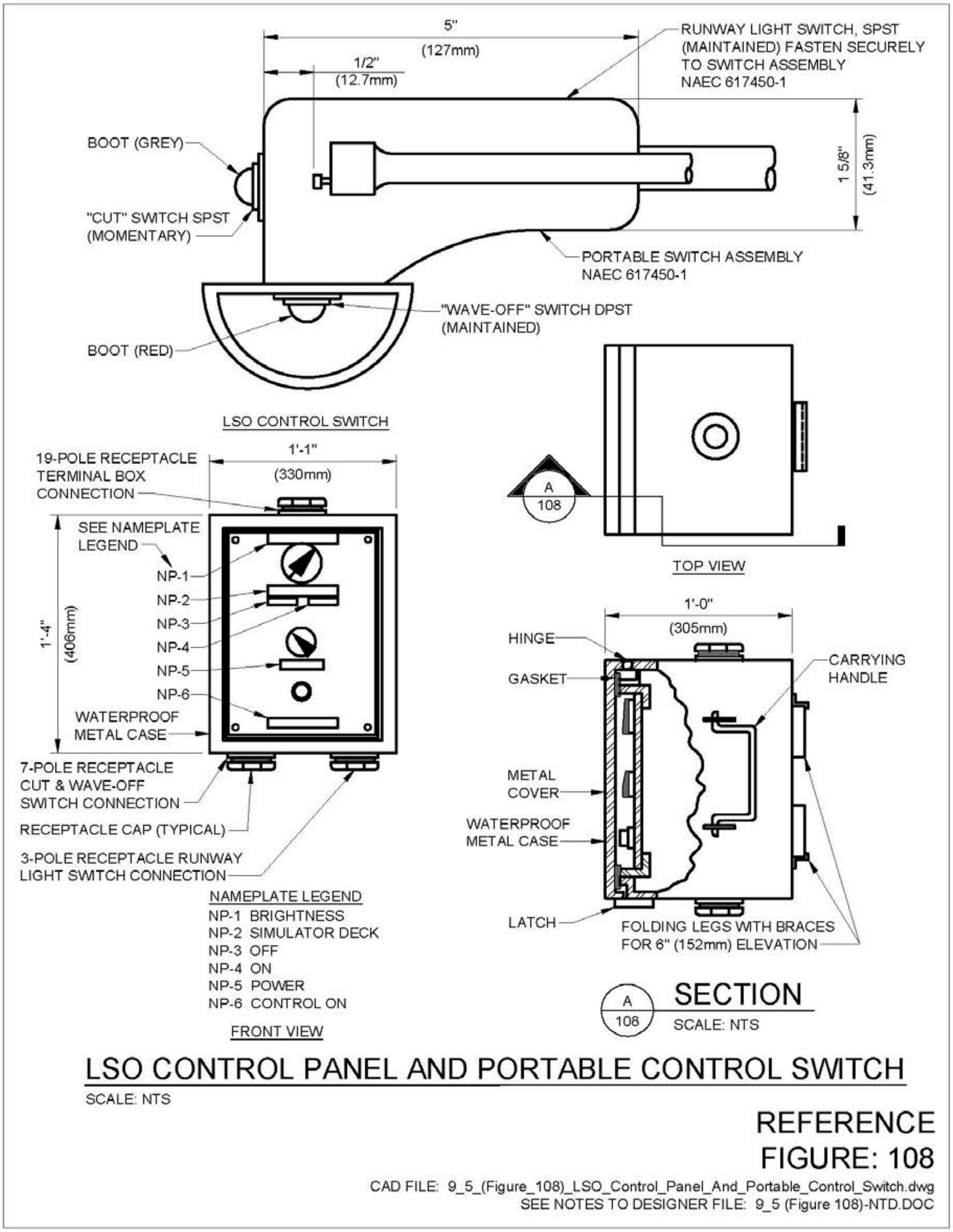
10-5.1 **Figure 108.**

10-5.1.1 **Notes to Designer.**

1. The control panel connects to the adjacent terminal box above the LSO handhole by a 19/c cable which mates with the above grade receptacle above the handhole.

2. Cabinet, cover and panel of landing signal officer control panel must be of 1/8" (3mm) aluminum alloy 5052-H32. Cover must be hinged and have two or more protective closing latches. Entire assembly must be NEMA 4, watertight and dust tight.

Figure 108. LSO Control Panel and Portable Control Switch



10-6 Simulated Carrier Deck Light Fixture – Shallow Base and Saw Kerf Installation.

10-6.1 Figure 109.

10-6.1.1 Notes to Designer.

1. The shallow base installation is used when a system is being installed on an existing runway. The #10 (6 square mm) branch circuit conductors and #6 ground are connected inside the base and run to a handhole at the edge of the pavement where the isolation transformers are housed.

2. The base has anti-rotational and anti-lift fins on the bottom. The base is held in place with rigid FAA type P-606 sealant that is installed flush with the top of the base. The sealant must be compatible with the pavement.

3. A spacer ring and flange ring with pavement ring is then installed on the base. The void between the rings and edge of pavement is then filled with a self-leveling silicone sealer which allows removal of fixture and rings. The sealer is flexible and compatible with both concrete and asphalt pavements.

4. The purpose of the spacer ring is to allow the fixture to be lowered in case of pavement slumping around the fixture. Different thickness rings are available in 1/16" (1.6mm) increments up to 2" (51mm).

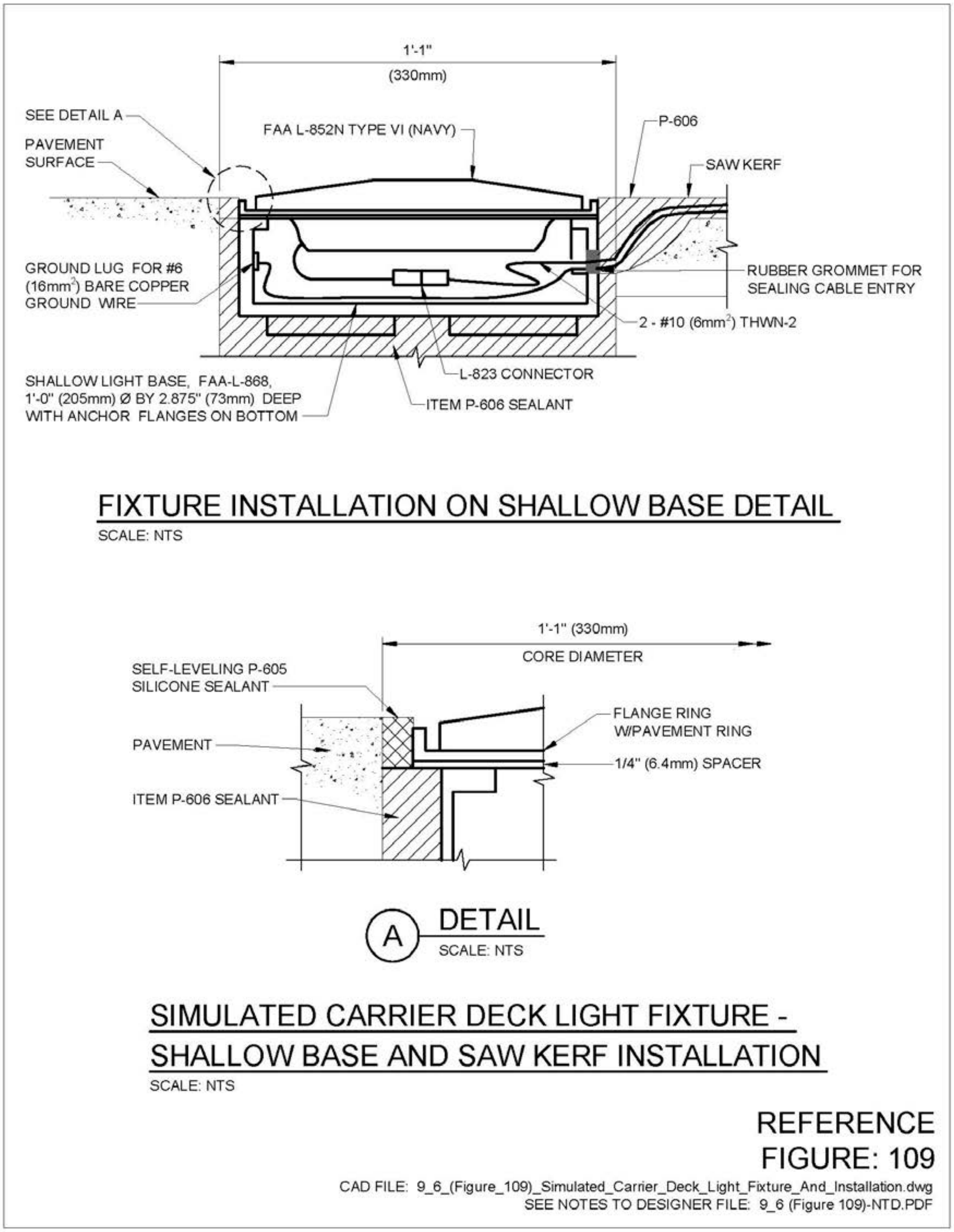
10-6.1.2 Drawing Notes for Figure 109.

1. Contractor must use a setting jig to hold the base at the proper elevation and azimuth while the P-606 is hardening.

2. Use sealants and embedding compounds that are chemically compatible with the pavement material. It is extremely important to carefully research past use history of the sealant to be specified.

3. Core dimensions must be verified with fixture manufacturer prior to core drilling.

Figure 109. Simulated Carrier Deck Light Fixture – Shallow Base and Saw Kerf Installation



10-7 Simulated Carrier Deck Light Core Details.

10-7.1 Figure 110.

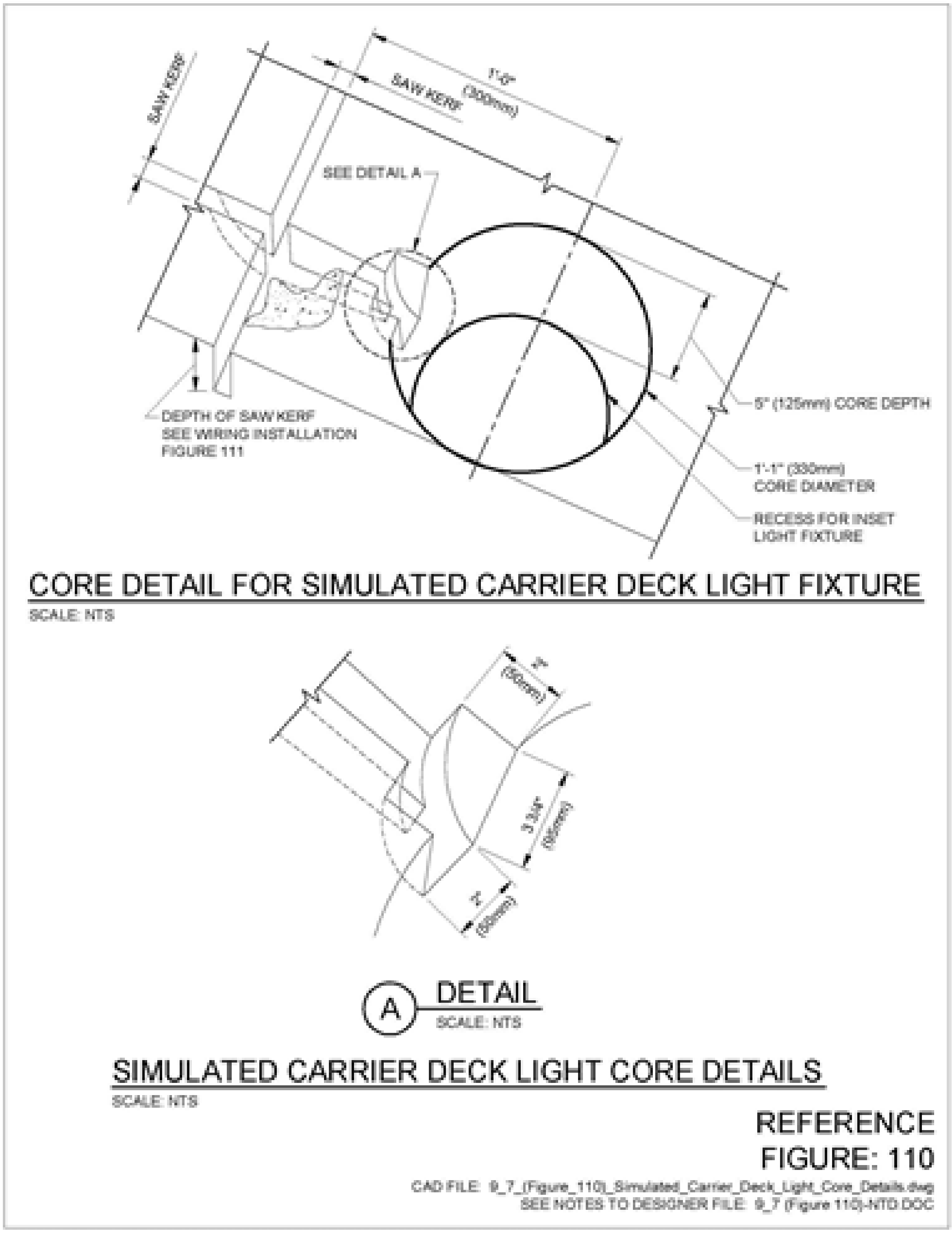
10-7.1.1 Notes to Designer.

1. Actual core depth and diameter should be verified with fixture supplier.
2. Ensure saw kerfs, walls and bottom of core are clean of any loose material or debris prior to fixture and wiring installation.
3. Detail A shows a channel for installing the wiring into the fixture.

10-7.1.2 Drawing Notes for Figure 110.

1. Edges of saw kerfs and fixture corings must be kept a minimum of 12" (300mm) from existing pavement joints. Where a conflict occurs, relocate fixtures longitudinally to avoid joints.
2. Where a new saw kerf crosses an existing saw kerf or pavement joint, new wiring must be installed as indicated in Figure 111.

Figure 110. Simulated Carrier Deck Light Core Details



10-8 Saw Kerf Wireway Details – Simulated Carrier Deck Lights.

10-8.1 Figure 111.

10-8.1.1 Notes to Designer.

1. The preferred method for installation of simulated carrier deck lights in new construction is to utilize a deep base at each light housing the individual isolation transformer. Each base is connected by a conduit system. Installation of lights in existing pavement utilizes shallow bases for the lights. The secondary wiring from the lights are run in a saw kerf to the side of the runway and into an L-867 base which houses the isolation transformer(s) for the lights.

2. More recent installations have been utilizing conduit for the secondary wiring in lieu of installing the wires directly in the saw kerf. If conduit is used, a water tight seal where the conduit enters the base must be specified.

3. The backer rod in the saw kerf serves three purposes. It acts as a shock absorber, it keeps the wiring in the saw kerf, and it acts as a sealant dam so if the wiring has to be changed they aren't encased in the sealant. The backer rod should be specified to have a diameter that is 25% maximum larger than the width of the saw kerf.

4. The sealant is a self-leveling cold applied silicone sealant that is compatible with both asphalt and concrete pavements.

10-8.1.2 Drawing Notes for Figure 111.

1. Diameter of backer rod must be 25% maximum larger than width of saw kerf.

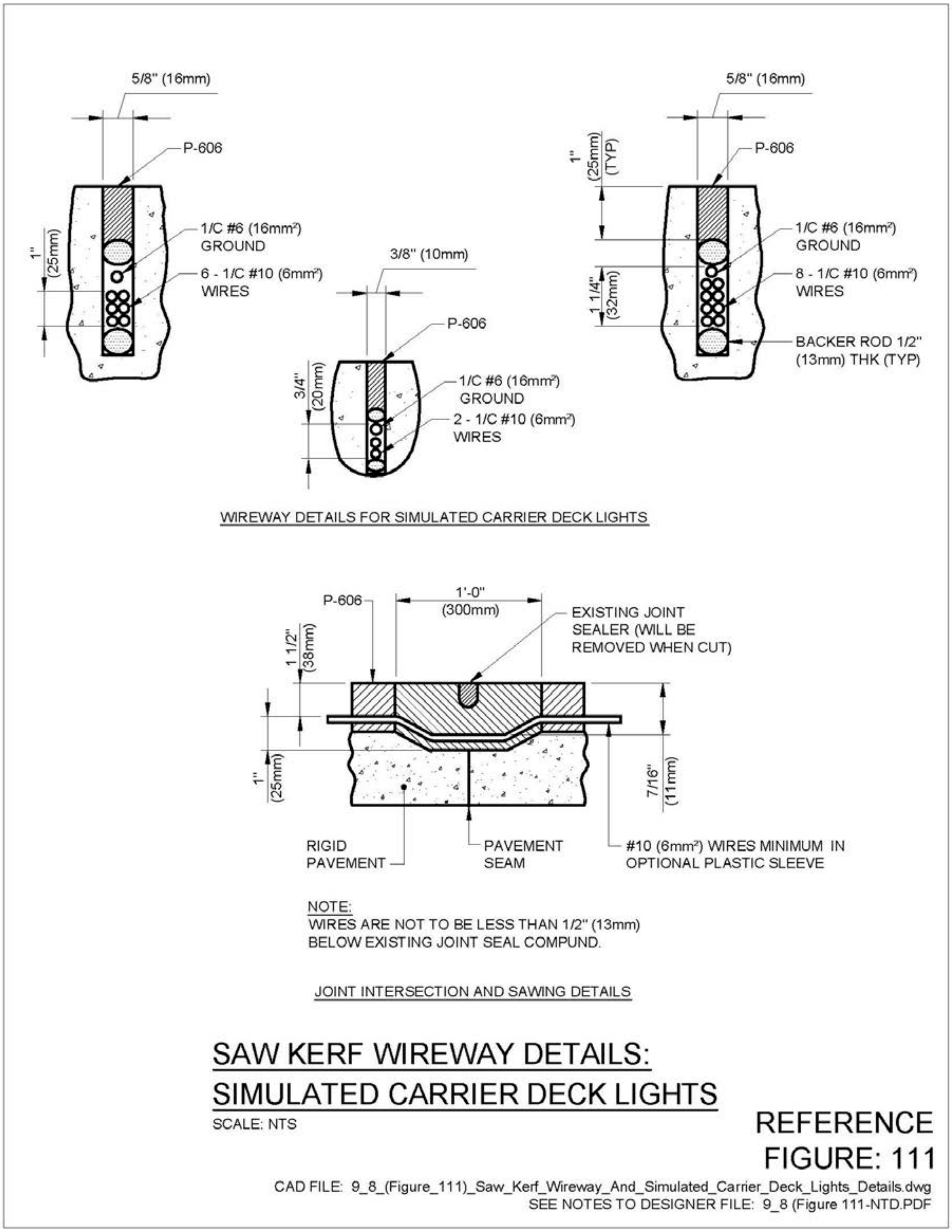
2. In existing pavement, the easiest method of installing in-pavement lighting is to core a hole for the fixture and make a saw kerf for the wireways. Primary cables and transformers in this case are located at the edge of the runway.

3. To assure a successful installation, care must be taken to see that all surfaces are sand blasted and dried before the sealer is applied.

4. Use sealants that are chemically compatible with the pavement material. It is extremely important to carefully research past use history of the sealant to be specified.

5. Bond #6 (16 square mm) ground wire from each fixture to a single #6 (16 square mm) ground wire and install with circuit conductors back to handhole.

Figure 111. Saw Kerf Wireway Details: Simulated Carrier Deck Lights



10-9 IFLOLS Pad Location.

10-9.1 Figure 112.

10-9.1.1 Notes to Designer.

1. The IFLOLS/MOVLAS (Improved Fresnel Lens Optical Landing System/Manually Operated Visual Landing Aid System) are optical landing aids which provide pilots with a visual signal to assist in intercepting and maintaining the correct approach glide slope.

2. Optical Landing Aids (OLA) is a required visual aid for landings on aircraft carriers, but on shore based airfields the OLA is primarily an aid for training or practice. The IFLOLS is a fixed signal system which automatically indicates to the pilot his position in relationship to the established glide path. Power Requirements for the IFLOLS is 10kVA, 120VAC, 60Hz three phase, 5 wire or 10kVA, 120VAC, 60Hz single phase, 5 wire. The wave-off lights in the IFLOLS are controlled by the LSO when FCLPs are being conducted. The MOVLAS is a temporary replacement system for which the LSO (Landing Signal Officer) controls the position of the source (meatball) light. Power requirements for the MOVLAS is 4.6kVA, 120V, single phase, 3 wire.

3. Both systems are mobile and normally government furnished. The equipment pad is at the simulated carrier deck centerline elevation. A permanent survey marker should be installed on the pad giving correct location and alignment of the IFLOLS centerline cells or MOLS mirror. A survey monument for the siting mirror is located 150' (45m) toward the runway threshold from the position for the face of the cells and parallel to the runway centerline. This monument or pad must have a permanent survey marker for correct location on the siting mirror and must be at the same elevation as the OLA equipment mounting pad.

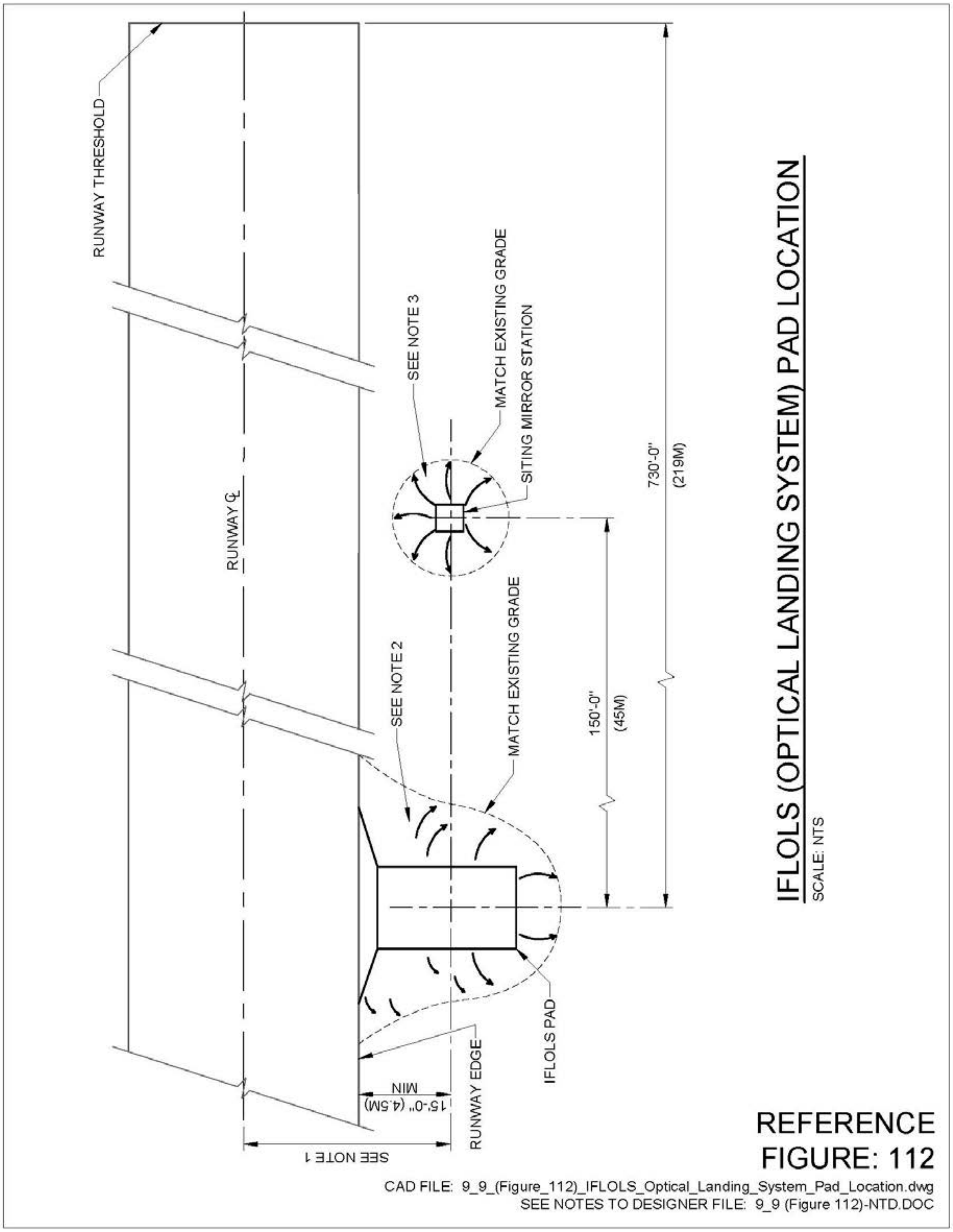
10-9.1.2 Drawing Notes for Figure 112.

1. Distance from R/W CL for runways 200' (60m) or less:
   a. 115' (34.5m) minimum
   b. 119' +1' / -0m (35.7m +0.3m / -0m) maximum
   c. For runways used by C-5A or B-747 or equivalent aircraft:
   d. 153' +1' / 0'
   e. (45.9m +0.3m / -0m)

2. Area to be filled, graded, and stabilized to allow vehicle access to pad. Maximum slope of graded fill material from top of pad elevation out to existing grade must be 2%.

3. Area to be filled, and graded from top of mirror station elevation out to existing grade with a maximum slope of 2%.

Figure 112. IFLOLS (Optical Landing System) Pad Location



10-10 **IFLOLS and Siting Mirror Pad Details.**

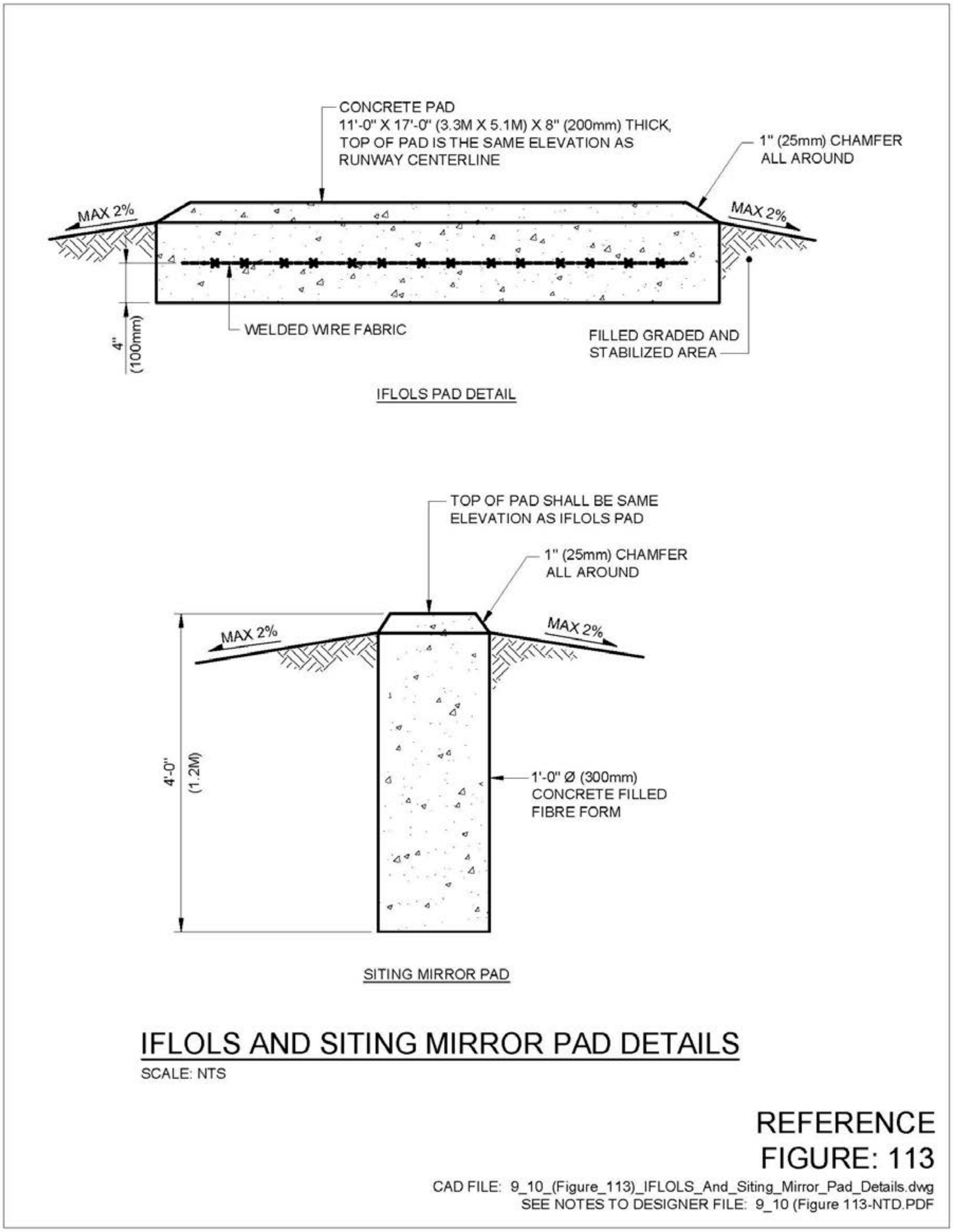
10-10.1 **Figure 113.**

10-10.1.1 **Notes to Designer.**

1. Top of pad elevations are required to be at the same elevation as the simulated carrier deck centerline. The requirement could put the top of the pads more than 3" (75mm) above existing grade and possible damage to aircraft could result if accidentally struck. Suggest sloping up to top of pad with graded material at a maximum slope of 2%. This would minimize damage to aircraft and allow for drainage. The material used around the IFLOLS pad should be stabilized enough to allow vehicle access while installing and removing a FLOLS or MOVLAS.

2. Each pad must have a permanent non-corrosive plaque (brass) set flush with top of pad. The plaque must be either engraved or brazed lettering identifying location alignment of the equipment. It should also state runway centerline elevation.

Figure 113. IFLOLS and Siting Mirror Pad Details



UFC 3-540-01
1 August 2014
Change 3, 26 January 2023

UNIFIED FACILITIES CRITERIA (UFC)

ENGINE-DRIVEN GENERATOR SYSTEMS FOR PRIME \1\ AND STANDBY POWER APPLICATIONS /1/

UNIFIED FACILITIES CRITERIA (UFC)

ENGINE-DRIVEN GENERATOR SYSTEMS FOR PRIME \1\ AND STANDBY POWER APPLICATIONS /1/

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **\1** ... /**1**/)

Change No.	**Date**	**Location**
1	10/24/17	Chapter 3 added to incorporate prime power applications.
2	11/5/19	Paragraph 2-5.3.2, added a provision for an external bypass design for AF projects that require ATS replacement capability without mission downtime; paragraph 2-5.3.1, added a requirement for submitting a design approval request to AFCEC/COSM at the 65 percent design mile stone for AF projects, a greater than 50 percent of rated load sizing requirement for all generators and a mission-essential facility load greater than 70 percent of the total facility load for a whole building generator; paragraph 3-3, clarified generator type for CONUS locations.
3	01/26/23	Format changes throughout and minor corrections, clarifications and updated references. AF Appendix G. Paragraph 1-7 sizing the generator for UPS Paragraph 1-8 facility-related control systems Paragraph 1-9 Reference to Appendix I Paragraph 1-10 Reference to Appendix A Paragraph 2-3 Fuel stored on site for 24-hour or longer Paragraph 2-4.2 References added Paragraph 2-4.5 Parallel operation of Generators Paragraph 2-4.7 Reference to 2-4.7.1 through 2-4.7.4. Table 2-2 note site-specific analysis Appendix A All references have been updated

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This UFC supersedes UFC 3-540-04N, *Design: Diesel Electric Generating Plants.*

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
CHANGE SUMMARY SHEET

Document: 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Applications*

Superseding:

- UFC 3-540-04N, *Design: Diesel Electric Generating Plants*

Description: This UFC provides criteria for the design and installation of engine generator systems for use as standby and prime power systems.

Reasons for Document:

- Provide technical requirements for design.
- Consolidate design criteria currently located in multiple documents.
- Update the existing material to reflect new and revised industry standards.

Impact: There are minor cost impacts associated with this UFC. However, the following benefits should be realized:

- Standardized criteria has been prepared to assist engineers in the development of the plans, specifications, calculations, and Design / Build Request for Proposals (RFPs).
- Overlap of material with other UFCs has also been eliminated with the issue of this UFC.
- Adopting NFPA 110 as a basis for engine generator design results in additional requirements; however, these requirements are intended to improve the reliability of emergency generator installations.

Unification Issues

None.

TABLE OF CONTENTS

FIGURES

TABLES

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CHAPTER 1 INTRODUCTION

1-1 REISSUES AND CANCELS.

This UFC supersedes UFC 3-540-04N, dated 16 Jan 2004.

1-2 PURPOSE AND SCOPE.

This UFC provides criteria for the design of engine-driven generator systems for standby and prime power applications. Information provided here must be used by engineers in the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP) and serves as the minimum design requirements. Project conditions may dictate the need for a design that exceeds these minimum requirements.

1-3 APPLICABILITY.

Compliance with this UFC is mandatory for the design and installation of engine-driven (fossil fueled) generator systems for standby and prime power applications at all DoD installations. Connection of generator systems to a facility is covered by this UFC. It applies to the traditional services customary for Design-Bid-Build construction contracts and for Design-Build construction contracts. Refer to Appendix H regarding generator connection design criteria. This UFC does not apply to tactical engine generators.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and referenced government criteria. Also, review siting for possible damage from flooding, wind/wind-blown debris, and seismic events.

Modernization of existing systems for the sole purpose of meeting design criteria of this UFC is not required. Upgrades or modifications of existing facilities should consider the design criteria in this UFC, but an entire facility may not require modernization solely because of a minor modification to a part of the facility.

1-5 EMI/EMP PROTECTION SYSTEMS.

Prime power generators and switchgear that serve mission critical, mission essential and Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) facilities must be evaluated for protection from electromagnetic interference (EMI) and electromagnetic pulse (EMP) in accordance with TM 5-690, QSTAG 244, Edition 4, MIL-STD-461G and MIL-STD-2169. Operation and maintenance of generator facilities must not introduce unacceptable levels of degradation into EMI/EMP survivability of a system scored to the above criteria. To ensure continued EMI/EMP survivability, a Life Cycle Nuclear Survivability program must be established in accordance with AR 70-75, DoDD 5000.1, and DoDI 3150.09.

1-6 PROJECT REQUIREMENTS.

Provide analyses that document the multi-discipline requirements and impacts of the following:

- Facility features and siting for passive survivability
- System sizing and rating
- System configuration
- System operation and control
- Physical and cybersecurity
- Emissions and permitting
- Noise mitigation
- Seismic classification
- Fuel
- Utility requirements for paralleling

Appendix C provides a checklist of items to consider as part of system planning and design.

1-7 MISSION FACILITY SUPPORT REQUIREMENTS.

Generator design must be based upon the mission's requirements for transient and steady state loads, startup, and charging of uninterruptable power supply (UPS). **3**\ For the Air Force, sizing the generator for UPS load will be based on maintaining a minimum float charge rather than a deep discharge or the full capacity. **/3/**

1-8 \3\ CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy. /**3**/

1-9 GLOSSARY.

3\ Appendix I contains acronyms, abbreviations, and terms. /**3**/

1-10 \3\ REFERENCES.

Appendix A contains a list of references used in this UFC. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies. References applicable to a specific topic are also listed and described in the appropriate sections of this UFC. /**3**/

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CHAPTER 2 STANDBY POWER GENERATORS DESIGN CRITERIA

2-1 APPLICATIONS.

Refer to Appendix F for a list of facility types and typical applications within DoD. For the Army and Navy, the major command or program element determines if a generator system for standby power is required and its classification.

2-1.1 Design Guidance.

Provide designs for non-medical backup power applications in accordance with IEEE Std 446. Refer to UFC 4-510-01 for generator system requirements associated with Medical Military Facilities.

2-1.2 NFPA 110 Compliance.

For permanently installed generator systems, comply with the NFPA 110 requirements for emergency power supply systems (EPSS) with the following clarifications.

2-1.2.1 Classification.

Designate the EPSS as Class X, where “X” is the required operating time in hours.

Designate the EPSS as Type 10 for medical systems covered by UFC 4-510-01 and Type 60 for all other applications.

2-1.2.2 Remote Manual Stop.

Provide a remote manual stop station for the EPSS in one of the following locations:

- In a separate room of the same building that houses the generator system.
- In a building separate from the building served by the generator system.
- On the outside of the building that houses the generator system.
- On the outside of an enclosure that contains the generator system.

The requirement for a remote manual stop station may be deleted, such as when it has been determined that a location that restricts access to unqualified operators is not available. The designer of record must receive documentation from the activity that the fire chief or designated equivalent concurs with this determination.

2-1.2.3 Remote Control and Alarm.

Provide a remote control and alarm panel for the EPSS in a separate room of the same building that houses the generator system or in a building separate from the one that the generator system is serving. The requirement for a remote control and alarm panel may be deleted when it has been determined that a location is not available that restricts access to unqualified operators or if not desired by the activity. The designer of record must receive documentation from the activity for this determination.

Provide a remote common audible alarm to a 24-hour staffed location when the EPSS location is not staffed 24 hours per day. The requirement for a remote common audible alarm may be deleted when it has been determined that a suitable location is not available or if not desired by the activity. The designer of record must receive documentation from the activity for this determination.

2-1.3 NFPA 70 and NFPA 110 Compliance.

Comply with NFPA 70 and NFPA 110 as follows.

- Generator systems required to comply with NFPA 70 Article 700 must also comply with NFPA 110 Level 1 criteria.
- Generator systems required to comply with NFPA 70 Article 708 must also comply with NFPA 110 Level 2 criteria.
- Systems using permanently installed generators not designated as emergency systems or critical operations power system (COPS) must comply with NFPA 70 Article 701 **3**\ **(**systems required by law) and NFPA 110 Level 2 (used when failure is less critical to human life and safety) /**3**/ criteria.
- Systems using portable generators must comply with NFPA 70 Article 702 (optional standby systems).

2-2 AUTHORIZED FUEL TYPES.

Select fuel oil (diesel or jet fuel) as the primary fuel source for applications where onsite storage is required. Natural gas may be used as the primary fuel source only for applications where onsite storage of fuel is not required.

- Diesel/natural gas dual fuel units are allowed.
- **For the Air Force:** Natural gas systems are not allowed.
- Bio-diesel and liquefied petroleum gas (LPG) fuel types are not allowed.

2-3 ONSITE FUEL STORAGE CAPACITY.

Provide a minimum of seven days of fuel storage either in a dedicated on-site main fuel tank or from a confirmed delivery source. If the fuel storage is from a confirmed delivery source, ensure the delivery source can provide reliable deliveries during long-duration power outages. Base this storage capacity on the fuel consumption required to support the mission load. When the seven-day requirement is accomplished by a delivery source, provide each generator set with a minimum local 24-hour capacity tank based on the full-load fuel consumption rate of the engine.

\3 Fuel stored on site for 24-hour or longer capacity for diesel generators/engines should not be bio-diesel because a 1-hour run time for a test never uses all the fuel in the storage tank**.** /**3**/ The above requirements may be modified when it is validated (documented in writing and dated) that mission operations require a different operational duration (longer or shorter). For Army secure critical missions, the Army will reduce the risk by being capable of providing necessary energy and water for fourteen days. See Army Directive 2020-03.

2-4 ANALYSIS REQUIREMENTS.

2-4.1 Design Analysis.

Provide a design analysis which covers the general facility design requirements in accordance with UFC 1-200-01 and its referenced documents. Document in the design analysis how compliance with NFPA 37, NFPA 70, and NFPA 110 is achieved. In addition to the UFC 3-501-01 requirements for preliminary basis of design and follow-on submittals (short circuit analysis, protective device time-current coordination study, arc flash analysis, voltage drop analysis, motor starting/flicker analysis), provide the following general system-specific analysis information.

2-4.1.1 Facility – Features and Siting.

- Facility design features for maintenance, including lay-down space for major overhauls and access for repair by replacement, without removal of major components or building system equipment/features.
- Geographic and operating environment, including coastal locations/corrosive conditions, humidity, altitude, seismic zones, and ambient temperature extremes.
- Exhaust system design, including stack height, sampling port orientation, and location.
- Vibration (transmitted to structures).
- Ventilation.

2-4.1.2 Engine Generator Sizing.

- Generator sizing calculations. The Designer of Record must use commercially available generator sizing software provided by a generator manufacturer to determine the required rating. **\3\ deleted /3/** Refer to Appendix D for additional information regarding generator sizing. Verify the commercially available sizing software addresses the generator sizing topics listed in Appendix D.
- Accommodate the effects or rating adjustments for nonlinear loads, transformer in-rush, motor starting, and UPS systems.

2-4.1.3 System Configuration.

- Classification of loads.
- Redundancy (reliability, availability, maintainability factors).
- Maintenance and testing.

2-4.1.4 System Operation and Control.

- Load shed plan.
- Communications plan.
- Electrical protection scheme.
- Modes of operation delineation and impacts analysis.
- Refueling capability to support generator operation during extended power outages at mission essential/critical facilities.

2-4.1.5 Focused Electrical System Analysis.

Perform harmonic analysis where switching power supplies contribute 25 percent or greater to the system loads, and/or electromagnetic filters are installed to mitigate the effects of high-energy EMP.

2-4.2 Environmental.

Evaluate environmental requirements (e.g., noise, air pollution, wildlife, storm water) developed during the initial project planning stages.

- Verify site is suitable for construction (e.g., are wetlands present, is the ground contaminated) without major environmental impacts.
- Field verify, through environmental and biological surveys, that impacts will be minimal and can be mitigated.
- All design and construction will provide electrical systems which must comply with Federal, state, and local environmental regulations. For overseas locations, follow the guidance specified in Host Nation-specific Final Governing Standards, or if none exist, the current DoD Overseas Environmental Baseline Guidance Document (OEBGD) and applicable Host Nation laws.
- **3**\ **For Air Force:** Consult AFI 32-7001 and AFI 32-7091 for additional guidance. /**3**/

2-4.2.1 Environmental Studies and Permitting.

Plan for a permitting process that may take years, with duration depending upon the selected system and the locality (country, State, county and municipality) that is jurisdictionally responsible. Federal, state, and local requirements will vary with the local ambient air quality, size of the project and potential emissions. All new or modified stationary power generators (both engine- and turbine-based) are required to comply with applicable Environmental Protection Agency (EPA) New Source Performance Standards (NSPS). The specific characteristics of an emissions source determine the applicability of a particular NSPS. See 40 CFR Part 60 Subpart KKKK or 40 CFR Part 60 Subpart JJJJ. Studies and permitting requirements exist at all levels (Federal, state, and local) and may include:

- 316(a) – thermal discharge
- 316(b) – cooling water intake
- air permitting
- aquatic ecology
- avian and bat studies / protection
- cultural resources
- dredge and fill
- endangered species
- encroachment
- erosion and sediment control
- floodplain management
- lake management
- land and right-of-way grants
- Native American consultation
- natural resources
- National Environmental Policy Act
  - Environmental Assessments (EAs)
  - Environmental Impact Studies (EISs)
- noise/odor
- river crossing permits
- transmission line routing
- stormwater/water quality
- wetlands permitting, mitigation and design

2-4.2.2 Noise Mitigation.

Comply with Federal, state, and local codes, and for overseas locations, Host nation laws, for maximum noise levels permitted at property line or Table 2.1, whichever is less. Use A-weighting filter criteria (dBA) as adopted by the Occupational Safety and Health Administration (OSHA) as the official regulated sound level unit.

Table 2-1 Generator Noise Level Regulation

Noise Zone	Peak Daytime dBA	Peak Nighttime dBA	Continuous Daytime dBA	Continuous Nighttime dBA
Residential	62	52	57	47
Light Industrial	67	57	62	52
Heavy Industrial	72	62	67	57
Hospital	45	40	35	30

2-4.3 Seismic Classification.

Comply with UFC 1-200-01, including all referenced criteria and standards.

2-4.4 Fuel Storage Design and Capacity.

Apply UFC 3-460-01 to petroleum fuel facilities designs.

2-4.5 Utility Requirements for Paralleling.

Where the generation equipment is connected to the utility's system bus and is required to operate in parallel with the utility's electric system, comply with specific utility provider guidelines on parallel generation connection accommodations.

3\ **For the Air Force:** Equipment Authorization Inventory Data (EAID) or Real Property Installed Equipment (RPIE) generators, or any generator owned by another agency, will not operate in parallel with any utility provider unless authorized by AFCEC/CO in accordance with AFMAN 32-1062. /**3**/

2-4.6 Power Rating Category.

Determine the required power-rating category in accordance with Electrical Generating Systems Association (EGSA) 101P for DoD facilities and International Standards Organization (ISO 8528-1) for Host Nation facilities, as appropriate.

Each manufacturer has developed its own unique rating definitions that may or may not comply with these standards.

2-4.6.1 Continuous Power.

Continuous power is the maximum power, which the generating set is capable of delivering continuously and safely, while supplying a constant electrical load when operated for an unlimited number of hours per year under the agreed operating conditions with the maintenance intervals and procedures being carried out as prescribed by the manufacturer.

Note: The continuous power category is unlikely to be required for the standby power applications associated with this UFC.

2-4.6.2 Prime Power.

Prime power is the maximum power a generating set is capable of delivering continuously while supplying a variable electrical load when operated for an unlimited number of hours per year under the agreed operating conditions and crucially with maintenance intervals being carried out as per the manufacturers guidelines. Typically an overload of 10% is allowed for 1 hour in 12. Prime power is also defined by IEEE 446 as “The source of supply of electrical energy that is normally available and used continuously day and night, usually supplied by an electric utility company, but sometimes supplied by base-loaded user-owned generators.” EGSA Standard 101P defines a prime power generator as “a utility-type power plant that will deliver continuous power under normal varying load factors.” Wind turbines or solar generation cannot, by definition, be prime power.

Note: The prime power rating category is required for generator systems designated as COPS in accordance with NFPA 70 Article 708.

2-4.6.3 Limited Time Running Power.

Limited time running power is the maximum power available, under the agreed operating conditions, for which the generating set is capable of delivering for up to 500 hours of operation per year with the maintenance intervals and procedures being carried out as prescribed by the manufacturer.

2-4.6.4 Emergency Standby Power.

Emergency standby power is the maximum power available during a variable electrical power sequence, under the stated operating conditions, which a generating set is capable of delivering in the event of a utility power outage or under test conditions for up to 200 hours of operation per year with the maintenance intervals and procedures being carried out as prescribed by the manufacturer.

2-4.7 Performance Class Transient Limits.

Determine the required electrical performance class in accordance with ISO 8528-1, **3**\ Part 1 and as described in paragraphs 2-4.7.1 through 2-4.7.4. /**3**/ Transient response limits are provided in Table 2-2 in accordance with ISO 8528-5:2013, Part 5.

2-4.7.1 Class G1.

Connected loads require only basic parameters of voltage such as general purpose lighting and other simple electrical loads.

2-4.7.2 Class G2.

In Class G2 applications, required voltage characteristics are very similar to those for the commercial public utility electrical power system with which it operates. When load changes occur, there may be temporary but acceptable deviations of voltage and frequency. Examples of this category include lighting systems, pumps, fans, and hoists.

2-4.7.3 Class G3.

In Class G3 applications, connected equipment makes severe demands on the stability and level of the frequency, voltage, and waveform characteristics of the electrical power supplied by the generating set. Examples of this category include telecommunications and thyristor-controlled loads. Note that both rectifier and thyristor-controlled loads may need special consideration with respect to their effect on generator-voltage waveform. Class G3 loads require an evaluation by the designer of record to document the system voltage and frequency limitations, including transient response.

2-4.7.4 Class G4.

In Class G4 applications, demands made on the stability and level of the frequency, voltage and waveform characteristics of the electrical power supplied by the generating set are exceptionally severe. Examples include data-processing equipment or computer systems. Class G4 loads require an evaluation by the designer of record to document the system voltage and frequency limitations, including transient response.

Table 2-2 Performance Class Transient Limits

Parameter	Performance Class			
	G1	G2	G3	*G4
Frequency Deviation (%) for 100 % Load Increase	<-15	<-10	<-7	TBD
Frequency Deviation (%) for 100 % Load Decrease	<+18	<+12	<+10	TBD
Frequency Recovery Time (sec) for 100 % Load Change	<10	<5	<3	TBD
Voltage Deviation (%) for 100 % Load Increase	<-25	<-20	<-15	TBD
Voltage Deviation (%) for 100 % Load Decrease	<+35	<+25	<+20	TBD
Voltage Recovery Time (sec) for 100 % Load Change	<10	<6	<4	TBD
Frequency Droop (%)	<-8	<-5	<-3	TBD
Steady-State Frequency Band (%)	<2.5	<1.5	<0.5	TBD
Steady-State Voltage Regulation (%)	<5	<2.5	<1	TBD

\3\ ***A site-specific analysis is required to determine voltage and frequency limits. See manufacturer's recommendations. **/3/

2-5 DESIGN CRITERIA.

Appendix B provides examples of various configurations.

2-5.1 Circuit Wiring for Legally Required and Optional Standby Systems.

For Legally Required (NFPA 70, Article 701) or Optional Standby Systems (NFPA 70, Article 702), keep the circuit wiring from the generator to the loads served entirely independent of all other wiring unless otherwise permitted in NFPA 70, Article 700.

2-5.2 Automatic Operation.

Use fixed (permanently installed) generators with automatic startup for facilities designated as emergency and COPS systems. Generators associated with facilities designated as standby systems may be either fixed or portable with automatic or manual operation. Equip generators configured for automatic operation with intelligent electronic controls to protect the generator sets and manage startup, operation, and shutdown.

2-5.3 Single Operation Generator Sets.

2-5.3.1 Configuration.

Configure single operation generator sets as separately derived systems.

Provide four-pole devices for a three-phase system to switch the supply to essential loads and to switch between multiple single operation generator sets.

2\ **For Air Force:** Submit a design approval request to AFCEC/COSM at the 65 percent design milestone. Generators must be sized to achieve greater than 50 percent rated load using only facility loads. Whole building generators are approved only when the mission-essential load is greater than 70 percent of the total facility load. /**2**/

2-5.3.2 Automatic Transfer Switches.

Use automatic transfer switches (ATS) listed in accordance with UL 1008. Provide automatic transfer switches with integral maintenance bypass isolation for systems designated as emergency, COPS, or where validated (documented in writing and dated) by the user as being required.

2-5.3.2.1 Double-Throw Safety Switches.

A design using double-throw safety switches to accomplish maintenance bypass is not allowed under any circumstances.

2\ **For Air Force:** Use of a double-throw design within line of site from the ATS to facilitate ATS replacement without mission impact is acceptable. /**2**/

2-5.3.2.2 Transition Transfer.

Provide an open transition transfer scheme unless facility operating procedures require paralleling with the utility. Closed transition transfer is rarely required for standby power applications. Closed transition will require coordination with the local utility and will require designing for the higher available short circuit current of the combined parallel power sources.

2-5.3.3 Metal Clad/Metal Enclosed Switchgear.

Provide free-standing metal clad or metal enclosed switchgear as required for generator voltage rating, load capacity, fault capacity (withstand/interrupting ratings), paralleling requirements, and operating scenarios.

CAUTION
To protect personnel, non-enclosed ATS must be contained in a dedicated isolated compartment when installed in switchgear or switchboards.

2-5.3.4 Automatic Transfer Switch Maintenance Access.

Provide switchboard or switchgear construction with draw out power or insulated case circuit breakers for the main power distribution equipment. Provide working clearance around each circuit breaker when in its withdrawn position in accordance with NFPA 70, Table 110.26 (A)(1).

2-5.3.5 Utility Service.

To allow for maintenance without incurring power outages when redundant utility services are provided, provide draw out circuit breakers to disconnect the utility service.

2-5.4 Requirements for Paralleling.

2-5.4.1 Parallel Operation with Public Utility.

Where the generation equipment is connected to the utility's system bus and is required to operate in parallel with the utility's electric system, comply with IEEE 1547 – Series, and specific utility provider guidelines on parallel generation connection agreements.

For the Air Force: EAID or RPIE generators or any generator owned by another agency will not operate in parallel with any utility provider unless authorized by AFCEC/CO in accordance with AFMAN 32-1062.

2-5.4.2 Parallel Operation with Other Distributed Energy Resources.

Where the generation equipment is connected to a local electrical distribution system bus and is required to operate in parallel with the other distributed energy generation resources (DERs) in islanded mode, comply with IEEE 1547–4.

For the Air Force: EAID or RPIE generators or any generator owned by another agency will not operate in parallel.

2-5.4.3 Main Power Distribution Equipment.

Provide switchboard or switchgear construction with draw out power or insulated case circuit breakers for the main power distribution equipment. Provide a minimum of 30 inches' working clearance around each circuit breaker when in its withdrawn position.

2-5.4.4 Control Power.

Provide redundant AC control power for systems designated as emergency, COPS, or where validated by the user as being required. Provide a redundant AC control power system that is selectable via an ATS.

Provide redundant DC control power for systems designated as emergency, COPS, or where validated by the user as being required. Provide a redundant DC control power system through a best battery selector.

2-5.4.5 Control System.

2-5.4.5.1 Provide generator and electrical system protection in accordance with IEEE Std 446 and IEEE Std 242.

2-5.4.5.2 Provide redundant IEDs to run the logic for all programmed and operator-initiated automatic system sequences. Redundant master programmable logic controllers (PLCs) must control and monitor the main breakers, the tiebreakers, the feeder breakers (if load shedding is required), and the common system auxiliaries via paralleled input/output points.

2-5.4.5.3 Provide separate, dedicated generator controllers to run the logic for operation of each generator set. Automatic startup of the generator sets must be achieved via commands from the master controllers. Design the system so that manual startup of the generator sets is achieved via operator initiated commands independent of the master controllers. Generator controllers must control and monitor the generator breakers and associated generator set auxiliaries.

2-5.4.5.4 Provide close control commands for synchronizing that are direct outputs from separate controllers for each respective utility source and generator circuit breaker.

2-5.4.5.5 Provide system operator interface via minimum 15-inch thin film transfer (TFT) color touch panels. Provide a touch panel for each generator set, plus one additional local panel and an optional remote panel. Each display controller must provide real-time graphical control and monitoring for the system and all generators.

2-5.4.5.6 Communication should be via Ethernet and support IEC 61850 communications functions and protocols for supervisory control and data acquisition (SCADA) and relay devices.

2-5.4.5.7 Provide a breaker control switch for each main breaker, tie breaker, feeder breaker (if control is required for load shedding), and generator breaker to enable automatic control when the switch is in the “normal after close” position and disable automatic control when the switch is in the “normal after trip” position.

2-5.4.6 Generator Electrical Protection.

Install current transformers (CT) on the neutral side of the generator windings. Use these CTs as an input to a generator protective relay for overcurrent protection. For medium voltage delta generators, provide zigzag grounding transformers with a grounding resistor connected to the generator bus via a circuit breaker. Provide differential protection for the zigzag transformer. Do not provide ground fault protection; the purpose of the zigzag transformer is to enable a reduced ground fault current.

Wye-wound generators require only a resistor or reactor from the wye point of the generator to ground. Install a CT in this circuit for ground fault protection.

\1\ CHAPTER 3 PRIME POWER GENERATORS /1/

\1\ 3-1 PRIME POWER GENERATORS.

3-1.1 Purpose.

This chapter defines requirements for fossil fuel (reciprocating, gas/steam turbine) generators used for prime power applications.

3-1.2 Definitions.

Prime power generators are classified by manufacturing standards and operational requirements. For manufacturing standards and equipment specifications, EGSA 101P is used by manufacturers to classify their equipment. For operational requirements, ISO 8528, NFPA 70, and NFPA 110 are used to classify generators.

3-1.2.1 EGSA Classification.

EGSA 101P classifies generators by generator set rating, application class, criteria of use, and classification of operation. Prime power is a generator set rating defined by EGSA 101P as a generator set rating to include power that the generator set will deliver when used as a utility-type power plant under normal varying load factors to run continuously with a minimum momentary overload capability of 10 percent.

3-1.2.2 ISO 8528 Classification.

ISO 8528 classifies reciprocating generators by application criteria and performance class. There are four different application criteria modes for reciprocating engine generators including continuous and prime. The ISO 8528 application criteria mode for prime power is for variable loads with unlimited running hours where a generator set is used to supply power 24 hours a day, 365 days a year where there is no supply network or electrical service available or the service is down.

3-1.2.3 NFPA Classifications.

NFPA 70 Articles 701, 702, or 708 are used to determine the application classification of the load as being legally required or emergency, optional standby, or COPS. The Air Force defines optional standby as Other Permanently Installed and also has separate classifications for POL/Fuels and Portable.

NFPA 110 classifies generators by Class, Type, and Level. The Class is the minimum time hours for which the generator is designed to operate at its rated load without being refueled. The Type is the maximum time, in seconds, permitted for the generator to start and the load to transfer. The Level establishes whether loss of human life or serious injury will result if the generator fails to perform.

3-1.3 Renewable Power.

Due to intermittent generation, solar and wind systems are not considered prime power. Geothermal and hydroelectric systems may be considered prime power, based upon their design. Similar generation and control systems exist for these systems; however, this UFC applies only to fuel-based prime power plants.

3-2 PRIME POWER GENERATOR CLASSIFICATION.

3-2.1 Rating Classification.

Determine generator rating classification as prime power per EGSA 101P for DoD facilities and ISO 8528 for host nation facilities, as appropriate. For combined heat and power plants, evaluate if generator is a continuous power classification with constant load and unlimited running hours. Unlike continuous generators that are designed for limited load fluctuations, prime generators can accommodate varying loads on an unlimited basis throughout the year. However, the average load factor cannot exceed 70 percent of the prime rating. Therefore, the primary calculations are to determine the load, the stability, and the amount of fluctuation.

3-2.2 Application Classes.

Determine generator application class per EGSA 101P for DoD facilities and ISO 8528 for host nation facilities as appropriate. ISO requirements are adopted by Europe and several other nations, and therefore are relevant only to those host nations which have adopted this standard.

3-2.3 Fuels Classification.

POL/fuels classification applies to Fuels Information Service Centers (Fuels Operation) and Type III, IV, and V hydrant fueling systems designed in accordance with Department of Defense Standard Designs AW 078-24-28 and AW 078-24-29 with a manual interlocked transfer switch. Size generators supporting hydrant fueling systems to 50 percent of pumping capacity for locations within the continental United States (CONUS) and 100 percent of pumping capacity for locations outside of the continental United States.

3-3 GENERATOR TYPE.

Generators must meet the requirements of ANSI C50.10, IEEE C50.13, and ANSI C50.14. **2**\ For CONUS locations, /**2**/ use reciprocating engine generators for prime power generators of 100 kW to 3 MW capacity and gas turbine generators for capacities of 1 to 20 MW. Use life cycle cost analysis and mission factors to decide between gas turbine and reciprocating engines in the 1 to 3 MW size. For combined heat and power plants, steam turbines may be used where there is waste heat recovery using heat recovery steam generators between 1 to 20 MW. For generators over 20 MW capacity, obtain user agency approval.

3-4 PRIME POWER GENERATOR DESIGN.

3-4.1 Reliability, Availability and Maintainability (RAM).

3-4.1.1 Goals.

RAM goals will be provided by the user and must be propagated throughout the generation system and supporting subsystems (electrical, fuel, cooling). The designer will determine the system configuration necessary to meet the RAM requirements, and accomplish the design. Support design selections with RAM analyses and calculations. IEEE 3006 series standards for reliability must be followed for Power Systems RAM analyses.

3-4.1.2 Resilience.

Depending upon mission requirements, a given level of high resilience will be required. Ensure generator sets can adapt to changing conditions and withstand, respond to, and recover from, disruptions.

The largest disruption known is cascading generator failure based upon loading too close to online generator capacity. When there are large amounts of critical loads that cannot be adapted to hierarchical elimination by frequency load shedding, spinning reserve must be employed. This will require multiple generators running at a maximum of 50% loading, so that if one generator fails, the entire load may be picked up by the other generator without shutting down the entire power source. This is different from reliability, as the focus is the capability to recover quickly from problems.

3-4.2 Capacity Factors.

Capacity considerations are found in Appendix D.

3-4.3 General Requirements.

Locate equipment for accessibility, and for ease of operation, maintenance and repair. Provide sufficient room between equipment items to facilitate ladders, working platforms, lifts and other equipment required for component removal and replacement.

3-4.4 Generator Sets.

Provide an alternator with a voltage capable of matching the distribution system on the facility. The alternator must have a base level with the prime engine.

Provide appropriate air circulation for generator set cooling.

3-4.4.1 Internal Combustion Engine.

Internal combustion reciprocating prime movers for prime power must use fuel oil (diesel, JP-5 or JP-8). Generators are revolving field, salient pole, air-cooled, open-type, and direct-connected, with amortisseur windings to dampen pulsating engine torque. The required number of poles is six or more to match low speeds typical of large fuel oil engines.

Prime mover for prime power can be diesel or spark-ignited natural gas engines. Cooling must be coolant based with an air exchanger. Engine speed should be determined by factors such as load profile, emissions limits, maintenance intervals.

3-4.4.2 Gas Turbine.

Prime mover for prime power gas turbine service must use natural gas, landfill gas, or fuel oil (diesel, JP-5 or JP-8) with alternators that are revolving field, non-salient or salient pole, self-ventilated, open drip-proof type. If outdoors, alternators must be Totally Enclosed Fan Cooled (TEFC).

3-4.4.3 Steam Turbine.

Use triple pressure, single, or multiple casing, condensing type steam turbines with a heat recovery steam generator. Design for a 30-year life cycle. Steam turbine-driven generators must be service rated for 5-20 MVA, revolving field, non-salient, two-pole, totally enclosed, air-cooled with water cooling for air coolers, direct connected, and 3,600 rpm for 60 Hz frequency (sometimes connected through a gear reducer up to 10 MVA or more). Self-ventilation is provided for generators larger than 5 MVA by some manufacturers, but this is not recommended for steam power plant service.

Steam turbine driven generators rated 5 MVA and below are revolving field, non-salient or salient pole, self-ventilated, open drip-proof type. Base the generator turbine, gear, and generator configuration on economic evaluation. Configuration analysis is typically done by the manufacturer. Steam turbines are not used for standby generation.

3-4.5 Liquid Fuel Systems.

For self-contained prime power generators, provide with under-belly tank or bulk storage fuel system. For bulk storage fuel system, provide a separate day tank for each generator. Calculate fuel storage on the mission run time, volume required for delays in delivery of replacement fuel and excessive fuel consumption. For bulk storage systems, provide fuel management, fuel maintenance and leak detection systems. Fuel system must meet the requirements of UFC 3-460-01. Provide duplex filters system to allow continuous operations during filter change out.

3-4.6 Air Intake System.

Locate air filters and silencers where readily accessible for maintenance. Silencers must be capable of reducing the noise level of the intake so the sound air pressure conforms to Table 2-1 and Occupational Safety and Health Act (OSHA) requirements. Perform analysis and document in accordance with UFC 3-450-01. The filtration system must protect the safety of life and prevent harmful foreign material, including water, from entering the system. Configure filtration system to the operational environment providing anti-icing and water separators as appropriate.

3-4.7 Lubrication System.

Provide either wet sump or dry sump lubricating systems. Provide lubrication system, filtration, and cooler per manufacturer recommendations.

3-4.8 Cooling System.

For packaged or modular (example, packaged in ISO containers or weather resistant containers) reciprocating engine prime power systems (example, packaged in ISO containers or weather resistant containers), use self-contained, liquid to air cooled heat exchanger system or air-cooled system.

For all other systems, use closed-cycle wet cooling system.

3-4.9 Exhaust/Air Emissions Control System.

Exhaust/air emissions from prime power generators must comply with federal, state, local and host nation air quality rules and regulations. Comply with approved operating permits. Adding a selective catalytic reduction (SCR) or other EPA-mandated emission control devices to a prime power generator may adversely affect its operation. Prior to adding SCR or other EPA-mandated emission control devices to a primer power generator, a thorough design review should be conducted and approved by the engine manufacturer prior to installation.

3-4.10 Starting System.

Mission requirements dictate reliability for starting systems. Select the starting system based upon mission requirements and life cycle cost analysis. Electric starters may be used for units up through 3 MW, if start times are met. Pneumatic starting may be used for units where a pneumatic system exists or the life cycle costs justify its use. For legally required or emergency stand-by generators, use electric starting systems.

3-4.11 Control System.

Provide generator and electrical system protection in accordance with IEEE Std 446 and IEEE Std 242.

3-4.11.1 Industrial Control Systems (ICS).

Provide an ICS for electrical power generation control and protection, either analog, programmable logic controllers, microprocessor, or distributed control system (DCS) as required by the sophistication required for operation of the generating units and associated systems.

3-4.11.2 SCADA.

Provide a SCADA system as required for operation of the generating units and associated subsystems and the needs for operator monitoring and control. Government will have a licensed copy of the required software and the right to operate changes in the controller's settings.

Power plant control systems are operational technology that must be standalone and meet the requirements of DoDI 8500.01 and NIST 800-82. NIST Special Publication 800-37 must be used during development of control system designs. Analog systems may be provided only as a part of an existing analog system. No new or grass root systems with analog controls are to be provided for new generators. Controls and redundancy including a supporting network must be based upon need (criticality and RAM factors). Open communication protocols (Modbus) must be deployed to allow future interface and connection to other manufacturers.

3-4.11.3 Subsystems.

Provide management control stations at strategic points in the plan for maintenance and redundant control requirements. Provide automated subsystems for the following:

- each engine-generator
- fuel system
- air pollution control equipment
- electrical substation
- emergency shutdown
- balance of plant controls

3-4.11.4 Analog.

Analog control is to be considered only when matching to an existing system.

3-4.11.5 Microprocessor-Based Control Stations.

Use programmable logic controllers (PLC) when fast response times are required, such as near real-time actions such as a safety shutdown or firing control. Provide a separate controller for safety systems. A PLC can handle only a few thousand input/output (I/O) points and is not easily scalable.

If redundancy is required, evaluate use of PLCs versus using a DCS.

3-4.11.6 Attributes.

The control system must include the following information and abilities:

- generator status information (for each generating unit)

- running/not running
- lubricating oil pressure
- engine temperature
- starting system status (battery/pneumatic receiver status)
- cooling system temperature
- starting aid status (jacket water/oil sump heater condition/temperature)
- fuel system status information
- switchgear breaker control switches available to the operator
- pressure and temperature indications of the engine and exhaust
- vibration notification
- generator loading, voltage, frequency and current
- cooling water temperature
- automatic synchronization
- startup, shutdown and emergency shutdown capability
- non-resettable run time hours
- exhaust pressure and/or temperature indicators to track/monitor operation of air emissions controls systems for environmental compliance with site permit

Note: Vibration monitoring is warranted on only limited applications and larger generator sizes.

3-4.11.7 Control Room.

The control room should be located in or close to the turbine/engine area to allow quick operational access. Provide a completely enclosed control room with sound attenuation. Mount instruments on a panel within the control room. Provide a heating/cooling system with high efficiency filtration to maintain positive pressure within the control room and to keep dust and other dirt particles from entering.

The control room must have:

- clean, dry atmosphere
- relatively constant temperature and humidity
- no vibration
- adequate light
- reliable electric power, free of surges in voltage and frequency

- air conditioning (a necessity for electronic distributive control systems and computers)
- direct visual (windows) or video surveillance of generators

3-4.12 Direct Current (DC) Power System.

Prime generator sets under 2500 kVA may not need a 125 VDC battery system, as other reliable power may be available. Those units that are stand-alone or requiring a black-start must have a 125 or 250 VDC dual power system comprised of two battery banks, one being the redundant set, two battery chargers and inverters, racks, and circuit breaker distribution for powering switchgear protection and metering. In addition, provide a dual 24 VDC power system with a UPS for generator controls, safety and emergency systems. Configure the DC power systems in crosstie configurations and provide battery disconnection means for safe battery maintenance. Stationary battery areas must comply with UFC 3-520-05.

3-4.13 Paralleling Switchgear.

Connect two or more generators and synchronize with respect to frequency, voltage, and phase angle using paralleling switchgear. This arrangement is suitable for paralleling switchgear operating at a voltage of 4.16 kV and up to approximately 10 MVA. For paralleling switchgear operating at 13.8 kV, this arrangement is the best for stations up to about 25 or 32 MVA.

For larger stations, the fault duty on the common bus reaches a level that requires more expensive feeder breakers, and the bus should be split. The bus and switchgear must be in the form of a factory fabricated metal clad switchgear. For plants with multiple generators and outgoing circuits, the bus must be split for reliability using a bus tie breaker to permit separation of approximately one-half of the generators and lines on each side of the split.

3-4.13.1 Integrated Paralleling Switchgear.

For permanent packaged or modular prime power plant configurations, pre-engineered integrated parallel switchgear may be used. Switchgear must provide automatic matching of on-line generators to loads. Provide with a dedicated controller and industrial graphical color HMI and include emergency stop buttons for each generator.

3-4.14 Distribution Switchgear.

If the plant is 20 MVA or larger, and the area covered by the distribution system requires distribution feeders in excess of two miles, it is cost advantageous to connect the generators to a higher voltage bus and feed several distribution substations from that bus with step-down substation transformers at each distribution substation. Distribution switchgear must conform to UFC 3-520-01 and UFC 3-550-01.

Select the high voltage bus configuration for reliability and economy. Alternative bus arrangements include main and transfer bus, ring bus, and breaker-and-a-half schemes. The main and transfer arrangement is the lowest cost alternative but is subject to loss of all circuits due to a bus fault. The ring bus arrangement costs only slightly more than the main and transfer bus arrangement and eliminates the possibility of losing all circuits from a bus fault, since each bus section is included in the protected area of its circuit. Normally, it will not be used with more than eight bus sections because of the possibility of simultaneous outages resulting in the bus being split into two parts. The breaker-and-a-half arrangement is the highest cost alternative and provides the highest reliability without limitation on the number of circuits.

Distribution selection is based upon criticality and reliability. Normal configuration for prime power generators is a two-bus (an A and B bus) system.

3-4.15 Split Bus.

A split bus panelboard has two separate portions of bus, one on top and the other on the bottom. The bottom bus may be sub-fed, or may be completely separate. The primary reason for this separation is to identify those items that must be fed by a generator, allowing the others to be switched off during a utility outage. This configuration is not recommended due to the possibility of someone assuming that the entire panel is off when in actuality it is not.

However, in controlled circumstances, where the labelling is done correctly, and the identification is correct, this methodology can be used to handle identification of loads requiring standby. This would occur in locations such as dining facilities (DFAC), where refrigerators and freezers require generator power, while room receptacles and auxiliary lighting do not require standby power. The preferred method is using separate panelboards for critical and non-critical loads. Refer to UFC 3-540-07 for additional guidance.

3-4.16 Black Start Generator.

For power plants with generators that cannot start without utility power, provide a self-contained engine generator that allows the power plant to recover from a total or partial shutdown and allows the individual generators to start from a completely dead or inactive state. Size the battery system to have reserve power that support a minimum of three firing attempts.

3-4.17 Communications and Alarms.

Communications systems must conform to UFC 3-580-01. Communication must allow operators to monitor generator loading and provide an alarm when the generator is near overload or in overload condition.

Alarms must encompass oil levels, fuel levels and flow, vibration, generator temperature, emissions, electrical system monitoring, relay systems and first out and subsequent trip list. Incorporate applicable NFPA 110 alarms.

3-5 ENVIRONMENTAL.

Comply with paragraph 2-4.2.

3-6 COMMISSIONING.

The purpose of commissioning is to make sure all parts of the generation system perform as designed and function properly according to the manufacturer's recommendations. Commissioning must be performed with a disruption of incoming power upstream of the incoming service. At the end of design, if a generator is de-rated for any reason, it must be documented in the O&M manuals and labelled appropriately.

Systems to be commissioned are:

- generator
- prime mover
- controls
- battery system
- switches
- fuel system
- load system transfer (ATS or switchgear)
- grounding

3-7 GENERATOR PLANT SECURITY.

Provide plants and facilities with security and protection against possible harmful events. Refer to UFC 4-010-01 for security requirements in buildings and facilities. /**1**/

APPENDIX A REFERENCES

Note: The most recent edition of referenced publications applies unless otherwise specified.

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APPENDIX B EXAMPLES OF SYSTEM CONFIGURATIONS

B-1 INTRODUCTION.

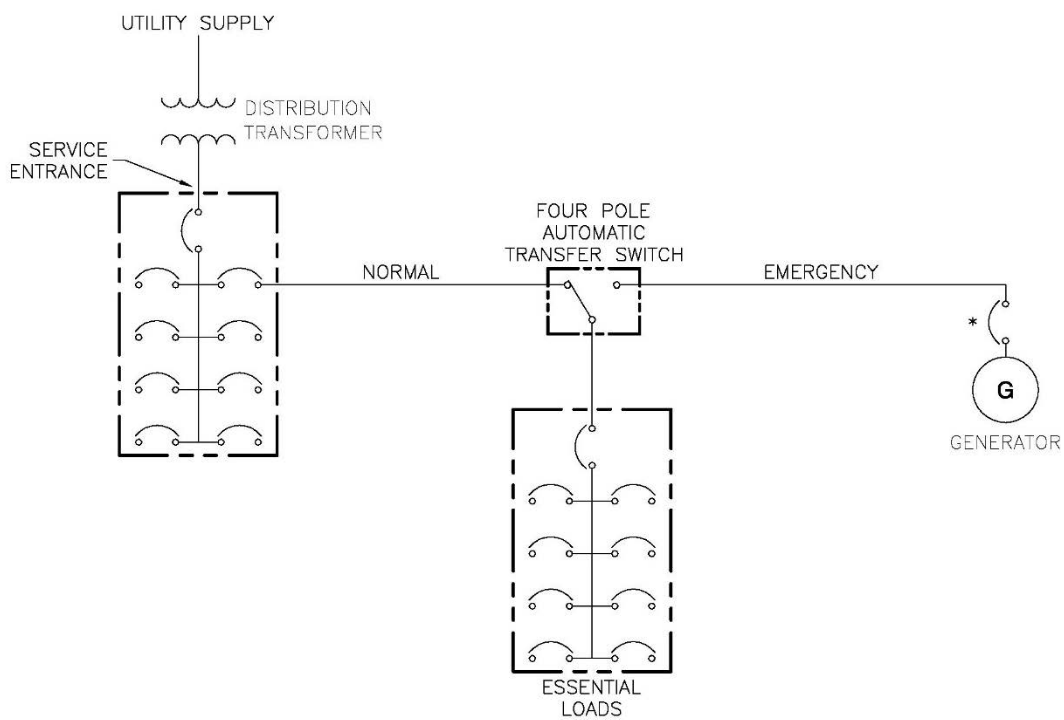
Appendix B provides examples and simple depictions of different configurations.

B-2 SINGLE GENERATOR SYSTEM CONFIGURATIONS.

B-2.1 Single Engine Generator Supply to Essential Loads.

If the facility has a permanently installed emergency power source, provide a separate panel to supply only the loads requiring emergency power. This panel will normally be supplied by the upstream main distribution panel. Figure B-1 provides an example of this configuration.

Figure B-1 Typical Single Engine Generator Configuration

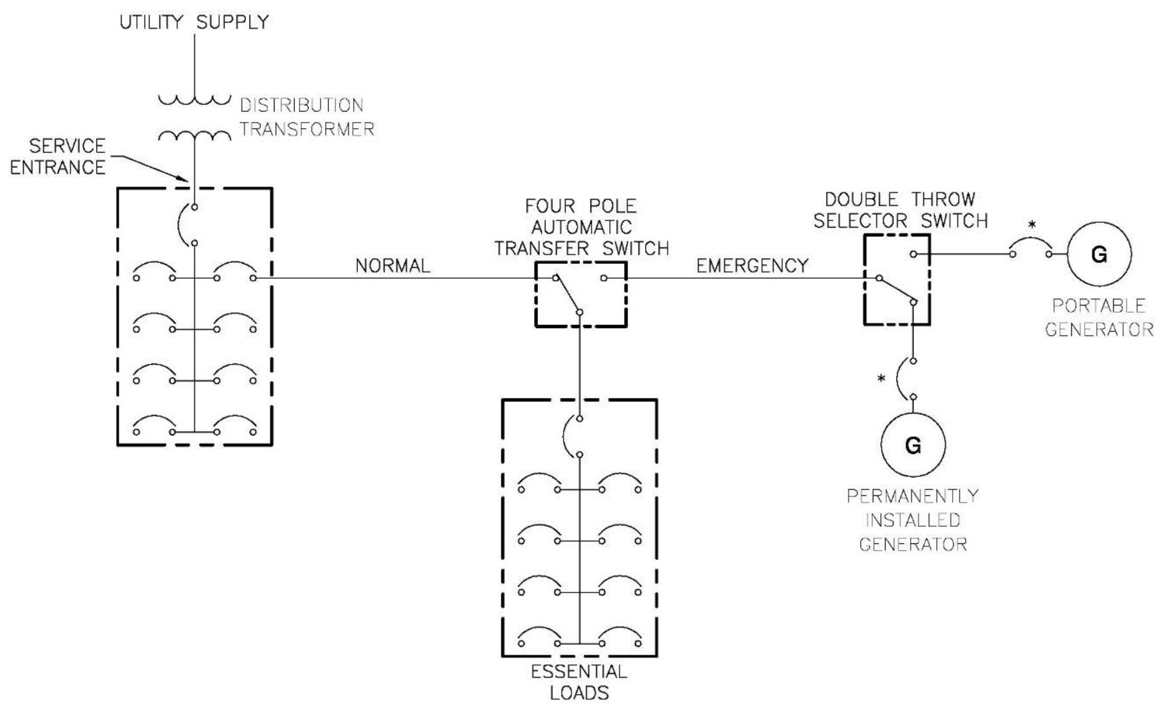


Note: The circuit breaker shown on the generator can be located on the generator skid, in a separate enclosure mounted adjacent to the ATS, or integral with the ATS.

B-2.2 Permanently Installed Engine Generator with Portable Connection.

If the facility is designed with a permanently installed generator and a connection for a portable generator, do not connect the conductors for both generators directly onto the emergency side of the associated ATS. Install a double-throw switch upstream of the ATS; connect the permanently installed generator and the portable generator connection to this double-throw switch, with the output of the switch connected to the ATS. Figure B-2 provides an example.

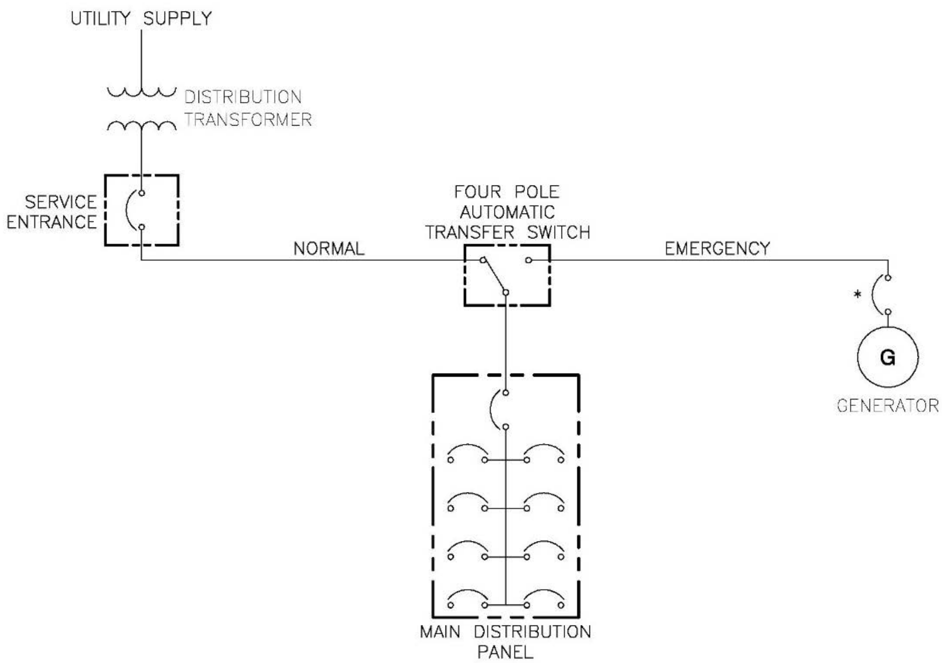
Figure B-2 Configuration for Permanently Installed and Portable Generators



B-2.3 Single Engine Generator Configuration for Whole Building Supply.

If the engine generator is designed to supply the entire facility, provide circuit breakers on each supply to the ATS as shown in Figure B-3.

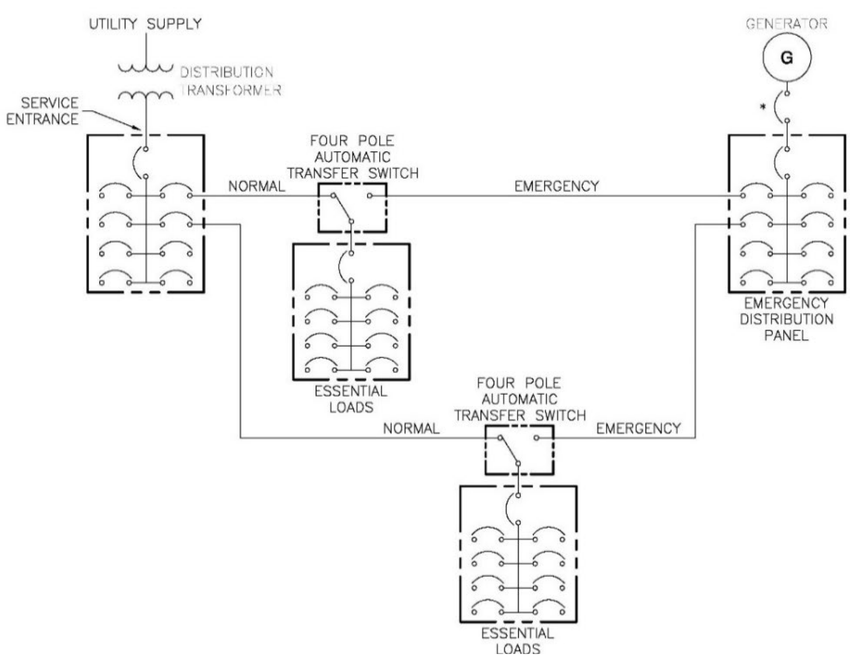
Figure B-3 Whole Building Generator Supply Configuration



B-2.4 Single Engine Generator Configuration with Multiple ATS.

If the engine generator supplies more than one ATS, install an emergency distribution panelboard or switchboard as shown in Figure B-4.

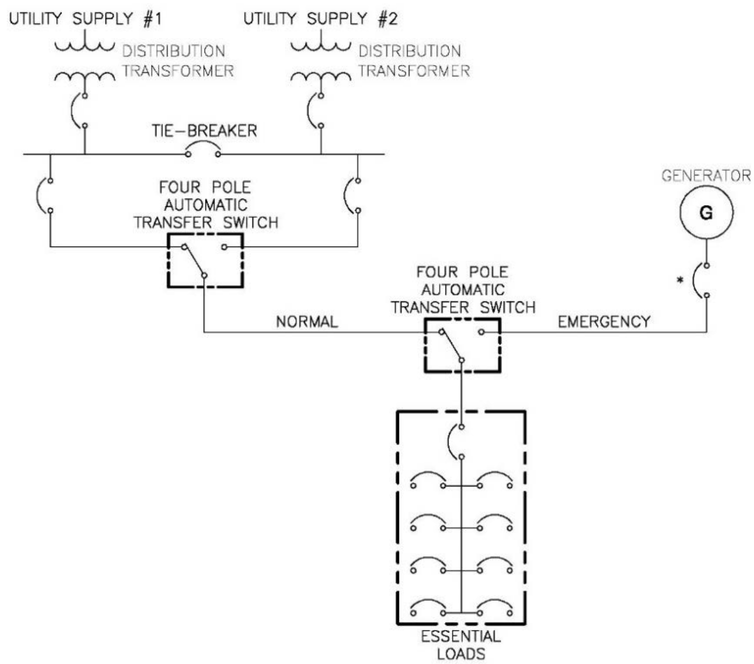
Figure B-4 Configuration to Supply Multiple ATS



B-2.5 Single Engine Generator with Redundant Utility Supply.

If redundant utility sources are available, design the system to select either normal utility source with the generator as a standby if both utility sources fail. See Figure B-5.

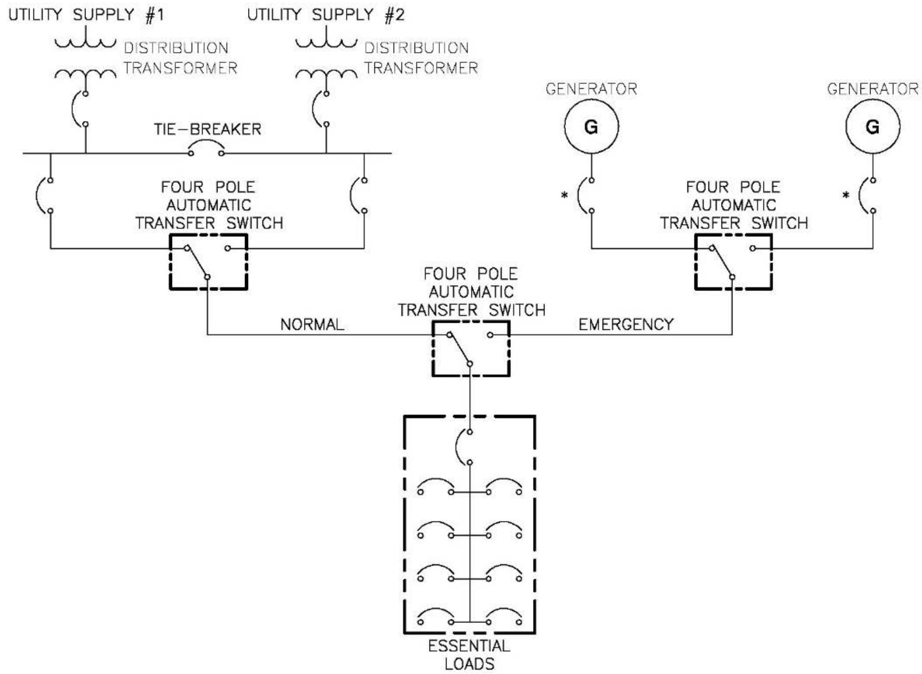
Figure B-5 Selection Between Redundant Utility Supply and Generator



B-2.6 Dual Engine Generator with Redundant Utility Supply.

If redundant utility sources are available, design the system to select either normal utility source with the generator as a standby if both utility sources fail. If dual rather than parallel generators are provided, use an ATS to select between the generator supplies. Figure B-6 provides an example.

Figure B-6 Selection Between Redundant Utility Supply and Dual Generators



B-3 PARALLEL GENERATOR SYSTEM CONFIGURATIONS.

B-3.1 Utility Supply.

Parallel generators require use of paralleling switchgear that results in a more complex operating system. Determine if a single utility supply (Figure B-7) satisfies reliability requirements. If additional system reliability is required, install an alternate commercial power supply as shown in Figure B-8. If feasible for the commercial power distribution system design, provide an alternate commercial power supply from a different source than the normal supply. Figure B-9 shows the preferred configuration if UPS systems are also supplied by alternate commercial and emergency power.

Figure B-7 Parallel Generators with Single Utility Supply

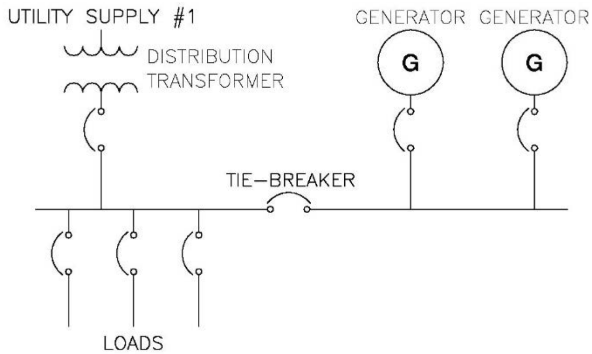


Figure B-8 Parallel Generators with Alternate Utility Supply

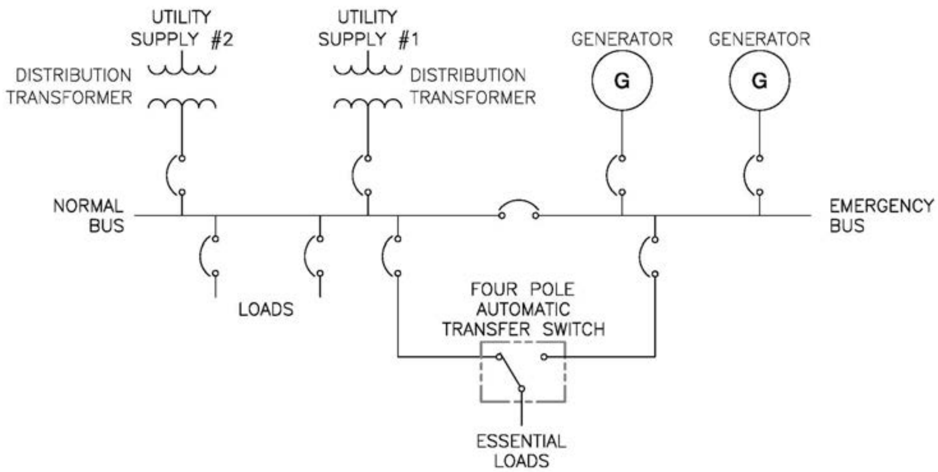
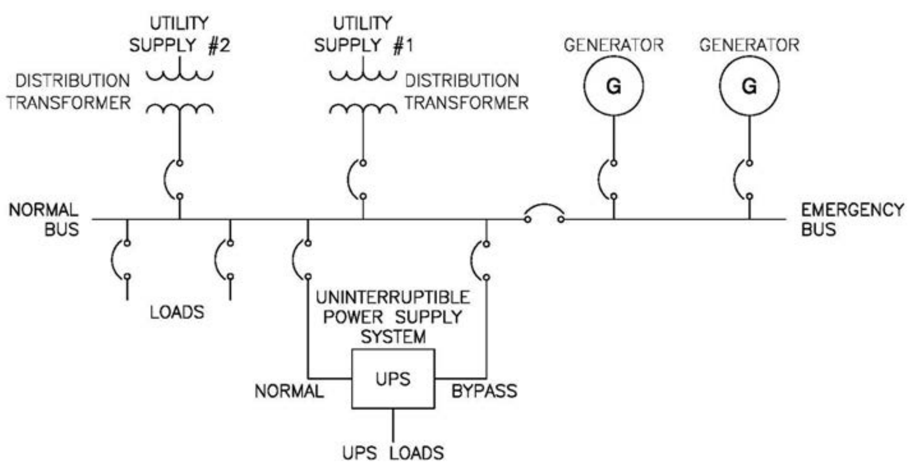


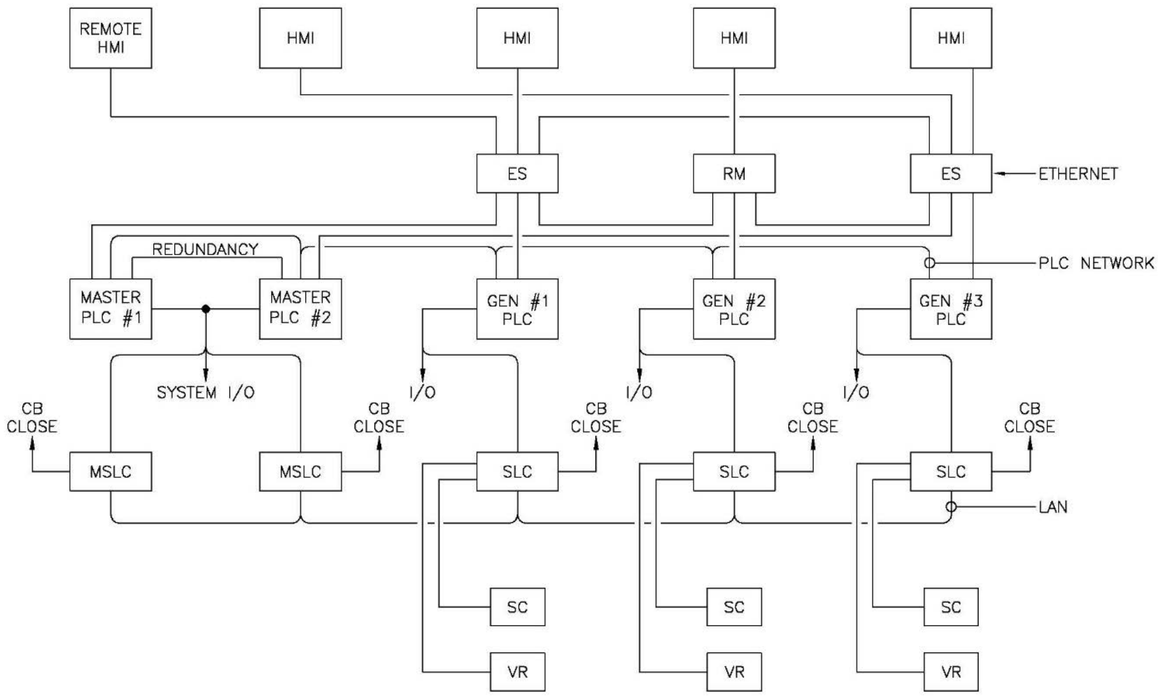
Figure B-9 Parallel Generators with Alternate Utility Supply for UPS Systems



B-3.2 Parallel Generator Control Systems.

Provide a redundant system in which any control system display can operate the control system. Design redundant PLCs for system control. A properly designed system can withstand a single failure and still operate. Figure B-10 shows an example of the control system architecture.

Figure B-10 Parallel Generator Control System Architecture



B-4 AUTOMATIC TRANSFER SWITCH CONFIGURATIONS.

Figure B-11 shows a simplified configuration with a four-pole ATS. For purposes of comparison, Figure B-12 shows a simplified configuration with a three-pole ATS.

Figure B-11 Figure

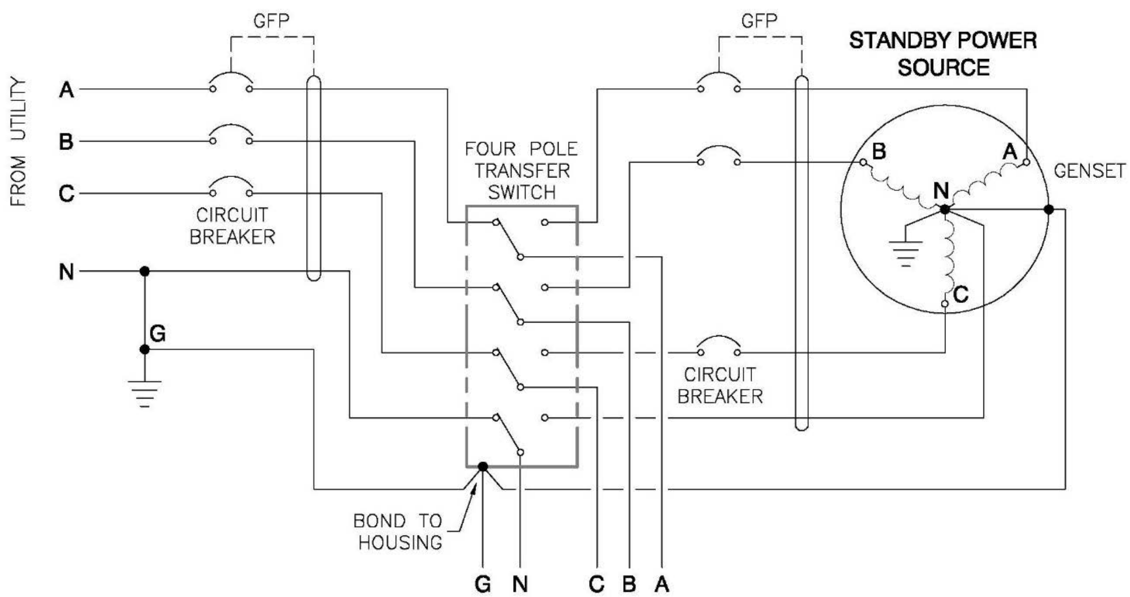
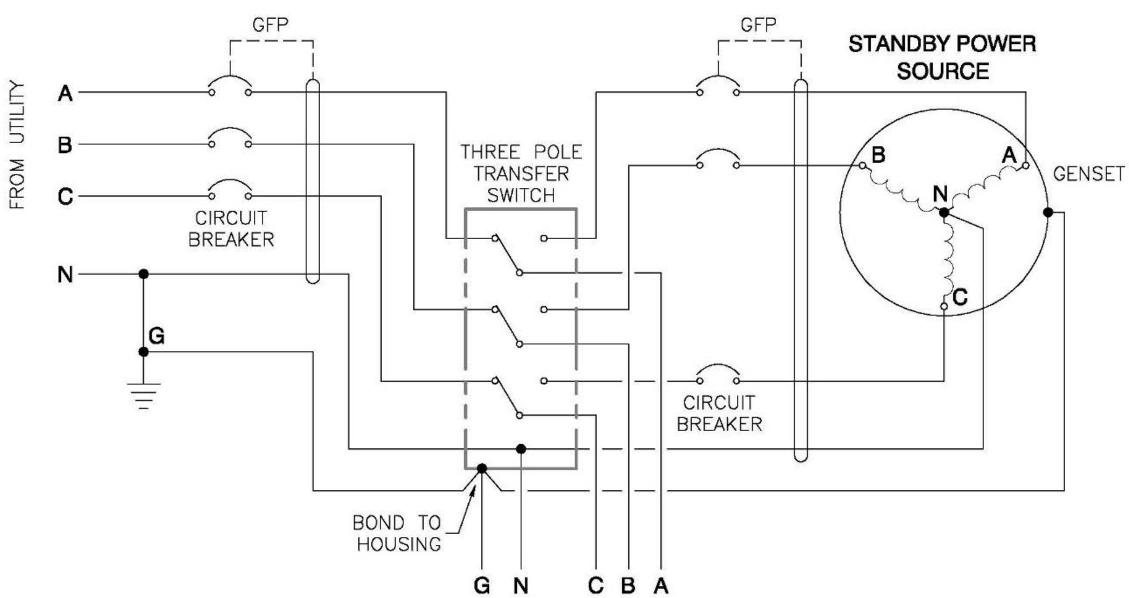


Figure B-12 Typical Three-Pole ATS Arrangement



APPENDIX C DESIGN CHECKLIST

C-1 INTRODUCTION.

This Appendix provides a design checklist of items to consider or address as part of the system design.

C-2 GENERAL.

A. <u>Physical Space Requirements</u>

Engine-generator dimensions
Operation and maintenance space
Cooling system space
Fuel system space
Ventilation (cooling air intake and exhaust)
Electrical panels, transfer switches, control panel spaces
Exhaust system space and silencer location
Starting system (electrical / air start)
Draw-out equipment requirements

B. <u>Power Rating</u> – Continuous, prime, limited time running power, or emergency standby power.

C. <u>Maximum time to start and be ready to assume load</u>

(Emergency application consequences)

D. <u>Emissions</u>

1. Exhaust gas composition and particulate limits

Noise limits
Thermal emissions (air/water)
Fuel system constraints

E. <u>Generator Paralleling</u>

1. Define sources.

Define configuration. Provide single-line diagram with the 35% design submittal.

C-3 ELECTRICAL.

A. <u>Generator Sizing</u>

1. Electrical load (kVA) – facility loads plus loads for fans, fuel pumps, lighting, battery charging

Motor starting kVA
Nonlinear loads and effect on generator rating

Power factor
Engine-generator application – single set / parallel
Frequency bandwidth (steady state)
Frequency regulation maximum – no load to full load
Voltage regulation – no load to full load
Voltage bandwidth – steady state
Frequency – 50/60 Hz
Voltage – output volts
Phases – 3 phase, wye / delta, single phase
Max step load increase – kVA
Transient recovery time – seconds (voltage and frequency)
Maximum voltage deviation (transient)
Maximum frequency deviation – Hz
Convenience duplex receptacles in generator room (for tools, testing, house-keeping)

B. Generator Protection

1. Subtransient reactance – percent (minimum)
Switchgear/breaker size, location, characteristics, enclosure
Parallel generators – current transformers installed on neutral side of generator windings

C. Automatic Transfer Switch

1. Sizing, controls, transfer options
Coordination of ground fault protection (four-pole/three pole)
In-phase protection for large motors downstream of transfer switch
Define sequence of operation "Upon loss of normal power" Define load shedding, motor starting sequence, if required, multiple generator operation, method of return to normal power (time delays).

D. Starting System (Electric-Start)

1. Battery location – on skid
Battery charger location
Circuit size and routing
Ventilation for battery charging
Battery temperature limitations

E. Starting System Controls

F. Generator Controls

G. Additional Circuits – coolant pumps, fuel transfer pumps, engine heaters, fuel heaters, piping heat-trace, cathodic protection

H. Grounding

1. Generator grounding - ungrounded, solidly-grounded, impedance-grounded

Equipment grounding
Building grounding and connections
Surge arrester grounding

I. Lighting

1. Equipment room normal lighting

Equipment room alternate-source lighting
Equipment room emergency lighting
Outdoor enclosure lighting (access for controls)

J. Electrical Connections

1. Connections with strain relief on power and communication connections to generator circuit breakers

K. Load Bank Requirements for Future Testing

L. Safety

1. Arc flash analysis and warning labels

Posting of applicable safety signage based on expected hazards (e.g., Personal Protective Equipment signage, high voltage)
Automatic External Defibrillators (AEDs) may be warranted if medical assistance is unable to respond within 4 minutes
Enclosure of electrical hazards
Posting of applicable safety signage based on expected hazards (e.g., Noise Hazard)

C-4 MECHANICAL.

Evaluate system for compliance with NFPA 30, 37, and 110.

A. Engine

1. Installation elevation above sea level (derating)

Maximum speed (900/1200/1800 rpm)
Fuel consumption
Starting system (air-start)
Ambient temperature extremes (HVAC, and/or derating)
Vibration limitations
Ancillary equipment

B. Fuel System

1. Main fuel tank (location, fill point, environmental requirements, cathodic protection) – UFC 3-460-01

Day tank (space, location, shape, venting, NFPA 30 – capacity constraints, elevation relative to fuel injectors)
Fuel level controls
Fuel transfer pump
Supply line/return line routing
Fuel coolers
Fuel heaters

C. Lube-Oil System

1. Integral to engine

External to engine
Space and provision for changing the oil

D. Governor

1. Type: droop or isochronous.

Frequency bandwidth (steady state).
Frequency regulation maximum – no load to full load.

E. Engine Cooling

1. Heat exchanger location (local / remote)

Cooling system design:

a. Local – Usually unit mounted radiator ducted through wall
b. Remote heat exchanger – Usually requires expansion tank, pumps, piping, local heat exchanger, remote heat exchanger (radiator, cooling tower)

Maximum summer outdoor temperature (ambient)
Minimum winter outdoor temperature (ambient)
Cooling medium (glycol/water, raw water)

F. Engine Room Ventilation

1. Cooling - Maximum allowable heat transferred to engine generator space at rated output capacity

Maximum summer indoor temperature (prior to generator operation)
Minimum winter indoor temperature (prior to generator operation)
Combustion air source (separate from cooling system)

G. Engine Controls (NFPA 37)

H. Exhaust System

1. Insulated/non-insulated)
Silencer (muffler location – inside/outside)
Penetration (roof/wall, location, thimble detail)
Multiple generating units - common exhaust considerations
Exhaust considerations: flappers, gooseneck, bird-screen, rain shields

I. Sound Limitations (OSHA, State, City Ordinances, Post Base Regulations)

1. Mechanical noise mitigation (interior/exterior)
Combustion-air intake noise mitigation (interior/exterior)
Exhaust noise mitigation (exterior)
Posting of signage - Hearing Protection Required

J. Safety

1. Guarding of mechanical hazards
Insulation of hot equipment
Enclosure of electrical hazards
Posting of signage for equipment which may auto-start
Posting of applicable safety signage based on expected hazards (e.g., Noise Hazard)

C-5 CIVIL/STRUCTURAL.

A. Seismic zone design

B. Vibration isolation

C. Foundation, house-keeping pads

D. Grading, fuel tank installation

C-6 ARCHITECTURAL.

A. Building design, louvers, doors

B. Bird screens for penetrations

C. Enclosure type – corrosion and high humidity location, desert environment

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APPENDIX D GENERATOR SIZING

D-1 INTRODUCTION.

Appendix D discusses the input data required as part of a generator sizing calculation.

D-2 LOAD EVALUATION.

When specifying engine-generator sets, the designer will analyze the load characteristics and profiles of the load to be served to determine the peak demand, maximum step load increase and decrease, motor starting requirements (represented as starting kVA), continuous and non-continuous loads (cyclical/periodic), and the non-linear loads to be placed on the engine generator set. This information represents the essential elements that determine generator capacity and controls requirements. Engine generator set configuration is determined to some degree by characterization of the loads to be served and the interaction of that load with the engine generator set. Size, speed, allowable alternator temperature rise, and generator controls are all greatly affected by the character of the load to be served, and any of the above factors may determine generator sizing.

D-2.1 Uninterruptible, Essential, and Nonessential Loads.

As part of the standby power load analysis, classify each load as to the type of power that it should have. Determine which loads within the facility need to continue to function following a loss of normal power. Evaluate which loads must be uninterruptible, those to which power must be restored to perform an essential function (essential), or are not required for the facility/mission to function if the normal power source is interrupted (non-essential).

- Uninterruptible – Loads in this category require continuous power and cannot experience even momentary power disruptions. Loads in this category usually involve life safety or include hazardous or industrial process equipment, or command, control, computer, data center, and communications systems. These loads will usually require use of battery standby or an uninterruptible power system (UPS) to power them until supplied with power from an engine generator system.
- Essential –Loads in this category require standby power, but can be de-energized until they can be supplied from an engine generator system. Loads in this category usually include HVAC loads to vital facilities or other load types that can be de-energized for short periods without severe consequence.
- Nonessential – Loads in this category can be de-energized for extended periods without severe consequence. Although these loads might be classified as nonessential, they might still be capable of being energized from engine generators, depending on the facility design. For most systems, nonessential loads do not require generator standby.

D-2.2 Conditions of Loading.

Peak demand calculation provides one factor that determines the alternator size. Peak demand is the sum of continuous loads and non-continuous loads that are likely to be coincident.

- Continuous loads are energized for periods greater than 3 hours, such as lighting, UPS systems, and some HVAC equipment.
- Non-continuous loads do not meet the definition of continuous and the proportion of on-to-off time varies with each load.
- Coincident loads are those that are not prevented by character or controls from being energized at the same time.
- Non-coincident loads are dissimilar loads, fed from a common source that are prevented by character or controls from being energized at the same time. An example of a non-coincident load might be all compressors on an air conditioning chiller that are sequenced by a control system such that they do not operate simultaneously.

D-2.3 Nonlinear Loads.

Identify loads that are nonlinear. Non-linear loads are loads that draw a non-sinusoidal current waveform when supplied by a sinusoidal voltage source. Typical non-linear loads include solid state switching power supplies, computer power supplies (including those found in desktop PCs, UPSs, variable frequency drives, radar power supplies, and solid state ballasts in fluorescent light fixtures. These loads cause distortion of the source voltage and current waveforms that can have harmful effects on many types of electrical equipment and electronics, including generators. A low generator sub-transient reactance minimizes the voltage waveform distortion in the presence of such loads. For this reason, when the non-linear loads comprise 25 percent or more of the loads served, the generator sub-transient reactance should be limited to no more than 0.12.

Provide the assessment of the proportion of linear versus nonlinear loads to the generator supplier. Depending on the proportion of nonlinear loads, the generator supplier might recommend oversizing the generator, might modify the generator control system, or provide a generator with a lower sub-transient reactance.

D-2.4 Step Loading.

Step load increase/decrease is used to account for the addition or loss of significant blocks of load. The significance of this is that the generator must be sized and controlled to maintain voltage and frequency within specific limits after sudden acquisition/loss of load (described as transient response). Establish the step loads that will be applied to or removed from the generator after startup. Some systems might apply all loads in a single step and other systems might establish multiple steps to limit the voltage and frequency transient during generator loading/unloading.

If the calculated generator size is based on transient response capability (control of voltage or frequency excursion from rated value) rather than peak load, consider load steps to reduce the amount of loads acquired at any single instant. Consider the following as part of the load analysis:

- Smaller generator systems will usually have a ATS and all required loads will be energized at the same time.
- Larger generator systems might have multiple ATS, which can allow staggering of the load with discrete load steps.
- Some connected loads can have restart time delays independent of any ATS time delay.
- Parallel generator systems will usually have multiple ATS or distribution circuit breakers in the paralleling switchgear to establish step loading time delays.

D-2.5 Motor Starting Requirements.

Motor starting requirements are important to properly size engine generator sets because the starting current (inrush) for motors can be as much as six times the running current, and can cause generator output voltage and frequency to drop, even though the generator system has been sized to carry the running load. The designer must analyze the motor loads to determine if the starting characteristics of a motor or a group of motors to be started simultaneously will result in inadequate system performance.

Provide a motor starting kVA value for the largest motor or combination of motors to be started simultaneously. An increase in the size rating of the engine generator may be necessary to compensate for the inrush current. This information assists the engine generator supplier in properly sizing the engine generator set.

D-3 GENERATOR RATING.

The generator rating depends on the load analysis results, the projected annual and continuous run-time, and the overall system design and configuration.

D-3.1 Industry Ratings.

The generators addressed by this UFC will normally be rated based on their limited time running power classification (EGSA 101P, ISO 8528-1), which engine generator manufacturers often refer to as the standby rating.

Apply the generator prime power rating for the installation if any of the following conditions apply:

- The expected annual operating time is longer than stated above, which might occur if the system will be used for utility peak shaving.

- The generator will be operating at near 100 percent of rating and the load is nonvarying. **Note:** Historical experience indicates that most diesel generators will rarely be loaded near 100 percent and less than 50 percent loading is common.
- The system is designated as a COPS in accordance with NFPA 70 Article 708.

D-3.2 Generator Capacity Rating.

The required generator capacity depends on:

- Load analysis results (refer to paragraph D-2). Size the generator based on expected power demand rather than connected load.
- Magnitude of load steps that will be applied to the generator, together with the desired transient response characteristics.
- Allowable voltage and frequency variation, including initial loading effect.
- Oversizing to mitigate the effects of nonlinear loads*.* **Note:** For combinations of linear and non-linear loads where the percentage of non-linear loads is small relative to the capacity rating of the generator (25% or less), standard generator configurations are normally acceptable.

Small generators with a relatively simple load analysis can be sized by hand calculations. Larger generator systems with a large proportion of nonlinear loads or multiple load steps will require software specifically designed for generator sizing. Generator suppliers can provide this software or will perform the calculations.

D-3.3 UPS Systems.

UPS systems can have a detrimental effect on generator control systems and need to be considered in the generator performance requirements and generator commissioning. Ensure the following are addressed in the design:

- Generator and UPS communication so that the UPS recognizes when it is operating on a generator.
- Allowed battery charging current while the UPS operates on a generator source. UPS battery charging is not considered a critical/mission-essential load during generator operation and should be reduced to the minimum allowed by the UPS design, if it is an available UPS design feature.
- Power walk-in – Limit the rate at which the UPS transfers from its internal battery to the generator, if available in the UPS design.
- UPS input filter energized only after adequate load is established. Generator sets inherently have difficulty controlling voltage with leading power factors, which can cause an increasing voltage as the voltage

regulator attempts to control voltage. This condition can be exacerbated during UPS startup by the power walk-in feature. Typically, a UPS has some means of gradually applying load to the source over a 3 to 60 second period. An unloaded input filter may cause a leading capacitive power factor load beyond the generator's voltage control ability. Other loads connected to the generator will counter this effect. Disconnecting the filter at lower UPS loads will minimize this effect. This is an essential design requirement.

- Rotary UPS on DC bus – Limit the rotary recharge rate when the UPS is operating on generator.
- If the system has step loading capability, energize nonlinear loads such as a UPS after other mechanical-type loads have been energized.

Ensure the engine generator commissioning process confirms acceptable operation of the fully connected system with the UPS systems in service.

D-3.4 Power Quality.

The load analysis described in paragraph D-2 requires an assessment of the proportion of linear versus nonlinear loads. Nonlinear loads can adversely affect the generator control system. Provide this information to the generator supplier for evaluation.

Ensure the engine generator commissioning process confirms acceptable operation of the fully connected system with the nonlinear loads in service. If power factor correction capacitors are installed, ensure they are energized during the commissioning process if they are to remain in service.

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APPENDIX E CONNECTION METHODS FOR PORTABLE GENERATORS

E-1 INTRODUCTION.

This (Cannon plug) or NFPA 70, UL-listed, CSA-certified, double-locking, single pole connectors (Cam-Lok style) as quick connection/disconnection devices for portable generator connections of 600 volts or less for facilities. This is the typical Air Force connection method for portable generators. Special use applications such as providing shore power for backup power to a nuclear reactor per UFC 4-150-02 is not covered in this UFC.

For Air Force: Portable generators are referred to as standby generators and are classified as EAID generators.

E-2 CONNECTION METHODS.

Generator facility connections must either be hardwired or employ connection methods as noted below.

E-2.1 MIL-DTL-22992F, Class L, QWLD-Rated Connectors.

Heavy-duty cylindrical, MIL-DTL-22992F, Class L, QWLD-rated connectors (Cannon plug) with appropriately rated disconnect switches selected in accordance with NFPA 70 are permitted as follows:

- Up to three (3) connections per generator are permitted. The maximum single connector rating must be 200 amperes. Mobile electric power (MEP) 6/806 units are permitted to use a single 200A Cannon plug connection.
- Combined loads from multiple connections must not exceed the rated capacity of the standby generator.
- The single conductor size used in any connector must not exceed #4/0 American Wire Gauge (AWG).
- Unused connector receptacles must be capped with manufacturer-recommended covers to prevent exposure to live electrical contacts. Plastic dust caps are not acceptable.
- A data plate style placard must be permanently attached, using sheet metal screws or rivets, adjacent to the connection(s), which reads:

DANGER

**UNUSED CONNECTOR RECEPTACLES ARE ENERGIZED
DURING GENERATOR OPERATION
EXERCISE EXTREME CAUTION
PROPER PPE REQUIRED WHEN MAKING CONNECTIONS**

- Cable assemblies connected in parallel must comply with all of the following:
  - Be the same length.
  - Have the same conductor material.
  - Be the same size in circular mil area.
  - Have the same insulation type, including cable assembly sheathing.
  - Be terminated in the same manner and be of the same rating. For example, a 200-ampere connection cannot be paralleled with a 60-ampere connection, even though the cable assemblies are rated for 200 amperes.
- All operators must be trained on the danger associated with multiple connections on the generator bulkhead. Supervisors must document this training.

E-2.2 Single-Pole (Cam-Lok style) Connectors.

Single-pole (cam-lok style) connectors and receptacles that are double-locking in accordance with the National Electrical Code (NEC) and NEMA 3R-rated are permitted with limitations. For standby generators, paralleled connections are prohibited. A single connector per phase must be used for each load and meet the following requirements (**Note:** MEP 6/806 units are permitted to use a single 200-ampere cam-lok style connector/plug connection per phase).

- Connectors and receptacles must be rated 200 amperes or less, UL listed and Canadian Standards Association (CSA) certified.
- Connector and receptacle contacts must be made of high-conductivity copper base alloy.
- Connector and receptacle must provide a double-locking means to ensure a minimum 600 lb/in^2 pressure on contact.
- Connector contacts must be recessed. A thermoplastic rubber or neoprene-insulated jacket must extend past the ends of both the male and female contacts and meet the strain relief requirements listed below.
- Receptacles must be provided with NEMA 3R color-coded (for phase and ground identification) snap-back covers (150 amperes and less) or protective caps.
- Cable plugs must be provided with color-coded (for phase and ground identification) protective caps with lanyards.
- Tapping tees are not permitted.
- Connectors and cable plugs must be fully rated for intended use.

- Cable-to-plug connections must be crimped. Set-screw connections are not allowed because of their tendency to loosen due to heating/cooling, high load, and vibration.
- The only approved cable strain relief is vulcanized style terminations.

Up to three (3) cam-lok style connectors (maximum twelve [12] single-phase connectors) per generator are permitted to allow connection to three separate loads. The maximum single connector rating must be less than 200 amperes.

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APPENDIX F FACILITY DESIGN TYPES

Appendix F discusses different facility design types that might be authorized to have a standby power system.

For Army: Each major command/program defines its standby and emergency power requirements based on mission requirements, location/environmental parameters, and the NFPA criteria (life-safety). Typical applications that require standby or emergency power include: Command, Control, Communications, Computers (data centers), health care, industrial process facilities, RDT&E facilities, laboratories, and Installation Critical Support Services (including Force Protection, Readiness, Community Support).

For Navy: Table F-1 provides a list of the types of facilities that are typically authorized to have emergency generators. This information was obtained from UFC 2-000-05N and is not considered a complete list; it only contains the occurrences in UFC 2-000-05N where generators are mentioned.

For Tri-Service: Table F-2 provides a summary of facilities that are authorized to have emergency power. This information was obtained from UFCs.

Table F-1 Naval Facilities Authorized for Standby Power

Category Code	Facility Type	Comments
12330	Vehicle and Equipment Ready Fuel Storage	Authorized for buildings and utilities that may be needed in a hurricane or other base emergency.
13120	Communications Relay Facility	Contains rack mounted communications receiving, amplification, and transmitting equipment, along with a UPS and an emergency generator.
13122	VHF/UHF Communications Facility	Contains a small UPS and an emergency generator.
13135	Receiver Building	Contains a UPS and an emergency generator.
13140	Telephone Exchange Building	Can contain the telephone switch, main distribution frame, intermediate distribution frame, staff support spaces, operators work positions, maintenance and storage spaces, and is supported by UPS and emergency generators.
13150	Transmitter Building	Contains a UPS and an emergency generator.
13372	Military Terminal Radar Approach Control Facility	Space is provided in the mechanical room for an emergency generator and UPS system.
13373	Fleet Area Control Surveillance Facility	The mechanical space should include sufficient room for as emergency generator and a UPS system.
13374	Joint Control Facility	The mechanical spaces should include sufficient space for an emergency generator and UPS system.
13375	Air Surveillance Radar (ASR) Facility	The building and its associated antenna tower are located in a remote area of the airfield and an access road and emergency generator are required.
14365	Operations Control Center	UPS and emergency generators are required for continuous operation during natural disasters and increased security postures.

Category Code	Facility Type	Comments
14380	Command, Control, Communications, Computers, and Intelligence Facility (C4I)	The technical and operational mission of a C4I will require that it contain, Secure Compartmented Information Facility (SCIF) areas, a UPS, emergency generators, and in selected cases, radio frequency interference (RFI) shielding, electromagnetic interference (EMI) shielding, and Telecommunications Electronics Material Protected from Emanating Spurious Transmissions (TEMPEST) protection.
14385	Joint Reserve Intelligence Center (JRIC)	The technical and operational mission of a JRIC will require that it contain, SCIF areas, a UPS, emergency generator(s), and in selected cases, RFI shielding, EMI shielding, and TEMPEST protection.
51010	Hospital	Standby/emergency electrical generation, operational fuel storage of the generators or building heat systems and electrical transformers in direct support of the medical facilities should have the BUMED activity as the User and Maintenance UIC. The BUMED facility is not a complete and useable facility without the inclusion of these directly supporting utility systems.
81159	Standby Generator Building	Standby generators are used to provide electrical power when the normal source of power is not available. This category includes all necessary equipment for the production of the commodity, including tanks, pumps, electrical equipment, and all other equipment for electrical generation.
81160	Standby Generator Plant	Standby generators are used to provide electrical power when the normal source of power is not available. This category includes all necessary equipment for the production of the commodity, including tanks, pumps, electrical equipment, and all other equipment for electrical generation.

Table F-2 UFCs Addressing Standby Power Requirements

UFC	Title	Requirement Summary
4-133-01	Navy Air Traffic Control Facilities	Requires emergency generators for various facility types, including radar air traffic control facilities (RATCF), fleet area control and surveillance facility (FACSFAC), joint control facility (JCF), and air traffic control tower (ATCT).
4-141-04	Emergency Operations Center Planning and Design	When required, only essential systems should be placed on the emergency system with a generator being the primary emergency power source. The type, size and number of generators is based on the operational requirements of the EOC.
4-141-10N	Design: Aviation Operation and Support Facilities	UFC 4-141-10N re-issues MIL-HDBK-1024/1 for use for Navy applications. Requires emergency generators for a variety of aviation operation and support facilities.
4-150-02	Dockside Utilities for Ship Service	Requires standby power for nuclear submarines.
4-211-01	Aircraft Maintenance Hangars: Type I, Type II, and Type III	Coordinate and provide emergency power as dictated by the mission. At a minimum, hangar doors must be operable in the event of utility power failure by means of a generator.
4-213-10	Graving Drydocks	Install a back-up emergency diesel generator near each pumphouse to run at least the drainage pumps and alarms in the event all electrical power is lost.
4-510-01	Design: Medical Military Facilities	Requires emergency generators for hospitals.
4-722-01F	Air Force Dining Facilities	AFMAN 32-1062 authorizes an emergency generator for one feeding facility per installation, with MAJCOM having authority to approve additional eating facilities.

UFC	Title	Requirement Summary
4-722-01N	Navy and Marine Corps Dining Facilities	Provide facility service entrance with the capability to temporarily connect a portable generator via an external connection point. Systems utilizing portable generators must comply with NFPA 70 Article 702. If the facility has been designated as a Mass Care feeding facility, provide a permanent, external self-contained emergency generator that must power the entire facility load. Provide 72 hours of fuel storage.
4-730-04AN (INACTIVE)	Military Police Facilities	Auxiliary support power backup power may be provided as auxiliary support by individual battery units, a central battery system or by an engine-generator set. Determination of the type of auxiliary support provided will be based upon economics alone. Special requirements exist for an automatic emergency source or power for critical communications and surveillance security systems using monitoring devices (CCTV I D alarms) linked to the MP desk and for other special equipment or functional areas where power outage would jeopardize mission-effectiveness.

UFC	Title	Requirement Summary
4-730-10	Fire Stations	Provide 100% emergency generator back-up power for HQ/main and large HQ stations. For satellite stations, provide emergency back-up power, at a minimum, for the following spaces/systems: • Apparatus bay lighting and doors. • Watch Desk/Dispatch and all associated equipment. • IT room systems related to the Dispatch and communication functions. • Lighting. If required by Installation mission requirements, consider providing emergency power for additional spaces, such as the Day Room, or providing 100% emergency back-up power for the entire satellite station.
4-470-02	Fitness Centers	Provide facility service entrance with the capability to temporarily connect a portable generator, via an external connection point. Systems using portable generators must comply with NFPA 70 Article 702. Coordinate with activity representatives to develop a written, manual load-shedding procedure for the facility. Document size of generator required to support design conditions.

APPENDIX G AIR FORCE GENERATOR AUTHORIZATIONS

Reference AFMAN 32-1062.

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APPENDIX H POWER PLANT CONSIDERATIONS

H-1 PLANT LOCATION FACTORS.

Power plant location should be determined after evaluating the factors listed in Table H-1. Design power plant and its systems to operate appropriately in the selected location's environmental conditions.

Table H-1 Power Plant Location Factors

Factor	Impact
Climate	Will determine type of architecture of building, wall and roof U factors, heating, and ventilating
Maximum and minimum dry bulb	Affects export heating, maximum wet bulb temperature load heating, and cooling degree days
Maximum and minimum wind	Affects heating load and velocities structural loading
Topography grades	Affects architecture and floor levels, fuel handling, fuel storage, and drainage.
Soil	Bearing value and water tables determine structural foundations, drainage, and underground pipe distribution.
Maximum high water	Affects floor levels, level pumps, suction lifts, and foundations
Frost line	Determines depth of water and sewer lines
Cathodic analysis	Determines cathodic protection requirements to reduce systems corrosion
Seismic zone	Determines structural reinforcement requirements
Future expansion	Affects allocation of space in plant for expansion
Altitude height above sea level	Affects air density and stack height
Orientation near air field	Determines maximum stack heights and hazards near docks, railroads, and affects transportation, roads of fuel and materials
Water supply	Determines condenser cooling, jacket cooling, makeup water, and domestic water. This affects plant location, water treatment and filtering requirements
Local rules and regulations	May determine materials of material construction, air pollution permit requirements, water, sewers, landfill and fuel storage

H-2 ACOUSTICAL CONSIDERATIONS.

Consider acoustical noise in selection of generator location using Table 2-1.

An economic study must show that modifications and additions to an existing plant, to serve additional loads, is the most economical approach compared to other options such as additional production using third-party-funded construction and operation.

H-3 PRIME POWER PLANTS.

Prime power plants must have adequate capacity to meet all peacetime requirements. Types of plants for installations not requiring export steam or heat:

- Purchased electric power.
- Reciprocating engine-generator or gas turbine-generator rated for prime or continuous duty.
- Steam boilers with turbine generators of matched capacity. Turbines can be straight condensing or combination condensing and back pressure as required to suit plant steam usage.

Types of plants for installations requiring export steam:

- Purchased electric power and steam plus steam heating boiler.
- High pressure steam boilers with backpressure steam turbines of matched capacity. Steam heating boilers can be used to supplement the requirements of the export steam load.
- High pressure steam boilers with automatic extraction condensing turbines. Steam heating boilers can be used to supplement the requirements of the export steam load.

H-3.1 Boiler Requirements.

Certify boiler operations in accordance with UFC 3-430-07. Obtain boiler operating permit from state and local authorities as appropriate and if required.

H-3.2 Load Requirements.

H-3.2.1 Electrical.

Determine loads in kW. Determine winter and summer, types of electric loads separately.

Table H-2 Electrical Load Types

Load Type	Notes
Export	See UFC-3-501-01
Plant	See UFC-3-501-01
Switchgear	See UFC-3-501-01
Line losses	12% of subtotal (unless more accurate data is available.
Total present load	Total of above
Total ultimate load	See UFC-3-501-01 (may be estimated by extending current load trend)
Minimum continuous	See UFC-3-501-01 (as for a summer night)
Emergency load	See UFC-3-501-01 (demand of services that cannot tolerate a 4-hour interruption)

H-3.2.2 Steam.

If steam is considered a requirement, then the following needs to be calculated as well. (Determine loads in kBtu/hr.) Determine winter and summer, types of steam load and winter loads separately.

Table H-3 Steam Load Types

Load Type	Notes
Condensing turbine	Rated kW × heat rate
Auto-extraction turbine	Rated kW × heat rate
Plant auxiliaries	Steam jet air ejector
Condensing turbine	Rated kW × heat rate
Fuel oil heating	
Export Space heating (radiation)	Use diversity factor of 1.0
Export space heating (ventilation)	Use diversity factor of 0.8
Export utilities (hot water and laundry)	Use diversity factor of 0.65 For kitchen use diversity factor of 1.0
Refrigeration (turbine drive)	

Load Type	Notes
Refrigeration (absorption type)	
Process use	
Distribution losses	
Total present load	Total of above steam loads.
Total ultimate load	Maximum expected steam load for electrical power generation plant steam requirements and export steam loads (including projected present and additional future load)
Minimum continuous	Same as distribution loss
Emergency load	Demand of services that cannot tolerate a 4-hour interruption
Typical load curves	For an example of a typical load curve, see Figure G-1.

H-3.2.3 Growth Curves.

In (a) of Figure H-1, note the normal trend growth of total steam and electric demands and the additional loads when new buildings or processes are added.

This curve is useful in timing power plant additions of equipment.

H-3.2.3.1 Load Curves.

The average of daily steam and electric demands, (b) of Figure H-1, for the season or year under consideration for each hour of a 24 hour day is also important. Such curves are useful in determining load factors and duration of certain demands, and in dividing the total load among the plant units.

Fire pump loading must be considered for any installation with an electric fire pump. This loading is covered under NEC 695-7. This means that the generator must be oversized to have a voltage dip no more than 15% during normal starting of the fire pump motor. Ensure minimum generator loading is at least 35% of the rated kW, without the fire pump load, to avoid wet stacking and soot buildup.

H-3.2.3.2 Load Duration Curves.

Plot the number of hours of duration of each load during a year for present and future load conditions of steam and electricity usage for the activity. See (c) of Figure H-1. This type of curve is useful in determining load factors and in sizing units of power plant equipment.

Load duration curves for various conditions are shown on Figures H-2, H-3 and H-4.

Figure H-1 Typical Steam and Electric Load Curves

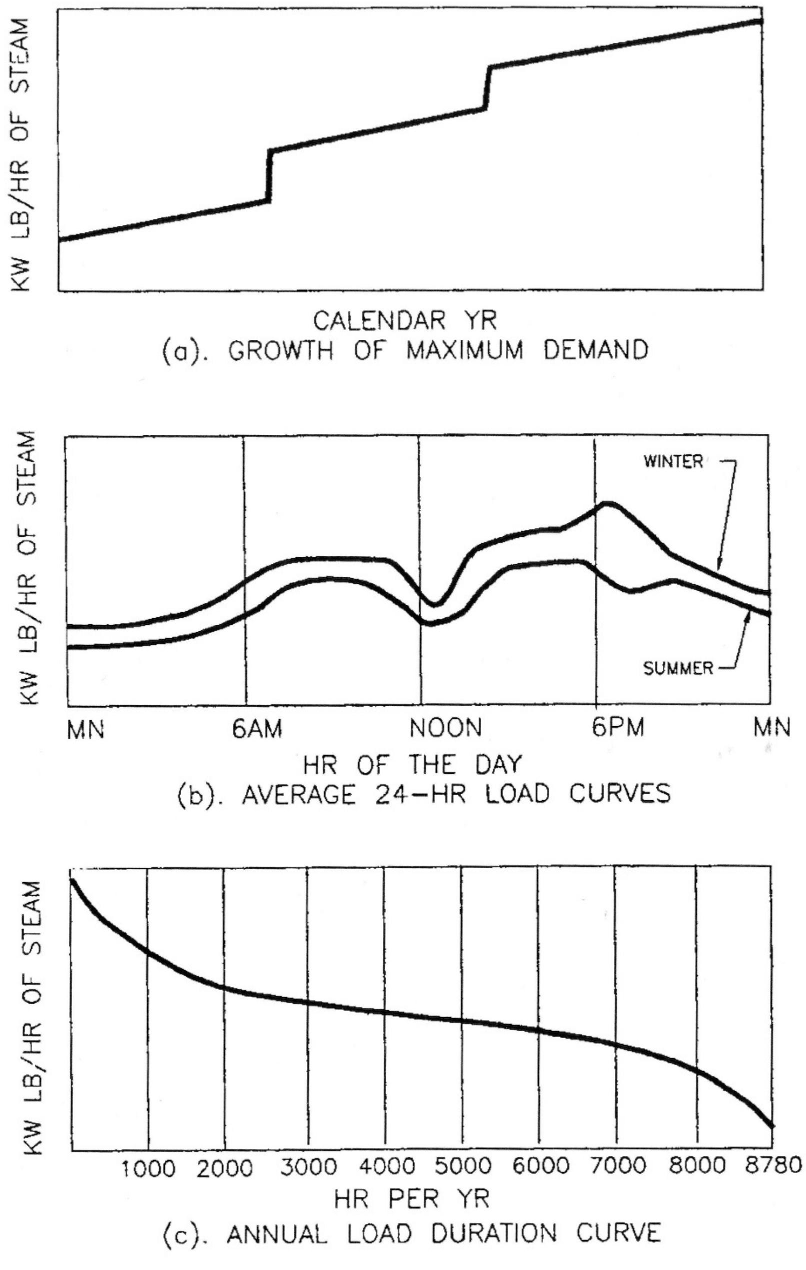

Figure H-2 Typical Load Duration Curves

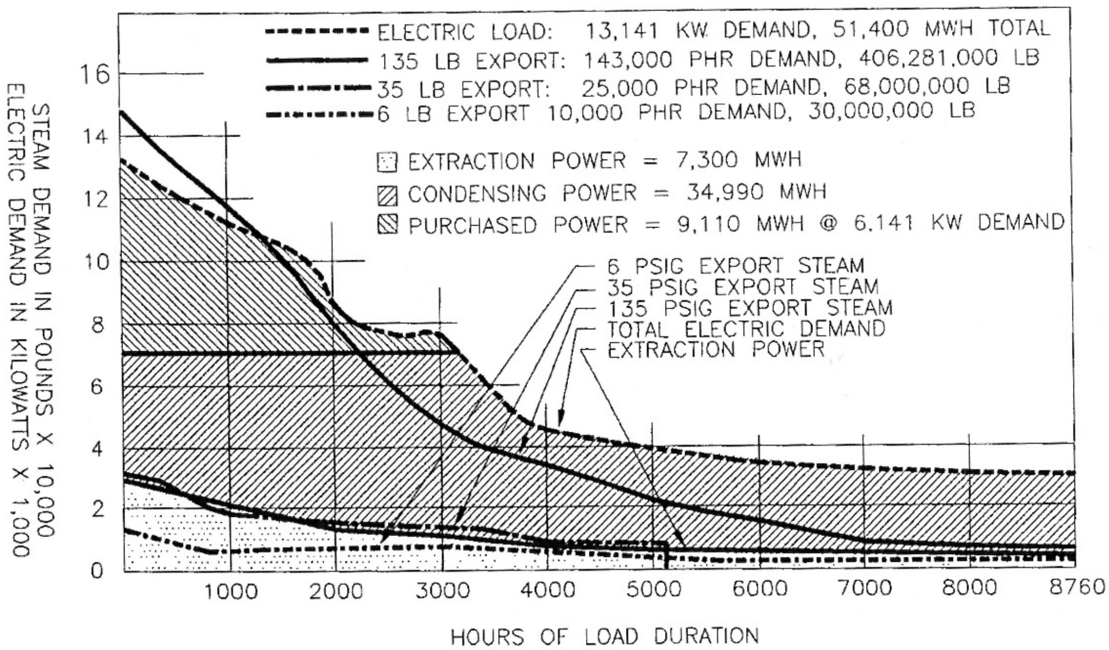

Figure H-2: Typical load duration curve - base load on power plant, load swings on purchased power, all export steam from power plant.

Figure H-3 Typical Load Duration Curves

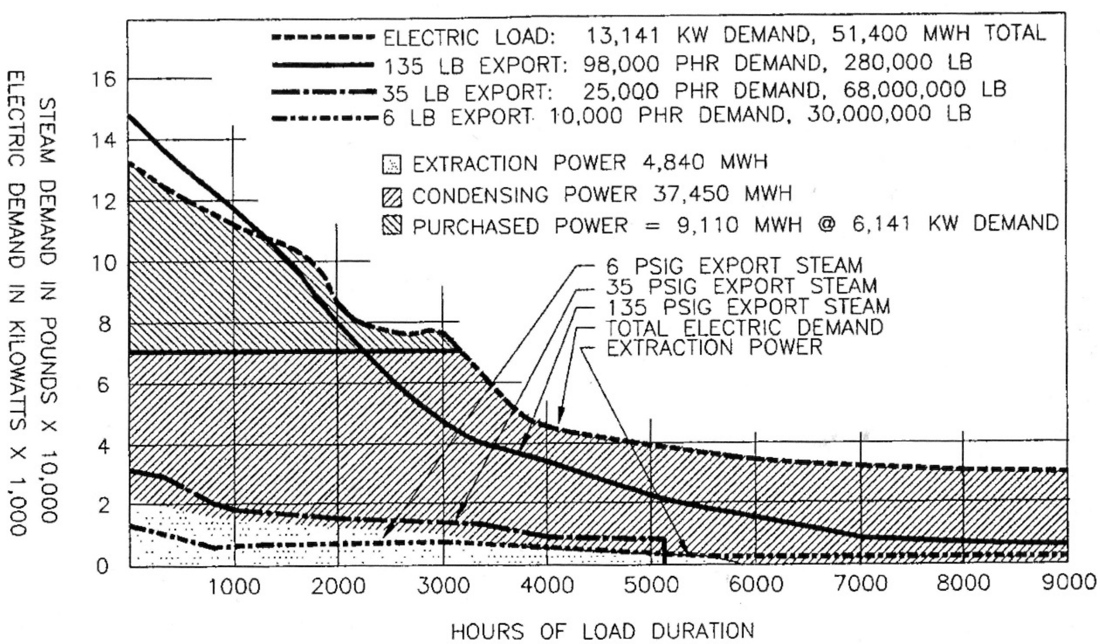

Figure H-3: Typical load duration curve - base load on power plant, load swings on purchased power, portion of export steam on central heating plant.

Figure H-4 Typical Load Duration Curves

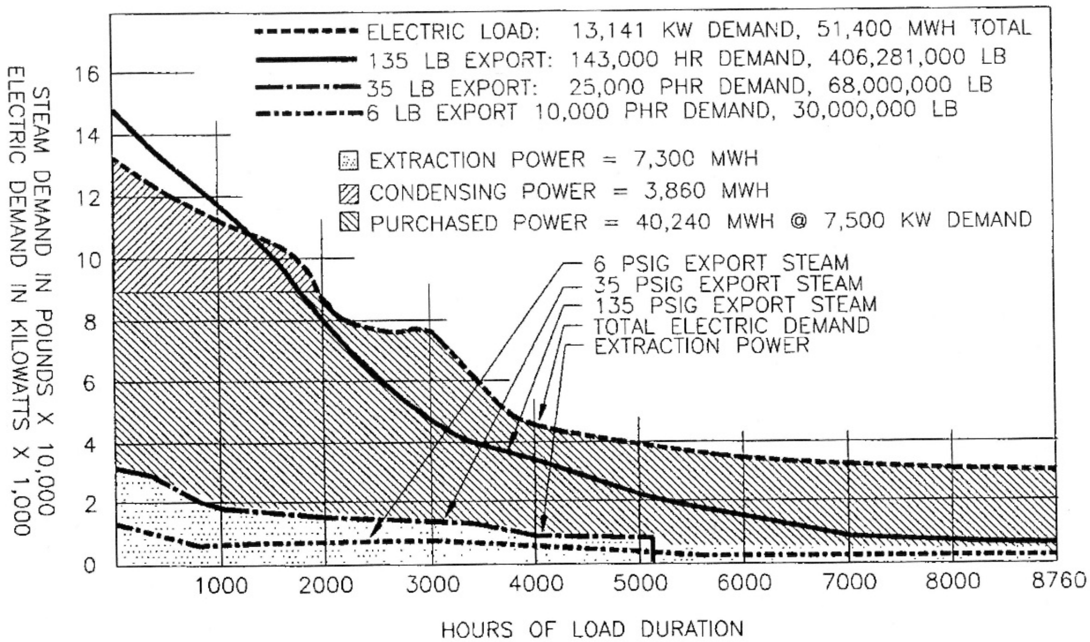

Figure H-4: Typical load duration curve – load priority as follows: (a) extraction generations; (b) purchased power; (c) condensing generation.

H-3.2.4 Utility Interconnect.

Under parallel operation, the generation plant is electrically interconnected and synchronized with an electric utility distribution or transmission system, with both the generator and electric utility generating electricity simultaneously. Under parallel operation, some electricity will be flowing either to or from the generation system. With few exceptions, the DoD does not own and operate a prime power plant in parallel with an independently owned upstream utility grid. This may be a consideration only in a national emergency, or if the plant is third-party owned and operated as part of an enhanced use lease agreement. In such situations, comply with utility provider requirements and IEEE 1547.

Integrated paralleling considerations must be taken into account prior to initial design. Paralleling generators offers expandability, flexibility, higher ease of maintenance, and higher cost effectiveness. However, to accomplish this, the controls between generators must be able to communicate. It is preferable that the generator controllers be identical, the voltages must be identical, and the generator pitch must be identical. Without these criteria, the generators will not work well together.

H-3.2.4.1 Utility Agreements.

The generators must first comply with Public Utility Regulatory Policies Act (PURPA) and all state and Federal regulatory requirements. The utility must approve any interconnection details prior to attachment to the utility system. Requirements vary depending upon:

- whether the transition transfer is open or closed
- system voltage
- interconnection power flow (one-way or two-way)
- size of the proposed generator

The utility will use their completed application and one-line diagram to determine if a preliminary interconnection study is needed. With the preliminary interconnection study, the utility will make a cost estimate and schedule to accommodate the proposed generation. Additional details will be requested as necessary. Since the study outcome may affect the equipment purchase, it is strongly recommended that no final purchase agreements are completed concerning the interconnection generator or switchgear until this study has been completed. Additional diagrams will be required, including site plans, relaying diagrams, metering diagrams, and telemetry, equipment specifications and details of generators, transformers, circuit breakers, protective relays, current transformers, voltage transformers, and isolation disconnects.

H-3.2.4.2 Metering.

Meters must be provided on fuel lines, electrical and water services to the buildings, and to the major equipment and boilers in the building. Advanced metering infrastructure (AMI) systems must be provided on these required locations. These requirements are promulgated by the Electric Power Research Institute (EPRI) and the United States Department of Energy (DOE).

Steam output metering of the header and at each steam generator must be provided for periodic reports and testing. Meters will be electronic in nature and capable of being polled remotely with single mode fiber-optic means.

APPENDIX I GLOSSARY

I-1 ACRONYMS.

A	amperes
AC	alternating current
AED	automatic external defibrillator
AFI	Air Force Instruction
AHJ	authority having jurisdiction
AFMAN	Air Force Manual
AMI	advanced metering infrastructure
ASR	air surveillance radar
ATS	automatic transfer switch
AWG	American Wire Gauge
BUMED	Navy Bureau of Medicine and Surgery
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CCTV	closed circuit television
CONUS	continental United States
COPS	Critical Operations Power Systems
CSA	Canadian Standards Association
CT	current transformer
dBA	decibels, A-weighted
DC	direct current
DCS	distributed control system
DDC	direct digital control
DER	distributed energy (generation) resources
DOE	Department of Energy

EA	environmental assessment
EAID	Equipment Authorization Inventory Data
EGSA	Electrical Generating Systems Association
EIS	environmental impact study
EMF	electromagnetic field
EMI	electromagnetic interference
EMP	electromagnetic pulse
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EPSS	emergency power supply system
FACSFAC	Fleet Area Control and Surveillance Facility
HMI	human-machine interface
hr	hour
HVAC	heating, ventilating, and air conditioning
Hz	hertz
I/O	input/output
ICS	industrial control systems
IED	intelligent electronic devices
ISO	International Standards Organization
JCF	joint control facility
JRIC	Joint Reserve Intelligence Center
kBtu/hr	thousand British thermal units per hour
kV	kilovolt
kVA	kilo-volt-amperes

kW	kilowatt
kWlb/hr	kilowatt-pounds per hour
lb/in^2	pounds per square inch
LPG	liquefied petroleum gas
MP	Military Police
MEP	mobile electric power
MVA	million-volt-amperes
MWh	megawatt hour
NAVFAC	Naval Facilities Command
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NSPS	New Source Performance Standards
OEBGD	(DoD) Overseas Environmental Baseline Guidance Document
OSHA	Occupational Safety and Health Act
PLC	programmable logic controller
POL	petroleum, oil, and lubricants
psig	pounds per square inch gauge
PURPA	Public Utility Regulatory Policies Act
QSTAG	*Quadripartite Standardization Agreement*
QWLD	quick (connect), waterproof, type l disconnect
RAM	reliability, availability, and maintainability
RATCF	radar air traffic control facilities
RDT&E	research, development, test and evaluation
RFI	radio frequency interference
RFP	request for proposal

RPIE	real property installed equipment
rpm	revolutions per minute
SCADA	Supervisory Control and Data Acquisition
SCIF	Secure Compartmented Information Facility
SCR	selective catalytic reduction
sec	second
TEFC	totally enclosed fan cooled
TEMPEST	Telecommunications Electronics Material Protected from Emanating Spurious Transmissions
TFT	thin film transfer
UFC	Unified Facilities Criteria
UIC	Unit Identification Code
UL	Underwriters Laboratories
UPS	uninterruptible power supply
VDC	volts, direct current

I-2 DEFINITION OF TERMS.

Automatic Transfer Switch (ATS): A switch designed to sense the loss of one power source and automatically transfer the load to another source of power.

Availability: The long-term probability of success with repair and scheduled maintenance of electrical power plants, generators, and power systems. Calculate availability as the ratio in percentage of total period minus repair downtime minus maintenance downtime to total period. The calculation assumes power generated meets quality standards.

Critical Operations Power Systems: Systems that are installed in vital infrastructure facilities that, if destroyed or incapacitated, would disrupt national security, the economy, public health or safety; and where enhanced electrical infrastructure for continuity of operation has been deemed necessary by governmental authority. COPS design criteria are specified by NFPA 70 Article 708.

Emergency Systems: As specified by NFPA 70, emergency systems are those systems legally required and classed as emergency by municipal, state, Federal, or other codes, or by any governmental agency having jurisdiction. These systems are intended to automatically supply illumination, power, or both, to designated areas and equipment in the event of failure of the normal supply or in the event of accident to elements of a system intended to supply, distribute, and control power and illumination essential for safety to human life.

Harmonic: A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.

Legally Required Standby Systems: Those systems required and so classed as legally required standby by municipal, state, Federal, or other codes or by any governmental agency having jurisdiction. These systems are intended to automatically supply power to selected loads (other than those classed as emergency systems) in the event of failure of the normal source.

Linear Load: An electrical load device that presents an essentially constant load impedance to the power source throughout the cycle of applied voltage in steady-state operation.

Listed: Applies to equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction. The organization periodically inspects production and certifies that the items meet appropriate standards or tests as suitable for a specific use.

Nonlinear Load: A steady state electrical load that draws current discontinuously or has the impedance vary throughout the input AC voltage waveform cycle. Alternatively, a load that draws a nonsinusoidal current when supplied by a sinusoidal voltage source.

Optional Standby Systems: Those systems intended to supply power to public or private facilities or property where life safety does not depend on the performance of the system. Optional standby systems are intended to supply on-site generated power to selected loads either automatically or manually.

Power Quality: The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.

Transfer Switch: A device for transferring one or more load conductor connections from one power source to another.

Uninterruptible Power Supply System: A system that converts unregulated input power to voltage- and frequency-controlled filtered AC power that continues without interruption even with the deterioration of the input AC power.

UFC 3-540-07
21 February 2018
Change 1, 5 November 2019

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE (O&M): GENERATORS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-540-07
21 February 2018
Change 1, 5 November 2019

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE (O&M): GENERATORS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	5 Nov 2019	Updated the Summary Sheet, Chapters 1, 2, 3, 5, and 8 (Chap. 8 formerly App. C) and App. A (formerly App. D); renumbered former Appendices A and B as Appendices B and C. Numerous non-substantive corrections throughout for format, grammar, missing/outdated references, and paragraph numbering; these changes are not marked.

This UFC supersedes Engineering Technical Letter (ETL) 13-4, *Standby Generator Design, Maintenance, and Testing Criteria.*

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and, in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and the Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing Service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective Service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet site below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
SUMMARY SHEET

Document: UFC 3-540-07, *Operation and Maintenance (O&M): Generators*

Superseding: Air Force ETL 13-4, *Standby Generator Design, Maintenance, and Testing Criteria*

Description: UFC 3-540-07 provides guidance for O&M of standby, emergency, and prime power generators.

Reasons for Document: Provide guidance for O&M of generators.

Impact: There are no impacts on design and initial cost, energy savings, or life cycle costs.

\1\ Unification Issues: Air Force-only requirements are in Chapter 8. **/1/**

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FIGURES

TABLES

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Proper O&M of generators is essential to ensuring continuous electrical system operation and reliability. A comprehensive O&M program with proven practices and well-performed maintenance prevents downtime and mission loss or delay.

1-2 PURPOSE AND SCOPE.

This UFC provides the minimum guidance and standards for O&M of standby, emergency, and prime power generators and is intended to be used by operations and maintenance personnel. It includes safety requirements, standard operating instructions, maintenance instructions, and test procedures. This UFC is intended to be used with the generator manufacturer's recommended operational procedures and maintenance manuals.

1-3 APPLICABILITY.

The guidance and standards contained within are the minimum requirements acceptable for military installations for efficiency, economy, durability, maintainability, and reliability of generator systems. The provided guidance does not automatically supersede equipment manufacturers' instructions and requirements. When conflicts exist, follow the most rigorous requirement. The guidance and standards herein are not intended to be retroactively mandatory. Provide, as a minimum, the level of maintenance required to meet critical mission reliability goals.

- Comply with the requirements of 29 CFR 1910, *Occupational Safety and Health Standards.*
- Comply with the requirements of Title 40 CFR 1 to 1100, *Environmental Protection Agency*.
- Comply with UFC 3-550-01, *Exterior Electrical Power Distribution*, for minimum system and component design standards.
- Comply with UFC 3-520-01, *Interior Electrical Systems*.
- Comply with UFC 3-560-01, *O&M: Electrical Safety*, for electrical safety requirements applicable to the installation and operation of electrical systems.
- Comply with UFC 3-540-01, *Engine-Driven Generator Systems for Backup Power Applications*, for backup power applications.

\1\ Note: The Air Force will follow operations, maintenance, and testing requirements outlined in Chapter 8. **/1/**

1-4 SAFETY.

1-4.1 Minimizing Hazards.

Before starting maintenance, be aware that a generator can start without warning and cause serious injury or death. Use lockout/tagout (LOTO) procedures and wear appropriate personal protective equipment (PPE). Comply with UFC 3-560-01 for electrical safety requirements.

Apply standard operating procedures (SOP), where available, for reducing/minimizing/eliminating potential hazards with PPE, proper training, and rescue procedures and equipment.

1-4.2 Qualifications of Generator and Electrical Workers.

1-4.2.1 Training.

Generator and electrical workers must be qualified through training and demonstrated skills and knowledge in specific hazards associated with their potential exposure in accordance with OSHA requirements and safety-related practices contained in NFPA 70E, *Standard for Electrical Safety in the Workplace*, and IEEE C2, *National Electrical Safety Code (NESC)*. Trained and qualified generator and electrical workers must be familiar with the following:

- The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment.
- The skills and techniques necessary to determine the nominal voltage of exposed live parts.
- The clearances specified in NFPA 70E and IEEE C2.
- Operating (starting, running, shutdown procedures) and maintaining generators, generator synchronizers, generator control system, fuel system, cooling system, exhaust system, and switchgear.

1-4.2.2 Generator Workers and Operators.

Maintain a list of qualified generator operators. The generator operator and worker must have the knowledge to monitor indicating devices that reflect system operation and manipulate controls necessary to properly start, operate, and shut down generator equipment. Ensure the facility manager or others (operators) at the facility are trained to operate and check generator status. It is the responsibility of the facility or mission owner to request annual training from the base civil engineer (BCE)/Public Works as required.

1-5 CYBERSECURITY.

Operate and maintain all generator-related control systems to maintain compliance with the network system authorization as required by DoDI 8500.01, *Cybersecurity*, and

DoDI 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*. See UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*, for additional information.

\1 [Deleted note.] **/1/**

1-6 PERSONNEL SAFETY.

Generator and electrical workers must wear proper safety clothing in the work area per OSHA 1910.132. Workers must be trained and certified in use and care of PPE, insulating protective equipment (IPE), and LOTO controls. Personnel must follow safety procedures, conduct hazard analyses, and attend job safety briefings in accordance with OSHA and UFC 3-560-01 safety requirements. Proper tools must also be used in accordance with 29 CFR 1926. Electrical gloves must be tested according to ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*. NAVFAC must also follow local specific regulations.

1-7 REFERENCES.

Appendix B contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance or edition of the reference is used.

1-8 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

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CHAPTER 2 GENERATOR CONFIGURATION

2-1 GENERAL REQUIREMENTS.

Maintenance of the generator consists of all systems associated with the generator, including cables, prime movers, and ancillary equipment.

Note: There are differences between the EPA and NFPA definitions for an emergency generator and generator operators must ensure they are using the correct reference within each context to avoid misunderstandings.

2-2 RECIPROCATING ENGINE PRIME MOVER.

There are two primary types of reciprocating engines: compression ignition and spark ignition. Compression ignition includes diesel fuel engines. Spark ignition includes gasoline, natural gas, and liquid petroleum gas (LPG) engines.

The major components of reciprocating engine requiring maintenance include:

- Engine block assembly (block, crankshaft, pistons and rings, camshaft, lifters, connecting rods, intake and exhaust valves, and cylinder heads)
- Fuel system
- Cooling system
- Exhaust system
- Lubrication system
- Starting system
- Battery and charging system
- Automatic transfer switch (ATS)
- **\1** Manual transfer switch (MTS) **/1/**
- Ignition system
- Air intake system
- Control system
- Exercise

2-3 GENERATOR.

2-3.1 AC Generator.

AC generators used are synchronous except for wind turbines.

2-3.2 Mechanical.

The mechanical portion of a generator system consists of the fuel system, starting system (either pneumatic or electric), lubrication system, cooling system, and intake/exhaust system.

2-4 FUEL SYSTEM.

A common reason for generators not starting is a clogged fuel filter due to old or contaminated fuel; therefore, the fuel filters and fuel must be checked as part of routine maintenance.

2-5 LUBRICATING SYSTEMS – RECIPROCATING ENGINES.

Reciprocating engine lubrication system components requiring maintenance typically include:

- Sump/oil tank
- Lubrication filter
- Lubrication cooler
- Oil pump
- Tubing, hoses, and fittings

On larger size engines, the clean oil tank, waste oil tank, and pre-lubrication pumps are separate and require maintenance.

2-6 ENGINE COOLING SYSTEMS.

Engine water cooling system components typically requiring maintenance include water pumps, radiator, thermostat, cooling fan, hoses, thermostats, and instrumentation.

2-7 INTAKE AIR AND EXHAUST SYSTEMS.

2-7.1 Intake Air.

The intake air system cleans the air entering the generator engine or turbine. Air filtration systems for reciprocating engines typically use weather protection and final filters.

Intake air system components typically requiring maintenance include filters, filter housings and air intake horns, dampers, damper actuators, inertial separators, moisture coalescers, anti-icing systems, and instrumentation.

2-7.2 Exhaust System.

The exhaust system removes the combustion gases from the engine. Exhaust system components that typically require maintenance include draining the condensate and examining the manifold for leaks and holes.

2-8 DC POWER AND CHARGING SYSTEM.

Two types of batteries are vented cell batteries and sealed cell batteries. The vented, or open, batteries require periodic liquid levels observation and refilling, as necessary. Lead calcium flooded batteries have typical lifetimes of 20 years. **\1** Sealed cell, valve regulated lead acid (VRLA) batteries generally recommended are versions of sealed wet cell or absorbent glass mat (AGM). **/1/** Pure lead versions of these batteries have lifetimes over four years. A lifetime cost analysis must be done to choose what type batteries are required for the application. Maintenance must be included in these calculations. Load test all batteries according to IEEE 450, *Recommended Practice for Maintenance, Testing, and replacement of Vented Lead-Acid Batteries for Stationary Applications*. According to manufacturers, the top two reasons standby generators fail to automatically start or run are that the generator START switch is in the OFF position instead of AUTO or the starting batteries are dead or insufficiently charged.

2-9 AC POWER DISTRIBUTION SYSTEM.

Refer to UFC 3-550-01 for exterior electrical power distribution.

2-10 AUTOMATIC TRANSFER SWITCHES (ATS).

Most standby and emergency generators will have an associated ATS that requires maintenance. Those systems that do not have an ATS will have switchgear that accomplishes the same result or synchronizes with the utility. The ATS is an integral part of a generator system and must be tested to ensure proper operation. Refer to UFC 3-540-01 for design requirements.

2-11 MANUAL TRANSFER SWITCHES (MTS).

MTSs must be maintained by visually inspecting for rust and corrosion and ensuring moving components are greased with electrically conductive grease. They must also be exercised during generator system testing.

2-12 GROUNDING SYSTEMS.

Grounding systems should be visually inspected during generator inspections and testing for physical continuity for separately derived systems is required every two years (specifically at expeditionary sites).

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CHAPTER 3 DEVELOPING AN O&M PROGRAM

3-1 O&M MANAGEMENT.

3-1.1 Administration and Structure.

The O&M administration structure must include the elements of operations, maintenance, engineering support, training, and administration. Operations is responsible for management and control of operation activities, equipment control and status, and operator knowledge and performance to support safe and reliable operations. Maintenance is responsible for effective management and control of maintenance activities, efficient performance of the work control system, safe conduct of maintenance activities, and maintenance procedures and documentation. Engineering support ensures effective implementation and control of technical support, equipment modifications, equipment performance monitoring, and engineer support of procedures and documentation. The Commanding officer, in conjunction with the generator subject matter expert (SME), must implement and control training activities, general training, maintenance training, operations training, training facilities, and equipment. Administration plans and implements policies, develops management objectives to improve performance, monitors activities, oversees industrial safety, and ensures personnel are appropriately trained.

Operational testing/operation must be done per the manufacturer’s recommendations. NFPA 110, *Standard for Emergency and Standby Power Systems*, also specifies emergency generator testing requirements. This includes full-load generator testing and exercise of circuit breakers and switches.

Note: The Air Force will follow the test requirements in Chapter 8.

3-1.2 Quality Assurance Program.

The O&M quality assurance program must measure the quality or effectiveness of the quality assurance program. Each plant is recommended to have a quality assurance plan to ensure the maintenance program is effective; however, it is not a minimum requirement.

3-1.2.1 Quality Assurance Metrics.

Use the following metrics to measure the quality or effectiveness of the quality assurance program:

- Plant reliability
- Work orders generated and closed out
- Corrective maintenance backlog
- Safety record
- Environmental record

- Energy use
- Inventory control
- Overtime worked
- Absentee rate
- Staff turnover

3-1.2.2 Base Period.

Track performance metrics on a periodic basis but not less than monthly.

3-1.3 Contracted Maintenance.

During the warranty period, the manufacturer must be contacted for resolution. Technicians will have documented training/experience on maintaining assigned generators. The contracted maintenance must include a submittal of a preventive maintenance schedule that meets or exceeds the generator manufacturer's recommended requirements.

3-2 TRAINING.

Fully train all personnel to perform O&M on specific installed generators. At a minimum, train personnel on the following:

- O&M of the equipment
- Proper use of tools, protective equipment, and precautionary techniques
- Electrical hazards associated with electrical equipment
- Techniques and skills to practice O&M activities on electrical equipment
- Job planning
- Maintaining a safe work environment
- Familiarization of the one-line electrical connection diagram/control diagrams for specific generator facility connection and layout

3-2.1 Qualifications of Generator Workers.

Personnel must be fully qualified/trained to perform O&M on generators and must follow/obey safety procedures in their work area.

3-2.1.1 Electricians.

Electrical workers must be trained and qualified to operate and maintain the electrical switchgear, including relays and circuit breakers, switchgear control system, transformers, DC power system, and other electrical ancillary equipment.

3-2.2 Safety.

Safety considerations must be taken into account to maintain the generators in accordance with UFC 3-560-01 and, for the Air Force, AFI 32-1064, *Electrical Safe Practices*. This involves access to generators, location of generators, tool locations, grouping of equipment, spacing requirements dictated by manufacturer's instructions, and NEC Article 110.

3-3 TOOLS AND EQUIPMENT.

3-3.1 Electrical Tools and Equipment Standards.

Industry standards describe the requirements for electrical protective equipment and tools. **\1** These standards were developed so tools, equipment, materials, and test methods used by electrical workers will provide protection from electrical hazards. Tool and equipment terminology and in-service maintenance and electrical testing are included in IEEE 935, *IEEE Guide on Terminology for Tools and Equipment to Be Used in Live Line Working*, and IEEE 516, *IEEE Guide for Maintenance Methods on Energized Power Lines*, respectively. **/1/** UFC 3-560-01 also contains tool and equipment requirements. In case of conflict, always use the most stringent safety requirement.

3-3.2 Standard Tools and Equipment.

For simplicity and convenience, the tools and equipment required for electrical inspection and maintenance are classified as follows:

3-3.2.1 Tools.

Tools include hand tools, digging tools, hot line tools, miscellaneous and special tools, and tackle.

3-3.2.2 Protective Equipment.

Protective equipment includes required PPE, such as eye and hearing protection, helmets, gloves, footwear, and arc flash clothing, and non-PPE items such as LOTO locks, barricades, and warning devices. Follow PPE requirements in UFC 3-560-01 and, for the Air Force, AFI 32-1062, *Electrical Systems, Power Plants and Generators*.

3-3.2.3 Large Portable and Mobile Equipment.

Large portable and mobile equipment includes relatively large and easily transportable equipment for use in maintenance work, such as line trucks, aerial lift trucks, motor-generator sets, posthole diggers, load banks, and similar apparatus.

3-3.3 Care and Storage of Tools and Equipment.

Tools and equipment will be kept in proper operating condition and used only for the purpose for which they were designed. If proper and safe tools are unavailable, report tool needs to a supervisor.

Inspect all tools at regular intervals and any tool that develops defects when in use will be taken from service, tagged, and not used again until restored to proper working condition.

3-3.4 Electrical Inspecting and Testing Equipment.

The number and types of testing/inspection devices needed depends on local needs. When available, follow the manufacturer’s instructions for the care and maintenance of test equipment. Schedules for calibrating and testing instruments and meters are dependent upon the particular installation. When precision is not essential, the period between tests is not critical and may be assigned as convenient. For units provided with built-in diagnostic capabilities, check diagnostics when their associated power apparatus is checked.

3-3.4.1 Maintenance of Instruments, Meters, and Test Equipment.

Only personnel trained and qualified to maintain instruments, meters, and test equipment, or personnel under the immediate supervision of such qualified personnel, are allowed to perform accuracy tests, repairs, calibrations, and adjustments of instruments and meters. When selecting meters, match meter accuracy to the requirements of which the reading and records are being used. Procuring equipment with higher accuracy than requirements dictate must be economically justified.

3-3.4.2 Frequency of Inspections.

If calibration standards and equipment are not available, instruments and meters of nearly the same rating can be checked against each other. When wide discrepancies are noted or the instrument or meter is obviously incorrect, recalibrate and make any needed repairs.

3-3.4.3 Test Instrument Calibrations.

Calibrate instruments according to manufacturer's recommendations and agency requirements.

- Air Force: Perform calibration in accordance with AFI 21-113, *Air Force Metrology and Calibration (AFMETCAL) Management*, and T.O. 00-20-14, *Air Force Metrology and Calibration Program*.
- Army: Perform calibration in accordance with U.S. Army Test, Measurement, and Diagnostic Equipment Activity (USATA) requirements, AR 750-43, *Army Test, Measurement, and Diagnostic Equipment*, and TB

43-180, *Calibration and Repair Requirements for the Maintenance of Army Materiel*.

- Navy and Marine Corps: Perform calibration in accordance with the NSWC Corona Measurement Science and Technology Laboratory Measurement and Calibration (METCAL) program.

3-3.5 Required Electrical Safety Program.

Implement and document an overall electrical safety program that directs activity appropriate for the electrical hazards, voltage, energy level, and circuit conditions. Refer to NFPA 70E and UFC 3-560-01.

Note: For the Air Force, see AFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards*, and AFI 32-1064.

3-4 HAZARDOUS MATERIAL PROCEDURES.

Implement a hazard communication program in accordance with 29 CFR 1910.1200 or 29 CFR 1926.59 and DoDI 6050.05, *DoD Hazard Communication (HAZCOM) Program*, as amended by agency guidance. The major hazardous items to which electrical workers may be exposed are asbestos, polychlorinated biphenyls (PCBs), sulfur hexafluoride (SF6), and some of the chemicals used to control undesirable brush or pests or to preserve wood. For PCBs, comply with 40 CFR 761 and DoD 4715.05-G, *Overseas Environmental Baseline Guidance Document* (OEBGD).

Note: For the Air Force, see AFMAN 91-203.

3-5 SYSTEM DATA, EQUIPMENT DATA, AND DOCUMENTATION.

3-5.1 Operating Procedures.

Operating procedures must be documented and readily available. Mandatory testing, validation, approval, and review requirements must be kept in a permanent or appropriate record for the various types of generator configurations.

3-5.2 Manufacturer O&M Manuals.

Ensure manufacturer O&M manuals, parts manuals, and technical manuals/orders (if applicable) are always available and in a convenient location for access. Manufacturer manuals provide essential guidance on recommended frequency for inspections and maintenance for generators. Ensure at least one set of O&M manuals are supplied by the generator manufacturer at the time of acquisition.

3-5.3 Derating.

If something has changed on the generator, such as moving it from one location to another, and therefore the altitude, secondary fuel, or environmental conditions change, the generator must be de-rated **\1** by the authority having jurisdiction (AHJ) for each

Service. This de-rating must be documented in the O&M manuals and properly labeled. **/1/**

3-5.4 Installation Drawings.

Ensure at least two sets of installation drawings are provided by the installation contractor and maintained by the shop to give guidance to the operator and maintainer on equipment installation and other related activities. Circuit drawings must be updated with any modifications by the responsible party as required by NFPA 70E and 29 CFR 1910.

3-5.5 Control Diagrams.

Control diagrams are functional representations of the interconnection of the electrical equipment and contain one-lines, schematics, and wiring diagrams. They include the required content, format, and verification process for control diagrams for the operator and maintainer.

3-5.6 Maintenance Forms and Records.

Record maintenance information and test data for generators on Service-approved forms and checklists. Forms serve as an equipment inspection guide or checklist in order to maintain the generators in optimum working condition. Retain records for the Service-defined period of time and make available to the AHJ, as requested. Figures 3-1, 3-2, and 3-3 are typical maintenance forms to use for generator inspection activities.

Figure 3-1 Engine Generator Inspection Checklist

ENGINE GENERATOR INSPECTION

SHEET NO. ________ OF ________

CUSTOMER ________ DATE ________ PROJECT NO. ________
ADDRESS ________ AIR TEMP. ________ REL. HUMIDITY ________
OWNER/USER ________ DATE LAST INSPECTION ________
ADDRESS ________ LAST INSPECTION REPORT ________
EQUIPMENT LOCATION ________
CIRCUIT IDENTIFICATION ________

ENGINE TYPE: ☐ GASOLINE ☐ DIESEL ☐ GAS TURBINE

MAKE ________ MODEL ________ SERIAL NO. ________ KS # ________
KVA ________ KW ________ VOLTAGE ________ F.L.A. ________
RPM ________ HZ ________ HP ________ TECH. BULL. # ________

1. ☐ Change oil and lube oil filters.
2. ☐ Remove unused oil from premises.
3. ☐ Change fuel oil elements.
4. ☐ Service crankcase breather.
5. ☐ Inspect air cleaner element, clean if required. If replacement is required, element(s) will be billed separately. Price of element(s) not included in contract price.
6. ☐ Check coolant level and maintain safe degree of protection. Engine mounted radiators only. (Remote radiators, cooling towers & heat exchangers serviced at user's request on a time and material basis.)
7. ☐ Check manifolds, brackets, mountings and flex connections.
8. ☐ Inspect fan belts, adjust if required.
9. ☐ Check pulley hub, bearings, lubricate if required.
10. ☐ Check operation of auxiliary water pump or fan motor.
11. ☐ Check operation of automatic louvers.
12. ☐ Repair minor fuel, coolant and lube oil leaks.
13. ☐ Check operation of jacket water heater(s).
14. ☐ Inspect generator, perform any routine maintenance as required.
    ☐ Megger
15. ☐ Inspect governor/actuator linkage.
16. ☐ Check battery electrolyte level and maintain to include:
    ☐ Temperature ☐ Specific Gravity ☐ Voltage
17. ☐ Check operation of charger and/or alternator.
18. ☐ Inspect fuel supply system for leaks or low level, inform owner of any discrepancies.
19. ☐ Drain condensation from day tank and check for any contamination. ONLY if day tank is equipped with a drain valve.
20. ☐ Check operation of transfer pump.
21. ☐ Check for correct generator output voltage & frequency, adjust if required.
22. ☐ Simulate & check operation of each safety shutdown and alarm device, relay type control panels only.
23. ☐ Check operation of generator control instrumentation; volts, amps, etc.
24. ☐ Test fault lamps & replace bulbs as required, panels with lamp test only.
25. ☐ Tank crankcase oil sample, owner to be notified of any discrepancies.
26. ☐ Submit report to owner
27. ☐ Auto start test.

REMARKS ________

SUBMITTED BY ________ EQUIPMENT USED ________

Courtesy of Northeast Electrical Testing NFPA 70B

Figure 3-2 Generator Set Survey

GENERATOR SET SURVEY

Date: ____________

Installation: ____________ Location: ____________

Number of generator sets at this location: ____________

Generator Set #1

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair
❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: ____________

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: ____________
- Model/Type: ____________ Rated Voltage: ____________
- Rated hp (or kW): ____________ Rated Current: ____________
- Power Factor: ____________ Frequency: ____________

Generator Data:

- Manufacturer: ____________
- Model/Type: ____________
- Generated Voltages: ____________ V Generated Frequencies: ____________ Hz
- Rated kVA: ____________ Rated kW: ____________
- Rated Currents: ____________ A Efficiency Factor: ____________
- Winding Connection (D/W/GW): ____________ Power Factor: ____________

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: ____________
- Measured Voltages: ____________ V Measured Temperatures: ____________ °F

Generator Set #2

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair
❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: ____________

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: ____________
- Model/Type: ____________ Rated Voltage: ____________
- Rated hp (or kW): ____________ Rated Current: ____________
- Power Factor: ____________ Frequency: ____________

Generator Data:

- Manufacturer: ____________
- Model/Type: ____________
- Generated Voltages: ____________ V Generated Frequencies: ____________ Hz
- Rated kVA: ____________ Rated kW: ____________
- Rated Currents: ____________ A Efficiency Factor: ____________
- Winding Connection (D/W/GW): ____________ Power Factor: ____________

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: ____________
- Measured Voltages: ____________ V Measured Temperatures: ____________ °F

Courtesy of U.S. Army Corps of Engineers NFPA 70B (p. 1 of 2)

GENERATOR SET SURVEY *(continued)*

Generator Set #3

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair ❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other:__________

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer:__________
- Model/Type:__________ Rated Voltage:__________
- Rated hp (or kW):__________ Rated Current:__________
- Power Factor:__________ Frequency:__________

Generator Data:

- Manufacturer:__________
- Model/Type:__________
- Generated Voltages:__________V Generated Frequencies:__________Hz
- Rated kVA:__________ Rated kW:__________
- Rated Currents:__________A Efficiency Factor:__________
- Winding Connection (D/W/GW):__________ Power Factor:__________

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other:__________
- Measured Voltages:__________V Measured Temperatures:__________°F

Generator Operation:

- Can these generators run in parallel with the utility power sources? ❑ Yes ❑ No
- The generators are being used as: ❑ Backup source ❑ Peak shaving ❑ Prime source
- Are the generators properly protected against overload? ❑ Yes ❑ No abnormal conditions? ❑ Yes ❑ No or reverse power flow (if generators can run in parallel with utility source)? ❑ Yes ❑ No
- Can the generators automatically start? ❑ Yes ❑ No and automatically shut off? ❑ Yes ❑ No
- How many times did generator fail to start or break down (with unknown reason) during the last few years?_____

Maintenance:

- Does the generator operation log book exist and is it up to date? ❑ Yes ❑ No
- How often does the generator run for maintenance? _____times per week/month, ❑ with loads or ❑ without loads.
- How long did the generator run during each maintenance period? _____ minutes
- How often is the generator fuel system checked? _____times per week/month

Generator Grounding System:

- ❑ Solidly grounded ❑ High resistance ❑ Low resistance ❑ Reactance
- Measured ground impedance in ohms:_____
- Is the generator's neutral bus connected to ground? ❑ Yes ❑ No
- Is the generator frame connected to ground? ❑ Yes ❑ No

Notes:

Courtesy of U.S. Army Corps of Engineers

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Figure 3-3 Generator Data Record

GENERATOR DATA RECORD

Site: ______________________ Date: __________ Page: __________

No.	Location	Type	kVA Rating	Generated Volts	Rated Current	Speed in RPM	Wiring Connections	Subtrans. Impedance	Ground Impedance	Power Factor

 NFPA 70B

3-5.7 Spare Parts Lists.

Identify high-rate-of-mortality parts by historical experience. Ensure spare parts for each system of the generator is available for use when there is a need for replacement. Refer to the spare parts lists provided by the equipment manufacturer.

3-5.8 Service Contract Documents.

Describe typical service contract types and contract documents necessary to manage the service contract program if a service contract is utilized.

CHAPTER 4 OPERATIONS

4-1 OPERATING PROCEDURES.

4-1.1 Responsibilities.

There are levels of approval required for **any** changes to occur to generators. Know the changes, who/what it impacts, and obtain appropriate approvals before executing.

Know and ask advice from the appropriate SME.

\1\ Note: The Air Force will follow operations, maintenance, and testing requirements in Chapter 8. **/1/**

4-1.2 Fire Emergency.

Train operators on fire safety procedures. In fire emergencies, call the fire department and identify the specific fire emergency area.

4-2 AIR QUALITY PERMITTING.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*, and agency-specific environmental regulations, restrictions, and specific applicable environmental guidance. In addition to the listed permitting activities herein, contact state and local environmental and development offices to verify additional permitting requirements. Maintainer/operator must coordinate with the local environmental office to ensure continued compliance with operating permits, especially when changes occur.

Obtain and maintain all required air permitting in accordance with the rules of the Clean Air Act (CAA) regulatory agency (federal or state/local/tribal) with delegated authority over the location of subject operations.

\1 [Note deleted] **/1/**

4-2.1 New Permits and Modifications to Existing Permits.

Initial permitting activities are accomplished during the design phase and prior to equipment installation. When changes are made to a unit (e.g., modified, remanufactured, relocated, and/or how it is used/operated), operators will immediately notify the appropriate environmental management office(s) that hold existing permit(s) of these changes and provide them with the necessary system information required to update those permits. This is necessary to ensure continued compliance with applicable federal, state, and local laws.

4-2.2 Changes.

Operational permitting is done during design and installation. Existing standby generators require additional permitting when operating hours exceed the permit. However, when changes are made to the unit or how it is used, the operators will immediately notify their office(s) that holds the existing operating permit(s) of these changes and provide them with the necessary system information required to update the operating permits. This will ensure continued compliance with applicable federal, state, and local laws.

4-3 COMPLIANCE MONITORING AND INSPECTIONS.

4-3.1 OSHA Compliance and Monitoring.

The generator must comply with the requirements and regulations of OSHA for personnel safety, including safe work practices.

4-3.2 Air Quality Compliance.

Generator engines must meet and maintain compliance with the requirements of federal, state, and local regulations and facility-specific permits. Air quality regulations/permits may specify monitoring, recordkeeping, and reporting requirements, as well as O&M frequencies/practices.

\1\ Note: The Air Force will follow operations, maintenance, and testing requirements in Chapter 8. **/1/**

4-3.3 Clean Water Act (CWA) Compliance and Monitoring.

Generators must comply with CWA regulations to prevent the spill of oil, petroleum, or other contaminants to the water.

4-3.4 Resource Conservation and Recovery Act (RCRA) Compliance Monitoring.

Generators are required by RCRA to properly control and manage hazardous waste.

CHAPTER 5 RELIABILITY MAINTENANCE-CENTERED PRACTICES

5-1 PURPOSE AND SCOPE.

This chapter provides guidance on typical preventive maintenance practices to keep generators in good performance.

5-2 PREVENTIVE MAINTENANCE ELEMENTS (TIME-BASED).

5-2.1 General.

Refer to manufacturers' manuals for maintenance and repair requirements, frequencies, and consumables specifications. On standby generators in locations without SCADA or communications links, the self-test alarm is not monitored. For these applications, or applications where there are no self-diagnostics on the relays, the relays should be tested every one to six years. The timespan is based upon the relay installation, atmosphere, debris, temperature, and humidity.

5-2.2 Load Bank Optimization.

Load banks are used for load optimization, allowing the generator to run at a higher load than needed for facility power to prevent engine damage to certain types of prime movers. Use load banks to augment facility load to optimize generator performance when the prime mover is operating at less than the manufacturer's minimum rated load for continuous operation.

5-2.3 Prime Mover (Engines).

Prime mover preventive maintenance activities are mandatory. These activities are required to ensure the prime mover reaches their expected life expectancy as they are an expensive and essential part of the generator set. Maintenance activities include the following:

5-2.3.1 Structures and Enclosures.

Check structures and enclosures for corrosion. For corroded areas, clean, prepare and apply corrosion-control treatment on affected surfaces to avoid further deterioration.

5-2.3.2 Power Takeoff Assemblies and Couplings.

Check for coupling alignment in accordance with manufacturer's maintenance schedule.

5-2.3.3 Bearing Lubrication.

Inspect and ensure the proper amount of grease on bearings and replace as required by the maintenance schedule.

5-2.3.4 Belt-Driven Equipment Checks.

Check misalignments on belt-driven equipment. Replace belts if damaged, as required.

5-2.4 Cooling System.

Dust can foul cooling passages, increase operating temperature, and negatively affect the generator's/engine's performance. Clean radiators of dust and debris. Use soft brush or cloth. Avoid damaging the fins. Use low-pressure air or water in the reverse direction from normal flow to clean the radiator.

5-2.4.1 Coolant Levels.

- Check the coolant levels during shutdown periods. Premix the coolant in a clean tank when replacing the coolant to an engine.
- Never add antifreeze directly into the engine cooling system.
- Avoid adding coolant to an overheated engine.
- Avoid adding coolant at a rate of more than 10 gallons per minute when filling and emptying the engine cooling system.
- Check heat exchangers. Poor coolant maintenance can result in heat exchanger damage.

5-2.4.2 Coolant.

Engines with wet liners are subject to liner pitting and pumps/seals are subject to failure if the cooling system is not properly maintained**.** Use the coolant recommended by the engine manufacturer.

The following are unacceptable coolant maintenance practices:

- Use of non-treated (distilled or de-ionized) water.
- Use of water alone as coolant.
- High or low concentrations of supplemental coolant additive (SCA).
- Use of anti-freeze or SCA that are high in silicates or do not meet original equipment manufacturer (OEM) specifications.
- Topping off coolant system without proper SCA.

5-2.4.3 Coolant Maintenance.

Perform the following coolant maintenance:

- Test the coolant a minimum of twice a year for freeze protection, coolant/water percentages, nitrite or SCA level, pH, visual color and appearance, and reserve alkalinity. Use a spectro-chemical test with results reported in parts per million (ppm) and SCA.
- Drain and replace coolant at intervals in accordance with the engine and/or coolant manufacturer's recommendation or when coolant analysis dictates replacement.

- When topping off, add coolant until the level is at the radiator cap's lower sealing surface.
- Store coolants out of direct sunlight and replace when shelf life has expired.

5-2.4.4 Air Intake/Ventilation Systems.

- Check for obstructions to cooling air lines or paths.
- Check for deterioration of cooling air ducts. This deterioration can lead to leakage of airflow, reducing its capacity.
- Check for dust and dirt of cooling air ducts.
- Check for loose or misaligned airline connections.

5-2.4.5 Coolant Pumps.

Inspect and maintain coolant pumps in accordance with maintenance schedule.

5-2.4.6 Engine Water Jacket Heaters.

Inspect engine water jacket heaters while in operation and observe for leaks at hoses, adapters, cylinder heads, pump seals, and block seals. Check for engine water jacket heater damage or deterioration. Inspect and maintain jacket water heaters in accordance with manufacturer's recommendations.

5-2.4.7 Valve Exercising.

- Verify correct position/alignment on valves.
- Check for leaking seals.
- Verify correct operation of valves.

5-2.4.8 Safety Relief Valve Tests.

- Check for leaks on safety relief valves and replace if leaks continue.
- Check that the safety relief discharge piping is working properly.
- Check that the safety relief valve opens at the acceptable pressure value.
- If the safety relief valve opens at a pressure below the acceptable range, it may indicate that the relief valve is in a deteriorated condition and requires replacement.
- If the safety relief remains closed, do not operate the system until the safety relief valve is completely replaced.

5-2.5 Lubrication System.

Maintain lubrication systems to comply with applicable standards and specifications.

5-2.5.1 Oil Level.

Ensure generator oil levels comply with the indications presented on the manufacturer's instruction manuals to keep the generator in good performance. Test the oil quality to determine oil level, conditioning, or replacement. For accurate readings on the dipstick, wait at least 10 minutes after shutting off the engine to allow the oil to drain to the bottom.

5-2.5.2 Oil Change.

- Replace oil according to the recommendations given by the manufacturer.
- Drain oil while warm.
- Test a sample of the drained oil to examine for fuel dilution, acidity, and the presence of solids and contaminants.
- Ensure oil change frequency is in accordance with manufacturer and environmental air quality regulatory requirements.

5-2.5.3 Oil Filter Change.

\1 Inspect oil filters periodically and replace when an accumulation of sludge or other contaminants is present. **/1/** The frequency is shown in Table 6.1.

5-2.5.4 Crankcase Breather.

Check crankcase breather each time the generator is taken down for maintenance to make sure it is not clogged and unusable.

5-2.5.5 Oil Leaks.

Check for oil leaks and follow the instructions of the manufacturer if oil leaks are found.

5-2.5.6 Gauges and Safety Mechanisms.

During maintenance, observe gauges and safety mechanisms and check fuel and temperature gauges to ensure proper operation.

5-2.6 Fuel System (Including Long-Term Fuel Storage).

Inspect and clean fuel systems. Remove contaminants such as dirt and sediments from tanks storing fuel to ensure proper engine operation. Test and analyze a sample of fuel taken from the storage tank to check for the presence of contaminants. One of these samples must include one sample taken from the inside bottom of the tank.

Note: For the Air Force, fuel testing should be coordinated with the Logistics Readiness Squadron (LRS) POL Fuels Lab.

5-2.6.1 Fuel Additives.

Check the proper levels of fuel additives in the system.

5-2.6.2 Fuel Filters.

Inspect and clean fuel filters as recommended by the manufacturer for identifying contaminants, sediments, or microorganisms.

5-2.6.3 Water/Condensate Removal.

Sample fuel from the fuel tank to detect the presence of water. Fuel and water tend to separate and water will sink to the bottom of the container. Remove water accumulation from storage fuel tanks with the provision and use of drain valves.

5-2.6.4 Fuel System Components.

Check fuel oil components such as fuel hoses, fuel pipes, fuel filters, injector pumps, etc. If damage to these components is encountered, replace following the instructions provided by the manufacturer. Make sure the lines are not rubbing against anything that could cause an eventual failure. Immediately repair any leaks or alter line routing to eliminate wear.

5-2.6.5 Gauges and Safety Mechanisms.

Check for accuracy on fuel level gauges and repair gauges as required.

5-2.6.6 Fuel Pumps.

Fuel pumps must be maintained to deliver sufficient fuel and sustain a satisfactory combustion to operate the generator. Fuel pumps must be cleaned by removing contaminants such as dirt, sand, and water.

5-2.6.7 Fuel Storage Tank Maintenance.

Clean and inspect fuel storage tanks every 10 years in accordance with API Standard 2015, *Requirements for Safe Entry and Cleaning of Petroleum Tanks*.

Drain tanks of water monthly to minimize corrosion of the inner tank surface. Bacterial growth in diesel fuel will be a problem in warm areas. **\1** Test fuel for contamination and polish as required if fuel is not used within three months. **/1/**

\1 [Note deleted.] **/1/**

5-2.7 Air Intake Systems.

5-2.7.1 Air Filters.

Prior to removing the intake air filters, remove accumulations of dirt from the air filter housing. Remove air filters and wipe to remove excess dust and dirt. Replace intake air filters per recommendations of the manufacturer.

5-2.7.2 Unlined Expansion Joints.

Inspect unlined expansion joint belts for cuts, worn sections, and cracks. Replace belts that are excessively worn and have cracks. Repair or replace belts with cuts per manufacturer's instructions. Inspect backing bars, mating flanges and hardware for corrosion. Refer to manufacturer's instructions for corrosion repair. Check fastener torque and re-torque to manufacturer's recommendations, as appropriate.

5-2.7.3 Unlined Duct.

Clean duct and check for corrosion and signs of water and air leakage. For paint, corrosion repair, and gasket replacement, refer to manufacturer's instructions.

5-2.7.4 Silencer Duct.

Clean duct and check for corrosion and signs of water and air leakage. For paint, corrosion repair, and gasket replacement, refer to manufacturer instructions.

Check acoustic insulation lining for water damage, corrosion, and cracking. For repair, refer to manufacturer's instructions.

5-2.7.5 Acoustically Lined Duct.

Clean duct and check for corrosion and signs of water and air leakage. For paint, corrosion repair, and gasket replacement, refer to manufacturer's instructions. Check acoustic insulation lining for water damage, corrosion, and cracking. Check access hatches and maintenance ports for air-tight seals. For repair, refer to manufacturer's instructions.

5-2.7.6 Trash Screens.

Inspect screen and framework for damage, including broken wires and missing screens. Replace damaged screens and tighten loose wires. Check screen frame and screen holder for corrosion. For repair, refer to manufacturer's instructions.

Check screen for deflection using hand pressure. If deflection is greater than 4 inches (100 mm), replace screen.

5-2.7.7 Expansion Joints.

Inspect expansion joint belts for cuts, worn sections, and cracks. Replace belts that are excessively worn and have cracks. Check manufacturer’s repair instructions for cracked belts as this typically indicates a system malfunction or alignment problem. Repair or replace belts with cuts per manufacturer’s instructions.

Inspect backing bars, mating flanges, and hardware for corrosion. Refer to manufacturer’s instructions for corrosion repair. Check fastener torque and re-torque to manufacturer’s recommendations, as appropriate.

5-2.7.8 Inlet Plenum and Cone.

Inspect and repair inlet plenum per manufacturer’s instructions.

5-2.8 Exhaust System.

Exhaust systems need to be maintained to keep the generator in good performance. Check for leaks at all connections, welds, gaskets, and joints. Make sure the exhaust systems are not heating the surrounding areas more than normal. Check for excessive smoke upon starting; this indicates air quality problems.

5-2.8.1 Air Induction Piping.

Exhaust system piping of generators must have suitable devices to prevent the entry of water from rain.

5-2.8.2 Turbochargers and Blowers.

Clean and maintain turbochargers in accordance with manufacturer’s recommendations.

5-2.8.3 Exhaust Manifolds.

Check exhaust manifolds for rust and corrosion.

5-2.8.4 Emissions System and Controls.

Maintain emissions system controls (e.g., catalytic oxidizers, exhaust particulate filters) and monitoring devices (e.g., continuous emissions monitoring systems) in accordance with manufacturer’s and environmental regulations/requirements. Manufacturer's instructions should be consulted for procedures specific to each model. Contact the environmental compliance office when problems are identified.

5-2.9 Generator Components.

Accomplish generator inspection, maintenance, and service in accordance with manufacturer’s requirements, environmental regulations/requirements, and/or recommendations or applicable technical orders. Listen and look for changes in performance or sound. Misfires and changes in oil consumption indicate service will be required.

There may be regulatory maintenance and maintenance recordkeeping requirements that vary greatly from engine to engine, according to whether the engine is:

- New or existing
- Located at an area source or major source of hazardous air pollutant (HAP) emissions
- A compression ignition or a spark ignition engine; include requirements associated with 40 CFR Part 63 Subpart ZZZZ, 40 CFR Part 60 Subpart JJJJ, and 40 CFR Part 60 Subpart IIII

5-2.9.1 Stator and Rotor Windings.

Clean stator and inspect the following items:

- Check coil ends for distortion or movement.
- Check damaged, missing, or broken wedges. Wedges that have lifted in the dovetail or have been burned must be replaced.
- **\1** Open, check, and clean cooling passages. **/1/**
- Check security of lashing and spacers.
- Check tightness of coil supports.
- Check partial discharge activity and other damages to coil insulation, including end windings and in the slot.
- Check connections between coils.
- Measure insulation resistance between winding and ground at the machine terminals.

Clean rotor and inspect the following items:

- Check clearance between blower and coils.
- Check damper winding for loose bars.
- Check proper connection between each bar and its ring segment.
- Check connections between field coils and collector rings.
- Check field coils for separation or movement.
- Clean oil and dirt from air passages and winding.
- Measure resistance between field coils.
- Check damaged bearings and journals.
- Check for insulation damages.

- Measure vibration limits at starting.

Refer to manufacturer's manuals for instructions on stator and rotor maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.2 Brushes.

Typical preventive maintenance practices on brushes are the following:

- Check brush faces for heat cracks and replace if damaged.
- Check for loose brush studs.
- Check brush shunts to ensure they are properly secured to the brushes and holders.
- Check that the brushes are resting at the correct angle and in the neutral plane.
- Ensure brushes are properly spaced on the commutator and brush holders are properly spaced from the commutator.

Refer to manufacturer's manuals for instructions on brush maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.3 Collector Rings.

Typical preventive maintenance practices on collector rings are the following:

- Clean collector rings using a solvent cleaner and a stiff brush.
- Check insulation resistance between ring and shaft for defective bushings and collars.
- Check brush holder endplay to prevent grooving of collector rings.

Refer to manufacturer's manuals for instructions on collector rings maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.4 Commutators.

Typical preventive maintenance practices on commutators are the following:

- Check commutator surface for grooving, scratches, or roughness.
- Check commutator concentricity with a dial gauge.
- Remove every trace of carbon, copper, or dust when the commutators are being cleaned.

Refer to manufacturer's manuals for instructions on commutators maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.5 Sleeve Bearings.

Typical preventive maintenance practices on sleeve bearings are the following:

- For old sleeve bearing types, the oil needs to be replaced at least every year.
- Check the oil level for new sleeve bearing types.
- Check that bearing insulation is not short-circuited by bearing temperature detectors or by lubricating oil piping. Bearing insulation is important to eliminate bearing circulating currents, preventing pitting of the shaft and bearing.

Refer to manufacturer's manuals for instructions on commutators maintenance and repairs and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.6 Ball and Roller Bearings.

Typical preventive maintenance practices on ball and roller bearings are the following:

- The bearing housing and bearing itself should be greased. Check the condition of the bearings and grease. Clean and add grease as needed.
- Follow manufacturer's manuals for recommendations regarding the type and quantity of lubricant/grease to be applied. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.7 Insulation Structures.

Typical preventive maintenance practices on insulation structures are the following:

- All insulation structures clogged with mud from weather events must be washed with pressure water not exceeding 25 psi (172.4 kPa), unless otherwise noted on the manufacturer's instruction manual.
- Dry all electrical insulations at 185 °F (85 °C) for four hours, followed by 225 °F (105 °C) to 248 °F (120 °C) for another four hours, unless otherwise noted on the manufacturer's instruction manual.
- After drying, measure winding insulation resistance with an insulation test instrument. The measurements must be in accordance with the insulation levels presented in IEEE 43, *IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery*.

5-2.10 DC Electrical System.

Check circuit breakers and exercise breakers. Check wiring for loose connections and perform an insulation test of all wiring.

5-2.10.1 Battery Electrolyte Level/Specific Gravity.

Typical preventive maintenance practices on insulation structures are the following:

- Inspect storage batteries, including electrolyte levels, every week and maintain by following the manufacturer's instructions.
- Check electrolyte levels before water is added by following the manufacturer's recommendations. Excessive water consumption can be an indication of overcharging, cell damage, or aging.
- Test and record monthly the lead-acid battery electrolyte specific gravity.
- Perform battery discharge tests a maximum of twice a year. This is also called load testing or capacity testing in some locations.

5-2.10.2 Battery Compartment.

- Inspect battery compartment damage as a result of vibration.
- If vibration is observed, isolate the batteries from vibration by following the manufacturer's prescribed procedures.

5-2.10.3 Battery Connections.

- Check battery interconnections for tight connections and corrosion.
- Clean and torque battery terminal connections.

5-2.10.4 Battery Charging System.

- Verify battery chargers' output voltage minimum of once per month.
- Check battery charger cable interconnections and cell connectors.
- Check for dirt, wear, and corrosion.
- Maintain battery chargers following the manufacturer's recommendations.

5-2.11 AC Electrical System.

Check relays and cable as scheduled and perform cable testing on medium-voltage cables every three years.

5-2.11.1 Voltage Regulator.

Follow manufacturer's instructions for maintenance of voltage regulators.

5-2.11.2 Control Panel.

Open up the control panels, look for corrosion, and dust, and perform an infrared (IR) scan of the inner equipment. Clean where necessary. Ensure the control system is logging data (where required).

5-2.11.3 Switchgear.

- Check for switchgear conditions causing carbon tracks.
- Check for damaged barriers and shutters.
- Perform insulation resistance tests (phase-phase [p-p] and phase-ground [p-grnd]) with the use of a megohmmeter.
- Check for discoloration of circuit breaker conductors, indicating overheating.
- Test circuit breaker contacts for opening and closing sequences.
- Test for alarm condition activation of switchgear alarms (if equipped).
- Consult manufacturer’s recommendations.

5-2.11.4 Automatic Transfer Switches (ATS).

Perform the following monthly, according to NFPA 110:

- Inspect, operate and lubricate mechanical linkages.
- Verify mechanical interlocks operation.
- Test switch performance and operation by manually initiating transfers in both directions.
- Verify correct indication light operation.

Consult manufacturer’s recommendations.

5-3 PREDICTIVE MAINTENANCE ELEMENTS (CONDITION-BASED).

5-3.1 General.

Refer to manufacturers’ manuals for maintenance and repair requirements, frequencies, and consumables specifications.

Note: The Air Force will follow requirements in Chapter 8.

5-3.1.1 Visual Inspections.

Perform visual inspections for every generator system as indicated in Figures 3-1 and 3-2.

5-3.1.2 Application and Scanning.

- Electrical and mechanical systems
- Electrical components
- Corrosion damage

5-3.2 Electrical and Mechanical Systems.

5-3.2.1 Electrical Components.

All switchgear, transformer connections, switchgear connections and panelboards should be IR scanned on a programmed basis based on available resources.

5-3.2.2 Corrosion Damage.

Remove any corrosion damage to base metal. Prime and paint with the same paint originally recommended by the manufacturer.

5-4 GENERATOR LOAD TESTING.

When load testing, use facility loads first and load banks as secondary loads only. Load banks should only be used when facility loads are insufficient to bring the generator to the required level of load/temperature.

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CHAPTER 6 TYPICAL INSPECTION AND MAINTENANCE SCHEDULES

6-1 PURPOSE AND SCOPE.

Follow manufacturer's maintenance schedules, as modified by generator loading.

6-2 PREVENTIVE MAINTENANCE (PM) SCHEDULES.

See Table A-1 for sample PM schedule.

6-3 PREDICTIVE MAINTENANCE SCHEDULES.

Provide typical predictive inspection and maintenance schedules and guidance—broken down by hourly, daily, weekly, monthly, and annually—for generator systems and components in table format (refer to Table 6.1 as an example). Review EPA regulations to ensure EPA-required O&M frequencies/practices for key systems have been incorporated into inspection and maintenance. Ensure requirements in 40 CFR Part 63 Subpart ZZZZ, 40 CFR Part 60 Subpart JJJJ, 40 CFR Part 60 Subpart IIII, and 40 CFR Part 89 are not violated (when applicable, based on generator age and location).

Emergency power supply systems (EPSS) should follow the maintenance schedule described in Annex A of NFPA 110 and Figure A.8.3.1(a) of that Annex.

Table 6-1 Typical Generator Maintenance Schedule

	Service Time		
Maintenance Items	**Monthly**	**6 Months**	**Yearly**
Visual inspection	X		
Check coolant heater	X		
Check coolant level	X		
Check oil level	X		
Check fuel level	X		
Check charge-air piping	X		
Check/clean air cleaner	X		
Check battery charger	X		
Drain fuel filter	X		
Drain water from fuel tank	X		
Check coolant concentration	X		
Check drive belt tension	X		
Drain exhaust condensate	X		
Check starting batteries	X		
Change oil and filter		X	
Change coolant filter		X	
Clean crankcase breather		X	
Check radiator hoses		X	
Change fuel filters		X	
Clean cooling systems			X

CHAPTER 7 PRIME POWER

7-1 GENERAL REQUIREMENTS.

The maintenance of the generator includes all associated generator systems, including cables, prime movers, and ancillary equipment. This chapter covers additional prime power considerations in addition to the requirements of the previous chapters.

7-2 CERTIFICATION OF GENERATOR WORKERS.

Turbine generator and power plant operators must have a valid power engineer's license or DoD plant operator license issued by the National Institute for the Uniform Licensing of Power Engineers, Inc. (NIULPE) (http://www.niulpe.org/certification.shtml) or an approved internationally recognized third-party certification agency. This licensing is only required for a power plant connected to the grid and **not** standby generators.

7-3 COMBUSTION TURBINE ENGINE.

Combustion turbine engines use a jet engine to burn fuel with the exhaust gases rotating a turbine generator. The major components of combustion turbine engine requiring maintenance typically include:

- Air intakes
- Compressors
- Combustors
- Turbines
- Afterburners
- Nozzles
- Cooling system
- Fuel system
- Starting system
- Ignition system
- Lubrication system
- Control system

7-4 GASEOUS FUELS.

Gaseous fuel systems components requiring maintenance include:

- Storage system (if not direct utility provided)
- Regulating stations and relief devices
- Automatic shutoff devices

- Coalescing filters
- Gas fuel heating system
- Gas fuel scrubber
- Corrosion control system

7-5 FUEL OIL.

Fuel oil system components that typically require maintenance include:

- A fuel receiving station(s) from either a truck, train, ship, or pipeline, or combination thereof
- Bulk storage system (above ground and below ground)
- Day tanks
- Transfer pumps
- Fuel maintenance (filtration) system
- Fuel coolers
- Supply and return piping system
- Corrosion control system
- Leak detection systems
- Control system

7-6 LUBRICATING SYSTEMS – GAS TURBINE ENGINES.

The typical components for a gas turbine engine requiring maintenance include:

- Tanks
- Pressure pumps
- Scavenger pumps
- Filters
- Oil coolers
- Relief valves
- Breathers and pressurizing components
- Pressure gauges and instrumentation
- Temperature regulating valves
- Oil-jet nozzles
- Magnetic chip detectors
- Tubing, hose, and fittings

7-6.1 Oil Analysis.

Test generator oil on a recurring maintenance schedule. General and physical tests are suggested twice a year.

7-6.1.1 Oil Sampling Technique.

Oil sampling in generator engines should be taken at the following sampling points and sealed:

- Through dipstick holder
- Sample valve on crankcase sump wall
- Return line before filter

7-6.1.2 Chemical and Physical Testing.

Perform chemical and physical testing for every generator system as specified in Figure 3-1.

7-6.2 Ultrasonic Scanning.

Check if weld leaks are detected in the lines or corrosive liquids are carried through the lines. Perform this validation at least once every five years.

Scanning welds requires a high level of operator training. It is recommended a third party be contracted to perform these inspections if in-house expertise is not available.

7-6.3 Weld Inspection.

Physically inspect welds to verify no cracks or corrosion are occurring on the welds for piping not ultrasonically tested. These should be examined every five years.

7-6.3.1 Instrumentation, Transducers, and Transformers.

Ensure calibration cycles are:

- As recommended by the manufacturer of the instrument;
- One year for electrical, electronic and mechanical test equipment or three years for mechanical test equipment made of solid materials not subject to deterioration.

Calibration intervals may be extended based on the following conditions and the reasons must be documented:

- Passive electrical test equipment, such as current shunts, current transformers, and potential transformers, may be extended to three years with good results for the initial calibration period and if not subject to severe-use conditions.

- Where there is sufficient calibration data to statistically establish a trend of the test equipment to assure good measurement results for a longer period.

7-6.3.2 Scanning Analysis.

After the test data is gathered, this data should be compared to earlier testing data to determine any changes. Data showing corrosion or high resistances must be addressed.

7-6.3.3 Application and Technique.

Items to look for when analyzing data include:

7-6.3.3.1 Applications.

- Surface breaking cracks
- Metal thinning
- Tube inspection
- Conductivity
- Thickness

7-6.3.3.2 Scanning.

- Multi-frequency
- Swept frequency
- Pulsed
- Remote field
- Impedance matching

7-6.3.4 Equipment and Probes.

The equipment for scanning is called a multi-frequency probe. It is hand-held, with ultrasonic scanner diagnostics. Other probes, such as pulsed and impedance matching, remote field, etc., can be found from the same manufacturers that produce other ultra-frequency scanners.

7-6.3.5 Inspection Analysis.

Inspection analysis can usually be gathered directly from the scanner or it can be available through a software application with input from the scanner.

7-6.4 Steam Turbine System.

There are two main types of steam turbines: superheated steam and saturated steam. In a saturated steam turbine, the increased moisture in the steam path accelerates blade erosion, diminishes efficiency, and requires a water removal system in the saturated steam inlet lines. The more complex saturated steam systems have increased maintenance requirements.

7-7 PRIME COOLING SYSTEMS.

7-7.1 Stator Cooling Systems.

On very large units (over 40 MW), there may be a stator cooling system. The stator cooling system maintains the stator bars and screen plates within operating temperature range using demineralized cooling water. Ensure the system operates at a pressure lower than the hydrogen seal pressure, filters particulates that can plug or damage the stator tubes, and the demineralized make-up water system provides required make-up water due to loss or leaks. Also, ensure the leak detection system is operating within the manufacturer's operating parameters and venting to atmosphere is provided for over-pressure of hydrogen gas.

Ensure the generator hydrogen seal oil system operates under all conditions and maintains the seal oil at correct operating temperatures and differential pressure.

7-7.1.1 Stator Water Cooling System.

Stator water cooling system components typically requiring maintenance include:

- Demineralized water system
- Pumps
- Emergency pump
- Water cooler
- De-oxygenating unit
- Strainer
- Resistance columns
- Gas detraining chamber

7-7.1.2 Stator Hydrogen Cooling System.

Hydrogen cooling system components typically requiring maintenance include:

- Gas supplies
- Hydrogen dryer
- Hydrogen gas analyzer

- Centrifugal fans
- Hydrogen coolers
- Seal oil pumps (AC and DC)
- Seal oil pump pressure control valve
- Seal oil loop seal
- Seal oil cooler
- Filters
- Detraining chamber
- Gas trap
- Bearing seals
- Hydrogen dryer
- Air scavenging
- Purity monitor
- Stator coolant system (strainers, demineralization plant, flow measurement instrumentation, gas alarm and automatic release chamber, and gas detraining chamber)

7-8 INTAKE AIR MAINTENANCE.

7-8.1 Gas Turbine Intake Air.

For gas turbine engines, the consequences of poor inlet filtration are more significant with foreign object damage, erosion, fouling, particle fusion, or corrosion of the compressor fans. As such, gas turbine air filtration systems typically use multiple stages of weather protection, inertial separators, pre-filters, coalescers, and final filters.

7-9 SPECIALTY TOOLS AND EQUIPMENT.

Consider acquiring and using the following specialty tools and equipment:

- Lube oil flush system
- Coolant flush system
- Valve and bearing inspection tools
- Exhaust analyzer
- Remote racking mechanisms for switchgear circuit breakers (Several manufacturers provide remote racking mechanisms that allow the electrical worker to stay well outside the arc flash boundary during circuit breaker racking operation.)

- Remote switching actuators for circuit breakers (Enables remote circuit breaker operation [open or close].)
- Thermal imaging cameras
- Power quality data loggers (For evaluating normal system parameters, such as voltage, current, power factor and harmonic distortion, as well as evaluating abnormal events, such as voltage swells, sags, or outages.)
- Wet/dry hot stick tester
- Fault locating equipment

7-10 TOOL SAFETY

7-10.1 Energized Lines.

The methods used when working on energized lines, such as gloving, use of hot line tools, and provision of electrically insulated buckets, will be in accordance with the applicable services' safety manuals. Safety rules governing the use of such tools and equipment are given in these manuals and in applicable OSHA regulations, 29 CFR 1910 and 29 CFR 1926.

7-10.1.1 Climbing Equipment.

When generators/equipment are over 6 feet (1.8 meters) in height, climbing equipment must be used if there are no permanent ladders and walkways. Climbing equipment includes body belts, safety and climber straps, climbers, and ladders. Refer to 29 CFR 1926.501 for OSHA details. Use personal fall arrest systems in accordance with 29 CFR 1910.269(g)(2)(iv)(B) and 1926.502(d).

7-10.2 Insulating Hydraulic Fluid.

An insulating-type hydraulic fluid is required in all hydraulic hand tools used on or near energized lines and in insulated sections of aerial lift trucks. Hazardous material procedures must be followed when dealing with such substances.

7-11 POWR PLANT OPERATIONS.

7-11.1 Load Shedding.

Load shedding should be the deliberate and selective dropping of electrical load in accordance with a preplanned program specific to a base. There must be a plan to load-shed circuits that minimizes impact to critical loads.

7-11.2 Methods of Load Shedding.

To have proper load shedding, a prioritized load-shedding program must be established and implemented. This scenario arises most often when loads are added after the initial installation. The criteria for load shedding are primarily frequency based, and must occur when the frequency drops below 56.6 Hz for diesel reciprocating units and 58 Hz for turbines.

7-11.3 Requirements for Load Reduction.

A scenario could involve an isolated plant (not interconnected with a utility), with several generating units loaded at or near their combined capability. Should one unit trip, the remaining units would experience a sudden load increase, possibly leading to loss of the plant.

7-11.4 Total Load Reduction.

The load-shedding plan must accomplish a total load reduction sufficient to relieve the plant overload and provide a slight underload so the plant will have reserve capacity to reaccelerate to the normal operating frequency. One must also consider the loss of capacity that results from under-frequency operation.

7-11.5 Methods of Load Shedding.

There are many methods of load shedding, both automatic and manual. The automatic methods include under-frequency relaying and various transfer-trip arrangements. All of these methods have relative advantages and disadvantages and the choice of the most advantageous method should be based on the specific conditions that prevail. However, load shedding by under-frequency relaying is the most common and generally the preferred method.

7-11.6 Electrical Usage and Criticality.

In general, the least-critical loads should be tripped first and the load-shedding should proceed in stages, with progressively more critical loads being shed at each stage. The following provides guidelines for the determination of the relative criticality of loads.

7-11.6.1 Critical Loads.

To develop a load-shedding plan, identify the critical loads first along with an estimate of the magnitude of each. Design the load-shedding plan so the critical loads are shed last. In some cases, it may be necessary to divide the critical loads into two or more categories and assign relative priorities to each category.

7-11.6.2 Mission-Critical Loads.

Mission-critical loads are loads essential for the operation of the facility and broader agency mission support. If these loads are shed, they would adversely affect the facility mission, national security, critical communications, the warfighting mission, or base security.

7-11.6.3 Life Support Loads.

Life support loads include hospitals and similar high-occupancy facilities where loss of power may endanger life.

7-11.6.4 Time-Critical Loads.

In many cases, load criticality will vary with time. Take time variations into account when designing the load-shedding plan.

7-11.6.5 Seasonal Variations.

In a severely cold climate, a load related to providing heat could be considered critical during the winter and noncritical during the summer. Under the same conditions, the power supply to a frozen food storage facility could be considered critical during the summer and non-critical during the winter.

7-11.6.6 Diurnal Variations.

The criticality of some loads may vary from day to night or from weekday to weekend because of changing usage. Examples may include auditoriums, theaters, and offices.

7-11.6.7 Interruptible Loads.

Some loads can withstand short interruptions but not lengthy interruptions. Examples may include community facilities with emergency (battery-powered) lighting. These loads can be classified non-critical for load shedding but could also be given a high priority for load restoration.

7-11.7 Stable Operation and Overload Capability.

Generating plants are highly sensitive to frequency drop. There are two major problem areas: motor speed and turbine blade fatigue.

7-11.7.1 Operating to Avoid Turbine Blade Fatigue.

The last rows of long, low-pressure blades in steam turbines are tuned to operate free of resonance in a narrow band of frequencies around 60 Hz. When running under heavy load at about 58.5 Hz or below, the steam excitation frequency approaches blade resonance. Under this condition, the blades may vibrate severely, producing fatigue stress. On average, blades should not be subjected to more than ten minutes of severe vibration total over their lifespan, as fatigue is cumulative. Operation below about 58.0 to 58.5 Hz should be avoided; the generator protective devices may trip the unit in this speed range, regardless of load. This is not applicable to emergency generators.

7-11.7.2 Motor Speed.

Motor-driven auxiliaries will slow down, reducing generator output. Safety margins in generator-cooling and bearing lubricating systems will be reduced. The lowest safe plant operating speed will depend on the safety margins included in the plant design. However, operation below the 56.6 to 57.5 Hz range is generally not advisable.

7-11.7.3 Other Implications.

In some cases, the selection of critical loads must be made on a purely subjective basis, considering the effect on the community of providing power or of not providing power to a specific load during a widespread power failure.

7-12 OPERATIONAL CONSIDERATIONS.

7-12.1 Isolated Operation.

Under isolated operation, the generator operates independently of the electric utility and provides all electricity and steam needed and used by the facilities that it serves.

7-12.2 Base Loads.

Under base load electric operation, the cogeneration equipment is sized and installed to generate electricity at a constant (base) load equal to the minimum annual (or some other period) electrical demand.

7-12.3 Alternate Energy Sources.

Variable renewable energy sources do not operate in parallel with mission-critical generation.

7-13 POWER PLANT OPERATIONS.

7-13.1 Power Plant Supervisors.

Power plant supervisor's and operator's responsibilities are set by each Service.

7-13.2 Work Schedule

Work in three shifts, 24 hours per day, all year. Schedule maintenance shifts, one shift or two, based upon size of the facility and have an on-call program to call maintenance personnel in case of an emergency.

7-13.3 Dead Plant Start-Up.

To start up power plants that are in the dead state, the operator must:

1) Ensure all loads to external switchgear are disconnected.
2) Ensure there is air for starting air-operated generators or battery power for generator starting.
3) If air or battery power is not available, start the black start generator manually if it has not started automatically. Energize lighting, fuel pumps, lube oil, and controls from the black start bus.

4) If there is no black start generator, use utility power to provide power to the plant controls, fuel pumps, lube oil, and lighting.

5) Once the black start bus has been energized, and all controls are activated, the prime power generator may be started. Start by making sure the fuel pumps, lube oil, and controls are operational. When this generator is started and running, energize the main bus and then synchronize to either the utility or another generator.

6) After one or more generators have been energized, pick up loads one-by-one and add onto the generator.

7) When all loads have been picked up and the power plant is operating in normal mode, shut down the black start generator and prepare it for the next occurrence.

7-13.4 Power Outage.

Ensure scheduled outages are communicated to all affected parties. Communicate unscheduled outage information to all applicable parties as soon as possible. Include the reason for the outage and, if the plant has not been re-started, an estimated plant restart time.

7-13.5 Emergency Plant Shutdown.

Emergency plant shutdown procedures are required for potential abnormal operating conditions, fire, or other natural event that may occur and damage or disrupt facility power generation. Ensure approved emergency plant shutdown procedures are readily available in the main plant control room and the procedures have clear roles and responsibilities for plant personnel duties. The procedures must ensure the following:

- Plant shutdown without injury to personnel, damage to equipment, and damage to the environment
- Minimum environmental emissions
- Protect equipment from over-pressure or over-temperature damage

7-13.6 Micro-Grid Operation.

The Department of Energy defines a micro-grid as, “A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that act as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid connected or island mode.” Only use micro-grid operations when feasible and when they do not interfere with mission-critical standby/emergency generators according to Service guidance and policy.

7-13.6.1 Island Mode.

There are three events to cause a transition to island mode:

- Emergency situation when a utility outage occurs and sufficient generation is available
- Black start when an outage occurs and sufficient generation is **not** online
- Planned island mode required due to combat situations, forecasts in unfavorable weather, and economic situations

7-13.6.2 Typical Island Mode Operational Sequence.

The typical operator actions for the island mode operations sequence include:

1) Operator finds out about an emergency.
2) The plant is islanded from the utility using breaker controls.
3) Additional generators are started to have rolling reserve capacity.
4) Enable load restoration of shed loads if any have been shed when emergency disconnect occurred.
5) If the emergency has passed, make sure that frequency and voltage in island operations are within tolerance ranges.
6) Re-synchronize, when possible.

7-14 OPERATIONAL PERMITTING.

See NERC Standard PRC-005-2, *Protection System Maintenance Program*, as appropriate for large systems over 75 MVA in total or 20 MVA individually.

7-14.1 Wastewater Discharge Permit.

As appropriate, obtain a National Pollutant Discharge Elimination System (NPDES) permit in accordance with the Clean Water Act (CWA). Renew the permit every five years or per the requirements of the issuing authority.

7-14.2 FAA Permit.

For prime power facilities located in the flight path of airports and heliports, obtain FAA permitting for exterior maintenance activities that exceed the height of existing facilities, could affect flight operations, or the stack height changes. Consult the FAA Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) (https://oeaaa.faa.gov/oeaaa/external/portal.jsp). This process should start with the nearest FAA Airports Regional Office. This is covered under 14 CFR 77, *Safe, Efficient Use, and Preservation of the Navigable Airspace*.

7-14.3 Incidental Take.

Obtain permits and retain compliance records required under the Endangered Species Act of 1973 for activities that may "take" (kill) native threatened or endangered species. Contact the nearest U.S. Fish and Wildlife Service (USFWS) Ecological Services Office to determine if the proposed facility is likely to result in a take, whether a permit is required, or if other options require consideration. Obtain an Incidental Take Permit in accordance with 50 CFR Part 13 and 50 CFR Part 17.

7-15 PREVENTIVE MAINTENANCE.

Table 7-1 provides a typical prime generator maintenance schedule. Review EPA regulations to ensure EPA-required O&M frequencies/practices for key systems have been incorporated into inspection and maintenance. Ensure requirements in 40 CFR Part 63 Subpart ZZZZ, 40 CFR Part 60 Subpart JJJJ, 40 CFR Part 60 Subpart IIII, and 40 CFR Part 89 are not violated (when applicable, based on generator age and location).

7-15.1 Corrosion Control.

Prime power plants have elements that can fail due to corrosion and cause equipment failure or create a life safety risk. Preventive maintenance must include corrosion control for the following elements: boilers, steam drums, feed water heaters, super heater, turbine, pipes, cooling tower, and structural supports.

Table 7-1 Typical Prime Generator Maintenance Schedule

Item/Component	Action					Frequency					
	Visual Inspection	Check	Change / Replace	Clean	Test	Daily	Weekly	Monthly	Quarterly	6 Months	Yearly
Prime Mover											
General Inspection	X						X				
Service air cleaner			X	X						X	
Governor oil level and linkage	X	X						X			
Governor oil			X								X
Ignition system	X	X	X	X	X						X
Choke setting and carburetor adjustment		X								X	
Injector pump and injectors					X						X
Generator											
Brushes	X	X		X						X	
Commutators and slip rings	X			X							X
Rotor and stator	X			X							X
Bearings	X		X								X
Bearing grease		X	X								X
Exciter	X	X		X							X
Voltage regulator	X	X		X							X
Resistance and insulation					X						X
Fuel System											
Main supply tank level		X					X				
Day tank level	X	X					X				
Tank float switch	X				X		X				
Transfer pump operation	X				X		X				
Solenoid valve operation	X				X		X				
Strainer and filter				X					X		
Water in system		X		X			X				
Flexible hose and connectors	X		X				X				
Tank vents		X			X						X
Piping	X										X
Lubrication System											
Oil level	X	X					X				
Oil change			X								X
Oil filter			X								X
Lube oil heater		X									X
Crankcase breather	X		X	X					X		

Item/Component	Action					Frequency					
	Visual Inspection	Check	Change / Replace	Clean	Test	Daily	Weekly	Monthly	Quarterly	6 Months	Yearly
Cooling System											
Level	X	X					X				
Antifreeze protection level					X					X	
Antifreeze			X				X				
Cooling water to heat exchanger		X					X				
Rod out heat exchanger				X							X
Fresh air through radiator		X					X				
Exterior of radiator				X							X
Fan and alternator belt	X	X						X			
Water pumps	X						X				
Flexible hose and connectors	X	X					X				
Jacket water heater		X					X				
Duct work and louvers	X	X		X							X
Louver motors and controls	X			X	X						X
Exhaust Systems											
Leakage	X	X					X				
Drain condensate trap		X					X				
Insulation	X								X		
Excessive backpressure					X						X
Exhaust system hangers and supports	X										X
Flexible exhaust sections	X									X	
Battery Systems											
Electrolyte level		X					X				
Cleanliness and tightness of terminals	X	X							X		
Corrosion	X			X				X			
State of charge					X			X			
Charger and charge rate	X							X			
Equalize charge		X						X			
Electrical System											
Transfer Switches											
Insulation resistance (p-p and p-grnd)					X						X
Contact resistance					X						X
Manual transfer switch operation					X						X
Transfer switch alarms	X				X						X
Transfer switch indicating lights	X				X						X

Item/Component	Action: Visual Inspection	Action: Check	Action: Change / Replace	Action: Clean	Action: Test	Frequency: Daily	Frequency: Weekly	Frequency: Monthly	Frequency: Quarterly	Frequency: 6 Months	Frequency: Yearly
Transformers											
Cleanliness	X									X	
Electrical insulation discoloration	X										X
Oil acidity					X						X
Discoloration	X				X						X
Dielectric strength					X						X
Transformer cooling system		X									X
Transformer alarms	X										X
Switchgear											
Carbon tracks on switchgear	X										X
Barriers and shutters	X										X
Insulation resistance (p-p and p-grnd)					X						X
Dielectric absorption					X						X
Power factor					X						X

7-16 BAGHOUSE LEAK DETECTION AND PERFORMANCE MEASUREMENTS.

7-16.1 Inspection.

Each sensor should be inspected at regular intervals to remove any buildup of material that may collect on the probe or insulator. A buildup of material on the probe may dampen or decrease the signal strength and material on the insulator can form a conductive electrical bridge across the insulator, increasing the signal strength and resulting in a high alarm.

7-16.2 Trial Period.

An initial 30-day trial period is recommended to verify the setup of the instrument is appropriate in order to prevent frequent false alarms and ensure the instrument has sufficient detection capability. Another reason such a trial period is recommended is to verify the system selected will perform reliably in the application and the environment to which it is exposed. Some monitors may have higher sensitivity upon initial installation but over a period of several days will stabilize and remain repeatable. The monitor lacks the ability to compensate for a buildup of particulate on the probe, so conditioning the system to the process environment is critical to reliable and repeatable operation.

After the sensitivity, response time, alarm levels, and alarm delay (if applicable) have been set and undergone the 30-day trial period, they should not be readjusted unless normal process conditions change in a manner that affects the characteristics of the particles or exhaust gas stream, such as:

- Change out of filter bags, repair of leaks, or other process improvement that would reduce particulate emissions.
- Slow drift of signal due to environmental factors such as humidity. If the sensitivity drifts more than -50 to 100 percent from the initial setup, the monitoring system and control device should be inspected and any necessary repairs performed.
- Equipment is taken out of service for repair, replacement, or upgrading.

7-17 SPECIALIZED INSPECTIONS (GAS TURBINE ONLY).

7-17.1 Borescope Inspection.

Conduct a borescope inspection of all compressor stages, buckets, and nozzles annually for natural gas and distillate fuels or semi-annually for heavy fuel oils. Inspect for signs of excessive gas path fouling, symptoms of surface degradation (such as erosion, corrosion, or spalling), displaced components, deformation or object damage, material loss, nicks, dents, cracking, indications of contact or rubbing, or other anomalous conditions.

7-17.2 Hot Gas Path Inspection.

Conduct an inspection of the turbine hot gas path at intervals recommended by the manufacturer (typically 24,000 hours) in accordance with the manufacturer’s O&M manual requirements.

- Inspect condition of nozzles, nozzle seals and hook fits, diaphragms, and diaphragm packings.
- Inspect bucket seals and cutter teeth on tip shroud buckets.
- Inspect turbine rotor and compressor.
- Inspect turbine shell.

7-17.3 Major Inspection.

Conduct a major inspection of the gas turbine at intervals recommended by the manufacturer (typically 48,000 hours) in accordance with the manufacturer’s O&M manual requirements. Inspection includes hot gas path inspection items and the following:

- Inspect casings, frames, and diffusers.
- Inspect compressor inlet and compressor flow paths.
- Inspect rotor and stator compressor blades and check tip clearance.

- Conduct a non-destructive inspection (NDI) of turbine buckets and wheel dovetails.
- Inspect bearings, liners, and seals.
- Inspect compressor and compressor discharge case and inner barrel.
- Check gas turbine to generator alignment.

7-17.3.1 Step-Up Transformers Associated with Power Plant.

- Check transformers for electrical insulation discoloration.
- Perform dielectric strength tests to insulating oil for liquid-filled transformers in accordance with ASTM D877, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*.
- Perform acidity tests to insulating oil for liquid-filled transformers in accordance with ASTM D1534, *Standard Test Method for Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration*.
- Perform color test to insulating oil for liquid-filled transformers in accordance with ASTM D1524, *Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field*.
- Check damage on cooling system equipment for transformers equipped with forced-cooling systems.
- Test for transformer alarm condition activation (temperature, level, pressure), if equipped.
- Check that cooling passages for transformers are not being fouled by dust.
- Remove and test transformer oil to record its temperature and observe if it is in optimum working condition.
- Perform the following tests:
    - Power factor/dissipation factor test
    - Dissolved gas/chromatograph test
    - Karl Fischer moisture test
    - Furanic compound test
    - Total dissolved combustible gases ppm
    - Dissolved metals test
    - Appearance
    - Dielectric breakdown test
    - Test on transformer oil every three years

7-17.3.2 Cable Testing of Medium Voltage Cables.

Periodic maintenance tests are needed during the life of the cable to determine whether or not there has been significant insulation deterioration due to operational or environmental conditions. The maintenance schedule for power cables only pertains to cables associated with critical equipment. High potential tests (hipot) effectively reduce in service failures from faults of the cable or its accessories. When done properly, maintenance tests can detect problems in cables that are approaching failure without accelerating the deterioration process. Except for infrared scanning, de-energize the cable circuit before maintenance. An insulation test using a DC ramp test is recommended at a five-year interval.

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CHAPTER 8 AIR FORCE REQUIREMENTS

8-1 SUMMARY OF REQUIREMENTS.

This chapter supplements AFI 32-1062 and applies to Air Force real property installed equipment (RPIE) and equipment authorized inventory data (EAID) electrical generator systems, inspection, maintenance, testing, and refueling criteria. The BCE or equivalent will operate, and maintain all RPIE electrical generator systems and equipment, including EAID electrical generators and equipment assigned to the BCE. Electrical generator systems not assigned to the BCE should have a signed memorandum of agreement (MOA) on file. Perform preventive maintenance in accordance with approved Air Force preventive maintenance procedures prescribed by AFI 32-1001, *Operations Management*, and testing requirement frequency outlined in this chapter. Documentation of preventive maintenance actions, electrical generator system testing (e.g., test records, run-times, electrical testing parameters), oil analysis results, and system repairs must be documented by the BCE. The Air Force Air Program Information Management System (APIMS), in accordance with recordkeeping requirements of AFI 32-7040, *Air Quality Compliance and Resource Management*, is recognized as an official record. The BCE is encouraged to use APIMS as their official record; however, if a shop uses APIMS as the official shop record then the shop must upload and manage the information in APIMS.

8-2 DEFINITIONS.

8-2.1 Standby power is an alternate power source that is available through either automatic or manual operation. Standby power may be RPIE or EAID based on AFCEC/COSM authorization.

8-2.2 Prime power is standby power capable of operating continuously. The generator may be considered prime when the utility source is not available or unreliable. Generators designed to operate in parallel with the utility are also considered to be prime power.

8-2.3 Backup generators may be RPIE or EAID portable units. RPIE generators support mission-critical functions where delayed power restoration is unacceptable. RPIE generators may be approved for missions that require immediate power restoration, uninterrupted power, or support to **\1** standby **/1/** systems defined in NFPA 70, *National Electrical Code* (NEC), Article 700. EAID generators support mission-critical or infrastructure-critical functions where delayed power restoration is acceptable. During a commercial power outage, a lack of infrastructure-critical function could result in an environmental or other non-mission-related condition.

8-2.4 Classifications of generator authorizations: RPIE – Emergency **\1** (same facility life-safety systems, i.e., not mission systems), **/1/** RPIE – COPS, RPIE – POLS/Fuels, RPIE – Other Permanently Installed; EAID – Portable, and EAID – POLS/Fuels. Refer to AFI 32-1062 for definitions or classifications and approval process.

8-2.5 Deployable generators are defined as those assigned to a Civil Engineering (CE) Squadron unit type code (UTC).

8-3 GENERATOR PREVENTIVE MAINTENANCE FREQUENCIES, MAINTENANCE REQUIREMENTS, AND TESTING.

- The minimum inspection and testing frequencies required for RPIE and EAID generator systems are prescribed in Table 8-1.
- Use the approved Air Force Preventive Maintenance Task List (AF-PMTL) for the required maintenance procedures per AFI 32-1001 on RPIE and EAID generator systems.
- AF-PMTLs are built to address reoccurring Air Force preventive maintenance requirements, common manufacturer's preventive maintenance requirements, and preventive maintenance requirements outlined in NEC Articles 700, 701, 702, 705, and 708, and in NFPA 110 (Level 1 and 2).
- AF-PMTLs do not address unique local laws, regulations, and uncommon manufacturer's unique reoccurring preventive maintenance. Coordinate local supplements to AF-PMTLs through the AFCEC/COO Preventive Maintenance Program Manager.

8-3.1 Requirements for Select Mission-Essential Facilities Compliance with Published Guidance.

- Exercise other **\1** standby **/1/** systems supporting navigational aids for air traffic control facilities according to AFI 13-204V3, *Airfield Operations Procedures and Programs,* in addition to requirements in this chapter.
- **\1** Exercise other standby systems supporting Defense Communications Systems (DCS) or related communications activities according to Defense Information Systems Agency Circular (DISAC) 350-195-2*, *Tests and Evaluations - Electric Power Systems for Department of Defense Information Network (DODIN) Facilities.* **/1/**
- Exercise emergency power systems that support medical facilities according to NFPA 99, *Health Care Facilities Code*, in addition to requirements in this chapter.
- Generator systems required to comply with NEC Article 708 must also comply with NFPA 110 Level 2 criteria. **\1** Application of NEC Article 708 is more costly than the other generator requirements of the NEC. **/1/**

Table 8-1 Generator System Inspection and Testing Frequency Requirements

Classification (ref: AFI 32-1062)	Preventive Maintenance / Inspection Frequency				
	Semi-Monthly[3](J)	Monthly (M)	Quarterly (Q)	Semi-Annual (SA)	Annual (A)
RPIE - Emergency	X	X		X	
RPIE - COPS	X	X		X	
RPIE - POL/FUELS		X	X		X
RPIE - Other Permanently Installed	X	X		X	
EAID - Portable		X	X		X
EAID - POL/Fuels		X	X		X
Supporting Equipment					
Transfer switch (ATS / MTS / paralleling switchgear)[1]	X	X	X	X	X
Fuel system[2]	X	X	X	X	X

Terms:

Semi-monthly: Twice a month; activities are generally separated by enough time so the occurrences are equally distributed across the month

Monthly: Once a month

Quarterly: Once every three months

Semi-Annual: Once six months

Annual: Once a year

Notes:

1: Inspect ATS / MTS / paralleling switchgear during each required PM frequency for the generator it is supporting.

2: Inspect fuel system during each required PM frequency for the generator it is supporting.

3: Geographically separated equipment located more than 20 miles (32 km) from the servicing installation may be inspected monthly if the batteries and generator operation are monitored by a remote monitoring system complying with UFC 4-010-06.

8-3.2 RPIE Generator and Transfer Switch Inspections and Operational Testing Requirements.

This section addresses generator system operational testing requirements for RPIE generator systems classified by AFCEC/COSM as RPIE - Emergency, RPIE – COPS, and RPIE - Other Permanently Installed.

Document all inspection actions on AF Form 487, *Generator Operating Log (Inspection Checklist)*, and file the form with the generator record.

8-3.2.1 Semi-monthly RPIE Generator and Transfer Switch Inspections.

Conduct and document visual inspection of the generator, ATS/MTS/switchgear, and system batteries. Engine start is optional.

8-3.2.2 Monthly RPIE Generator and Transfer Switch Testing.

Test the RPIE generator system monthly by exercising the generator for a minimum of one hour using either Exercising Method 1 or 2. Load generator with facility load first, annotate load on AF Form 487 and, if facility load is not adequate to meet minimum operating conditions for the selected Exercising Method, use a load bank in combination with facility load to increase the total load on the generator to meet the Exercising Method. Test generator systems monthly under facility load with the electrical service entrance to the transfer switch/switchgear switched off.

8-3.2.2.1 Monthly Generator Exercising Method 1.

Conduct this test under loading that maintains the minimum exhaust gas temperature (EGT) recommended by the manufacturer. The one-hour generator exercise time for Method 1 operational inspections includes warmup, load test, and cool-down.

8-3.2.2.2 Monthly Generator Exercising Method 2.

Conduct this test under operating temperature conditions and at no less than 50 percent of the generator nameplate kW rating. The one-hour generator exercise time for Method 2 operational inspections includes warmup, load test, and cool down.

Note: RPIE generators rated 25 kW and lower are not required to meet monthly generator Exercising Method 1 or 2 and shall be tested with actual facility loads for a minimum of one hour.

Note: Additional semiannual testing is required if a monthly test accomplished between semiannual tests does not meet the requirements of either monthly generator Exercising Method 1 or 2.

8-3.2.2.3 Monthly Exercising of \1\ MTS/Switchgear. /1/

Test the **\1** MTS/switchgear **/1/** monthly by exercising the operation of the switch with facility loads. The monthly test of the switch must consist of operating the switch from its primary position to the electrical generator power source position and then return to the primary position upon completion of the generator test.

The criteria set forth in NFPA 110 Section 4.3 and Table 4.1(b) is not required during the monthly testing of the EPSS.

8-3.2.2.4 Monthly Exercising of Paralleling Switchgear.

Test the paralleling switchgear monthly by exercising the operation of the paralleling switchgear with facility loads. The monthly test of the paralleling switchgear must consist of operating the paralleling switchgear, paralleling of the connected generators, and operating the switchgear from its primary position to the electrical generator power source position and then return to the primary position upon completion of the generator test.

8-3.2.3 Semiannual RPIE Generator Full-System Testing.

Test the full generator system semiannually with the facility electrical service entrance power switched off upstream of the facility for a minimum of one hour. **\1** A longer generator test of greater than one hour is strongly encouraged on an annual basis to verify the proper configuration and operation of all downstream loads. **/1/** Testing conducted with only the power source disconnected to the transfer switch/switchgear will only test the generator system and does not assure that mission equipment and facility support equipment are connected to the correct electrical distribution panels. Testing the generator system with the facility electrical service entrance power switched off upstream of the facility verifies which mission equipment and facility support equipment is sustained by the generator system and which portions of the facility are not sustained by the generator system. **\1** Where multiple generators provide standby power to the same facility, a custom test plan must be developed to verify proper configuration and operation. **/1/**

Note: Additional semiannual testing is required if a monthly test accomplished between semiannual tests does not meet the requirements of either monthly generator Exercising Method 1 or 2. For generator systems not meeting the monthly testing methods, load the generator system with available facility load (augmented with load banks, as necessary) to achieve not less than 50 percent of the generator nameplate kW rating for one continuous hour and then not less than 75 percent of the generator nameplate kW rating for one additional continuous hour, for a total test duration of not less than two continuous hours.

8-3.2.3.1 Exemptions to Semiannual Inspection and Testing.

Generators supporting an actual power outage during a six-month period do not require an additional semiannual full-system test, provided the following conditions are met:

- The outage duration was at least one hour. Separate outages cannot be added together to meet this requirement.
- The transfer switch operated properly during the outage.
- All items were checked/annotated on AF Form 487, including the facility representative section.
- A post-operational inspection was accomplished.
- **\1** Generator load was greater than 50 percent. **/1/**

8-3.2.3.2 Denial Authority for Semiannual Testing.

Refer to AFI 32-1062 regarding denial of semiannual RPIE generator full-system testing.

8-3.3 RPIE POL/Fuels Generator and Transfer Switch Testing.

This section addresses generator system operational testing requirements for RPIE generator systems classified by AFCEC/COSM as RPIE POL/Fuels.

Document all inspection actions on AF Form 487, Generator Operating Log (Inspection Check List) and file the form with the generator record.

8-3.3.1 Monthly RPIE POL/Fuels Inspections and Testing.

Conduct and document visual inspection of the generator, ATS/MTS/switchgear, and system batteries. Engine start is required.

8-3.3.2 Quarterly RPIE POL/Fuels Testing.

Test the RPIE POL/Fuels generator system quarterly by exercising the generator system for a minimum of one hour using the designed pumping capability. Verify operation of transfer switch or interlocked switching devices.

8-3.3.3 Annual RPIE POL/Fuel Testing.

Test the RPIE POL/Fuels generator system annually by exercising the generator with a load bank, as necessary to achieve not less than 50 percent of the generator nameplate kW rating for one continuous hour and not less than 75 percent of the generator nameplate kW rating for one continuous hour, for a total test duration of not less than two continuous hours. Facility load is not required during annual test.

8-3.4 EAID Generator and Transfer Switch Inspections and Operational Testing Requirements.

This section addresses generator system operational testing requirements for EAID generator systems classified by AFCEC/COSM as EAID Portable and EAID POL/Fuels.

Document all inspection actions on AF Form 487 and file the form with the generator record.

8-3.4.1 Monthly EAID Inspections and Testing.

Conduct and document visual inspection of the generator, ATS / MTS / Switchgear, and system batteries. Engine start is required.

8-3.4.2 Quarterly EAID Testing.

Test the EAID generator system quarterly by exercising the generator system with a load bank to achieve not less than 50 percent of the generator nameplate kW rating for 30 continuous minutes and not less than 75 percent of the generator nameplate kW rating for one continuous hour, for a total test duration of not less than 90 continuous minutes.

8-3.4.3 Annual EAID Testing.

Test the EAID generator system annually by exercising the EAID generator system connected to the facility or system they primarily support, transfer facility, or system electrical load to the EAID generator. Exercise the generator for one continuous hour.

Test the ATS/MTS/switchgear connected to the EAID generator by exercising the operation of the switch with facility loads. The test of the switch must consist of operating the switch from its primary position to the electrical generator power source position and then return to the primary position upon completion of the generator test.

The criteria set forth in NFPA 110 Section 4.3 and Table 4.1(b) is not required during EAID generator system testing.

8-3.4.4 Portable Generator Facility Connections.

Portable generator facility connections must comply with UFC 3-540-01. Generator connections described in UFC 3-540-01 cannot also be used as an emergency means of isolation required by the NEC.

Inspect portable generator electrical connection plugs and receptacles for corrosion before each use. Repair as necessary and coat contacts with proper electrical connection corrosion-preventive compound.

8-3.5 Deployable Generator Inspections and Testing.

This section addresses generator system inspection and testing for generators defined as deployable generators.

Deployable generators are defined as those assigned to a CE Squadron UTC.

Document all inspection actions on AF Form 487 and AF Form 719, *Historical Record – Diesel-Electric Generator and System*, and file the forms with the deployable generator record.

8-3.5.1 Deployable Generators Testing Upon Receipt.

Power production personnel must test CE deployable generators upon initial receipt. After testing and documenting operating parameters, purge, shelve, and prepare the generators for immediate deployment.

8-3.5.2 Annual Inspection and Operational Testing.

Inspect and operationally test CE deployable generators annually for a minimum of one continuous hour while loaded to at least 75 percent of rated capacity.

8-3.5.3 CE Deployable Generator Maintenance.

Maintain CE deployable generators in accordance with T.O. data or manufacturer’s manuals.

8-3.5.4 Non-CE Deployable Generators.

Maintenance, testing, and operation of non-CE deployable generators (e.g., Combat Communication, Air Control Squadron, and Maintenance Squadron) are governed by their own T.O.s or the manufacturer's guidance instead of this chapter.

8-4 MISSION UNINTERRUPTIBLE POWER SUPPLIES (UPS).

\1 [Deleted paragraph] **/1/**

Mission operators, e.g. UPS owner, should not plan for UPS support longer than 15 minutes. If generators do not operate correctly during commercial power outages, mission operators should take immediate actions following their established mission shut-down and transfer processes to avoid mission disruption and equipment damage. During generator inspection and testing events, the mission operator should monitor their UPS status to ensure they do not falsely conclude the mission load was carried by the generator.

\1\ Note: Power condition and continuation interfacing equipment (PCCIE), which typically includes UPSs, is classified as equipment and must be owned by the mission and not the BCE. For guidance on acquisition and maintenance of UPS equipment, contact the PCCIE Product Group Manager, 500 CBSS/GBLD, Building 1207-N, 6029 Wardleigh Road, Hill AFB, UT 84056-5838. **/1/**

8-5 LUBRICATING OILS.

Follow the engine manufacturer's recommendations for the type and grade of oil as closely as possible. Lubricating oils satisfying minimum requirements of military specifications MIL-PRF-2104, *Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service*, and MIL-PRF-46167, *Lubricating Oil, Internal Combustion Engine, Arctic*, are acceptable for many diesel engines but may not be adequate for some high-speed engines.

Confirm the suitability of military specification lubricating oils with the engine manufacturer before use.

This section addresses deviations from manufacturer's service intervals for RPIE and EAID generator engine lubrication systems.

8-5.1 Deviation from Manufacturer's Service Intervals.

Refer to AFI 32-1062 regarding deviation authority from manufacturer's service intervals.

8-5.1.1 RPIE Oil Change Interval Deviations.

RPIE generator engine oil change intervals may be extended from the manufacturer's specified service interval to 24 months or 1,000 engine hours between engine oil and oil filter change if all of the following apply:

- Ensure requirements in 40 CFR Part 63 Subpart ZZZZ (all stationary prime power generators), 40 CFR Part 60 Subpart JJJJ (all stationary spark ignition [SI] generators), 40 CFR Part 60 Subpart IIII (all stationary compression ignition [CI] generators), and 40 CFR Part 89 (portable diesel generators), are not violated (when applicable, based on generator age and location).
- Verify the RPIE generator is not under warranty and is at least three years old.
- Ensure oil change interval never exceeds 24 months or 1,000 engine hours of operation.
- Verify oil analysis results conducted at the same frequency specified for changing the oil are within the required limits specified by the manufacturer and 40 CFR Part 60 Subpart IIII and 40 CFR Part 63 Subpart ZZZZ paragraph 63.6625(i). The analysis must include viscosity, acid content, particulates, water, or other contaminants, and recommended actions after results are provided. Total engine hours and time since last oil change must be printed on the oil analysis results.
- **\1** [Deleted text] **/1/**
- Ensure the servicing environmental office is engaged to determine if deviation affects permitting requirements.
- Maintain a copy of the approved deviation memo with the RPIE generator maintenance record.

8-5.1.2 EAID Oil Change Interval Deviations.

EAID generator engine oil change intervals may be deferred up to 12 months from the manufacturer’s specified service interval if all of the following apply:

- Verify the EAID generator is not under warranty.
- Ensure oil change interval never exceeds 24 months or 1,000 engine hours of operation.
- Total operating hours are less than 150 within the last 12 months.
- Verify oil analysis results conducted at the same frequency specified for changing the oil are within the required limits specified by the manufacturer and 40 CFR Part 60 Subpart IIII and 40 CFR Part 63 Subpart ZZZZ paragraph 63.6625(i). The analysis must include viscosity, acid content, particulates, water, or other contaminants, and recommended actions after results are provided. Total engine hours and time since last oil change must be printed on the oil analysis results.
- **\1** [Deleted text] **/1/**

- Ensure the servicing environmental office is engaged to determine if deviation affects permitting requirements.
- Maintain a copy of the approved deviation memo with the RPIE generator maintenance record.

8-5.1.3 Oil Analysis.

Oil analysis requirements (40 CFR 63.6625 condemning factors: total base number is less than 30 percent of the total base number of the oil when new; viscosity of the oil has changed by more than 20 percent from the viscosity of the oil when new; or percent water content [by volume] is greater than 0.5) are in 40 CFR Part 63 Subpart ZZZZ. The oil analysis must be part of an oil analysis program and included in the engine's maintenance plan. If any of the condemning limits are exceeded, the oil must be changed within two business days of receiving the results.

Sample in accordance with manufacturer's recommendations and field test using oil analysis kit NSN 6630-01-096-4792, *Test Kit, Oil Condition*, or an independent oil analysis company test kit (e.g., Cummins Filtration #CC2543, Caterpillar S•O•SSM, Wix filters; verify the kit meets EPA requirements). Record results on AF Form 487 and AF Form 719. If an approved field test kit is not available or the above tests are not performed, the oil must be changed.

8-6 FUELS.

This section addresses fuel types approved for use with RPIE and EAID generator systems, fuel-related training, fuel tanks, and fuel supply.

8-6.1 Fuel Oils.

\1 Fuel oils used for RPIE and EAID generators must meet ASTM D975, *Standard Specification for Diesel Fuel Oils*, or European Committee for Standardization EN 590, *Automotive Fuels - Diesel - Requirements and Test Methods*, or host nation equivalent. Consult T.O. 42B-1-1, *Quality Control of Fuels*, for additional information. Follow the specific temperature and applicable service conditions and ensure sulfur content does not exceed environmental restrictions or original equipment manufacturer's fuel requirements. Do not mix different grades of fuel. Consult T.O. 42B-1-1 and MIL-STD-3004-1, *Quality Assurance for Bulk Fuels, Lubricants and Related Products*, for additional information. Comply with 40 CFR 60.4207 (stationary CI internal combustion engines) and 60.4216 (engines located in Alaska). ***/1/***

8-6.2 Jet Fuels.

\1 Jet fuel potentially may be used with required additives when diesel is not available. Consult AFCEC/CO or the installation environmental office and the EPA for emission restrictions. Deviation from requirements to use diesel fuel in 40 CFR 60.4207 can be authorized through the provisions of 40 CFR 60.4216, 60.4217, or 40 CFR 1068.225 (National Security Exemption) where applicable. Use of non-standard fuels in diesel equipment may incur significant costs for testing and permitting efforts. Consult T.O.

42B-1-1 for more information. Consult the manufacturer for kW de-rating when using JP-8, JP-5, TS-1, F-24 (Jet A with additives), Jet A-1, or Jet A. **/1/**

8-6.3 Natural Gas, Liquid Petroleum Gas, and Bio-Diesel.

\1 Use of natural gas (NG), liquid petroleum gas (LPG), or bio-diesel/bio-diesel blend fuels is not permitted for RPIE or EAID generator authorizations. NG, LPG, or alternative fuels (renewable diesel fuel blend where the alternative fuel is produced using a hydro-treating process) may be authorized for prime power generation or co-generation. BCEs must either program existing generators that use NG, LPG, or bio-diesel/bio-diesel blend for replacement within five years or request a waiver from AFCEC/CO for continued operation. Consult T.O. 42B-1-1. BCEs will ensure refueling plans address backup fuel support for existing generators using NG or LPG in the event of fuel supply disruption.

Rewrite paragraph A-7.1 of this UFC to read: "Diesel fuel should comply with ASTM D975, EN 590, or host nation equivalent. These specifications include winter (No. 1) and summer (No. 2) grades available as both low sulfur and ultra-low sulfur. All are suitable for use under applicable temperature and service conditions. Alternately, MIL-DTL 83133 (JP-8), MIL-DTL-5624 (JP-5), or MIL-DTL-16884 (F-76) can be used as a diesel fuel substitute, noting that all have a high sulfur content and are not suitable for equipment requiring low sulfur or ultra-low sulfur diesel fuels. Different grades of fuel should not be mixed. It should be noted that all diesel specifications allow for a limited content of bio-diesel. Consult T.O. 42B-1-1 for additional information." **/1/**

8-6.4 Fuel Storage Tank Training.

Personnel must be trained to manage fuel storage tanks in accordance with AFI 23-204, *Organizational Fuel Tanks*.

8-6.5 Fuel Tanks of Emergency Generators.

Emergency generator fuel tanks must comply with requirements of NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, NFPA 54, *National Fuel Gas Code*, NFPA 58, *Liquefied Petroleum Gas Code*, NFPA 110, and applicable state regulations.

8-6.5.1 Fuel Tanks for New Systems.

For new systems, coordinate with BCE's Installation Management Flight to ensure the emergency generator fuel tank is included on the installation Spill Prevention Control and Countermeasures (SPCC) plan per 40 CFR 112 and included in the installation fuel tank inventory per AFI 32-7044, *Storage Tank Environmental Compliance*.

8-6.5.2 Containment.

Provide secondary containment as required by 40 CFR 112 or equivalent where required and at overseas locations.

8-6.5.3 Signage.

Install hazard identification signs as specified in NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, on stationary aboveground tanks or per Final Governing Standards for overseas locations. Ensure storage tanks are marked according to fuel type and warning signs are appropriately located. If an external fuel tank is installed, post a one-line diagram of the fuel system indicating tank size and valve locations.

8-6.5.4 Inspection.

Emergency generator fuel tanks will be inspected monthly and annually as required by AFI 32-7044 with results of inspections posted in the Storage Tank Accounting and Reporting (STAR) system.

8-6.5.5 Fuel Supply.

Plan for and provide a minimum seven-day fuel supply (based on actual generator load), either in a dedicated on-site storage tank or from a confirmed delivery source when a delivery source is used to meet the seven-day requirement. The refueling schedule must take into account the assigned EAID generator tank capacity. RPIE generators will have a minimum 24-hour local capacity based on the actual generator load fuel consumption rate of the engine.

8-7 COOLANT.

The coolant used in diesel engines usually consists of a mixture of ethylene glycol antifreeze, corrosion inhibitor, and fresh water. When the engine is used in an extremely cold area, such as Arctic regions, a special antifreeze mixture is used. Specifications related to the mixtures are as follows:

- **\1** Antifreeze, Ethylene glycol MIL-A-46153
- Specification for cooling system conditioner and inhibitor is MIL-C-10597
- Antifreeze, Ethylene glycol A-A-52624
- Antifreeze, Arctic-type A-A-52624
- 5 Inhibitor, Corrosion MIL-A-53009 or MIL-A-46153 **/1/**

8-7.1 Engine Water Treatment.

8-7.1.1 Acceptable Conditions.

In most modern diesel engines, the following cooling water conditions are acceptable:

- pH 8.5 to 10
- Chloride and sulfate 100 ppm

- Total dissolved solids 500 ppm
- Total hardness 200 ppm

8-7.1.2 Softened Water.

If possible, softened water should be used to reduce the total hardness level of the engine cooling loop. The use of softened water will increase engine performance by reducing the precipitation of calcium and magnesium at elevated temperature conditions, ensuring higher heat transfer rates.

8-7.1.3 Antifreeze.

Typical engine cooling systems incorporate antifreeze solutions that inhibit scale and protect the cooling system when temperatures are encountered below freezing. Ethylene glycol mixed with a corrosion inhibitor such as triazoles form an inhibiting film on metal surfaces that acts as a barrier to the corrosion process. Table A-18 concentrations should be utilized when adding glycol solutions to the engine cooling system.

8-7.1.3.1 Concentration.

The ethylene glycol concentration should exceed 30 percent. If more than 60 percent of solution is added, two effects will be realized: 1) a decrease in heat transfer rates, 2) a lowering of the system freeze protection.

8-7.2 Cooling System Maintenance.

Maintenance consists of periodically testing the antifreeze, inspecting the coolant for cleanliness, and flushing or cleaning the system with compound when necessary.

8-7.2.1 Testing Antifreeze.

Perform tests to verify freeze protection and reserve alkalinity:

- Test for freeze protection using the combination antifreeze and battery tester (stock number 6630-00-105-1418). Instructions for using the tester are included with it.
- Test for reserve alkalinity (corrosion protection) using the reserve alkalinity test kit (stock number 6630-00-169-1506).
- Cooling systems with freeze protection below -7 °F (-22 °C) that fail the reserve alkalinity test may be replenished with corrosion inhibitor (stock number 6850-00-753-4967). Replenishment is a one-time service. If the reserve alkalinity test is failed again, replace the coolant. If the system passes the test, record the date.

8-7.2.2 Inspecting Coolant.

Inspect the coolant visually for cleanliness. Obtain a coolant sample and place it in a clean glass container. After allowing about five minutes for settling, examine the sample for contamination (rust, foreign particles, and/or sediment). The sample may have some color (same color as original antifreeze) and should be clear.

Examine the sample to determine the type and quantity of contamination. Rust, a chemical combination of iron, water, and air, is frequently found. The presence of rubber particles usually indicates deterioration of hoses. Replacement hoses may be indicated. Sediment may be caused by impurities in the water used in the coolant. Contaminants in the coolant can clog a radiator or heat exchanger and cause engine and generating system breakdown.

8-7.2.3 Cleaning the System.

Clean the cooling system whenever the coolant is drained. Usually the system requires nothing more than a thorough flushing with fresh water. Refer to the engine manufacturer's literature for instructions. If any part of the system is rusted or partially clogged, it is necessary to use cooling system cleaning compound and conditioner, stock number 6850-00-598-7328. Do not use the compound as a routine maintenance procedure. Instructions for using the compound are included with it.

8-7.2.4 Filling the System.

Refer to the engine manufacturer's literature for instructions on filling the cooling system. This is applicable to either new systems or those just cleaned and serviced.

8-7.2.4.1 Ethylene Glycol Antifreeze.

Cooling system protection is required for all liquid cooled diesel engines. In areas where temperatures no lower than -55 °F (-48 °C) are expected, prepare a solution according to the information presented in Table A-18. When temperatures below freezing are not expected, use a weak solution such as 1 pint of ethylene glycol antifreeze for each gallon of solution for general protection against rust buildup and scale formation within the engine.

8-7.2.4.2 Arctic-Type Antifreeze.

Use arctic-type antifreeze in areas where temperatures below -55 °F (-48 °C) are expected. Do not dilute arctic-type antifreeze with water or inhibitor; it is ready for use as issued.

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8-8 ACCOUNTING FOR GENERATORS.

8-8.1 RPIE Generators.

Notify the real property office if these generators are temporarily or permanently relocated from one facility to another. Document and account for all RPIE generators awaiting installation in the appropriate work order documents. For excess generators and associated equipment (i.e., ATS), request MAJCOM review and disposition instructions before removing the generator and associated equipment from a RPIE facility. After removing a generator, account for it on DD Form 1149, *Requisition and Invoice/Shipping Document*, if the generator is shipped to another base or to CEMIRT. If the generator is turned in to the Defense Reutilization and Marketing Office, account for it on DD Form 1348-1A, *Issue Release/Receipt Document*.

8-8.2 EAID Generators.

EAID generators are listed in the Allowance Standard (AS), requisitioned from Warner Robins Air Force Life Cycle Management Center (AFLCMC/WNZEC), 235 Byron Street (Building 300-West Wing, Bay D), Robins AFB, GA 31098-1647, DSN 472-1640, commercial (478) 222-1640, and accounted for by Base Supply and AFLCMC/WNZEC. EAID units must be reclassified as RPIE and coordinated with the Item Manager, AFLCMC/WNZEC, when they no longer meet the definition for an EAID or turned in to Base Supply.

8-8.3 AFLCMC/WNZEC.

Report excess EAID generators to AFLCMC/WNZEC. Any RPIE or commercial EAID generators that are no longer required or are inoperable must be identified to the MAJCOM for review and disposition coordination. Disposal of mobile electric power (MEP) EAID generators must first be coordinated with the EAID Item Manager at AFLCMC/WNZEC. If generators are not required or needed by AFLCMC/WNZEC, they must be disposed of in the same manner as RPIE and commercial EAID generators.

8-8.4 Reporting RPIE Generators.

If functional load testing indicates the generator is loaded less than 30 percent of rated capacity over a 12-month period, BCEs will take actions described in paragraphs 8-8.4.1 through 8-8.4.1.2.

8-8.4.1 Compile a list of generators that do not meet the required 30 percent loading for facility loads over a 12-month period. Categorize and certify the generators as “Replacement Eligible,” “Replace by Attrition,” or “Replacement Not Feasible” and document the category in a memo and file it with the generator records.

8-8.4.1.1 RPIE generators used to support large in-rush currents may be sized for starting current. These generators may be excluded from paragraph 8-8.4.1.

8-8.4.1.2 RPIE generators for fire pumps and RPIE generators rated 25 kW and lower are not required to comply with paragraph 8-8.4.1.

8-8.4.2 Any generator installation (new or replacement) and generator removal or relocation requires AFCEC/CZ coordination to ensure EPA clean air compliance regulations are met.

8-8.4.3 Consult with AFCEC/CZ when an EPA-permitted generator is removed from the base; that generator must be removed from the Clean Air Act Title V air permit. Additionally, because the permit requires an accurate list of active permitted generators on base, the BCE must check with AFCEC/CZ to determine if the generator size is small enough to be excluded from the permit.

8-8.4.4 By 1 October each year, MAJCOM senior engineers will review base generator inventory reports and provide AFCEC/COM CEMIRT a list of “Replacement Eligible” generators that cannot be redistributed within their command.

8-8.4.5 By 1 August, BCEs must revalidate the generator authorization memorandum for changes to mission or modifications to the authorized RPIE electrical system and provide a list of “Replacement Eligible” generators to AFCEC/COM.

8-8.4.5.1 AFCEC/COSM must be notified by the BCE when a generator authorization is no longer required.

8-8.4.5.2 The BCE will prepare a plan for all generators that do not have an AFCEC authorization and are available for relocation or disposition. The plan is included as a part of the annual revalidation process. **/1/**

APPENDIX A SAMPLE O&M PROCEDURES AND FREQUENCY

A-1 STRUCTURE AND ENCLOSURES.

Perform structure and enclosure preventive maintenance per Table A-1.

Table A-1 Structure and Enclosures PM Schedule

Item No.	Maintenance Item	Service Time							
		Daily	Weekly	Bi-Weekly	Monthly	3 Months	6 Months	Yearly	Other
1.0	Structure and Enclosures								
1.1	Exercise damper actuators	X							
1.2	Lubricate door hinges						X		
1.3	Lubricate door locks						X		
1.4	Fastener checks				X				
1.5	Corrosion control checks						X		
1.6	Rodent control checks		X						
2.0	PTO Assemblies/Couplings								
2.1	PTO access door / cover		X						
2.2	Noise checks	X							
2.3	Coupling alignment check							X	
3.0	Bearing Lubrication								
3.1	Rotor bearings								X
3.2	Engine bearings								X
4.0	Belt-Driven Equipment								
4.1	Check Belts for Wear		X						
4.2	Replace drive belts							X	
4.3	Check pulleys/idler wheels			X					

A-1.1 Service Practices.

A-1.1.1 Maintenance Program.

Service practices for diesel engines consist of a complete maintenance program built around records and observations. The maintenance program includes appropriate analysis of these records. DD Form 2744, *Emergency/Auxiliary Generator Operation Log*, should be used to record inspection testing of emergency/auxiliary generators.

A-1.1.1.1 Recordkeeping.

Engine log sheets are an important part of recordkeeping. The sheets must be developed to suit individual applications (i.e., auxiliary use) and related instrumentation. Personnel must use Service-approved forms, such as AFTO Form 781A, *Maintenance Discrepancy and Work Document*, and, for the Air Force, AF Form 487. Accurate records are essential to good operations. Notes should be made of all events that are or appear to be outside of normal range. Detailed reports should be logged. Worn or failed parts should be tagged and protectively stored for possible future reference and failure analysis. This is especially important when specific failures become repetitive over a period of time, which may be years.

A-1.1.1.2 Log Sheet Data.

Log sheets should include engine starts and stops, fuel and lubrication oil consumption, and a cumulative record of the following:

- Hours since last oil change
- Hours since last overhaul
- Total hours on engine
- Selected temperatures and pressures

A-1.1.2 Troubleshooting.

Perform troubleshooting procedures when abnormal operation of the equipment is observed. Maintenance personnel should then refer to log sheets for interpretation and comparison of performance data. Comparisons of operation should be made under similar conditions of load and ambient temperature. The general scheme for troubleshooting is outlined in the following paragraphs.

A-1.1.2.1 Industrial Practices.

Use recognized industrial practices as the general guide for engine servicing. Service information is provided in the manufacturer’s literature and appendixes.

A-1.1.2.2 Reference Literature.

The engine user must refer to manufacturer’s literature for specific information on individual units. For example, refer to Table A-2 for troubleshooting an engine that has developed a problem.

Table A-2 Diesel Engines Troubleshooting

Cause	Remedy
HARD STARTING OR FAILS TO START	
Air intake restricted	Check intake and correct as required.
Fuel shut-off closed	Make sure shut-off is open and supply is at proper level and not low.
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Clogged injector	Clean all injectors.
Injector inlet or drain	Check all connections and correct as required.
Engine due for overhaul	Schedule the overhaul and correct as required.
Incorrect timing	Perform timing procedure.
ENGINE MISSES DURING OPERATION	
Air leaks in fuel suction lines	Check fuel suction lines and correct as required.
Restricted fuel lines	Check fuel lines and correct as required.
Leakage at engine	Refer to manufacturer's instructions and correct valves as required.
Incorrect timing	Perform timing procedure.
EXCESSIVE SMOKING AT IDLE	
Restricted fuel lines	Check fuel lines and correct as required.
Clogged injector	Clean all injectors. Refer leaking head gasket to manufacturer's instructions and correct as or blow by.
Engine due for overhaul	Schedule the overhaul and correct.
Incorrect timing	Perform timing procedures.

Cause	Remedy
EXCESSIVE SMOKING UNDER LOAD	
The same causes for “idle” apply	The same remedies for “idle” apply.
Air intake restricted	Check air intake and correct as required.
High exhaust backpressure	Check exhaust system and turbocharger; correct as required.
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Engine overloaded	Reduce load to proper level.
LOW POWER OR LOSS OF POWER	
Air intake restricted	Check air intake and correct as required.
Poor quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Clogged injector	Clean all injectors.
Faulty throttle linkage or governor setting too low	Check linkage and governor; refer to manufacturer’s instructions and correct as required.
Clogged filters and screens	Clean filters and screens.
Engine overloaded	Reduce load to proper level.
Engine due for overhaul	Schedule the overhaul and correct as required.
Incorrect timing	Perform timing procedure.
Engine requires tune-up	Perform tune-up procedure.
DOES NOT REACH GOVERNED SPEED	
The same causes for “low power” apply.	The same remedies for “low power” apply.
EXCESSIVE FUEL CONSUMPTION	
Air intake restricted	Check air intake and correct as required.
High exhaust back-pressure	Check exhaust system and turbocharger; correct as required.

Cause	Remedy
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Faulty injector	Clean all injectors.
Engine overloaded	Reduce load to proper level.
Engine due for overhaul	Schedule the overhaul and correct as required.
Incorrect timing	Perform timing procedure.
ENGINE QUITS	
High exhaust backpressure turbocharger	Check exhaust system and correct as required.
Air intake restricted	Check air intake and correct as required.
Fuel shut-off closed; low supply of fuel	Make sure shut-off is open and supply is at proper level.
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Faulty injector	Clean all injectors.
ENGINE SURGES AT GOVERNED SPEED	
Air leaks in fuel suction lines	Check fuel suction lines and correct as required.
Faulty injector	Clean all injectors.
Leaks in oil system	Check for oil leaks, check oil lines, check crankcase drain plug and gasket; correct as required. Piston rings or cylinder liners may be worn.
Engine due for overhaul	Schedule the overhaul and correct as required.
SLUDGE IN CRANKCASE	
Fouled lubricating oil strainer or filter	Check strainers and filters, remove and service as required, reinstall on engine with new gaskets.

Cause	Remedy
Faulty thermostat	Check coolant thermostats; engine may be too cool.
Dirty lubricating oil	Drain old oil, service strainers and filters, refill with fresh oil.
LUBRICATING OIL DILUTED	
Fuel in lubricating oil	Check for loose injector inlet or drain connection; correct as required. Drain old oil, service strainers and filters, refill with fresh oil.
Coolant in lubricating oil	Check for internal coolant leaks. Correct as required. Drain old oil, service strainers and filters, refill with fresh oil.
LOW LUBRICATING OIL PRESSURE	
Faulty oil line, suction level	**\1** Check oil lines for good condition; fill oil to proper oil level. **/1/** Piston rings, crankshaft bearings, or cylinder liners may be worn.
Engine due for overhaul	Schedule overhaul and correct as required.
ENGINE RUNNING TOO HOT	
High exhaust backpressure	Check exhaust system and turbocharger; correct as required.
Faulty thermostat	Check coolant thermostats; correct as required.
Low lubricating oil level	Fill to proper level with fresh oil.
Engine overload	Reduce load to proper level.
Faulty cooling system component (pump, hose, radiator fan belt)	Check components; correct as required. Fill cooling system to proper level with coolant.
Low coolant level	Air in system. Refer to **\1** TM 5-685, Appendix D. **/1/**

Cause	Remedy
ENGINE KNOCKS	
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Air leaks in fuel suction lines	Check fuel suction lines and correct as required.
Engine overloaded	Reduce load to proper level.
Engine running too hot	Repeat the procedures for “too hot” above.
Faulty vibration damper or flywheel	Correct as required; refer to manufacturer’s instructions.
Engine due for overhaul	Schedule the overhaul and correct as required.

A-1.1.3 Overhaul Procedure.

Engine overhaul requires disassembly of the engine. Verify that all engine parts comply with the manufacturer’s specifications and tolerances.

A-1.1.4 Inspection of Structural Parts.

Inspect structural parts as follows:

- Foundations for deformation and cracks.
- Bedplate for cracks and distortion; bearing supports for good condition.
- Foundation bolts for tightness and general good condition, including straightness.
- Frames for cracks, distortion, and general good condition.
- Cylinders and cylinder blocks for cracks; water jacket areas for corrosion, scale, and rust; machined surfaces for smoothness.
- Cylinder heads for cracks; water jacket areas for corrosion, scale, and rust; valve seats for cracks; machined surfaces for smoothness.
- Covers and gaskets for distortion and cracks; use compliant gaskets only after annealing; use new seals and gaskets other than copper.

A-1.1.5 Moving Parts.

Inspect moving parts as follows:

- Crankshaft for out-of-alignment condition; journal surfaces for highly polished condition and absence of scratches, nicks, etc.; and counterweights, gears, and flywheels for proper condition. Verify that crankshaft complies with manufacturer's requirements. An engine crankshaft is a costly and vulnerable component. Special care in handling is required. Accurate alignment is essential to good engine operation. Removal or installation may require hoisting. Refer to the manufacturer's instructions for details and proper procedures.
- Main bearings for highly polished condition, cracks, deformation and absence of scratches, nicks, etc.
- Thrust bearings for cracks and deformation; surfaces for smoothness and absence of scratches and nicks.
- Camshaft cams and cam faces for worn or deformed condition; journal surfaces and bearings for highly polished condition and absence of scratches, nicks, etc.; cam contours and cam followers for good condition.
- Connecting rods for cracks or other flaws by magnaflux or dye penetrant method and for bending and parallelism; bearings for highly polished condition and absence of scratches, nicks, cracks, and deformation.
- Pistons for cracks and warped condition; verify pistons, rings, and pins comply with manufacturer's requirements; rings and pins for general good condition.
- Timing gear mechanisms for good condition; backlash for manufacturer's tolerance requirements; gear teeth for general good condition.
- Auxiliary or accessory drives for good operating condition. Consult the specific manufacturer's literature for instructions.

A-1.1.6 Repair Parts and Supplies.

Certain repair parts and supplies must be available for immediate use. Refer to specific manufacturer's literature for recommendations. The following information is a general guide:

- The following parts should be renewed at each component change: gaskets, rubber sleeves, and seals. Adequate quantities should be maintained.
- The following parts have a reasonably predictable service life and require replacement at predictable periods: fuel injectors, pumps, governors, and valves. A one-year supply should be maintained.
- The following parts have a normally long life and, if failure occurs, could disable the engine for a long period of time: cylinder head, cylinder liner, piston and connecting rod, gear and chain drive parts, and oil pressure pump. One item of each part for an engine should be available.

A-1.1.7 Parts Salvage.

Certain parts may be replaced prior to their failure due to a preventive maintenance program. It may be possible to restore these parts to specified tolerances. Refer to specific manufacturer's literature for recommendations and instructions. The following information is a general guide:

- Worn pump shafts and cylinder liners may be built up and machined to specified dimensions.
- Grooves in pistons may be machined and install oversize rings specified for use.
- Press-fitted bushings and bearings may loosen. The related body part may be machined to a new dimension and oversize bushings and bearings fitted.
- Worn journals on crankshafts and camshafts may be built up and machined to specified dimensions.

A-2 GENERATOR MAINTENANCE.

A-2.1 Service and Troubleshooting.

Service consists of performing basic and preventive maintenance checks that are outlined in Table A-3. If troubles develop or if these actions do not correct a problem, refer to Table A-4. Maintenance personnel must remember that the manufacturer's literature supersedes the information provided herein.

A-2.2 Operational Check.

Check the equipment during operation and observe the following indications:

- Unusual noises or noisy operation may indicate excessive bearing wear or faulty bearing alignment. Shut down and investigate.
- Equipment overheats or smokes. Shut down and investigate.
- Equipment brushes spark frequently. Occasional sparking is normal but frequent sparking indicates dirty commutator and/or brush or brush spring defects. Shut down and investigate.

A-2.3 Preventive Maintenance.

Inspect the equipment as described once a month. Maintenance personnel should make a checklist suited to their particular needs. The actions listed in Table A-3 are provided as a guide and may be modified. Refer to manufacturer's instructions.

A-2.4 Troubleshooting.

Perform general troubleshooting of the equipment as outlined in Table A-4 if a problem develops. Table A-6 provides guidance on interpreting insulation test results and Table A-7 provides low voltage circuit breaker troubleshooting checks. Refer to the manufacturer's literature for repair information after diagnosis.

Table A-3 Generator Inspection Checklist

Inspect	Check For
Brushes	Amount of wear, improper wear, spring tension
Commutator	Dirt, amount of wear, loose leads, loose bars
Collector rings	Grooves or wear, dirt, carbon and/or copper accumulation, greenish coating (verdigris)
Insulation	Damaged insulation; measure and record insulation resistance
Windings	Dust and dirt, connections, loose windings or connections
Bearings	Loose shaft or excessive endplay, vibration (defective bearing)
Bearing housing	Lubricant leakage; dirt or sludge in oil (sleeve bearings)
Ventilation and cooling	Obstruction of air ducts or screens; loose or bent fan blades

Table A-4 Generator Troubleshooting

Cause	Remedy
NOISY OPERATION	
Unbalanced load or coupling	Balance load and check alignment misalignment
Air gap not uniform	Center rotor by replacing or shimming bearings
Coupling loose	Tighten coupling
OVERHEATING	
Electrical load unbalanced	Balance load
Open line fuse	Replace line fuse
Restricted ventilation	Clean; remove obstructions
Rotor winding shorted, opened, or grounded	Repair or replace defective coil

Cause	Remedy
Stator winding shorted, opened, or grounded	Repair or replace defective coil
Dry bearings	Lubricate
Insufficient heat transfer of cooler	Verify design flow rate: repair or replace unit
NO OUTPUT VOLTAGE	
Stator coil open or shorted	Repair or replace coil
Rotor coils open or shorted	Repair or replace coils
Restricted ventilation	Clean; remove obstructions
Shorted slip rings	Repair as directed by manufacturer
Internal moisture	Dry winding (indicated by low-resistance reading on megger)
Voltmeter defective	Replace
Ammeter shunt open	Replace ammeter and shunt
OUTPUT VOLTAGE UNSTEADY	
Poor commutation	Clean slip rings and reseat brushes
Loose terminal	Clean and tighten all contact connections
Fluctuating load	Adjust voltage regulator and governor speed
OUTPUT VOLTAGE TOO HIGH	
Over-excited	Adjust voltage regulator
One leg of delta-connected stator open	Replace or repair defective coils
FREQUENCY INCORRECT OR FLUCTUATING	
Speed incorrect or fluctuating	Adjust speed-governing device
VOLTAGE HUNTING	
External field resistance in out position	Adjust resistance
Voltage regulator contacts dirty	Clean and reseat contacts
STATOR OVERHEATS IN SPOTS	
Open phase winding	Cut open coil out of circuit and replace at first opportunity; cut and replace the same coil from other phases
Rotor not centered	Realign and replace bearings, if necessary

Cause	Remedy
Unbalanced circuits	Balance circuits
Loose connections or wrong connections	Tighten connections or correct wrong polarity coil connections
Shorted coil	Cut coil out of circuit and replace at first opportunity
FIELD OVERHEATING	
Shorted field coil	Replace or repair
Improper ventilation	Remove ducts obstruction, clean air filter
ALTERNATOR PRODUCES SHOCK WHEN TOUCHED	
Reversed field coil.	Check polarity. Change coil leads.
Static charge.	High-speed charge belts build up a static. Connect alternator ground strip frame to a ground strip.

Table A-5 Interpreting Insulation Resistance Test Results

Test Results Condition	What to Do
Fair to high values and well-maintained	No cause for concern
Fair to high values but showing a constant tendency towards lower values	Locate and remedy the cause then check the downward trend
Low but well-maintained	Condition is probably all right, but cause of low values should be checked
So low as to be unsafe	Clean, dry out, or otherwise raise the values before placing equipment in service (test wet equipment while drying out)
Fair or high values, previously well-maintained but showing sudden lowering	Make tests at frequent intervals until the cause of low values is located and remedied; or until the values have become steady at a lower level but safe for operation; or until values become so low that it is unsafe to keep the equipment in operation

Table A-6 Condition of Insulation Indicated Absorption Ratios by Dielectric Insulation

Insulation	60/30-Second Ratio	10/1 - Minute Polarization Ratio Index
Dangerous	--	Less than 1
Questionable	1.0 to 1.25	1.0 to 2
Good	1.4 to 1.6	2 to 4
Excellent	Above 1.6	Above 4

Table A-7 Low Voltage Circuit Breaker Troubleshooting

Issue	
Cause	**Remedy**
Note: Refer to manufacturer's literature for specific information on circuit breakers.	
OVERHEATING	
Contacts not aligned	Adjust contacts
Contacts dirty, greasy, or coated with dark film	Clean contacts
Contacts badly burned or pitted	Replace contacts
Current-carrying surfaces dirty	Clean surfaces of current-carrying parts
Corrosive atmosphere	Relocate or provide adequate enclosure
Insufficient bus or cable capacity	Increase capacity of bus or cable
Bolts and nuts at terminal connections not tight	Tighten but do not exceed elastic limit of bolts or fittings
Current in excess of breaker rating	Check breaker applications or modify circuit by decreasing load
Inductive heating	Correct bus or cable arrangement
FAILURE TO TRIP	
Travel of tripping device does not provide positive release of tripping latch.	Adjust or replace tripping device.
Worn or damaged trip unit	Replace trip unit
Mechanical binding in overcurrent trip device	Correct binding condition or replace overcurrent trip device

Issue	
Cause	**Remedy**
Electrical connectors for power sensor loose	Tighten, connect, or replace electrical connectors
Loose or broken power sensor connections	Tighten or re-connect tap coil tap connections
FALSE TRIPPING	
Overcurrent pick-up too low	Check application of overcurrent trip device
Overcurrent time setting too short	Check application of overcurrent trip device
Mechanical binding in over condition current trip device	Correct binding or replace overcurrent trip device
Captive thumbscrew on power sensor loose. Fail safe circuitry reverts characteristics to minimum setting and maximum time delay.	Adjust power sensor. Tighten thumbscrew on desired setting.
Ground sensor coil improperly connected	Check polarity of connections to coil. Check continuity of shield and conductors connecting the external ground sensor coil.
FAILURE TO CLOSE AND LATCH	
Binding in attachments preventing resetting of latch	Realign and adjust attachments
Latch out of adjustment	Adjust latch
Latch return spring too weak or broken	Replace spring
Hardened or gummy lubricant	Clean bearing and latch surfaces
Safety pin left in push rod	Remove safety pin
Motor burned out	Replace motor
Faulty control circuit component	Replace or adjust faulty device
BURNED MAIN CONTACTS	
Improper contact sequence (main not sufficiently parted when arcing contacts part)	Increase arcing contact wipe. Adjust contacts contact opening sequence. Refer to manufacturer’s literature for contact maintenance and adjustment information.
Short-circuit current level above interrupting rating of breaker	Requires system study and possible replacement with breaker having adequate interrupting capacity.

A-3 MEDIUM-VOLTAGE ELEMENTS.

A-3.1 Troubleshooting.

Use recognized industrial practices as the general guide for servicing. Refer to manufacturer's literature for specific information on individual voltage regulators. Troubleshooting procedures include the following: (a) check voltage for compliance with manufacturer's specifications, and (b) check for loose or insecure electrical connections.

A-3.2 Switchgear Equipment Troubleshooting.

Use recognized industrial practices as the general guide for servicing. Refer to manufacturer's literature for specific information on individual voltage regulators.

Troubleshooting procedures include the following:

- Check voltage for compliance with manufacturer's specifications.
- Check for loose or insecure electrical connections.
- Check for correct setting; refer to manufacturer's literature.
- Check for unregulated voltage; refer to manufacturer's literature.
- Check the enclosure; should be weather-tight.
- Check motor for proper operation and loose connections. Clean and lubricate as required. Refer to manufacturer's literature for details.
- Voltage regulators and associated equipment are normally mounted within switchgear equipment and are interconnected with different components. The proper operation and troubleshooting of voltage regulator equipment can depend on these different components. Perform the procedures in Table A-8.

Table A-8 Switchgear Equipment Troubleshooting

Issue	
Cause	**Remedy**
Note: Refer to manufacturer's literature for specific information on individual equipment.	
WATTHOUR METER INACCURATE	
Meter may be dirty or damaged	Install new meter, return faulty meter to repair depot for repair and calibration.
Faulty wiring or connections	Inspect and repair as necessary.
WATTHOUR METER FAILS TO REGISTER	
Blown potential transformer fuse, wiring broken wires, or other fault in connections	Renew blown fuses. Check and repair as required.
Wedge or block accidently left at time of test or inspection	Remove wedge or block. Verify that meter is in good operating condition.
DAMAGED CONTROL, INSTRUMENT TRANSFER SWITCH, OR TEST BLOCKS	
Burned or pitted contacts	Dress or clean burned contacts or replace with new contacts if necessary.
RELAYS FAILING TO TRIP BREAKERS	
Improper setting	Adjust setting to correspond with circuit conditions. Refer to manufacturer's instructions.
Dirty, corroded, or tarnished contacts	Clean contact with knife or tile. Do not use emery cloth or sandpaper.
RELAYS FAILING TO TRIP BREAKERS	
Contacts improperly adjusted	Adjust contacts. Verify proper wipe action.
Open or short circuit connections	Check to verify that voltage is applied and current is passing through relay in question.
Improper application of target	Verify proper tripping action of target and holding coil.
Faulty or improperly adjusted timing devices	If timing device is of bellows or oil-film type, clean and adjust. If an induction-disk type, check for mechanical interference. Refer to manufacturer's literature.
NOISES DUE TO VIBRATING PARTS	
Loose bolts or nuts permitting excessive vibration	Tighten to proper torque value.

Issue	
Cause	**Remedy**
Loose laminations in cores of transformers, reactors, etc.	Tighten loose nuts or core clamps to proper torque value.
CONNECTIONS OVERHEATING	
Increase of current due to overload conditions	Increase the carrying capacity (increase the number or size of conductors). Remove excess current.
Connecting bolts and nuts not tight	Tighten ail bolts and nuts to proper torque value.
FAILURE IN FUNCTION OF ALL INSTRUMENTS AND DEVICES HAVING POTENTIAL WINDINGS	
Loose nuts, binding screws, or broken wire at terminals	Tighten all loose connections to proper torque value or repair broken wire circuits.
Blown fuse in potential transformer circuit	Renew blown fuses.
Open circuit in potential transformer primary or secondary circuits	Repair open circuit and check entire circuit for continuity and good condition.
BREAKER FAILS TO TRIP	
Mechanism binding or sticking	**\1** Lubricate breaker mechanism; refer to manufacturer's instructions. **/1/**
Mechanism out of adjustment	Adjust all mechanical devices (toggles, stops, buffers, opening springs, etc.) according to manufacturer's instructions.
Failure of latching device	Examine surface of latch; replace latch if worn or corroded. Check latch wipe; adjust according to manufacturer's instructions.
Damaged trip coil	Replace damaged coil.
Blown fuse in control circuit (where trip coils are potential type)	Replace blown fuse.
Faulty connections (loose or broken wire) in trip circuit	Repair faulty wiring; tighten all binding screws to proper torque value.
OIL CONTAMINATED	
Carbonization from too many operations	Drain oil and filter; clean or replace. Add fresh oil. Clean inside of tank and all internal parts of breaker; refer to manufacturer's instructions.
Condensation due to atmospheric conditions	Same procedure as above.
Overheating	Eliminate cause of overheating.

Issue	
Cause	**Remedy**
RELAY TROUBLESHOOTING	
Note: Refer to manufacturer’s literature for specific information on individual equipment.	
MAGNET-OPERATED INSTANTANEOUS TYPE	
High Trip Action	
Faulty coil	Install coil with correct rating.
Low Trip Action	
Shorted turns on high trip	Test coil and replace with new coil if found defective.
Mechanical binding; dirt, corrosion	Clean parts.
Assembled incorrectly	See manufacturer’s instructions.
MAGNET-OPERATED INVERSE-TIME TYPE	
Slow Action Trip	
Fluid too heavy, vent too small, or temperature too low	Change fluid and open vent slightly; regulate temperature.
Worn parts	Replace and adjust.
Fast Trip Action	
Worn, broken parts	Replace and adjust.
Fluid too light, vent too large, or temperature too high	Change fluid to proper grade. Close vent slightly or regulate temperature. Clean dashpots and refill with fresh fluid or proper grade.
THERMAL TYPE	
Fails to Trip, Causing Motor Burnout	
Wrong size heater	Check rating with recommendations on instruction sheet.
Mechanical binding; dirt, corrosion	Clean and adjust.
Relay damaged by short circuit	Replace relay.
Motor and relay in different ambient temperature	Install motor and control near each other or make temperature uniform for both.

A-3.3 Routine Maintenance.

Routine maintenance instructions for prime movers consist of short- and long-term checklists for diesel and gas turbine engines.

A-3.3.1 Diesel Engines Short-term Checklist.

Before performing any tasks required by Table A-9, review the station log sheets, related records, and manufacturer's recommendations.

Table A-9 Diesel Engines Short-Term Checklist

Item	Action
Valves	Check valve operation.
Fuel injection nozzles	Check fuel-injection nozzles for secure mounting and connections each time the engine is shut down. Torque down the nozzle according to the manufacturer's instructions.
Starting system	Check the general condition of the air compressor, air lines, and valves, when applicable. Briefly open the system's safety valve weekly. Check for proper operation. Refer to manufacturer's instructions for details.
Governor alarms and instruments	Check operation of governor alarms and instruments. Refer to manufacturer's instructions.
Pressure gauges	Check pressure gauges and clean exposed indicating elements. Refer to manufacturer's instructions.
Intake and exhaust systems	Check air filters and engine exhaust. A smoking exhaust indicates incorrect adjustments. Clean air filters as necessary.
Exhaust lines	Clean and inspect exhaust lines. On two-cycle engines, remove carbon from exhaust ports and clean thermocouples. Refer to manufacturer's instructions for frequency of checks.

Item	Action
Evaporative cooling	Refer to manufacturer's instructions for cooling tower maintenance. Inspect and oil fan shaft bearings, oil damper bearings, and linkage. Inspect spray nozzles; clean as necessary. Clean pump suction screen. Clean sump pan. Inspect cooling coil. If scale has formed, circulate cleaning solution. Do not operate fan while cleaning coil. Check belts for condition and proper tension. Refer to manufacturer's instructions.
Fuel oil system	Clean fuel oil strainers as required by operating conditions. Check the system components for clean condition. Refer to manufacturer's recommendations.
Fuel filters and centrifuges	Check fuel oil filters and centrifuges. Check fuel oil system for leaks and correct as required. Refer to manufacturer's instructions.
Lubricating systems	Check mechanical lubrication hourly during operation. Oil all hand lubrication points, following manufacturer's instructions. Correct leaks.
Sight-feed lubricators	Clean sight-feed lubricating oil strainers as necessary. Check for adequate lubricant supply.
Lubricating oil filters	Check lubricating oil filters. Clean and replace filter elements as necessary.
Piston assembly and connecting rods	On two-cycle engines, remove upper handhole inspection cover from side of engine immediately after the engine is shut down and inspect the piston for proper lubrication.
Cylinders and cylinder heads	Use compressed air to blow out indicator connections. Clean indicators and install. Refer to manufacturer's instructions.
Crankshaft, crankpin and main bearings	Remove crankcase covers immediately after engine is shut down. Check main and crankpin bearings for proper lubrication. Check bearing temperatures for excessive heat by hand-touch. Refer to manufacturer's instructions for frequency of checks.

Item	Action
Gauges and instruments	Verify that gauges and instruments have up-to-date calibration certifications. Read and record all indications of gauges, thermometers, and other instruments at regular intervals as required by the operating log.
Turbocharger	Observe every four hours during operation. Check for general condition and signs of vibration. Evaluate vibration if present.
Turbocharger impeller	Check turbocharger impeller for accumulated dirt and axial endplay. Dirt may indicate faulty filtering equipment. Clean and service according to manufacturer’s instructions.

A-3.4 Diesel Engines Long-Term Checklist.

Performance of checklist tasks is related to frequency and extent of use of the auxiliary power plant. Table A-10 tasks should be performed annually unless otherwise noted, following performance of short-term checks.

Table A-10 Long-Term Checklist for Diesel Engines

Item	Action
Valve inspection	Inspect exhaust valves; clean and remove carbon on two-cycle engines and valves as necessary. Refer to manufacturer’s instructions.
Inlet valves	Inspect and regrind inlet and exhaust valves and valve seats as necessary. Refer to manufacturer’s instructions.
Valve springs and guides	Check valve spring length and tension and inspect valve stems, bushings, and guides annually or after 2,000 hours of use, whichever comes first. Replace parts as necessary. Refer to manufacturer’s instructions.
Camshaft and drive	Check and adjust gears and/or timing chain. Refer to manufacturer’s instructions.
Camshaft bearings	Inspect and adjust camshaft bearing clearances. Refer to manufacturer’s instructions.

Item	Action
Fuel injection nozzle inspection	After 2,000 hours of use, remove and check nozzles in the test stand. Service and adjust nozzles following manufacturer's instructions.
Fuel injection pumps	Inspect fuel injection pumps for secure mounting, cleanliness, and proper operation.
Fuel injection pump inspection	Disassemble and recondition all injection pump nozzles after 2,000 hours of use. Repair or replace worn or damaged parts. Reassemble and adjust, following the manufacturer's instructions.
Air lines	Drain water from air lines and tank monthly or as necessary. Drain valves are usually located at the lowest point(s) in the air feed system.
Air valves	Clean air valves and reseat if necessary. Refer to manufacturer's instructions.
Air compressor	Disassemble and overhaul air compressor and starting equipment every five years based on frequency of use of the auxiliary power plant.
Pressure gauge inspection	Check the date of calibration. Verify that gauges have valid calibration certification. Calibrate per manufacturer's instructions as required.
Governor overhaul	Overhaul the governor after 2,000 hours of use or when needed, as indicated. Repair or replace worn or damaged parts. Reassemble and adjust, following the manufacturer's instructions.
Muffler (silencer)	Keep the muffler and waste heat equipment, boiler, or heat exchange clean. Accumulations of unburned lubricating oil and soot or carbon are potential fire hazards. Make sure fuel combustion is as efficient as possible. Refer to manufacturer's instructions.
Cooling systems	Inspect piping and valves for leaks and clean the heat exchanger. Perform cooling system maintenance; refer to manufacturer's instructions.
Cooling tower	Drain and clean cooling tower; clean and inspect piping, circulating pumps, and equipment.

Item	Action
Cooling system service	Clean and inspect entire cooling system yearly. Overhaul pumps and recondition valves and other equipment as necessary. Refer to manufacturer's instructions.
Fuel oil tanks and lines	Drain service tanks and lines. Remove water and sediment. Check heating coil for proper operation.
Lubricating oil cooler	Clean and inspect lubricating oil cooler for leaks and good condition. Clean outer surfaces more often under dusty operating conditions for more efficient cooling. Refer to manufacturer's instructions.
Crankcase	Drain crankcase semiannually or more frequently based on number of hours run per manufacturer's recommendations or acceptable industrial engine maintenance procedures. Inspect lubricating oil pumps; flush crankcase and refill. **\1** Refer to manufacturer's instructions and, for Army, PAM 750-8, *The Army Maintenance Management System (TAMMS) User's Manual*. **/1/**
Lubricating oil pump	Inspect the pump after 2,000 hours of use for proper operation. Refer to manufacturer's specifications for the pump.
Cylinder heads	Remove cylinder heads according to manufacturer's instructions after 2,000 hours of use. Inspect cylinder liners. Clean and inspect water jackets. Remove scale and corrosion as necessary. Inspect and measure diameter of cylinder liners. Check gaskets for annealing, brittleness, or cracks. Install new gaskets if necessary.
Piston assembly inspection	On four-cycle engines, pull one piston after 2,000 hours of use and inspect for proper cooling, lubrication, and carbon deposits. Inspect piston rings and wrist pin and the cylinder liner for compliance with engine manufacturer's specifications.
Pistons inspection	Pull pistons after 4,000 hours of engine use. Clean and inspect all parts for wear, proper lubrication, and cooling. Verify that rings and ring clearances comply with engine manufacturer's specifications.

Item	Action
Cylinder inspection	Use the barring device (jacking bar) to turn each piston to top dead center during inspection. Inspect each cylinder liner for scoring. Refer to manufacturer's instructions.
Anchor bolts	Check anchor bolts for proper torque value.
Flywheel bolts	Check flywheel bolts for proper torque value. Refer to manufacturer's instructions. Verify alignment and coupling to generator; comply with specifications.
Main and crankpin bearings	Remove bearing caps; check journals and bearings for proper lubrication, wear, or scoring. Check main bearings for proper alignment. Refer to manufacturer's instructions.
Crankshaft	Verify compliance with engine manufacturer's specifications. Examine crankshaft for cracks. Measure distance between crank webs for crankshaft deflection. Check journal level and clean oil passages. Replace bearings as necessary and adjust running clearance, following the manufacturer's instructions.
Turbocharger inspection	Disassemble, clean, and inspect entire turbocharger following manufacturer's instructions and specifications.
General overhaul	Overhaul diesel engines and driven equipment every ten years or about 16,000 hours of auxiliary use. Follow the manufacturer's recommendations and instructions. Comply with the manufacturer's specifications.

A-3.5 Short-Term Checklist for Gas Turbines.

Checks are limited to inspection and cleaning tasks that can be performed on the exterior of an engine.

A-3.5.1 General.

Before performing any tasks required by the following checklist, review the station log sheets, related records, and the manufacturer's recommendations. The following precautions must be met.

- Shut the engine down.
- Apply "Do not operate" tags to the operating controls.

- Open the engine automatic start circuit.
- Deactivate the fire extinguishing system.
- Keep all engine enclosure doors open while working on the engine.
- Allow engine to cool down before working on it.

A-3.5.2 Short-Term Checklist.

Table A-11 provides a short-term checklist for gas turbines.

Table A-11 Gas Turbine Short-Term Checklist

Item	Action
Inlet inspection	Verify the inlet drain at lower part of duct is open and free of any obstruction so moisture (rain or condensation) can run off. Check inlet temperature sensor for signs of damage. Clean sensor and surrounding area with approved solvent to remove dirt and contaminants. Refer to manufacturer’s instructions. Make sure sensor is securely attached to engine.
Exhaust Inspection	Visually inspect engine exhaust casing, struts, and center body for cracks, nicks, and other signs of damage. Refer to manufacturer’s instructions. Inspect exhaust stack for freedom from obstructions and general good condition
Chip Detectors	Engines usually have plugs with magnetic chip detectors at lubrication sumps. During normal operation, some fuzz-like particles will be found on the detectors. Also, other materials (non-metallic sludge and/or flakes, bronze powder, aluminum chips, etc.) may accumulate on the plugs. Refer to manufacturer’s literature for specific information. Check chip detectors for electrical continuity while installed. Continuity is an indication of contamination. Remove chip detectors if contaminated. Discard packing and clean chip detector. Check chip detector for good thread and proper magnetism. Place new packings on chip detectors and install on engine. Tighten to proper torque.

Item	Action
External Inspection	Inspect engine tubes, hoses, tube/hose fittings, electrical assemblies and connectors for security, and overheating and damage due to leakage. Perform inlet and exhaust inspection as previously described. Check standoffs, brackets, and struts for looseness, cracks, and damage. Check ignition exciter, igniter plugs and leads for damage, overheating, and security. Check mechanical control for signs of excessive wear, damage, and security. Check fuel manifold for leaks, signs of damage, and security. Check for rust and/or corrosion.

A-3.6 Long-Term Checklist for Gas Turbines.

Long-term checks usually affect interior areas of the engine and are seldom performed in the field. Repairs, if necessary, may involve changes in component balance relationships and should be performed at the designated overhaul location. Refer to the manufacturer’s literature for information.

A-4 GENERATORS AND EXCITERS.

Routine maintenance instructions for generators and exciters consist of short- and long-term checklists for rotating and static type equipment.

A-4.1 Short-term Checklist.

Before performing any Table A-12 tasks, review the station log sheets, related records, and the manufacturer's recommendations.

Table A-12 Generators and Exciters Short-Term Checklist

Item	Action
Air screens or filters	Air screens or filters should be changed when the air flow is restricted enough to increase generator operating temperature. Refer to manufacturer's literature.
Exciter coupling (if applicable)	When generator unit is shut down prior to operation, wipe off excess lubrication from the coupling to prevent spatter.
Coupling leaks and alignment	When generator has been shut down, check for lubrication leaks and tightness of coupling. Note any evidence of improper alignment and correct if necessary.
Axial position	Check axial position of the prime mover, generator, and exciter shafts for correct alignment and angularity.
Bearings	Lubrication of generator and exciter bearings is required. Refer to manufacturer's literature for instructions for pressure and non-pressure lubricated bearings.
Rotary exciters, brushes, and brush rigging	Remove carbon dust from collector ring and commutator with vacuum and dry with compressed air at about 25 psi (172 kPa) monthly. Check brushes for wear and indications of arcing and chattering monthly. Check condition of slip rings. Refer to manufacturer's instructions.
Static exciters	Verify the equipment is clean and free from dirt and moisture. Verify all connections are tight. Check connections for corrosion and clean as required.

A-4.2 Long-term Checklist.

Table A-13 tasks should be performed annually unless otherwise noted in manufacturer's instructions, and following execution of short-term checks.

Table A-13 Generators and Exciters Long-Term Checklist

Item	Action
Coupling lubrication	Drain lubricant, disassemble, and clean coupling annually or whenever necessary. Reassemble, using new gaskets and fresh lubricant. Refer to manufacturer's instructions for flexible coupling.
Brush replacement	When brushes have worn to half their original length, replace, seat properly, and adjust brush rigging tension from 2.5 to 3.6 psi (17.2 to 24.8 kPa) on brush riding surface. Repair and replace damaged or worn brush rigging parts. Refer to manufacturer's instructions.
Brush electrolysis	Electrolytic action can occur at collector ring surfaces. This action forms a greenish coating (verdigris) on brass, bronze, or copper. Effects of this action can be reduced or eliminated by reversing the polarity annually or as required. Refer to manufacturer's instructions.
Commutator and collector rings	Clean commutator and collector rings with vacuum. Clean oil film and dirt with approved solvent. Dry with compressed air at about 25 psi (172 kPa). Check for roughness, hard spots, and out-of-round condition. Service commutator and collector rings as necessary, following manufacturer's instructions.
Rotor winding	Rotor maintenance begins with measuring and recording the insulation resistance before the unit is placed in service. Refer to manufacturer's literature for instructions. The rotor should be thoroughly cleaned annually and inspected as follows: • Check the damper winding for loose bars and the connection of each bar to its ring segment. • Check the joints in the ring segments between poles. Refer to manufacturer's instructions. • Check clearance per manufacturer's specifications between blower and coils.

Item	Action
	• Check the field coils for movement and separation. • Clean dirt and oil from winding and air passages. • Check condition of turn-to-turn insulation on strap field coils. • Verify condition of ground insulation on pole pieces. • Check all connections between field coils and lead-out connections to collector rings. • Measure and record insulation resistance between field coils and ground, including the collector rings. Refer to manufacturer's instructions. • Check bearings and journals for damage or excessive wear. • Compare micrometer readings with the manufacturer's table of wear limits. • Repair or replace mechanical parts to meet these specifications. • Dry out according to manufacturer's instructions. • Repair insulation damage and coat with approved insulating varnish.
Rotor balancing	Measure and record vibration limits of repaired unit when it is started. Refer to manufacturer's specifications for vibration limits for the specific unit. Perform static or dynamic balancing of the unit, according to instructions, if necessary.
Stator winding	Measure and record insulation resistance between stator winding and ground at the machine terminals annually.
Stator service	Open up the stator annually. Clean thoroughly and inspect for the following: broken, damaged, loose, or missing wedges; movement or distortion of coil ends; security of all lashing and spacers; tightness of coil supports; cooling passages are open and clean; looseness of coils in slots; cracks or other damage to coil insulation; and connections between coils and around the frame. Measure and record insulation resistance between winding and ground at the machine terminals. Compare the values with those recorded when the machine was first put in service.

A-4.3 Checklist and Schedule for Solid-state Exciters.

Solid-state equipment does not require long-term checks. If the equipment does not function properly, refer to the manufacturer's literature for information. Repair or replace as required.

A-5 SWITCHGEAR MAINTENANCE.

Routine maintenance instructions for switchgear consist of short- and long-term checklists. De-energize switchgear before performing maintenance. Disconnect primary and secondary sources of power.

A-5.1 Short-Term Checklist.

Before performing any tasks in Table A-14, review the station log sheets, related records, manufacturer's recommendations, and NFPA 70E.

Table A-14 Switchgear Maintenance Short-Term Checklist

Item	Action
Panels and other exterior surfaces	Panels and exterior surfaces must be kept scrupulously clean at all times.
Relays and actuating mechanisms	Clean and inspect relays and actuating mechanisms monthly. Many types of relays are used. Identify the relays such as thermal, current overload, over speed, liquid level, lubricating oil pressure and/or flow, frequency change, etc. Refer to manufacturer's literature for inspection procedures. Verify all connections are tight and free of corrosion.
Conductors and coils	Clean and inspect conductors and coils monthly. Verify coating of insulating varnish is in good condition (clean, smooth, and polished) and there are no indications of overheating or corona arcing.
Switches	Inspect switches for proper alignment, firm contacts, and smooth operation monthly. Burned or pitted copper contact surfaces may be dressed with 2/O sandpaper. Do not dress silver contacts.
Circuit breakers	Trip and close circuit breakers; check for proper operation quarterly. Check time delay and freedom of movement. Refer to manufacturer's instructions.
Coils and heaters	Check coils and heaters quarterly for secure mounting and circuit continuity. Check controls and thermostats for proper operation; refer to manufacturer's instructions.
Contactors	Check magnet surfaces of contactors quarterly for cleanliness. Remove gum, rust, or corrosion. Adjust for even contact pressure according to manufacturer's instructions.
Voltage regulators	Check voltage regulators for proper operation and adjustments quarterly. Various makes and types are used. Refer to manufacturer's literature for instructions.

A-5.2 Long-term Checklist.

Performance of tasks is related to frequency and extent of use of the auxiliary power plant. Table A-15 tasks should be performed annually unless otherwise noted in manufacturer's guidance and following the execution of short-term checks. The procedures are general but apply primarily to draw-out equipment.

Before performing any tasks required by the following checklist, review the station log sheets, related records, manufacturer's recommendations, and NFPA 70E.

Table A-15 Switchgear Maintenance Long-Term Checklist

Item	Action
Panels and other exterior surfaces	Panels and exterior surfaces must be kept clean at all times.
Meters and instruments	Check meters and instruments against a verified standard. Return defective or inaccurate meters and instruments to the manufacturer or designated repair location for service and calibration.
Buses	Inspect buses and connections for signs of overheating or weakening of insulating supports. Overheating is indicated by discoloration of the bus bar. Inspect insulators for cracks and/or arc tracks. Replace defective insulators. Tighten bus bar and terminal connections to the proper torque value.
Indicating devices and interlocks	Check indicating devices and interlocks for proper operation. Refer to manufacturer's instructions.
Disconnecting devices	Check primary disconnecting device contacts for signs of overheating or abnormal wear. Clean contacts with silver polish. Clean disconnecting device contacts and apply light coating of approved lubricant.
Enclosure	Verify that interior anchor bolts and structural bolts are tight. Inspect cable connections for signs of overheating. Tighten loose connections as required.
Circuit breakers	Manually operate each breaker while in test position; verify proper operation. Refer to manufacturer's instructions.

Item	Action
Environmental conditions	More frequent inspections of the switchgear must be made when unusual service conditions exist, such as contaminating fumes, excessive moisture, or extreme heat or cold. Additional protection may be required if adverse conditions are present.
Ground resistance	Measure and record ground resistance values using a ground resistance test set. Compare these values with those recorded during previous tests. The tests indicate grounding system effectiveness and possible deterioration since the last tests.

A-6 OIL MAINTENANCE PROCEDURES.

Table A-16 provides a general guide for maintenance of lubricating oil. Table A-17 provides normal and maximum oil quality standards.

Table A-16 Oil Maintenance

Item	Action
Water and sediment	Clean by centrifuging.
Viscosity	Treat with oil reclaimer to drive off dilution. Centrifuge (hot) to remove heavy sludge. If necessary, add straight run mineral oil of lower viscosity.
Corrosion	Treat with activated-type reclaimer. If an additive oil is in use, the presence of corrosive qualities indicates the additive is exhausted. New oil must be used if the benefit of additives is required. Used oil may be reclaimed and used for other services not requiring the additive.
Particles	Passage of particles larger than the filter’s specifications are a definite sign of channeling or structural damage to filter elements. Replace filter cartridges.

Table A-17 Oil Quality Standards

Item	Normal	Maximum
Water and sediment	1.0%	5.0%
Water	0.5%	3.0%
Sediment	0.5%	2.0%
Viscosity	±5%	±10%
Corrosion (copper strip)	None	Dull
pH	7% or higher	6.8%
Filtered particles (% of total residue)		
Larger than oil filter	None	2%
Metallic under 1 micron	Few	1%
Over 5 microns	None	1%

A-7 FUEL AND FUEL STORAGE.

A-7.1 Diesel Fuel.

Diesel fuel should comply with Federal Specifications W-F-800 MIL-F-16884, or specifications for JP-8. These specifications include grades DF-A, DF-1, DF-2, or types I and II. All are suitable for use under applicable temperature and service conditions. Different grades of fuel should not be mixed.

\1\ Note: For Air Force, see paragraph 8-6.3. **/1/**

A-7.1.1 Cleanliness.

Fuel must be clean. All dirt, dust, water, sediment, and other contaminants must be kept out of the fuel to prevent damage to engine fuel injection equipment. The specified grade of clean fuel must be used to ensure long, economical engine operation. Handling of fuel must be reduced to a minimum to avoid entry of contaminants. Delivery of fuel to storage tanks and then pumping it directly to the day tank through filters is a recommended procedure. Filters must be installed in all engine fuel lines and must be cleaned as recommended by the engine manufacturer.

A-7.1.2 Contamination.

Stored fuel and fuel storage systems must be inspected at regular intervals at a minimum of every 90 days. **\1** Consult T.O. 42B-1-1 for additional information on fuel contamination, testing, and quality surveillance. **/1/** Samples for detecting fuel contaminations are as follows:

1) Inspect fuel filters for indication of microorganism growth, rust, scale, or sediment. In a glass jar, collect a sample of diesel fuel from the bottom of the tank. Solid contaminants will settle and collect at the bottom of the jar. Clean the filters as directed by manufacturer's instructions.

2) Detect water in diesel fuel by collecting in a glass jar a sample of fuel from the bottom of the tank. Fuel and water will separate when the sample is allowed to settle, water will sink to the bottom of the jar. Fuel with water in it may appear white and cloudy when agitated.

3) Detect gasoline or kerosene in diesel fuel by collecting a sample (see above). Fuel and contaminants will separate when the sample is allowed to settle; the gasoline or kerosene will float on the fuel.

4) Detect oil-soluble soaps in diesel fuel by having an appropriate laboratory test performed. Avoid this kind of contamination; do not use galvanized storage tanks or piping.

5) Prevent condensation within storage tanks by keeping the tanks full. Tanks must be kept full during cold weather.

A-7.1.3 Storage.

Fuel tanks used for storage must have drain valves for removal of bottom water (to be done once every six months). Deterioration of stored fuel is caused by three factors: oxidation, microorganism contamination, and corrosion.

1) Oxidation occurs directly or through catalytic action. Oxygen from the air or fuel combines with fuel hydrocarbons, causing oxidation. Resultant oxidation continues as long as oxygen is present. Metals suspended in the fuel act as catalysts. Metals can enter the fuel during refining, distribution, or storage. The engine fuel system can thereby be damaged.

2) Microorganism contamination is caused by bacteria and fungus that exist in the bottom water. Waste by-products of the microorganisms form a self-sustaining corrosive environment. The byproducts can form a gelatinous mass that plugs fuel lines and filters and forms a fuel sludge, thereby reducing engine efficiency and possibly damaging the engine.

3) Corrosion of the storage tank does not directly deteriorate the fuel. Corrosion can destroy a metal storage tank, usually at the bottom. Metals that enter the fuel act chemically to speed up oxidation. The combination of microorganism growth and water causes oxidation.

A-7.2 Gas Turbine Fuel.

\1 Fuel for gas turbines consists of natural gas or light distillate oil such as kerosene, military jet engine fuel (JP-8, JP-5, TS-1, F-24), or commercial jet engine fuel (Jet A, Jet A-1). All are suitable for use under applicable temperature and service conditions. Most gas turbines can burn fuels used by diesel engines. Gas and oil fuels should not be mixed. Consult T.O. 42B-1-1 for additional information. **/1/**

A-7.2.1 Cleanliness.

Fuel must be clean. All dirt, dust, water, sediment, and other contaminants must be kept out of fuel to prevent damage to engine components. Only the specified grade of clean fuel should be used to ensure reliable engine operation. Handling of fuel must be reduced to a minimum to avoid entry of contaminants. Natural gas should be passed through several fine screen filters to remove solid particles and water vapor before it is fed to the gas turbine engine.

A-7.2.2 Contamination.

Stored fuel and fuel storage systems must be inspected at regular intervals at a minimum of every 90 days. Perform the following checks when cleaning filters for a natural gas system.

- Inspect the solid particles removed by fine screen filters. Determine if the particles are dust or dirt, or the type of metal if metallic.
- Inspect water accumulation for acid or alkaline content.

A-7.3 Storage.

Information relating to storing natural gas fuel follows:

- Natural gas can be stored in low-pressure surface containers or high-pressure sub-surface containers and metal bottles.
- Liquefied natural gas can be stored in insulated metal tanks installed as sub-surface units.
- The type of storage employed for natural gas depends on plant requirements and fuel availability.

A-7.4 Fuel Storage Maintenance Procedures.

Provide the base engineer’s office with the reports and results of inspections performed. The base engineer will review this data and take appropriate corrective action, which may include any or all of the following:

- Add an antioxidant to prevent oxidation or “aging” of a fuel.
- Add a fungicide or biocide to destroy organisms present in the water beneath stored fuel.
- Add a metal deactivator because metals in fuel catalyze or speed up oxidation. Inhibitors that place an amine film on metal surfaces are available. Amines are organic compounds that neutralize an electrical charge in metals.

Note that any chemical or additive that is added to stored fuel must be approved by the EPA. Also, the base engineer's office should monitor the removal of bottom water from storage tanks.

A-8 LUBRICATING OIL.

A-8.1 Diesel Engine Oil.

\1 Lubricating oil for diesel engines should comply with specifications MIL-PRF-2104 and MIL-PRF-9000. Oil that complies with the specifications produces acceptable amounts of carbon residue during engine use and has acceptable pour, flash, and fire points. Straight mineral oil is the basic ingredient. Inhibitors or chemicals are added to the oil by the oil refiner to ensure compatibility with a range of engines operating under varying conditions. The user must observe recommendations by the engine manufacturer for specific types and grades of oil for optimum engine performance. **/1/**

A-8.1.1 Characteristics.

Engine lubrication requires selection of the proper oil. Refer to the engine manufacturer's instructions. Examples of required oil characteristics are as follows:

- Oil should have sufficient viscosity to prevent metal-to-metal contact. Oils with lower SAE numbers are lighter and flow more readily than oils with higher numbers. Heavier oils, those with higher SAE numbers, may cause sluggish operation and power loss.
- Oil should remain stable during use under changing temperatures and conditions for satisfactory service.
- Check the engine periodically, such as every six months, for accumulation of sludge in the engine filters and strainers and around valve springs. Refer to the engine manufacturer's literature for specific information.
- Oil must be free of water and sediment. Collect a sample of oil in a glass jar. Allow the sample to settle. Water and solid contaminants settle to the bottom of the jar.

A-8.1.2 Additives.

Straight mineral oil does not have detergent qualities; therefore, various compounds are added to the oil. These additives keep the engine clean by controlling varnish formation or resisting chemical changes to reduce oxidation. Other additives form a protective film against corrosive acids.

A-8.1.3 Mixing Oils.

Different refineries may use different types of additives or certain characteristics of the mineral oil may vary. Mixing types of oil may change the necessary detergent actions. To obtain maximum benefit from additive type oils, do not mix them with straight mineral oil. Concentrations of the additives are reduced when detergent oils and straight oils are mixed.

A-8.1.4 Changing Oil.

Lubricating oil must be changed periodically. Refer to recommendations by the engine manufacturer to specific conditions, time intervals, and instructions. General oil change procedures are as follows:

- Operate the engine before draining old oil. Oil should be drained while warm and immediately after engine shutdown because contaminants are in suspension and will readily drain.
- Obtain a sample of the drained oil and deliver it to the base engineer for testing. Drained oil should be examined for fuel dilution, acidity, and presence of solids and other contaminants. Testing helps establish the overall condition of the engine and approximate frequency of need for oil changes.
- Observe the viscosity of drained oil. In diesel engines, oil viscosity increases during service due to the gradual oxidation of the oil. Viscosity decreases if fuel gets into the oil by passing the piston rings or through leaks.

A-8.1.5 Oil Analysis Program.

Personnel in the engineer’s office and other cognizant personnel should refer to PAM 750-8, *The Army Maintenance Management System (TAMMS) User’s Manual*, for sampling and analysis information. The analysis of periodic samples of the lubricating oil should report the character and amount of contaminants, wear-metals, and additives in the oil. However, some amounts of wear metals and contaminants will have been collected by the chip collectors, strainers, filters, separators of the system, and also as sludge. To secure the total picture it is necessary to analyze all such collected material to determine the total rate of increase/decrease of each. This will indicate what has occurred during the period between samples.

Log and use all such data to track trends that give warning of conditions that may result, if uncorrected, in major problems.

A-8.2 GAS TURBINE OIL.

\1 Lubricating oil for gas turbines should comply with specifications MIL-PRF-23699 or MIL-PRF-7808. Oil that complies with the specification can withstand the high temperatures encountered during engine operation. **/1/**

A-8.2.1 Additives.

Various compounds are added to mineral oil to provide the special characteristics required for use in gas turbines. The user must observe lubricating oil recommendations by the engine manufacturer for optimum engine performance.

A-8.2.2 Changing Oil.

Refer to the engine manufacturer's literature for recommendations related to specific conditions, time intervals, and instructions for changing the lubricating oil. An oil analysis program is usually recommended, including a spectrometric analysis of the metal particles. It is necessary to collect and evaluate data for type and quantity of engine wear-metals. Study of this data shows trends of engine wear and expected future reliability.

- Collect a sample of old oil when oil is drained from the engine storage tank. Examine the drain plug or valve, filter, and chip detector (if used) for metal particles. Save the particles for analysis.
- Deliver the drain oil sample and particles to the base engineer for tests and analysis. The presence of some particles in the drain oil is usually considered normal by the engine manufacturer.

A-8.3 Coolant.

\1 The coolant used in diesel engines typically consists of a mixture of ethylene glycol antifreeze, corrosion inhibitor, and fresh water. When the engine is used in an extremely cold area, such as Arctic regions, a special antifreeze mixture is used. Specifications related to the mixtures are as follows:

- Antifreeze, Ethylene glycol MIL-A-46153
- Specification for cooling system conditioner and inhibitor is MIL-C-10597
- Antifreeze, Ethylene glycol A-A-52624
- Antifreeze, Arctic-type A-A-52624
- 5 Inhibitor, Corrosion MIL-A-53009 or MIL-A-46153 **/1/**

A-8.3.1 Engine Water Treatment.

A-8.3.1.1 Acceptable Conditions.

In most modern diesel engines, the following cooling water conditions are acceptable:

- pH 8.5 to 10
- Chloride and sulfate 100 ppm
- Total dissolved solids 500 ppm
- Total hardness 200 ppm

A-8.3.1.2 Softened Water.

If possible, softened water should be used to reduce the total hardness level of the engine cooling loop. The use of softened water will increase engine performance by reducing the precipitation of calcium and magnesium at elevated temperature conditions, ensuring higher heat transfer rates.

A-8.3.1.3 Antifreeze.

Typical engine cooling systems incorporate antifreeze solutions that inhibit scale and protect the cooling system when temperatures are encountered below freezing. Ethylene glycol mixed with a corrosion inhibitor such as triazoles form an inhibiting film on metal surfaces that acts as a barrier to the corrosion process. Table A-18 concentrations should be utilized when adding glycol solutions to the engine cooling system.

A-8.3.1.4 Concentration.

The ethylene glycol concentration should exceed 30 percent. If more than 60 percent of solution is added, two effects will be realized: 1) a decrease in heat transfer rates, 2) a lowering of the system freeze protection.

A-8.3.2 Cooling System Maintenance.

Maintenance consists of periodically testing the antifreeze, inspecting the coolant for cleanliness, and flushing or cleaning the system with compound when necessary.

A-8.3.2.1 Testing Antifreeze.

Perform tests to verify freeze protection and reserve alkalinity:

- Test for freeze protection using the combination antifreeze and battery tester (stock number 6630-00-105-1418). Instructions for using the tester are included with it.
- Test for reserve alkalinity (corrosion protection) using the reserve alkalinity test kit (stock number 6630-00-169-1506).
- Cooling systems with freeze protection below -7 °F (-22 °C) that fail the reserve alkalinity test may be replenished with corrosion inhibitor (stock number 6850-00-753-4967). Replenishment is a one-time service. If the reserve alkalinity test is failed again, replace the coolant. If the system passes the test, record the date.

A-8.3.2.2 Inspecting Coolant.

Inspect the coolant visually for cleanliness. Obtain a coolant sample and place it in a clean glass container. After allowing about five minutes for settling, examine the sample for contamination (rust, foreign particles, and/or sediment). The sample may have some color (same color as original antifreeze) and should be clear.

Examine the sample to determine the type and quantity of contamination. Rust, a chemical combination of iron, water, and air, is frequently found. The presence of rubber particles usually indicates deterioration of hoses. Replacement hoses may be indicated. Sediment may be caused by impurities in the water used in the coolant. Contaminants in the coolant can clog a radiator or heat exchanger and cause engine and generator system breakdown.

A-8.3.2.3 Cleaning the System.

Clean the cooling system whenever the coolant is drained. Usually the system requires nothing more than a thorough flushing with fresh water. Refer to the engine manufacturer's literature for instructions. If any part of the system is rusted or partially clogged, it is necessary to use cooling system cleaning compound and conditioner, stock number 6850-00-598-7328. Do not use the compound as a routine maintenance procedure. Instructions for using the compound are included with it.

A-8.3.2.4 Filling the System.

Refer to the engine manufacturer's literature for instructions on filling the cooling system. This is applicable to either new systems or those just cleaned and serviced.

A-8.3.2.4.1 Ethylene Glycol Antifreeze.

Cooling system protection is required for all liquid cooled diesel engines. In areas where temperatures no lower than -55 °F (-48 °C) are expected, prepare a solution according to the information presented in Table A-18. When temperatures below freezing are not expected, use a weak solution such as 1 pint of ethylene glycol antifreeze for each gallon of solution for general protection against rust buildup and scale formation within the engine.

A-8.3.2.4.2 Arctic-Type Antifreeze.

Use arctic-type antifreeze in areas where temperatures below -55 °F (-48 °C) are expected. Do not dilute arctic-type antifreeze with water or inhibitor; it is ready for use as issued.

Table A-18 Antifreeze Solutions

Guide for Preparing Ethylene Glycol Antifreeze Solutions	
Lowest Estimated Temperature in Area	**Pints of Antifreeze Needed to Prepare 1 Gallon of Solution**
+20 °F (-7 °C)	1.50
+10 °F (-12 °C)	2.00
0 °F (-18 °C)	2.75
-10 °F (-23 °C)	3.25
-20 °F (-29 °C)	3.50
-30 °F (-34 °C)	4.00
-40 °F (-40 °C)	4.25
-50 °F (-46 °C)	4.50
-55 °F (-48 °C)	4.75

A-9 ATS MAINTENANCE.

The following ATS maintenance actions are recommended:

- Follow NFPA 110 for visual inspection and cleaning, specifically Annex A.
- De-energize the switchgear and the ATS.
- Bypass isolation ATS may remain energized only to rack out the automatic switch.
- Remove the arc chutes and pole covers. Consult the manufacturer's information for proper procedure. This step will allow visual inspection of the main and arcing contacts.
- Test and recalibrate all trip-sensing and time-delay functions in the switchgear. Depending on the manufacturer, the steps required will vary. The focus should be to verify and record what current settings are and ensure the current adjustments meet the customer's needs and expectations. If adjustments are necessary, the means to make and verify those adjustments need to be examined. For example, a voltage pick-up or dropout adjustment may require the use of a variable source, such as a variable ac transformer. The standby engine can be a source of variable frequency, etc. Refer to manufacturer’s recommendation.
- Vacuum the accumulated dust from the switchgear and accessory panels. Do not use air to blow out dirt.

- Inspect for moisture or signs of previous wetness or dripping.
- Clean grime with an approved solvent. Consult the manufacturer's recommendations.
- Inspect all insulating parts for cracks or discoloration due to excessive heat. Use infrared scan if available.
- Inspect all main arcing contacts for excessive erosion. Replace contacts if damaged.
- Inspect all main current-carrying contacts for pitting and discoloration due to excessive heat.
- Inspect all control relay contacts for excessive erosion and discoloration due to excessive heat. If damaged, replace.
- Manually operate the main transfer movement to check proper contact alignment, deflection, gap, and wiping action.
- Check all cable and control wire connections to the transfer switch control and sensing panel and other system components and tighten if necessary.
- Re-energize the switchgear and conduct a test by simulating a normal source failure.
- ATS must be operated monthly.
- Circuit breakers should be tested under simulated overload conditions every two years.
- Simulate a power outage without turning off the normal power.

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APPENDIX B REFERENCES

CODE OF FEDERAL REGULATIONS

https://www.ecfr.gov/cgi-bin/ECFR?page=browse

14 CFR 77, *Safe, Efficient Use, and Preservation of the Navigable Airspace*

29 CFR 1910, *Occupational Safety and Health Standards*

29 CFR 1926, *Safety and Health Regulations for Construction*

40 CFR 1 through 1100, *Environmental Protection Agency*

50 CFR 13, *General Permit Procedures*

50 CFR 17, *Endangered and Threatened Wildlife and Plants*

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Clean Air Act (CAA), https://www.epa.gov/clean-air-act-overview/clean-air-act-text

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Resource Conservation and Recovery Act (RCRA), https://www.epa.gov/rcra

DEPARTMENT OF DEFENSE

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DoDI 6050.05, *DoD Hazard Communication (HAZCOM) Program*

DoDI 8500.01, *Cybersecurity*

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DD Form 1149, *Requisition and Invoice/Shipping Document*, https://www.esd.whs.mil/Directives/forms/dd1000_1499/

DD Form 1348-1A, *Issue Release/Receipt Document*, https://www.esd.whs.mil/Directives/forms/dd1000_1499/

DD Form 2744, *Emergency/Auxiliary Generator Operation Log*, https://www.esd.whs.mil/Directives/forms/dd2500_2999/

DISA Circular 350-195-2*, *Electric Power Systems for Department of Defense Information Network (DODIN) Facilities*, https://www.disa.mil/-/media/Files/DISA/About/Publication/Circular/dc3501952.pdf

MIL-STD-3004-1, *Quality Assurance for Bulk Fuels, Lubricants and Related Products*

AIR FORCE

https://www.e-publishing.af.mil/

AF Form 487, *Generator Operating Log (Inspection Checklist)*

AF Form 719, *Historical Record – Diesel-Electric Generator and System*

AFTO Form 781A, *Maintenance Discrepancy and Work Document*

AFI 13-204V3, *Airfield Operations Procedures and Programs*

AFI 21-113, *Air Force Metrology and Calibration (AFMETCAL) Management*

AFI 23-201, *Fuels Management*

AFI 23-204, *Organizational Fuel Tanks*

AFI 32-1001, *Operations Management*

AFI 32-1062, *Electrical Systems, Power Plants and Generators*

AFI 32-1064, *Electrical Safe Practices*

AFI 32-7040, *Air Quality Compliance and Resource Management*

AFI 32-7044, *Storage Tank Environmental Compliance*

AFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards*

T.O. 00-20-14, *Air Force Metrology and Calibration Program*, https://www.wpafb.af.mil/Portals/60/documents/aftmetcal/AFMETCAL-Technical-Manual-TO%2000-20-14.pdf

T.O. 42B-1-1, *Quality Control of Fuels*

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AR 750-43, *Army Test, Measurement, and Diagnostic Equipment*, https://armypubs.army.mil/ProductMaps/PubForm/Details.aspx?PUB_ID=4605

PAM 750-8, *The Army Maintenance Management System (TAMMS) User's Manual,* https://armypubs.army.mil/ProductMaps/PubForm/Details.aspx?PUB_ID=81693

TB 43-180, *Calibration and Repair Requirements for the Maintenance of Army Materiel*, https://armypubs.army.mil/ProductMaps/PubForm/Details.aspx?PUB_ID=1007300

TM 5-685, *Operation, Maintenance and Repair of Auxiliary Generators*, https://armypubs.army.mil/ProductMaps/PubForm/Details.aspx?PUB_ID=74515

TM 5-692-1, *Maintenance of Mechanical and Electrical Equipment at Command, Control Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*, https://armypubs.army.mil/ProductMaps/PubForm/Details.aspx?PUB_ID=78972

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http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *DoD Building Code (General Building Requirements)*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-540-01, *Engine-Driven Generator Systems for Backup Power Applications*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-560-01, *O&M: Electrical Safety*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

NATIONAL INSTITUTE OF STANDARDS

https://www.nist.gov/

SP 800 series, *An Introduction to Computer Security*

SP 1800 series, *NIST Cybersecurity Practice Guides*

AMERICAN NATIONAL STANDARDS INSTITUTE

https://www.ansi.org/

ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*

AMERICAN PETROLEUM INSTITUTE

API Standard 2015, *Requirements for Safe Entry and Cleaning of Petroleum Tanks*, https://www.api.org/

ASTM INTERNATIONAL

https://www.astm.org/

D1524, *Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field*

D1534, *Standard Test Method for Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration*

D877, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*

D975, *Standard Specification for Diesel Fuel Oils*

F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*

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EN 590, *Automotive Fuels - Diesel - Requirements and Test Methods*

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

https://www.ieee.org/

IEEE C2, *National Electrical Safety Code (NESC)*

IEEE 43, *IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery*

IEEE 67, *IEEE Guide for Operation and Maintenance of Turbine Generators*

IEEE 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*

IEEE 450, *Recommended Practice for Maintenance, Testing, and replacement of Vented Lead-Acid Batteries for Stationary Applications*

IEEE 492, *IEEE Guide for Operation and Maintenance of Hydro-Generators*

IEEE 516, *IEEE Guide for Maintenance Methods on Energized Power Lines*

IEEE 935, *IEEE Guide on Terminology for Tools and Equipment to Be Used in Live Line Working*

NATIONAL FIRE PROTECTION ASSOCIATION

https://www.nfpa.org/

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*

NFPA 70, *National Electrical Code* (NEC)

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 110, *Standard for Emergency and Standby Power Systems*

NFPA 99, *Health Care Facilities Code*

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*

NFPA 30, *Flammable and Combustible Liquids Code*

NFPA 54, *National Fuel Gas Code*

NFPA 58, *Liquefied Petroleum Gas Code*

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC Standard PRC-005-2, *Protection System Maintenance Program*, https://www.nerc.com

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APPENDIX C GLOSSARY

C-1 ACRONYMS AND ABBREVIATIONS.

°C	degrees Celsius
°F	degrees Fahrenheit
AC	alternating current
AFCEC/CO	Air Force Civil Engineer Center, Operations Directorate
AFCEC/COM	Air Force Civil Engineer Center, CEMIRT
AFCEC/COO	Air Force Civil Engineer Center, Operations Maintenance
AFCEC/COSM	Air Force Civil Engineer Center, Mechanical Engineering
AFCEC/CZ	Air Force Civil Engineer Center, Environmental Directorate
AFI	Air Force Instruction
AFLCMC/WNZEC	Air Force Life Cycle Management Center
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
API	American Petroleum Institute
AR	Army Regulation
ASTM	American Society for Testing and Materials
ATS	automatic transfer switch
BCE	base civil engineer
CAA	Clean Air Act
CE	Civil Engineering
CEMIRT	Civil Engineer Maintenance Inspection Repair Team
CFR	Code of Federal Regulations
CWA	Clean Water Act
DC	direct current
DoD	Department of Defense

DoDI	Department of Defense Instruction
EAID	Equipment Authorization Inventory Data
EPA	Environmental Protection Agency
EPSS	emergency power supply system
FAA	Federal Aviation Administration
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
IR	infrared
km	kilometer
kPa	kilopascal
kW	kilowatt
LOTO	lockout/tagout
LPG	liquid or liquefied petroleum gas
MAJCOM	major command
MIL-PRF	performance specification
MTS	manual transfer switch
MVA	megavolt-ampere
MW	megawatt
NEC	National Electrical Code
NERC	North American Electric Reliability Corporation
NETA	National Electric Testing Association
NFPA	National Fire Protection Association
NG	natural gas
NIST	National Institute of Standards
NSWC	Naval Surface Warfare Center
O&M	operations and maintenance

OSHA	Occupational Safety and Health Administration
p-grnd	phase to ground
pH	scale to specify how acidic or basic a water-based solution is
PM	preventive maintenance
PMTL	Preventive Maintenance Task List
p-p	phase to phase
PPE	personal protective equipment
ppm	parts per million
psi	pounds per square inch
PTO	power take off
RPIE	real property installed equipment
SAE	Society of Automotive Engineers
SCA	supplemental coolant additive
SCADA	supervisory control and data acquisition
SME	Subject Matter Expert
T.O.	Air Force Technical Order
TB	Army Technical Bulletin
UFC	Unified Facilities Criteria
UPS	uninterruptible power supply
UTC	Unit Type Code

C-2 DEFINITIONS OF TERMS.

Generator Assembly: Assembly of prime mover, electrical machinery, and all ancillary equipment. In this UFC context, it is shortened to “generator.”

Power Plant: A building or group of buildings necessary for the generation of power, including generators.

Prime Mover: Combustion engine that provides the mechanical energy in alternating electrical power. Synchronous AC machines are alternators. DC machines are generators, but not covered by the scope of this UFC.

Take: Includes to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb wildlife. This is based upon 16 USC 1531, 16 USC 668, and 50 CFR 223.

UFC 3-540-08
23 January 2017

UNIFIED FACILITIES CRITERIA (UFC)

UTILITY-SCALE RENEWABLE ENERGY SYSTEMS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

UFC 3-540-08 UTILITY-SCALE RENEWABLE ENERGY SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 3-540-08, Utility-Scale Renewable Energy Systems

Superseding: None

Description: This UFC provides requirements for the planning, design, construction, and operations and maintenance of solar photovoltaic, horizontal axis wind turbine, waste to energy, landfill gas, and geothermal renewable energy power generation systems.

Reasons for Document:

- To provide unified Department of Defense renewable energy power generation criteria and create more consistency in DoD designs.

Impact:

This uniform effort will result in the more effective use of DoD funds in the following ways:

- Standardized guidance of utility-scaled renewable energy power production planning, design, construction, and operations and maintenance among the Services.
- Consolidation of utility-scaled renewable energy power technologies and summary requirements in UFC 3-540-08 allows Services to evaluate technologies and infrastructure needs to economically use available site specific resources.

Unification Issues:

- None

TABLE OF CONTENTS

FIGURES

TABLES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) provides guidance for designing and installing renewable power generation (RPG) systems that interface with an installation's power grid. The criteria contained herein are intended to ensure durable, efficient, and reliable systems and installations. Whenever unique conditions and problems are not specifically covered by this UFC, use the applicable referenced industry standards and other documents for design guidance.

1-2 ORGANIZATION.

Chapter 2, *Planning and Development*, provides preliminary planning considerations for technologies applicable to installation location. Site attributes, including available space, topography, accessibility, location, and ecology, impact the technology selection. Chapters 3-7 provide additional details on each renewable power generation technology and Chapter 8 provides interconnection guidance.

1-3 APPLICABILITY.

This UFC applies to the planning, design, and construction, of utility scaled renewable energy facilities and installations, regardless of funding source. Per DoD Instruction 4270.5, the design criteria of this UFC do not apply to privatized housing or to projects acquired through a real property exchange agreement. This UFC also applies to overseas facilities, considering mission objectives and Host Nation standards, to the greatest extent practical.

Compliance with this UFC is mandatory for the design of renewable power generation systems that interface with an installation's power grid at all facilities and bases. This UFC applies to the creation of utility scaled power generation systems for installation power needs, and not for individual facility systems. For facility-level renewable energy systems, refer to UFC 3-440-01.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines, building systems, accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to the UFCs and government criteria referenced therein.

1-5 ENERGY RESILIENCE.

All energy systems must be planned, designed, acquired, executed, and maintained in accordance with DoD Instruction 4170.11, Installation Energy Management, and as required by individual Service and Defense Agency policies on energy resilience.

1-6 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

1-7 COPYRIGHT RELEASES.

National Renewable Energy Laboratory (NREL) developed maps and charts are not to be used to imply an endorsement by the NREL, the Alliance for Sustainable Energy, LLC, the operator of NREL, or the U.S. Department of Energy.

Use of energy associations' and organizations' data and references does not imply any DoD endorsement. Use of associations' and organizations' data is subject to individual terms of use.

1-8 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-9 GLOSSARY.

Appendix G contains acronyms, abbreviations, and terms.

CHAPTER 2 PLANNING AND DEVELOPMENT

2-1 INTRODUCTION.

This chapter provides preliminary planning considerations for renewable power generation technologies applicable to the installation location. Site specific attributes, including resource quality, space availability, topography, site location and accessibility, and ecology, impact the technology selection.

2-2 TECHNOLOGY SELECTION.

Installation location is a significant factor that governs which renewable energy sources are available for economic power generation development.

NREL provides dynamic resource maps, graphic information system data, and analysis tools for preliminary evaluations. The National Resources Conservation Service (NRCS) provides annual precipitation in the lower 48 states. Higher annual precipitation indicates increased biomass potential. National Oceanographic and Atmospheric Administration (NOAA) provides current and historical severe weather data for planning and design considerations. Review current resource maps and data for preliminary site analysis and planning only. Additional selection considerations are provided in individual RPG technologies chapters.

- NREL: http://www.nrel.gov/gis/re_potential.html
- NRCS: http://www.wcc.nrcs.usda.gov/climate/prism.html
- NOAA: https://www.ncdc.noaa.gov/data-access/severe-weather

2-3 CAPACITY FACTORS.

Capacity factor is a representation, in percent, of a generator's actual energy production divided by the generator's maximum power that it is rated to produce at continuous full power operation during the same period. For illustration, a one (1) megawatt (MW) generator at a 50% capacity factor produces 4,380 MW hour (MWh) of power annually (1MW x 50% capacity x 8,760 hours/year).

Waste to Energy (WTE), Landfill Gas (LFG), and geothermal plants are more stable power producers than solar or wind, whose generation capacity can vary significantly during any given hour due to clouds, gusts, and other environmental effects. Table 2-1 provides a summary of historical generation capacity factors, based upon Jan 2013-Feb 2015 data available from U.S. Energy Information Administration. Understand and account for the limiting factors and availability associated with each technology when determining an installation's overall energy supply portfolio.

Table 2-1 Generation Systems Capacity Factors

Technology	Capacity Factor Range		
	Low	Median	High
Solar Photovoltaic (PV)	15.6%	27.8%	32.0%
Wind	28.0%	33.1%	43.1%
Geothermal	67.3%	71.2%	76.8%
Solid Waste and LFG	61.4%	68.9%	72.4%

2-4 PLANT LOCATION FACTORS.

2-4.1 Siting Considerations.

Use the joint Natural Resources Defense Council / DoD primer, *Working with the Department of Defense: Siting Renewable Energy Development*, to screen renewable energy development, generation, or transmission sites.

2-4.2 Transmission Infrastructure.

The North America transmission system is monitored and controlled by the *Independent Systems Operators/Regional Transmission Operators* (ISO/RTO) (http://www.isorto.org). Bulk system reliability is under the *North American Electric Reliability Corporation* (NERC) (www.nerc.com) jurisdiction. Compliance with applicable NERC and ISO/RTO standards and requirements is mandatory. Coordinate with the applicable ISO/RTO for RPG system for transmission grid information, connection requirements, and future grid expansion.

Evaluate and address any gap(s) between the transmission infrastructure at/near the RPG site(s) and the required infrastructure/right of ways necessary to connect to installation's grid. Coordinate with the local ISO/RTO or the ISO/RTO Council, for smart grid connection requirements and ISO/RTO areas of responsibilities. Comply with Chapter 8 "UTILITY INTERCONNECTION" requirements.

2-4.3 Site Acreage Requirements.

Renewable energy power generation requires an extensive footprint. Actual site requirements are a function of location, system configuration, resource quality, and system efficiency as shown by the standard deviation column in Table 2-2. For initial planning purposes, use NREL average values as presented in Table 2-2 for initial RPG acreage planning factors, unless more actuate local data is available. For photovoltaic (PV) systems, the minimum footprint requirement can be calculated with the following formula:

$$A(\varphi) = 0.00205 \cdot \varphi^2 + 0.0493 \cdot \varphi + 2.21$$

Where: *A* is area in acres and φ is latitude in degrees North.

Table 2-2 Renewable Power Systems Footprints

Technology Type	Size (acres / MW) (tons / MW for LFG)	Size Std. Dev.(acres / MW)
Photovoltaic 1 – 10 MW	6.1	1.7
Wind 1 – 10 MW	44.7	25.0
Biomass Combustion Combined Heat and Power	3.5	1.9
Geothermal	1.6	-
Landfill Gas (LFG)	7900 tons/MW[1] (7200 metric ton/MW)	

[1] For planning purposes, use tonnage or gate-yard receipts, if available. Six gate-yards is approximately one ton of MW. If receipts not available, compacted landfill density ranges from 750-1,250 pounds per CY.

2-5 LOAD REQUIREMENTS.

2-5.1 Electrical Load Considerations.

Determine desired peak and annual power generation requirements. Address 24-hour and annual load considerations, and capacity factors associated with the evaluated RPG system. Account for RPG plant operational loads that reduce power transmitted to the grid.

2-5.2 Cogeneration Considerations.

Consider installation needs for secondary use of waste heat generated.

2-5.3 Energy Storage Considerations.

Consider thermal storage for off-generation use of thermal energy. Consider energy storage systems for power management of solar and wind systems. Energy storage is classified by its energy form: mechanical, chemical, electrochemical, thermal, magnetic, or electric field. Commercial utility scaled energy storage technologies in use include pumped hydroelectric (significant majority of U.S. capacity), compressed air, and conventional battery. Other technologies in use, and in development, include capacitors, flywheels, high temperature and flow batteries, superconducting, thermal storage, hydrogen, and potential energy systems.

2-5.4 Capacity Factors.

Account for capacity factors in project planning, and installation microgrid and islanding strategies. Use solar or wind power generation as a complementary power source, not as the sole primary power replacement option, unless a suitable storage technology is being utilized to provide power when solar and wind are not available.

2-6 UTILITY INTERCONNECT.

Individual states may have power connection limits. The Database of State Incentives for Renewables & Efficiencies (DSIRE) website, www.dsireusa.org, provides a summary of State interconnection policies and applicable State contact information. Coordinate with applicable State offices, local power company, and the ISO/RTO for limits and interconnection requirements. Comply with Chapter 8 titled "UTILITY INTERCONNECTION" requirements and IEEE 1547.

2-7 METERING.

Comply with the local utility company's metering requirements as well as the OUSD (AT&L) *Utilities Metering Policy* as detailed in the following website: (http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html) and DoDI 4170-11 Installation Energy Management.

2-8 SITE SPECIFIC DESIGN PLANNING.

2-8.1 Seismic.

Comply with UFC 1-200-01, including all referenced criteria and standards.

2-8.2 Topography.

Evaluate topography for system interferences and optimization, flood plains, and accessibility during planning, construction, and operation.

2-8.3 Site Access.

Evaluate transportation routes to site for accessibility for oversized loads and weights. Evaluate routes for impact and costs from construction traffic and loading. Ensure adequate laydown area is available during construction period and service roads to sites and supporting structures are provided.

2-8.4 Safety.

Comply with UFC 1-200-01 and UFC 3-600-01 for fire and life safety compliance.

2-8.5 Environmental.

Evaluate environmental requirements (e.g. noise, air pollution, wildlife, storm water) developed during the initial project planning stages in accordance with the National Environmental Policy Act NEPA.

2-8.5.1 Site Suitability

Confirm site is suitable for construction without major environmental impacts (e.g. are wetlands present?, is the ground contaminated?, endangered species?, etc.). If environmental concerns are present, survey and evaluate if they can be economically mitigated to meet applicable regulatory requirements.

2-8.5.2 Surveys

Field verify, through environmental, ecological, and biological surveys, that project's environmental impact will be minimal and can economically mitigated, if present.

2-8.5.3 Permitting

Once all environmental impacts have been assessed, then the actual permitting can begin. Permitting that is required by local and federal law has to address the renewable energy project construction and operational phases.

2-8.5.4 Compliance

All design and construction will provide electrical systems which must comply with Federal, State, and local environmental regulations. For overseas locations, follow the guidance specified in Host Nation-specific Final Governing Standards, or if none exists, the current DoD Overseas Environmental Baseline Guidance Document (OEBGD) and applicable Host Nation laws. For Air Force, consult AFI 32-7006 for additional guidance.

2-8.6 Environmental Studies and Permitting.

Plan for a permitting process that may take years, with duration depending upon the selected system and the locality (country, State, county and municipality) that is jurisdictionally responsible. Studies and permitting requirements exist at all levels (Federal, State, and local) and may include:

- 316(a) – Thermal discharge;
- 316(b) – Cooling water intake;
- Air permitting;
- Aquatic ecology;
- Avian and bat studies/protection;
- Cultural resources;
- Disposal (ash, slag);
- Dredge and fill;
- Encroachment;
- Erosion and sediment control;
- Floodplain management;
- Lake management;

- Land and right-of-way grants;
- Native American consultation;
- Natural resources;
- National Environmental Policy Act (Environmental Assessments (EAs), Environmental Impact Studies (EISs))
- Noise/Odor;
- River crossing permits;
- Threatened and Endangered species;
- Transmission line routing;
- Stormwater / Water quality; and
- Wetlands permitting, mitigation and design

2-8.6.1 Typical Permitting Process.

The next phase of a typical permitting process, after identifying all required permits, consists of the following six stages.

2-8.6.1.1 Stage 1 Pre-application.

Pre-application may take a few days to a year prior to filing a permit application. During this phase, developer and permitting agencies should meet to help ensure that both understand the project concept, permitting process, and possible issues. Make sure no gaps exist to minimize project schedule delays.

2-8.6.1.2 Stage 2 Permit Development and Submittal.

Complete all permit applications thoroughly, honestly, and timely. Use professional environmental consultants or attorneys if complexity of project warrants.

2-8.6.1.3 Stage 3 Application Review.

Activities vary, depending upon the agency reviewing the applications. Expect requirements for public sessions, meetings, and site visits to allow for discovery and alternative/modifications.

2-8.6.1.4 Stage 4 Decision Making.

Reviewing agencies will provide a decision with compliance requirements. This phase likely requires public hearings.

2-8.6.1.5 Stage 5 Administrative and Judicial Review.

If the decision is contested, the first avenue of appeal is administrative and it is directly to the decision maker. If the administrative appeal is not granted, the second stage is judicial review to assess if decision was fairly executed within accepted legal procedures.

2-8.6.1.6 Stage 6 Permit Compliance.

This phase is the final stage and extends throughout the project's lifetime including construction inspection and monitoring; operation; and decommissioning, to ensure project complies with all the terms and conditions of its permit and applicable laws.

2-8.6.2 Federal and State Policies and Incentives.

The DSIRE website provides a convenient source for Federal and State renewable energy policies and incentives. Review and address policies applicable to the site, and incorporate available incentives into economic analysis.

2-8.7 Industrial Control Systems and Network Risk Management.

Information systems connected to, or software loaded onto DoD information grids, must receive an interim or full authorization to operate/test prior to connection to the DoD information grid in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

2-9 COST FACTORS.

Provide project life cycle cost analysis. NREL provides summary costs charts for RPG at http://www.nrel.gov/analysis/tech_cost_dg.html. Chart data is from U.S. Department of Energy (DoE) Federal Energy Management Program (FEMP).

Note: The cost factors referenced in the NREL site are representative of an average commercial acquisition, and may not reflect the cost factors associated with Federal government acquisition methodologies.

2-9.1 System Useful Life.

Use Table 2-3 for initial planning factors and life cycle cost analysis.

Table 2-3 Renewable Power System Useful Life

Renewable Power System	Useful Life
Photovoltaic Cells	25 to 40 yrs.
Inverters	10 yrs.
Wind	20 yrs.
Biomass Combined Heat and Power	20 to 30 yrs.
Biomass Heat	20 to 30 yrs.

2-9.2 Historical Capital and Operations and Maintenance (O&M) Costs.

RPG capital, operation, and maintenance costs are highly dependent upon location and plant size. Use The NREL average Table 2-4 costs for solar, wind, and biomass combustion systems for initial cost planning purposes.

Table 2-4 NREL Distributed Generation Renewable Energy Installed Costs

	Generator Type / Size System		
	PV 1–10 MW	**Wind 1–10 MW**	**Biomass Combined Heat & Power***
Mean installed cost $/kW	$2,667	$2,644	$6,067
Installed cost Std. Dev +/- $/kW.	$763	$900	$4,000
Fixed O&M $/kW-yr.	$20	$36	$91
Fixed O&M Std. Dev. +/- $/kW-yr.	$10	$16	$33
Variable O&M $/kWh	n/a	n/a	$0.06
Variable O&M +/- $/kWh	n/a	n/a	$0.02
Lifetime yr.	33	20	28
Lifetime Std. Dev. yr.	9	7	8
Fuel or water cost $/kWh	n/a	n/a	$0.04
Fuel or water Std. Dev. $/kWh	n/a	n/a	$0.02

*Unit cost is per kilowatt of the electrical generator, not the boiler heat capacity.
Geothermal cost breakdown not available. See Appendix F for planning factors and cost models.
Costs are NREL update of August 2013.

2-9.3 Levelized Cost of Energy.

Table 2-5 illustrates projected ranges of cost to produce a MWh of energy, by generation technology/energy source, before incentives are included. Both renewable and non-renewable systems are provided as a reference. As renewable energy technologies improve, their levelized cost of energy may become very competitive with or exceed most traditional energy sources.

Evaluate and make preliminary RPG system selections based upon current energy costs, quantifiable and non-quantifiable benefits to mission, and system life cycle cost. More cost effective renewable systems may not be suitable for specific installation or mission requirements. NREL website, http://www.nrel.gov/analysis/tech_lcoe.html, provides a planning calculator for levelized cost of energy.

Table 2-5 Levelized Cost of Energy

Regional Variation in Levelized Cost of Electricity (LCOE) for New Generation Resources, On Line Starting 2020 Range for Total System LCOE (2013 $/MWh) w/o subsidies			
Plant type	**Minimum**	**Average**	**Maximum**
Renewable			
Geothermal	$ 43.80	$ 47.80	$ 52.10
Biomass	$ 90.00	$ 100.50	$ 117.40
Wind	$ 65.60	$ 73.60	$ 81.60
Solar PV	$ 97.80	$ 125.30	$ 193.30
Conventional			
Conventional Coal	$ 87.10	$ 95.10	$ 119.00
Advanced Coal	$ 106.10	$ 115.70	$ 136.10
Advanced Coal with CCS*	$ 132.90	$ 144.40	$ 160.40
Natural Gas-fired			
Conventional Combined Cycle	$ 70.40	$ 75.20	$ 85.50
Advanced Combined Cycle	$ 68.60	$ 72.60	$ 81.70
Advanced CC with CCS*	$ 93.30	$ 100.20	$ 110.80
Conventional Combustion Turbine	$ 107.30	$ 141.50	$ 156.40
Advanced Combustion Turbine	$ 94.60	$ 113.50	$ 126.80
*CCS Carbon Control and Sequestration			

2-10 FUNDING SOURCES AND ECONOMIC ANALYSIS.

DoD funding is very limited for large scale RPG. One funding program is the Energy Conservation Investment Program (ECIP). Execution is through the standard construction contract mechanisms.

Third party funding options include Power Purchase Agreements (PPA) and Enhanced Used Lease (EUL)/out grant/leases. Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs) are financed contracting options which do not require DoD funding upfront. Additionally, ESPCs provide risk mitigation through performance guarantees and contracted O&M and repair and replacement services (beyond just warranty period services) for the financed contract term up to 25 years. Energy savings in UESCs are stipulated by the Utility as well as the Government. O&M, repair, and replacement services can be included; however, the contract term is most often shorter.

2-10.1 Power Purchase Agreement (PPA).

Under a PPA, a developer typically installs a renewable energy system on agency property under an agreement that the agency will purchase the power generated by the system. However, in some cases the renewable energy system can be installed on property owned by the developer and the energy production can be delivered either behind the meter through the base distribution system or ahead of the meter through the commercial grid into the base distribution system. After installation, the developer owns, operates, and maintains the system for contract life.

2-10.2 EUL/Out Grant/Leases.

Title 10 USC § 2667, gives DoD the authority to enter into long-term and short-term leases for non-excess DoD controlled land or facilities.

Evaluate In-Kind Consideration and the Deposit and Use of Proceeds from EUL/out grant/leases in accordance with 10 USC § 2667, Office of the Under Secretary of Defense Financing of Renewable Energy Projects Policy, and other associated directives.

2-10.2.1 Energy EUL/Out Grant/Leased Facility.

An energy EUL/out grant/leased facility may be designed and operated completely independent from an installation's power grid, that is, generated energy is transmitted to the commercial grid. In this configuration, the facility is typically designed and operated in accordance with commercial specifications, agreements, and contracts between the utility and the private sector developer. The facility is not designed for Government use or occupation, so UFC compliance is limited to interoperability, safety, and security requirements.

Consideration from energy EUL/out grant/leases may include capabilities that enable installation energy security or fund specific energy initiatives. In this configuration, the facility is generally designed and operated in accordance with commercial specifications, but also includes certain interfaces with an installation's power grid. Ensure these interfaces are compatible with the paragraph titled "GENERAL COMPLIANCE REQUIREMENTS" in Chapter 1.

2-10.2.2 EUL/Out Grant/Lease Objective.

EUL/out grant/lease program's primary objective is to optimize the value of non-excess properties in accordance with Executive Order 13327, which promotes the efficient and economical use of America's real property assets. Demonstrating and documenting that a proposed out grant/lease is technically and economically viable and compliant with applicable statutory authorities is the responsibility of each Service. Economic and technical analysis, mission compatibility and other out grant/lease project specific due diligence is conducted in accordance with Service specific out grant/lease Playbooks, Instructions and Directives.

Contact Service leads for additional EUL/out grant/leased information and requirements:

- Army: http://www.nab.usace.army.mil/Businesswithus/realestate/EUL.aspx
- Air Force: http://www.afcec.af.mil/EUL/

2-10.3 Additional Cost Considerations.

Include operations and maintenance, decommissioning, and site restoration costs in economic analysis.

2-10.4 Economic Analysis.

Use UFC 3-730-01, UFC 3-740-05, applicable design agency guidance, and installation policies and procedures.

2-11 COORDINATION.

2-11.1 Office of the Secretary of Defense (OSD) Coordination.

32 CFR Part 211 requires OSD to conduct mission compatibility evaluation of proposed projects. Request a preliminary determination from the OSD Clearing House (website: http://www.acq.osd.mil/dodsc/) at osd.dod-siting-clearinghouse@mail.mil once preliminary details are available.

A formal review is mandatory for projects filed with the 49 USC Section 44718, as well as other projects proposed for construction within military training routes or special use airspace, whether on private, State, or Federal property, such as Bureau of Land Management lands. See http://www.acq.osd.mil/dodsc/ for specific data and reporting requirements.

2-11.1.1 Airspace Coordination.

Comply with UFC 3-260-01 when evaluating renewable power generation systems and equipment siting near an airfield or related facilities and equipment used to sustain flight operations. Provide applicable data items required for the OSD coordination. Submit plans to site renewable power generation systems and equipment near an airfield to the Airfield Manager and Safety Officer for approval.

2-11.1.2 Military Training Route and DoD Siting Clearinghouse.

The Military Training Route (MTR) program is a joint venture by the Federal Aviation Administration (FAA) and the DoD to develop routes for the purpose of conducting low-altitude, high-speed testing, and training activities. Improper site planning can negatively affect the MTR program. Contact the DoD Siting Clearinghouse (http://www.acq.osd.mil/dodsc/) during initial planning, and prior to applying for permits on any Federal or non-Federal lands, for project site vetting. Provide applicable data items required for the DoD Siting coordination.

2-11.1.3 FAA Requirements.

FAA requires early planning coordination for structures and assessment of glare from solar panels. For structure assessment, complete FAA Form 7460-1. Glare assessments are covered under FAA interim policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports. This interim policy requires use of the

Solar Glare Hazard Analysis Tool (SGHAT). Provide both FAA Form 7460-1 and SGHAT report to the DoD Siting Clearinghouse. SGHAT registration located at: www.sandia.gov/glare. Coordinate international sites through the DoD Siting Clearinghouse to ensure International Civil Aviation Organization (ICAO) requirements are addressed.

2-12 PROGRAMMING.

Use Table 2-6 to determine primary Category Codes for RPG projects. No geothermal Category Code currently exists.

Table 2-6 Category Codes

	PV	Wind	WTE	LFG
Air Force	811145	811146	811145	811145
Army	81122	81146	81113	81117
Navy	81150	81146	81125	81145

CHAPTER 3 DESIGN CRITERIA - PHOTOVOLTIAC (PV) SYSTEMS

3-1 INTRODUCTION.

This chapter identifies typical applications and defines the data that must be developed to establish engineering design bases, to evaluate between various solar PV designs, and ownership alternatives for utility scaled PV systems (system output greater than 1 MW).

3-1.1 Technology.

Solar PV technology generates direct current (DC) electrical power from semiconductors when they are excited by the sun. DC power is converted into alternating current (AC) through inverters and voltage stepped up for transmission.

3-2 PLANNING.

If not previously established, create an energy capacity plan covering the installation's planning vision, goals, and objectives to identify the system power and operational requirements. Coordinate plan with the system owner and utility provider to allow a comprehensive economic and site selection evaluation. Ensure economic analysis includes currently available local, state, and Federal incentives. Complete an environmental impact study to ensure project site is viable.

3-2.1 DoD Siting Clearinghouse.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

3-2.2 Climatic Zones.

Basic engineering practices governing design and construction of electrical power systems in arctic and subarctic zones will comply with agency criteria and UFC 1-200-01. Refer to UFC 3-440-05N (for Navy). For other Agencies, use UFC 3-440-05N as a reference and comply with Agency specific guidance for design and construction of electrical power systems in temperate areas.

3-2.3 Permitting.

Comply with paragraph titled "DESIGN APPROVALS AND PERMITS" in UFC 3-201-01 for permitting requirements.

3-2.4 Interconnection Analysis and Coordination.

Contact the local utility provider for utility-specific interconnection equipment and ownership requirements in the design concept stage due to utility-specific requirements. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

3-3 DESIGN CRITERIA.

Address mounting systems, solar PV modules, raceways and DC cabling, system grounding, lightning protection system, surge protection, raceway and AC cabling, metering, system criteria and selection, interconnections, warranty requirements, and site maintenance considerations in the design.

3-3.1 Structural Components.

Comply with UFC 1-200-01, including all referenced criteria and standards for all structures and structural elements, including PV array structures.

3-3.1.1 Mounting Systems.

Mounting systems are either active or fixed tracking. Select mounting system appropriate for site conditions and project requirements. Evaluate the cost verses power generation benefit of using an active tracking system over a fixed tracking system. Include initial and operation and maintenance costs in the cost analysis.

3-3.1.2 Ground Mounting.

Comply with UFC 3-301-01 for requirements related to the foundation, soil stability, and seismic analysis. Use ground mounting systems of the same manufacturer for the entire project array. The system must withstand the expected wind loads for the location. Complete an environmental impact assessment for the site. Foundation must be either concrete, concrete pad ballast, driven pile, or helical pile.

3-3.1.3 Tracking Array System.

Design for solar PV tracking system in accordance with IEC 62727.

3-3.1.4 Array Tilt Angle.

Tilt the array to the latitude plus or minus 10 degrees. It should be noted that as the tilt angle increases, the minimum spacing between rows must be increased due to shading. Do not allow inter-row shading between 9 a.m. and 3 p.m., when the bulk of the energy collection occurs.

3-3.1.5 Array Azimuth Angle.

For optimum performance, orient the module true south in the northern hemisphere and true north in the southern hemisphere; however, slightly west of south or north (azimuth angle of true south or north plus 10 degrees) may be preferable in some locations if an early morning haze or fog is a regular occurrence. Design the array's azimuth angle off of due south or north as coordinated with the Basis of Design.

3-3.1.6 Site.

Account for shading, grounds maintenance requirements, and winter snow levels when determining mounting heights, spacing, and ground cover. Closed landfill sites require non-penetrating foundations to avoid breaching cap.

3-3.2 Direct Current (DC) System Components.

3-3.2.1 Solar PV Module.

Conform to UL 1703 and IEC 61215 for crystalline types, or IEC 61646 for thin film types. Require submission of manufacturer's guarantee on backsheet and encapsulant construction. Select one commercially-available PV module type based on life cycle cost analysis, required energy production, site location environmental conditions, space available, and maintainability.

3-3.2.2 Solar PV Array.

Comply with National Fire Protection Act (NFPA) 1 for array arrangement requirements.

3-3.2.3 Raceway and DC Cabling.

Provide UL 4703 listed PV wiring. Comply with UFC 3-501-01 for requirements related to raceway and DC cabling sizing.

3-3.2.4 Combiner Box.

Provide UL 1741 listed combiner box.

3-3.2.5 DC Switching.

If stand-alone unit, DC disconnect switches must conform to UL 98 or UL 98B. Rate switch for maximum system voltage and maximum system continuous and short circuit currents. If combined with inverter, refer to paragraph entitled "Inverter" for guidance.

3-3.2.6 Inverter.

Conform to UL 1741, comply with IEEE 1547 and NFPA 70, and be identified for use in solar PV power systems for allowance of monitoring. The selection of inverter type, i.e. central, micro-inverter, or string inverter, will depend on the system size, budget, and site-specific parameters. Consider use of inverters with integral medium voltage transformers. Place inverters in location to allow for adequate air circulation. Where possible, employ maintainable design practices when selecting number of inverters for project to prevent the failure of one inverter from affecting the entire system. Limit inverter sizes to 750 kW maximum, with a minimum 95% efficiency.

3-3.3 Alternating Current (AC) System Components.

3-3.3.1 Transformer.

Provide transformers in accordance with IEEE Std 1547 and NFPA 70. Provide primary and secondary over-current protection in accordance with NFPA 70. Refer to UFC 3-520-01 and 3-550-01 for additional requirements. Use USACE ETL 1110-3-412 (Army only) as a reference for the selection and application of transformers and dielectrics. Ensure transformer and separately derived systems installation strictly comply with NFPA 70, Article 250.

3-3.3.2 Raceway and AC Cabling.

Provide UL 4703 listed PV wiring. Raceway and AC cabling sizing must conform to UFC 3-520-01 and NFPA 70. Install all cabling in raceways unless specifically indicated otherwise.

3-3.3.3 AC Switching.

Rate switch for maximum system voltage and maximum system continuous and short circuit currents. If stand-alone unit, AC disconnect switches must conform to UL 98 or UL 98B. If combined with inverter, refer to paragraph entitled “Inverter” for guidance.

3-3.3.4 Metering.

Coordinate revenue metering requirements with the utility provider and DoD installation regarding interconnection-specific data and guidelines. Coordinate with Activity and utility provider for requirements and plan of action to manage excess energy, including the utilization of net metering.

3-3.3.5 System Monitoring.

Provide system monitoring in accordance with IEC 61724. Provide features to transmit real time system and status data to an energy information system (via network system assets or cellular technology).

3-3.4 Grounding and Lightning Protection.

3-3.4.1 System Grounding.

Grounding is a common system failure point. Strictly comply with UFC 3-550-01, NFPA 70, and IEEE C2 for requirements related to general system grounding.

3-3.4.2 Lightning Protection System.

Provide surge protection in accordance with NFPA 780. Comply with UFC 3-520-01 for requirements related to providing a lightning protection system. Provide side flash calculations as required by NFPA 780.

3-3.4.3 Surge Protection.

Provide surge protection devices for all systems identified in NFPA 780 and UFC 3-575-01. Show location of all surge protective devices on drawings.

3-3.5 Climatic Considerations.

Design system to operate under the location's maximum and minimum documented temperatures during summer and winter. Account for snow depths and known snowdrift patterns when determining locations and mounting heights in Snowbelt locations.

3-3.6 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

3-4 OPERATION AND MAINTENANCE.

Maintenance considerations consists of two categories: scheduled/preventive maintenance and unscheduled maintenance/troubleshooting. Treat solar PV equipment with the same caution and care as regular electrical power service equipment. Comply with the requirements of UFC 3-560-01 and manufacturers' documentation, as required. Refer to Appendix E for additional O&M guidance.

3-4.1 Preventive Maintenance.

Preventive maintenance scheduling and frequency is dictated by a number of factors including, but not limited to, technology selected, site environmental conditions, warranty terms, and seasonal variances. Conduct scheduled maintenance at intervals in accordance with the manufacturers' recommendations, as required by equipment warranties, and at times to reduce production impacts.

3-4.2 Unscheduled Maintenance.

Unscheduled maintenance, or troubleshooting, is carried out in response to equipment failures. Refer to manufacturer's system documentation for troubleshooting steps for the failed components.

It is important to maintain an adequate supply of spare components in stock to facilitate rapid response times. The number of required spares depends on the system size, site-specific parameters, parts availability, budget, and desired system availability (reliability).

3-4.3 Safety.

Comply to applicable provisions in 29 CFR 1910, 29 CFR 1925, and 29 CFR 1926, and local/agency codes and requirements.

3-4.4 Warranty.

Specific system components warranties vary by manufacturer. PV module warranty typically ranges from 5-10 years with top brand providing 20 to 25 year warranty. Performance warranty is based upon minimum continuous power output of 80 percent at typically 20 years. Inverter warranties average from 5-10 years, dependent upon manufacturer and technology. PV mounting system warranty typically varies between 5-10 years.

Require a minimum of a five (5) year Contractor parts and labor warranty for component failure due to workmanship, defective components or assemblies on the entire solar PV system, regardless if the component manufacturers are still in business or not. Include warranty costs in the economic analysis.

3-4.5 Security.

Comply with UFC 4-010-01 and UFC 4-020-01 for security concerns, theft and vandalism protection, and unauthorized area entry.

CHAPTER 4 DESIGN CRITERIA – WIND SYSTEMS

4-1 INTRODUCTION.

This chapter presents the planning, design, and O&M requirements for renewable energy produced by a wind driven utility scaled (greater than 1 MW total output) horizontal axis wind turbines (HAWT).

4-1.1 Technology.

Two primary wind turbine configurations exist: HAWT and vertical axis wind turbine (VAWT).

4-1.1.1 HAWT.

HAWT configuration has the rotor blades' plane perpendicular to the wind direction and with the axis of main rotor shaft rotation lying in the horizontal plane. HAWTs are the most widely used turbine technology utilized in the world.

HAWT systems with a minimum of three (3) years of proven commercial power generation are generally approved for use in the DoD for utility-scaled power generation.

4-1.1.2 VAWT.

VAWT configuration has the main rotor shaft axis of rotation lying in the vertical plane. VAWTs have minimal utility-scale power generation history.

VAWTs are not approved for use in the DoD for utility-scaled renewable power generation.

4-1.2 Application.

Large commercial and utility-scale wind turbines (0.5 - 7.5 MW) are generally grouped in wind 'farms' for producing power plant scale energy for sale. The increased efficiency and high availability rates for these systems allow for cost-competitive electricity generation. Due to the height, size, and land requirements for utility-scale wind power generation, projects require extensive environmental, utility, and public coordination, detailed site resource assessments, legal and financial due diligence, utility integration, and financial analysis planning before project execution.

4-2 PLANNING.

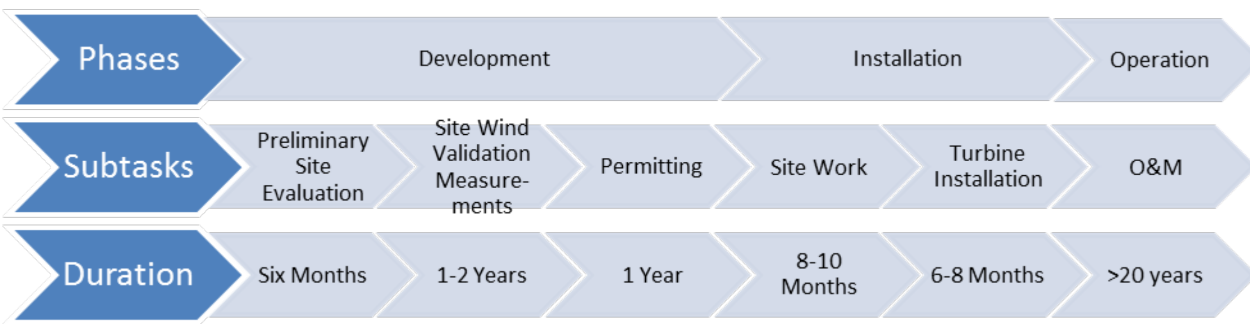
4-2.1 DoD Siting Clearinghouse.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

4-2.2 Wind Farm Project Development.

ASCE/AWEA RP2011 provides a planning flow chart for a typical commercial wind farm project, from initial site evaluation through operation that will aid wind farm planners. A wind farm project may take up to four years from concept to full production. Figure 4-1 provides typical project timeline.

Figure 4-1 Wind Turbine Typical Project Timeline



4-2.3 Site Selection.

4-2.3.1 Adequate Wind Resources.

DoE Energy Efficiency & Renewable Energy (EERE) web site provides utility scale wind resource maps. Use the 260 ft. (80 m) wind resource map for initial planning considerations for commercial power generation. Localized site data is also available from commercial sources. Once initial planning indicates viable wind resources are available, a site-specific wind study is required to categorize wind energy characteristics for feasibility analysis.

4-2.3.2 Transmission Lines.

Perform transmission study to evaluate, as a minimum, line proximity, available line capacity, reliability, and connection costs. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

4-2.3.3 Site Footprint.

Use Table 2-2 for initial site size planning factors. Turbine(s) layout depends upon site’s topography, site boundaries, exclusion zones, and setback/buffer zones. Layouts are typically either linear (single or multiple strings, or parallel) or clustered. Wind turbines are typically not sited within five (5) rotor diameters of each other. Require computational optimization of turbine layout, as a little as 1% improvement in efficiency provides a significant long-term energy production benefit.

Account for acreage required for short-term (construction) and long-term (operations). Identify and address staging and lay down areas and impacts during planning. Estimate short-term site impact as twice the acreage as the final operation area boundaries. Identify final site layout to include operational areas, exclusion zones, safety zones, and buffers.

4-2.3.4 Site Access.

Account for the construction access for heavy and long/oversized loads. Perform delivery route analysis for roads, bridges, underpasses, inclines/declines, and overhead utilities.

4-2.4 Wind Assessment.

Perform a two-phase site wind assessment: 1) preliminary evaluation using historical data and 2) site specific analysis using meteorological towers to collect wind direction, speeds, and frequencies. If commercial financing is being sought for the project, an investment grade wind resource study is required to establish the quality, reliability, and value of the wind resource. Wind resource assessment guidance including a Wind Resource Assessment Handbook is available at the following National Renewable Energy Laboratory (NREL) website:
http://www.nrel.gov/wind/resource_assessment.html

4-2.4.1 Historical Data.

Historical wind data is available from NREL and commercial sources. Use historical data to perform preliminary site assessment. Sites with greater than 6 meters per second (m/s) average wind speed are considered viable.

4-2.4.2 Site Assessment.

Once site passes preliminary assessment using historical data, perform site specific wind analysis using meteorological towers. Quality of wind depends upon turbine location with respect to plains, buttes, ridges, facilities, and general topography roughness on the turbine’s windward site. If site topography varies significantly, more than one meteorological tower may be required to adequately characterize site’s wind potential. Perform site assessment for at least one year to account for seasonal changes.

Collect wind speed and direction using anemometers and wind vanes. Place sensors two or three heights (two anemometers and one vane per height) on the tower. Place top sensors as close to projected turbine hub height as possible to ensure more accurate power estimates. Use booms for sensors to reduce tower wake effects on wind data. Collect average wind speed and direction at 10-minute intervals.

4-2.4.3 Site Energy Projections.

Site wind speeds, frequencies, directions, and durations are utilized to generate power projections. Use collected wind data to generate site power production projections using specific wind turbines' power curves.

4-2.5 Community Concerns.

Early community involvement is critical for project success. Typical community concerns include generated sound, visual impacts to include blade flicker (shadows), and increased traffic during construction. Initiate a community outreach program early in the planning stage to ensure community concerns and requirements are known and mitigated early in the program development.

4-2.5.1 Sound.

The dominant noise-generating component of large-scale wind turbines is aerodynamic. Conduct baseline and predictive noise studies to generate maps of isophones to determine potential mitigation areas and for community discussions. Follow IEC 61400-11.

4-2.5.2 Visual.

Installation of 260 ft. (80 m), or higher, wind towers will change the site and surrounding areas visual aspect. Conduct a Zone of Visual Influence Study to calculate where the wind farm will be visual and to what extent. Conduct Worst-Case Scenario Study for shadow fluttering on surrounding occupied structures and active roadways. Mitigate negative findings by adjusting turbine siting, diameter, or height. Use studies to articulate impact with community and to analyze mitigation actions.

4-2.5.3 Traffic.

Construction and materials movement will affect local communities. Coordinate with local communities on routes, impacts, and timing.

4-2.6 Environmental.

4-2.6.1 Endangered Species.

Evaluate site for seasonal and year-round endangered species. Address and implement mitigation actions. Obtain permits and authorizations required under the Endangered Species Act of 1973 for activities that may take native threatened or endangered species. Contact nearest U.S. National Fish and Wildlife Service (USFWS) Ecological Services Office and determine if the proposed project is likely to result in "take," whether a permit is required, and if other options are required to be considered.

4-2.6.2 Avian and Bat Studies.

Conduct avian and bat study for projected impacts. Address recommendations and implement mitigation actions.

4-2.6.3 Historical, Cultural and Archeological Studies.

Evaluate site for historical, cultural, and archeological aspects. Address findings and implement mitigation actions.

4-2.6.4 Wetlands Reviews.

Conduct wetland reviews. Address findings and implement mitigation actions.

4-2.7 Federal Aviation Administration Coordination.

4-2.7.1 Flight Path Concerns.

The FAA has legal jurisdiction over structures 200 ft. (61 m) tall and above. Additionally, structures less than 200 ft. (61 m), but within 20,000 ft. (6 km) of a runway, may still penetrate navigable airspace. FAA evaluation starts with submitting FAA Form 7460-1. The FAA will issue either a Determination of No Hazard, or a Determination of Presumed Hazard, which may initiate a process of negotiation and appeal.

4-2.7.2 Radar Concerns.

Static electricity generated by the blades moving through the air may create radar 'blind spots.' The OSD and U.S. Air Force coordination with the FAA will analyze the site for conflicts and mitigation requirements, if required.

4-2.8 Interconnect Studies.

Designer must perform interconnect studies. Refer to Chapter 8 titled "UTILITY INTERCONNECTION" for guidance.

4-2.9 Permitting.

4-2.9.1 Land Use Permits.

Coordinate with OSD Clearinghouse and Bureau of Land Management for public lands, and State environmental and energy planning offices for land use permits.

4-2.9.2 Building Permits.

Comply with applicable city/State / Federal for building permits requirements.

4-2.9.3 Incidental Take Permit.

Obtain Incidental Take Permit in accordance with 50 CFR Part 13 and 50 CFR Part 17.

4-2.10 Economics.

4-2.10.1 Power Projections.

Require developer to provide life cycle power projections based upon site specific resource conditions, and turbine manufacturer and model.

4-2.10.2 Rate Structures and Terms.

Coordinate with local power company and ISO/RTO for installation site rate structures. Engage the following offices for utility term negotiations:

- U.S. Air Force: U.S. Air Force Civil Engineer Center, Energy Directorate (AFCEC/CN).
- U.S. Army: U.S. Army Engineering and Support Center, Huntsville, Energy Division, Commercial Utilities Program.
- U.S. Navy: Naval Facilities Engineering Command Headquarters, Public Works Business Line, Utilities and Energy Management, Washington Navy Yard, Washington, D.C. (NAVFAC HQ PW UEM).

4-2.10.3 Project Costs.

Installed costs fall under three categories, turbine cost, soft costs, and balance of station costs. For preliminary project estimation, use values in Table 2-4 and use the percentages in Figure 4-2 to estimate sub-factor capital costs.

4-2.10.4 Operations and Maintenance Contracts.

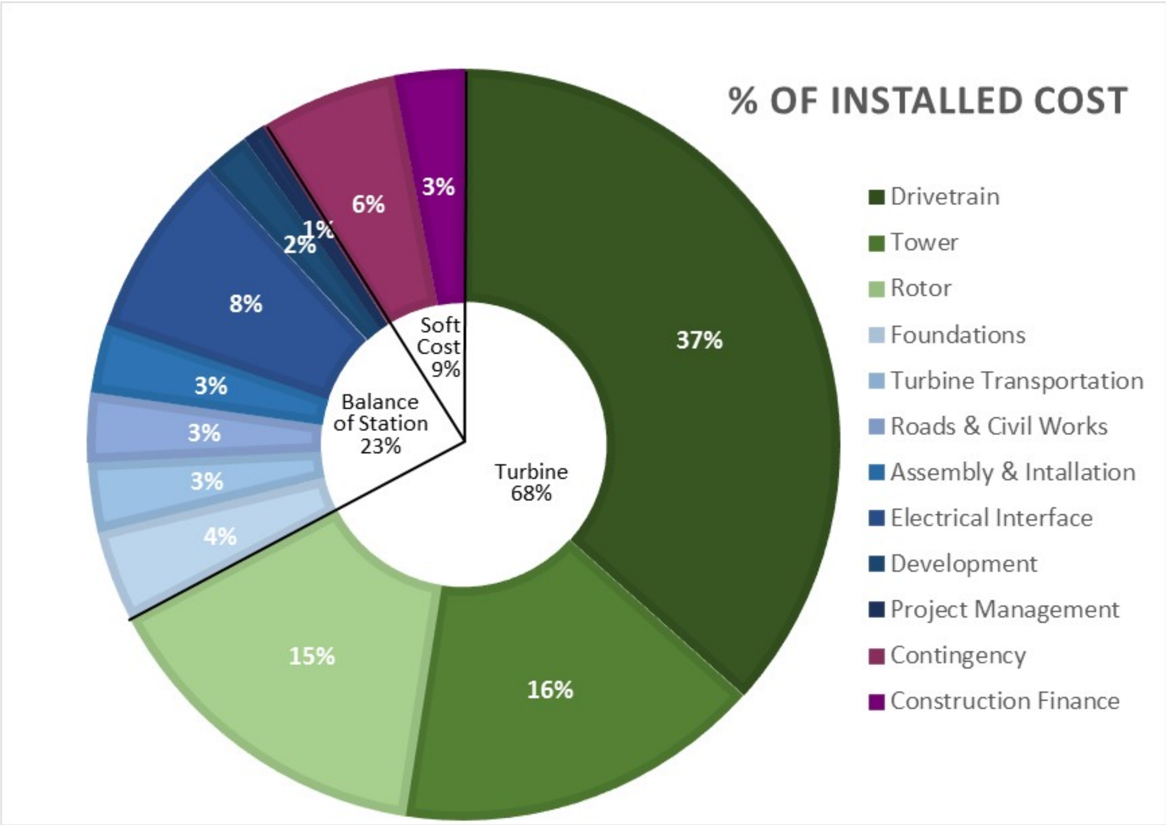
Use American Wind Energy Association's *Operations and Maintenance Recommended Practices* for O&M requirements in contract statement of works and basis for cost estimation.

4-2.10.5 Extended Warranties.

Estimated economical life of wind turbines is 20 years. Perform cost/benefit analysis to obtain extended equipment warranties versus cost of O&M contracts for the period between the standard warranty and the extended warranty.

Note: At end-of-life, wind turbines may be decommissioned and site restored; components refurbished; and/or replaced with new turbine systems, depending up economics and available technology. As a minimum, use similar end-of-life scenarios to determine economic differences between the selected options in the economic analysis.

Figure 4-2 Land Based Wind Turbine Systems Installed Capital Costs (AWEA)



4-3 DESIGN CRITERIA.

Primary wind industry design standards are codified under the International Electrotechnical Commission (IEC) IEC 61400 series. A lead wind association assisting in codifying U.S. standards is the American Wind Energy Association. Review both resources for current design requirements.

4-3.1 Wind Turbine System.

4-3.1.1 Classes.

Comply with IEC 61400-1. Table 4-1 represents IEC 61400-1 wind turbine classifications data. A class IIB wind turbine, for example, is designed for average wind conditions, at hub height, for 95 mph (42.5 m/s) with medium turbulence characteristics. Designer of Record to select the wind turbine class based upon site conditions.

Table 4-1 Wind Turbine Classes

Wind Turbine Class	I	II	III	S
Average wind speed over 10 minutes at hub height.	50 m/s (112 mph)	42.5 m/s (95 mph)	37.5 m/s (84 mph)	Values specified by designer
	Expected turbulence intensity at 15 m/s (33 mph)			
A – high turbulence characteristics	0.16			
B – med turbulence characteristics	0.14			
C – low turbulence characteristics	0.12			

4-3.1.2 Design Life.

Require wind turbine design lifetime for a minimum of 20 years.

4-3.1.3 Components.

Evaluate during site planning phase the individual wind turbine component shipping, site access, and lay down area requirements. Common blade lengths range from 100 – 165 ft. (30 – 50 m) long. Towers range from 195 – 260 ft. (60 – 80 m) high, but are typically shipped in three sections. Component lengths will eliminate certain road access routes. Heavy components, such as hubs which weight from 7 – 20 tons (6,350 – 18,147 kg), may eliminate bridge or road routes due to weight limits.

4-3.1.4 Structural Design.

Structural design, including foundations, to comply with ASCE/AWEA PR2011, as updated.

4-3.2 Electrical.

Figure 4-3 diagramically presents a wind farm electrical system and connection to transmission grid. Comply with current editions of UFC 3-501-01 and UFC 3-550-01. Comply with Chapter 8 titled “UTILITY INTERCONNECTION” and coordinate electrical system with host utility provider.

4-3.2.1 Grounding.

Comply with NFPA 70.

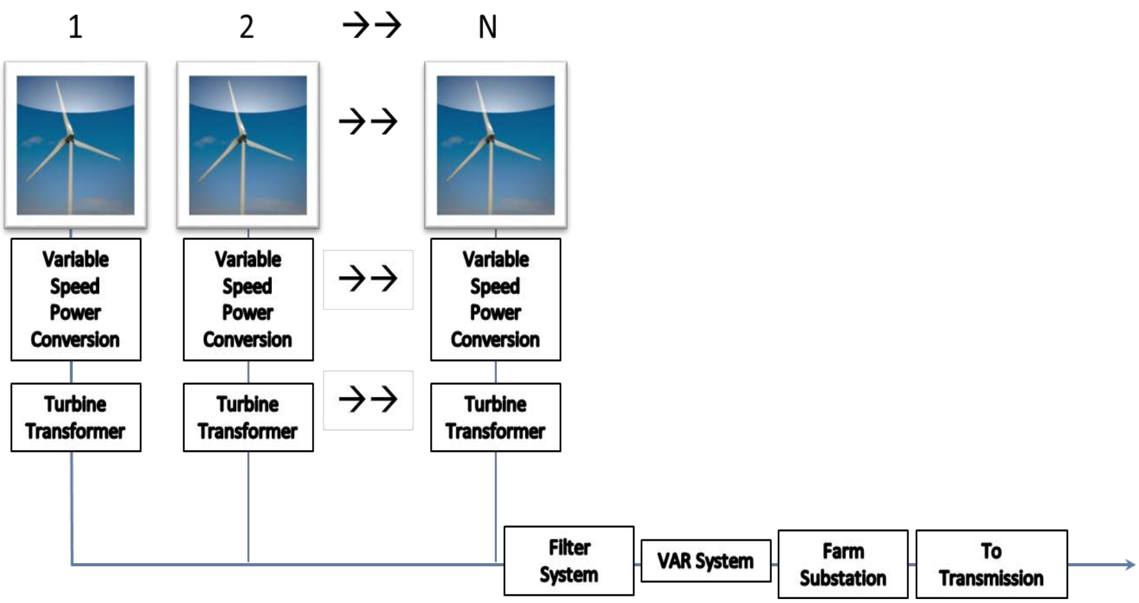
4-3.2.2 Lightning Protection.

Comply with IEC 61400-24 and NFPA 780.

4-3.2.3 Interconnection.

Comply with Chapter 8, titled “UTILITY INTERCONNECTION,” IEEE 1547, and IEEE 519.

Figure 4-3 Illustrative Wind Farm Components



4-4 OPERATIONS AND MAINTENANCE.

4-4.1 Contract Based Operations and Maintenance.

O&M service contracts starts after the warranty period expires and are typically based upon a system operating life of 20 years. Contracts are based on either time (e.g. years) or amount energy produced. Address site and equipment O&M requirements and ensure O&M is available at turbine startup, either by warranty contract or by service contract. Appendix E provides additional O&M guidance.

Comply with specific turbine manufacturer’s recommendations. Use predictive maintenance on high value components, such as yaw and pitch systems, gearbox, and generators. Perform annual infrared study on mechanical and electrical components. Use preventive maintenance on remaining components, such as structures and supporting infrastructure.

4-4.1.1 Turnover Inspections.

Perform a turnover inspection a minimum of three (3) months prior to warranty ending to identify and resolve warranty-based issues. Minimum inspection requirements include:

- Visual structural and component inspection;

- Qualitative checks on items such as bolting torque settings, component oil leaks, pitch linkage wear, cable routing, electrical terminations and installed safety equipment;
- Gearbox vibration monitoring;
- Oil sampling and analysis;
- Site-wide infrared analysis;
- Review of all service reports and parts usage during the warranty period; and
- Perform condition baseline inspection at start of O&M contract.

4-4.1.2 Monitoring.

Require 24-hour remote monitoring of wind turbine systems to include predictive maintenance sensors for key attributes, e.g. rpm, wind speeds, blade positions, vibration, temperature, fluid levels, power output.

4-4.2 Safety.

Establish safety and response plans for the following items:

4-4.2.1 Solid and Hazardous Wastes.

Address the transportation, handling, storage, and disposal of hazardous materials to and from site.

4-4.2.2 Ice Shedding.

Provide ice detection and shutdown response to reduce ice projection and blade imbalance. Conduct ice throw risk assessment to identify potential risks. Provide warning signs in impact zones to alert operational personnel of potential of falling ice.

4-4.2.3 Blade Failure.

Provide warning signs for potential blade impact zones, in case of a catastrophic blade failure.

4-4.2.4 Fire.

Create fire response plans and provide close coordination with and training for local firefighters. Train all on-site personnel on fire and emergency response plans. Adhere to regular and appropriate maintenance schedules.

4-4.2.5 Lightning Strikes.

Adhere to safety protocols including stopping work when thunderstorm warnings or watches are issues. Require annual training on awareness and evacuation procedures.

Identify site designated shelter and provide lightening prediction and warning system, with communications, to maintenance team.

4-4.2.6 Worker Fall Protection.

Compliance with work fall protection standards is critically important due to wind turbine heights and operating environment. Comply with applicable 29 CFR 1910 and 29 CFR 1926 standards. Primary fall standards include 29 CFR 1910 Subpart D; 29 CFR 1910 Subpart I; 29 CFR 1910.269(g), 29 CFR 1926 Subpart E, 29 CFR 1926 Subpart M, and ANSI Z359.

4-4.3 Non-Performance.

Ensure non-performance and remedy clauses are in maintenance contract to address non-conformance. Ensure liquidated damages address power generation revenue loss and mission impacts.

4-4.4 Warranties.

Typical wind turbine installation warranties are for two to five (2-5) years, followed by a service contract modeled on an operating life of 20 years.

Specific component warranties will vary with manufacturer. Warranties are typically limited to repair or replace, at manufacturers' discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages. If warranty does not include O&M requirements, ensure O&M contract is in place once turbine is operational.

4-4.5 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

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CHAPTER 5 DESIGN CRITERIA – BIOMASS SOLID WASTE TO ENERGY SYSTEMS

5-1 INTRODUCTION.

Solid Waste to Energy conversion is a biomass process that converts solid waste into various forms of fuel that can be used to produce thermal and electrical energy.

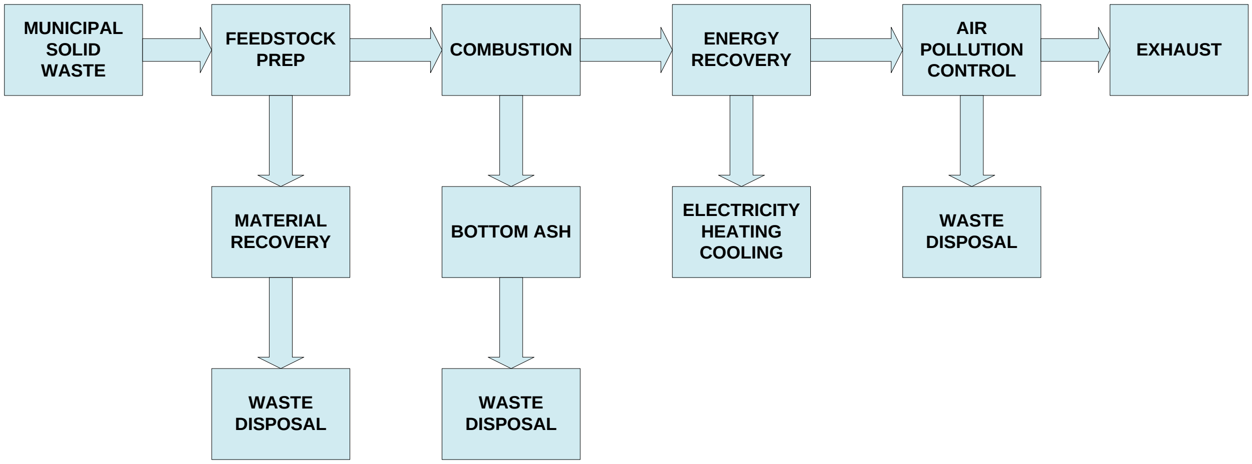
This chapter establishes the requirements for thermal conversion of solid waste to generate steam and produce electricity using combustion of municipal solid wastes in what is described as a mass burn, water wall plant.

5-1.1 Technology.

The predominant large solid waste combustors technology is the Mass Burn / Water Wall type combustor. In this type system, minimum or non-processed waste is delivered by overhead crane into the furnace through a feed hopper that uses hydraulic rams and reciprocating or roller grates.

The mass burn thermal conversion process is depicted in Figure 5-1. The mass burn plant is a direct combustion process for producing heat, electrical power, combined heat and power, or combined heat, power and cooling. The solid waste is delivered to the plant where it is prepped for feedstock by removing recyclable and hazardous materials. The feedstock is then burned with the ash being sent to waste disposal and the heat being recovered for generation of electricity, steam or high temperature hot water, and in some plants, chilled water using adsorption chiller units. The flue emissions are processed through air pollution control (APC) equipment with removal of toxic gases, acids, and particulate matter then exhausted from the plant.

Figure 5-1 Mass Burn Process of Solid Waste to Energy



5-1.2 Application.

Mass burn solid waste to energy plants require a large and continuous source of municipal waste, a large land area with access to water, sewer and natural gas, and proximity to utility transmission lines. Locate plant near large town or city industrial areas. Extensive environmental studies and permitting are required as well as extensive utility and public coordination. These plants are best suited for a municipal and utility partnering agreement using a design-build-operate contractor approach.

5-2 PLANNING.

The planning section identifies biomass technology unique planning requirements including determining the energy recovery potential, complying with environmental regulations and restrictions, and permitting.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

5-2.1 General Requirements.

Design and operate facility to cost effectively maximize power generation and district heating (if available) capacity. The fuel supply is from municipal solid waste delivered by solid waste haulers and self-haulers. 10 USC 2692 restricts the types, storage, and use of non-DoD materials, and may affect projected fuel supply. Design facility for 24 hour/365 day operation at maximum continuous rating and at maximum continuous turndown for extended time without supplemental natural gas fuel firing. Design facility life for thirty (30) years.

Provide appropriate redundancy in the chute to stack, furnace/boilers, turbine-generators, steam distribution, electrical switchgear and transformation, pollution control, and other equipment, to minimize unscheduled outages. Provide normal and emergency power systems, with the facility being self-powered during operations except in emergencies and start up conditions. Provide natural gas supplementation for boiler system start up and maintenance heating.

5-2.1.1 General Development Plan.

Prepare a general development plan for the project life cycle. Include the following phases as a minimum: feasibility, design, construction, operation, and decommissioning.

5-2.1.2 Site Planning and Development.

Use UFC 3-240-05A, Chapter 2 (for Army), and UFC 3-430-02FA, Chapter 2 (for Army/Air Force), for general site planning and development. *Note: Navy to use UFC 3-*

240-05A and UFC 3-430-02FA as reference only. Follow local shore installations planning guidance. Consider Table 5-1 during site planning evaluation:

Table 5-1 Plant Site Planning Considerations

Area	Consideration
Zoning	• Use local land use planning and zoning regulations in siting plant. • Plant should be located in a heavy industrial area, preferably close to existing power plants. • Locate plants in open areas where flue emissions are not trapped by terrain or wind patterns and the emissions are not prone to create smog. • Locate plant away from airfields and flight paths to accommodate the flue stack(s).
Economics	• Plant should be within economic range for transfer or waste truck delivery. • A properly designed and operated landfill for disposal of ash and waste residue must be within plant economic range. • Plant should be located in proximity to the waste generation area. • If supplying district heating or cooling, locate plant in economic proximity to existing district heating/cooling supply and return mains.
Infrastructure	• An adequate source of water must be available for plant operations. • Natural gas must be available for furnace starting and boiler operation in the event of a solid waste fuel interruption. • Municipal sanitary sewer should be nearby to receive the wastewater discharge polluted by waste storage liquids, slag cooling, and flue gas cleaning system. • Electrical power transmission lines and available right of ways should be nearby to connect the plant to the electrical network without high construction costs.

5-2.2 Critical Criteria.

The following criteria are critical to the municipal solid waste to energy plant planning:

5-2.2.1 Energy Recovery Potential Assessment.

Use the NREL Renewable Energy Optimization (REO) tool to model the energy generation and costs in the project defined location. Use the U.S. EPA – Research Triangle Institute (RTI) International Municipal Solid Waste Decision Support Tool (MSW-DST) (https://mswdst.rti.org/) to conduct a comprehensive energy, environmental impact, and cost model for the determining the preliminary energy recovery potential and life cycle cost analysis. Develop model based upon waste generation from residences, multi-family residences, and commercial entities.

5-2.2.2 Local Conditions / Existing Waste Management Practices.

Conduct a waste survey and forecast to establish the expected amount and composition of waste generated during the facility lifetime using the RTI MSW-DST. Assume a 30 year life cycle period.

5-2.2.3 Waste Physical and Chemical Characteristics.

Solid waste used for fuel includes Municipal Solid Waste (MSW) per 40 CFR Part 60.51b. The average lower calorific value of waste must not be less than 3,000 Btu/lb (7 MJ/kg). If actual MSW caloric value not known, use an aggregate heating value of 5,000 Btu/lb (11.6 MJ/kg) for fuel energy calculations. MSW with higher caloric values reduces the volume necessary for same unit of energy produced. Evaluate other non-MSW combustible solid waste streams as a fuel source, as permitted. Consider the following solid waste streams in planning and characterization:

- Wood pallets, clean wood, and land clearing debris;
- Packaging materials;
- Clothing materials; and
- Rugs, carpets, and floor coverings except asbestos materials.

Some solid waste, other than MSW, may be allowed in a limited segregated burn scenario, if authorized by State and Federal permits. Consider the following solid waste streams in planning and characterization:

- Waste tires;
- Construction debris;
- Waste oil and waste oil products; and
- Human and animal processed product waste (e.g. foodstuff, personal care products, pharmaceuticals, cosmetics, cleaners, detergents, waxes, etc.).

5-2.2.4 Prohibited Materials.

10 USC 2692 restricts types and use of non-DoD materials. Design and operate plant to prevent combustion of:

- Materials prohibited by State and Federal laws;
- Hazardous waste;
- Nuclear and radioactive waste;
- Explosives;
- Sewage sludge;
- Biomedical and biological waste;
- Waste containing beryllium (40 CFR Part 61, Subpart C);
- Waste containing mercury;
- Lead acid batteries;
- NiCad batteries; and
- Pressure treated wood.

5-2.2.5 Seasonal Fluctuations in Waste Quantity and Quality.

Design plant systems to account for seasonal fluctuations in waste quantities and quality.

5-2.2.6 Treatment of Rejects / Effluents.

Provide for treatment/re-use of liquid rejects / effluents from APC process wastewater, other process wastewater (boiler feed, blowdown, and bottom ash system), sanitary sewer, storm wastewater, and cooling towers. Evaluate and implement as appropriate the following best available technologies: on-site physical/chemical treatment; re-circulation of wet scrubber effluent; effluent flow buffering and storage; scrubber dioxin and furan breakthrough control; and ammonia stripping.

5-2.3 Environmental Regulation and Restrictions.

5-2.3.1 General.

Comply with UFC 1-200-01 and agency specific environmental regulations, restrictions, and specific applicable environmental guidance. In addition to Federal regulations, State and local municipality regulations may require permits, licenses, and approvals for construction and operation. Identify and compile these regulatory items and documentation requirements during the mass burn plant design, construction, and operation.

5-2.3.2 Air Quality Regulations.

A mass burn plant is subject to multiple provisions of the Clean Air Act of 1990. Comply with the two main provisions applicable to mass burn plants including Section 129 Solid Waste Combustion and Section 165 Pre-Construction Requirements. The mass burn plant will be designed to satisfy all emission requirements of 40 CFR Part 257 and 40 CFR Part 60.

5-2.3.3 Water Quality Regulations.

Design and operate the plant to ensure surface water is not polluted in accordance with the Water Pollution Act of 1956 or the Clean Water Act of 1990. Design and operate the plant to ensure ground water is not polluted in accordance with the Clean Water Act of 1972 and 40 CFR Part 257.

5-2.3.4 Solid Waste Disposal Regulations.

Limit ash emissions to not to exceed 5%, as determined by EPA Reference Method 22 per 40 CFR Part 60.

5-2.4 Interconnect Studies.

Perform interconnect studies. Refer to Chapter 8 titled "UTILITY INTERCONNECTION" for guidance.

5-2.5 Permits.

Obtain pre-construction and operating permits required to ensure facilities comply with applicable Federal, State, and local laws to ensure the facilities operators and public health and safety protection, to prevent and reduce polluting the environment, and to protect endangered species. In addition to the listed permitting activities herein, contact the state and local environmental and development offices to verify additional permitting requirements.

5-2.5.1 Environmental Impact Statement.

Perform a project Environmental Impact Statement / Environmental Assessment.

5-2.5.2 Air Permits.

Obtain State and local permitting as required under 40 CFR Part 70. For states that have not been granted full approval authority under 40 CFR Part 70, Indian country, outer continental shelf areas, and other areas/authorities not covered by 40 CFR Part 70, permitting is required under 40 CFR Part 71.

5-2.5.3 Wastewater Discharge Permits.

Waste Water or Stormwater Permit. Obtain a National Pollutant Discharge Elimination System (NPDES) permit in accordance with the Clean Water Act.

Solid Waste Disposal Permit. Regularly sample and test the mass burn solid waste ash and other residues in accordance with permit requirements to determine if ash is hazardous waste. Hazardous material and hazardous waste ash must be disposed of as hazardous waste in accordance with the Resource Conservation and Recovery Act (RCRA) and 40 CFR Parts 266-273.

5-2.5.4 Dredge and Fill Permit.

Structures or work affecting the course, condition, location, or capacity of navigable waterways or wetlands requires a Department of the Army Permit from the United States Army Corps of Engineers (USACE).

5-2.5.5 Haze and Visibility / Prevention of Significant Deterioration (PSD).

Consultation and agreement with U.S. Department of Interior - National Park Service and USFWS, and U.S. Department of Agriculture - National Forest Service Federal Land Manager(s) is required if plant is located within 185 mi (300 km) of a Class I area in accordance with 40 CFR Part 81.

5-2.5.6 Incidental Take Statement / Permits.

Obtain permits and authorizations required under the Endangered Species Act of 1973 for activities that may “take” (kill) native threatened or endangered species. Contact the nearest USFWS Ecological Services Office and determine if the proposed project is likely to result in a take, whether a permit is required or if other options require consideration. Obtain an Incidental Take Permit in accordance with 50 CFR Part 13 and 50 CFR Part 17.

5-2.5.7 FAA Permit.

Comply with 14 CFR Part 77 and file a Notice of Proposed Construction or Alteration with FAA.

5-2.5.8 Other State and Local Permits.

Contact State and local environmental, development, and transportation offices for construction and operating permits for the following:

- Boiler / pressure vessel;
- Elevator and kindred equipment;
- Oversize/overweight vehicles;
- Highway construction;
- Land use; and
- Historic sites review.

5-2.5.9 Permits.

Coordinate and obtain utility permits for water, sanitary sewer, fuel gas, and electric utilities.

5-2.6 Cost Estimation / Analysis.

Use the MSW-DST to provide a screening level cost and a report of environment aspects for the proposed waste to energy plant.

5-2.6.1 Capital Costs.

Use capital cost data from the U.S. Energy Information Administration for initial capital cost estimates. Capital costs to include the total investment costs for equipment, construction, and engineering, for the plant, electrical grid connection, roads, utilities, and new infrastructure to support the plant.

5-2.6.2 Operation and Maintenance Costs.

For initial planning, calculate fixed O&M and variable O&M costs using O&M cost data from the U.S. Energy Information Administration.

5-2.6.3 Sale of Energy.

Include the sale of energy from the plant in the economic analysis. The income includes the sale of electricity and, where district heating is available, can include the sale of steam or high temperature hot water.

5-2.6.4 Sale of Materials Recovery.

Include in the economic analysis the potential value of selling recovered materials. As a minimum, include ferrous and alumina recovery.

5-2.7 Coordination.

Establish an institutional framework consisting of the four major project stakeholders of government authorities, waste sector companies, community groups, and energy sector companies. Review with the stakeholders the financial, environmental, and waste flow issues. Perform a comprehensive stakeholder analysis for both the existing waste disposal and future waste to energy plant. Establish agreements that resolve issues before the plans are made to build the plant.

5-3 DESIGN CRITERIA.

5-3.1 General Buildings.

Administrative, maintenance, operations, security, and other similar facilities of the plant must comply with UFC 1-200-01. Refer to UFC 3-240-05A (for Army) for additional facility requirements. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

5-3.2 Mass Burn Plant.

5-3.2.1 Functional Design of Plant.

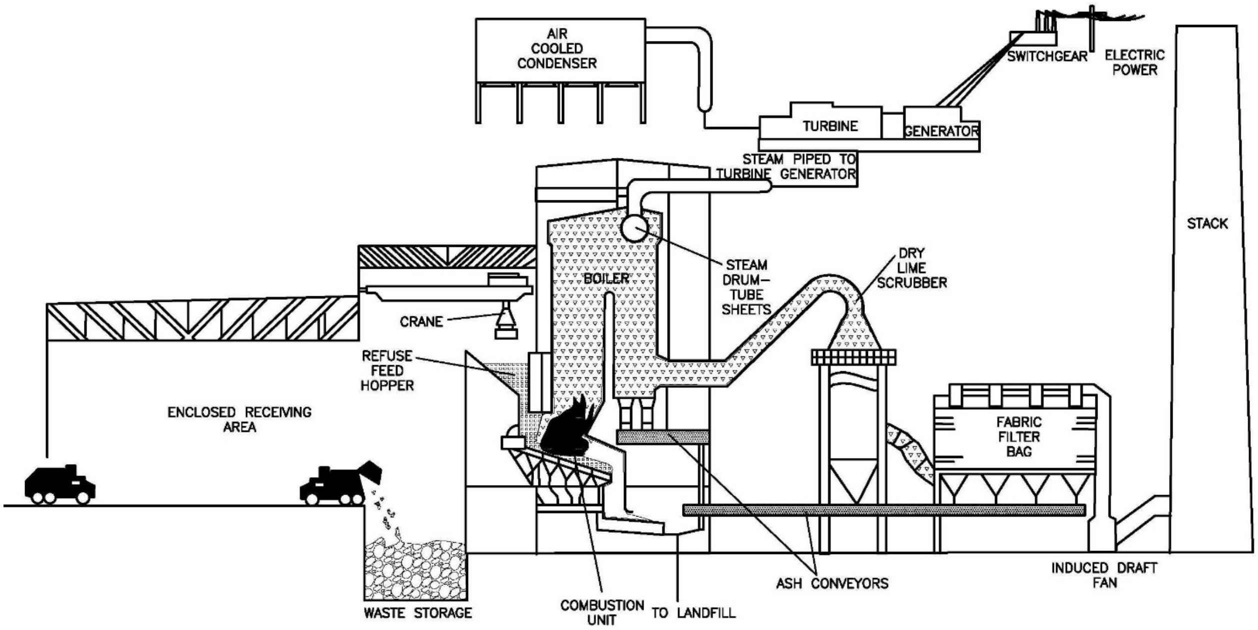
The Mass Burn Plant primary functions are to include: 1) receive the solid waste; 2) process and store the waste; 3) convert the solid waste to energy; 4) distribute the energy from the solid waste conversion; and 5) energy conversion process waste by-products disposal. To accomplish this, provide the following main systems: refuse receiving, handling and storage system; combustion and steam generation system; flue gas system (APC equipment); power generation system; steam condenser and make up water systems; residual waste disposal system; and supporting systems.

5-3.2.2 Process Flow and Layout.

Use the Figure 5-1 process flow as a guide to developing the plant layout. Figure 5-2 presents a typical plant layout. The waste to energy plant receives MSW on the tipping floor where it is prepped for feedstock. Large, bulky, and hazardous items are removed from the waste. In some operations, metals are removed and waste reduced to an optimum burning size. MSW moves from the storage pit to the boiler feed hopper for combustion. The feed hopper places MSW onto a grate using control gates and hydraulic rams to push the waste on to a grate in the furnace where it is dried out and combusted on the grate. Ash is discharged through the grate bottom into a water filled quench pit, and then transferred by a conveyor to an ash load out area for disposal in a landfill.

Energy recovery from the combustion process is transferred by water from the boiler walls and from the flue gas off the boiler. The heat absorbed creates steam that is used to operate a steam turbine. The steam from the turbine is condensed through a cooling tower and re-cycled through the boiler. The turbine is connected to a synchronous generator that rotates and produces electricity. In many applications, the heat is also transferred to district heating through steam or high temperature hot water systems. In some applications, the heat is converted to chilled water using absorption chiller units. The flue emissions are processed through APC equipment including spray dryers for acid gas, activated carbon injection for mercury control, ammonia for NOx control, and a baghouse for fly ash. The flue gas is then released through the plant flue stack.

Figure 5-2 Solid Waste to Energy Mass Burn Plant



5-3.2.3 Specific Building Requirements.

Provide the following solid waste to energy plant facilities:

- Gatehouse / scales;
- Tipping floor / waste sorting;
- Waste storage pit;
- Boiler building;
- Spray dryer;
- Baghouse;
- Waste material storage facility;
- Turbine-generator building;
- Cooling towers;
- Switchgear facility;
- Utility substation;
- Black start generator plant;
- Continuous Emission Monitoring System (CEMS) facility;
- Fire pump house;
- Administration;

- Maintenance; and
- Security guardhouse.

5-3.2.4 Layout.

Design facility with the concept of providing efficient operations and maintenance activities throughout the facility life. The design process must include a general configuration of all proposed buildings and structures, roads, parking and paved areas, as well as drainage features and any associated retention basins.

Design the facility roadway system to provide a traffic pattern allowing simultaneous traffic to both enter and exit the facility, and allow unencumbered travel of vehicles in both directions throughout the facility.

5-3.2.5 Materials.

Select all materials used for durability and longevity.

- Facility structure: concrete or steel construction.
- Exterior wall surfaces: steel with factory finished coating system or architectural masonry.
- Roofing: metal, sloped for drainage.
- Exterior personnel doors: painted galvanized insulated core steel with window lights where appropriate.
- Overhead doors: painted galvanized steel.
- Windows: insulated double pane glass with insulated aluminum jambs.
- Floors: select finishes based upon safety and use.
- Open grate working platforms, open grate stairs, ladders, ladder cages, and handrails: use steel with galvanized coated after fabrication. Where exposed to corrosive materials, coat steel with a suitable coating system resistant to the specific corrosive materials.

5-3.3 Refuse Receiving, Handling and Storage System.

The refuse receiving, handling and storage system includes the refuse receiving area, tipping floor, waste storage, and overhead grappling cranes.

5-3.3.1 Refuse Receiving Area.

The refuse receiving area accommodates the business operation for logging, weighing and receiving waste from commercial waste haulers and self-haulers (residential customers). Design the receiving area for:

- Weighing all vehicles entering and leaving;

- Eliminating waste transfer trailers and trucks backing up needs, except at the tipping floor;
- Allowing only commercial waste haulers to enter the tipping floor;
- Providing separate area for residential customers to unload into a container area with the containers shuttled to the tipping floor by the plant personnel;
- Locating site refuse receiving area facilities to eliminate or minimize: intersections; backing up; sharp turns or U-turns; and
- Adequate off-street queuing during peak operating times.

Design on-site traffic control in accordance with the Federal Highway Administration Manual of Uniform Traffic Control Devices requirements. Provide a truck helper shelter before the scales so that only the truck driver is permitted to enter the tipping floor to maximize safety by minimizing the number of personnel in the facility. Provide heating and cooling of truck helper shelter and include single toilet room with lavatory and water closet. Provide area lighting in accordance with UFC 3-530-01. Provide area lighting for all process equipment that may require maintenance after dark. Numerous states have siting and design requirements for waste transfer operations. Consult these requirements for the state where the plant is being located.

5-3.3.2 Scale House.

The scale house is located after the entry gate and usually set back sufficiently from the gate to ensure off-road queuing. Provide:

- A scale house building with number of scales sized for the daily and hourly arrival patterns of waste delivery;
- Capability for adding additional future scale(s) for growth;
- Inbound and outbound truck scales with unattended self-service terminal and remote weight display (aboveground pit-less, full truck, concrete deck type with weighbridge supported by the load cells);
- Truck scales (in the United States and North America) compliant with United States National Institute of Standards and Technology (NIST) Handbook 44 requirements and carry the National Type Evaluation Program (NTEP) Certification issued by the National Conference on Weights and Measures;
- Truck scales (in other areas) that meet the local government or the International Organization of Legal Metrology requirements, as appropriate;
- Walk up deck adjacent to aboveground scales, receiving windows and doors on inbound and outbound sides, trucker lobby with customer window, business area, employee toilet room, employee break area,

storage area, IT and scale equipment closet, and separate truck helper shelter;

- Inbound and outbound automated gates; and
- Telecommunications equipment.

Provide two radiation detectors at the scale house to monitor for radioactive materials. Detectors are to alarm at the scale house, security guardhouse, administration building, and central control room. Provide a paved area, at safe distance from occupied structures, to allow vehicles with detected radioactive material to park until State authorities are notified and can verify concentration levels.

5-3.3.3 Tipping Floor.

Use the following requirements in the tipping floor design:

- Provide metal building with partial reinforced concrete walls;
- Reinforce concrete tipping floor walls to a minimum height of 5 ft. (1.5 m);
- Construct walls and floors subject to damage through repeated impacts with 6000 psi (41 MPa) reinforced concrete;
- Provide truck receiving area to accommodate multiple waste trucks without stacking;
- Provide truck doors with minimum opening of 20 ft. wide by 20 ft. high (6 m x 6 m);
- Provide protective bollards inside and outside truck doors;
- Totally enclose the tipping floor and sized for a minimum of 130 sq. ft. (12 sq. m) for each ton-per-day incinerator capacity per UFC 3-240-05A (for Army). For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance;
- Size tipping floor area for peak container unloading and for tractor trailer size load of solid waste delivery;
- Size tipping floor for tractor trailer turn radius with minimum width of 150 ft. (46 m);
- Provide tipping floors to accommodate vehicles with maximum of 75 ft. (23 m) length and maximum legal weight limit of 80,000 lbs. (36,000 kg) gross, single axle of 20,000 lbs. (9,100 kg), tandem axle of 34,000 lbs. (15,400 kg), triple axel of 42,000 lbs. (19,000 kg), and quad axle of 50,000 lbs. (22,700 kg);
- Provide tipping floor with an additional 3 in (7.6 cm) concrete wear layer;
- Provide embedded galvanized steel protection on outside corners and edges subject to damage from trucks and grappling cranes; and

- Provide vehicle stops in front of each pit with spacing for drainage and broom cleaning of tipping floor into pit.

5-3.3.4 Sorting and Contaminant Removal.

Hand picking, hazardous material removal, and size reduction are required processes to render the waste easier to handle and make particles the size required by the furnace. Provide hand picking area with tables, hoppers and sorting belts, at tipping floor to remove large items (i.e. appliances, refrigerators, and equipment), batteries, and other specified hazardous materials. Size reduction can be single or multi-stage depending upon the furnace size and combustion requirements. Evaluate guillotine hydraulic shears and shredders for reducing oversized material for combustion based upon oversized material volume, explosion risk, and economic analysis. Provide size reduction equipment based upon the analysis. Provide guillotine-type hydraulic shears for reducing oversized items. Provide adequate access, lighting, overhead hoists, and welding equipment receptacles for equipment maintenance.

Evaluate throughput, availability, and redundancy for the material recovery and contaminant removal system. Include environmental control equipment for dust collection, noise suppression, odor control, explosion control, and HVAC. Refer to UFC 3-240-05A (for Army) for waste processing and bypass requirements. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

5-3.3.5 Ferrous Recovery.

For ferrous metals, use multi-stage magnetic separators to achieve a minimum recovery yield of 85% consisting of magnetic belts, mixed waste conveyor, ferrous waste conveyors, and non-ferrous collection conveyor. Provide conveyor to transfer to ferrous bulk storage.

5-3.3.6 Aluminum Recovery.

Use eddy current separators to eject aluminum material from the moving waste stream. Provide a can flattener for ejected waste. Provide a conveyor to transfer to aluminum bulk storage.

5-3.3.7 Waste Storage.

Provide a waste storage building sized for a minimum five (5) day capacity at facility's maximum continuous rating to facilitate major equipment repairs. Site the waste storage building adjacent to the boiler building.

5-3.3.8 Pit Storage.

Design the waste storage pit for a minimum five (5) day capacity based upon a bulk density of 500 lb/yd^3 (300 kg/m^3). The pit storage volume will be based upon the pit volume up to the tipping floor and the volume above the tipping floor assuming the waste above the tipping floor is stacked at a 45 degree angle from the charging floor wall to the tippling floor. The pit storage capacity will include 2/3 below the tipping floor and 1/3 above the tipping floor as geotechnical conditions allow. The pit depth should be 30 to 45 ft. (9-14 m) below grade, if possible, as groundwater conditions allow. The number and arrangement of bays for refuse truck unloading will be based on the peak container flow.

Include the following storage pit components/requirements:

- Construct using 6000 psi (41 MPa) reinforced concrete, minimum;
- Slope storage pit floor to perimeter sump;
- Totally enclose storage pit under negative pressure using the boiler combustion air system;
- Provide dust control spray system;
- Provide rodent and bird controls; and
- Include fire canons controlled from the pit operator control station and standpipe systems at tipping floor and charging floor.

5-3.3.9 Refuse Handling Crane.

Provide a minimum of two (2) refuse handling cranes. Select cranes rated for MH CMAA 70 Class F (continuous severe service) in accordance with UFC 3-240-05A (for Army). For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance. Cranes are to be overhead bridge, non-riding, type meeting the requirements of ASME B30.2. Specify cranes for continuous operation configured to manage refuse in the receiving and storage facility as well as to feed refuse to the charge hoppers to the boilers and capable of operating with a full load at minimum speeds. Cranes must be capable of weighing each bucket or grab load prior to discharge into feed chute. Provide separate motors for the hoist bridge, trolley drive, and grapple. Use interchangeable orange peel type grapples. Size the grapple based upon duty cycle quantity analysis of material being moved from the pit to the furnaces, the distance to move the material, crane speeds, and time required for mixing and stacking material in the pit.

Design the crane operator control station (or pulpit) to accommodate a minimum of two operators and control consoles, and allow operation of both cranes simultaneously. Design the control station to provide full view of the storage pit and charging hoppers. Provide control station with independent heating, ventilation and air conditioning system at positive air pressure relative to the pit and tipping floor. Provide control station with CCTV to monitor charging hopper level and incoming waste delivery at the tipping floor. The cranes will be equipped with semi-automatic operation features to minimize operator stress.

5-3.4 Combustion and Steam Generation System (Boiler).

5-3.4.1 Feed System.

The charging hopper discharges the solid waste into the delivery chute. Provide a top loading charging hopper for each combustion train. Design charging hoppers to be large enough to prevent spillage on the charging floor and with slopes steep enough to prevent solid waste bridging. Provide hydraulically actuated gate between the charging hopper and upper chute. Gate to automatically close in the event of a power failure.

Design the waste chute feeding the refuse stokers for sufficient height to provide an air seal to the furnace stokers. Design chutes with dimensions and contour for self-relieving to avoid bridging, but not less than 4 ft. (120 cm) wide and the furnace width. Provide means of access to reposition or remove particles in the chute and to assist in firefighting. Provide charging throat with water cooling and refractory lining. Include chute refuse level sensor to alarm crane operator and control room, and include hydraulic shutoff grate to prevent back burn during shutdown.

5-3.4.2 Refuse Stokers and Grates.

Design stokers and grates for burning solid waste, to avoid excessive refuse turning, and to even incoming waste distribution. Use a minimum of three grate sections, including drying grate, burning grate, and finishing grate. Bottom ash is discharged from the finishing grate into a water quench pit, and from there, it is transported by conveyor to the ash storage facility. Locate grates mechanisms outside the furnace. The grates are typically air cooled independent of primary air. If high calorific waste is used, water cool the grates. Feed waste refuse onto the grate with a charging ram. Charging rams will be hydraulic type with at least one hydraulic cylinder for each longitudinal grate section.

Provide a complete hydraulic system for each boiler system for operation of grates, charging rams, feed chute, and ash recovery. Include a fully automatic, forced, central lubrication system for lubricating the stoker with pumps and alarm system.

5-3.4.3 Auxiliary Fuel Burners.

Provide auxiliary fuel burners for use during start-up and shut down with total capacity of not less than 40% of the boiler's maximum continuous rating. Burners are water cooled, natural gas type with low NOx emission. Design burner in accordance with NFPA codes.

5-3.4.4 Ash Quench Pit.

Ash quench pits are water filled troughs with submerged chain driven mechanical conveyors powered by hydraulic motors. Provide double chamber troughs formed from a single piece of steel. Provide with abrasion resistant side wear liners and plate separators. Provide dewatering ramp and chute for disposal of ash into concrete bunker. Extend boiler seal plates directly into the water in the upper trough or provide transition hopper. Seal plate pinch point minimum clearance is 4 ft. (120 cm). Include roll out wheels to allow the entire system to move on rails to the side to allow boiler shutdown maintenance.

5-3.4.5 Combustion Air.

Use 100% excess air to burn municipal solid waste. Pull all combustion air from the refuse storage and reception building to minimize dust and odor. Provide primary combustion air beneath the grate with adjustable zoning. Inject secondary combustion air at high velocity above the grate through ports spaced equally around the grate's perimeter. Regulate primary and secondary combustion air flow against feed rate, type of waste temperature, and oxygen levels using computer controls.

Provide a minimum of one underfire fan with pre-heat, one overfire fan, one induced draft fan, and one secondary air fan for each boiler with air ducts. Provide 20% to 40% of total air as overfire air and 60% to 80% as under fire air to allow a total maximum air flow of 120%. Size fans for combustion air requirements and ambient conditions. Locate induced draft fan after APC equipment. Pre-heat under-fire air with steam heating coil located between the underfire fan and air plenums. Size coils for worst-case ambient conditions and provide freeze protection. Fit air duct systems with non-plugging type flow measuring device with a transmitter for remote read out and use in combustion rate control systems. Provide ducts with straight sections or flow straighteners upstream and downstream of the flow measuring device to assure the measuring device's accuracy.

5-3.4.6 Ash Load Out.

Discharge moist ash from ash quench pits by conveyor system and transport to the storage area using an ash conveying system. Design the complete ash conveying system to consist of both a primary and secondary conveyor to transport furnace bottom ash, grate siftings, fly ash and APC fly ash to a centralized location. Provide two (2) 100% capacity ash conveyors to remove bottom ash from the boilers and convey the bottom ash and fly ash to the ash load out area, for maximum combustion units' availability. Provide two (2) 100% capacity conveyors to transfer APC fly ash from the APC fly ash collection equipment to the storage area. Include provisions for combining the APC fly ash with bypassed bottom ash in the event that the metals recovery system is not operational. Design the ash conveying system for a minimum of 100 lb/ft^3 (1602 kg/m^3).

5-3.4.7 Interior Equipment.

Place interior equipment (the grizzly scalper, ferrous and non-ferrous metal separating equipment, and fly ash conditioning equipment) and support steel at grade elevation on six (6) in (15 cm) minimum concrete housekeeping pads. Design the structural steel above the ferrous recovery system for hoisting equipment as required for optimizing system performance and maintenance. Protect all exterior walls that come in contact with ash laden water, such as the area around the inclined ash conveyor entrance and walls adjacent to the ferrous recovery equipment, with fiberglass panels or other corrosion resistant materials. Provide translucent panels for lighting during daylight hours to minimize energy use.

5-3.4.8 Waste Material Storage.

Design the waste material storage building for processing and storing ash load out, ferrous and non-ferrous metals, and oversized materials. Include a grizzly scalper and the inclined conveyor in the footprint of this structure. Provide wheel wash system for ash and metal handling trucks prior to exiting the structure. Accommodate a minimum of five (5) days storage for processing, separating, and storage of non-ferrous and ferrous metals in the ash load out area. Protect all interior panels, purlins, grits, steel structures, and equipment against high pH ashes, high humidity, and a hot atmosphere. Apply a protective coating to structural components and non-metallic building siding. Enclose the area within a concrete structure with cladding to ensure dust suppression. Design the ash concrete bunker as a water retaining structure, with draining slopes at the bottom of the trench to a sump.

Route wastewater from the waste material storage building drains to a settling basin located immediately outside of the building. Include removable covers to prevent rainwater from entering the settling basin system. Position the sump such that water may drain from the ash bunkers into the sump by means of sleeves located at the building wall base. Gravity drain collected sump wastewater through a minimum of 24 in (61 cm) wide floor trenches fitted with removable diamond plating and route wastewater to the settling basin.

5-3.4.9 Material Recovery.

Design the ferrous recovery, associated conveying and storage area to achieve a throughput rate of 150% of projected recovery tonnage per day. Provide a ferrous recovery system with a minimum collection rate of 80% of magnetic ferrous materials within the ash waste over one (1) in (2.5 cm) in diameter including ferrous metal removed by the grizzly scalper. The ferrous metals recovery system is located at the discharge end of the quenched bottom ash conveyors in the Ash Load Out building. Provide a separate storage area for ferrous materials inside the Ash Load Out building. Provide roll-off containers or other suitable vehicle for transport for recovered ferrous material loaded the storage areas. Design the separation and recovery system with at least one magnet, one vibratory feeder screen, and necessary chute work and product distribution conveyors. Provide transfer conveyors as required to transport ferrous metals and remaining ash residue to separate storage bunkers or containers. Include ample space and access for maintenance of all system components. Design the system to minimize residual ash being carried with the recovered metal.

Design the non-ferrous recovery, associated conveying and storage area to achieve a throughput rate of 150% of projected recovery tonnage per day. Provide a non-ferrous recovery system with a minimum collection rate of 60% of non-ferrous materials greater than 5/8 in (1.6 cm). Recovery to occur upon completion of recovery of ferrous materials from the ash. Use eddy-current separators in order to minimize possible damage from errant ferrous material. Provide a separate storage areas for non-ferrous metal inside the Ash Load Out building. Recovered non-ferrous material is then loaded from its storage bunker into roll-off containers or other suitable vehicle for transport. Provide transfer conveyors as required to transport non-ferrous metals and remaining ash residue to separate storage bunkers or containers. Include ample space and access for maintenance of all system components.

5-3.4.10 Waste Heat Recovery / Steam Generation System.

Provide single drum, multiple pass water tube type with integral welded membrane waterwall cooled furnace, superheater and economizer steam generating equipment. Directly couple each boiler to its respective refuse combustion stoker.

Design each combustion train to be automatically controlled when in operation and control of each combustion train is independent of the others. Provide manual controls to select desired steam flow. Ensure control system maintains all process conditions within safe limits and that emissions, including NOx, $S0_2$, HCl, dioxin and furnace concentrations, are within specified limits of the environmental permits.

5-3.4.11 Heat Transfer Cleaning System.

Determine cleaning frequency by the fouling problem severity. Perform trade off analysis of cleaning process while the plant remains in operation (on-line cleaning) and for when plant is shut down the (off-line cleaning). Implement the best approach comparing operational, technical, and cost factors.

Steam soot blowers, mechanical rappers, or combination of methods may be utilized in conjunction with on-line water washing, if needed, to meet on-line operating requirements and downtime limitations as well as environmental guarantees. Space and arrange tubes to minimize erosion, slagging, and fouling and to promote effective cleaning of tube surfaces with soot blowers or a rapper system.

5-3.5 Flue Gas System.

5-3.5.1 Air Pollution and Control Equipment.

Use UFC 3-430-03 for identification of air pollution emission rates and selection of control equipment required to meet, local, State and Federal compliance levels.

5-3.5.2 Air Quality Control Requirements.

Ensure APC equipment has capability to meet U.S. EPA and State requirements for control of NOx, dioxin, mercury, acid gas, and particulate removal. Provide separate APC systems for each combustion train in the plan. Dump stacks that release any untreated flue gases are not allowed.

Select air pollution and control equipment by using EPA Best Available Control Technology (BACT) Analysis. BACT air pollution emissions are limited based upon the maximum degree of reduction for each type of regulated pollutant achievable through processes and systems available. BACT is determined by State permitting agencies on a case-by-case basis considering energy, environmental, economic, and other costs in its determination. BACT cannot be less stringent than the Federal New Source Performance Standards (NSPS), but it can be more. BACT requires that emissions of any pollutant not exceed the standards under 40 CFR Part 60 and 40 CFR Part 61.

5-3.5.3 NOx Control.

Use one of two the different methods for control of NOx used in North America: Selective Catalytic Reduction (SCR) or Selective Non-catalyst Reduction (SNCR). Perform operational trade off and life cycle cost analysis and determine the best approach to meet NOx control objectives.

5-3.5.4 Activated Carbon Injection (ACI) System – Mercury/ Volatile Organics Control.

ACI is currently designated as the BACT by the EPA to control the release of trace organics including dioxins, furans, and mercury into the atmosphere by adsorbing these chemicals onto its surface. Use powered activated carbon (PAC) injection. One ACI system will be provided for each boiler/furnace system. Include redundancy of spare blowers and feeders to assure reliable operation. Injection will be between the spray dryer and the baghouse.

For the ACI System, include the following:

- Storage silo for minimum seven (7) day storage;
- Feed hopper;
- Truck unloading station;
- Blowers to provide motive air for transporting PAC to the injection points;
- Feeder;
- Controls to include truck unloading control, radar level sensing, and bin vent filter pressure differential; and
- Personnel safety equipment.

5-3.5.5 Acid Gas Scrubber.

Provide acid gas scrubbers to control acid gas emissions of HCl, SO_2, and HF. There are numerous technologies for acid gas removal including wet scrubbing, semi-wet scrubbing, and dry scrubbing. Provide dedicated acid gas spray drying scrubber for each combustion train using spray drying method. Design the scrubber so that the flue gas exiting the spray dry scrubber is kept above the acid dew point temperature.

For the Acid Gas Scrubber system, include the following:

- Spray drying scrubber (also known as spray dryer adsorber) of lime slurry reagent to meet Subpart E. b. emission standards for SO_2 and HCl and the BACT Emission limit for sulfuric acid mist and fluorides;
- Truck unloading station;
- A minimum of two lime/hydrated lime storage silos;
- Two lime slurry preparation systems;
- Spray dryer absorber vessel, atomizers, product removal system, and support equipment;
- Instrumentation and controls; and
- Personnel safety equipment.

5-3.5.6 Fabric Filter System (Baghouse).

Provide fabric filter system. Use reverse air or pulse jet type cleaning baghouse with multi-compartments to facilitate cleaning and maintenance. Provide a filter bag leak detection system that is capable of continuously monitoring relative particulate emissions (dust) loadings in the baghouse exhaust in order to detect bag leaks and other upset conditions. Include hoppers to store collected ash discharged from the baghouse filters during the cleaning process. Provide instrumentation and controls for the baghouse to include air pressure monitoring, cleaning cycle control, hopper level alarms, hopper heater control, differential pressure measurement, fan motor current, and inlet gas temperature measurement.

Provide inspection access at the following points:

- Stack exit;
- Filter clean side;
- Bags, cages and bag attachments;
- Cleaning mechanisms and equipment;
- Stack pressure gauges;
- Solid discharge valves; and
- Hoppers.

5-3.5.7 Flue Stack.

Design and construct flue stack in accordance with ASCE/SEI 7 and NFPA 211. Base flue stack height upon pollutant dispersion analysis and FAA requirements. Design stack for all environmental and seismic conditions which it may be subjected.

Construct flues of steel with circular cross section. Provide an insulated, self-ventilating flue liner to limit heat loss of flue gas to not more than ten (10) ^{o}F (-12 ^{o}C) after exiting the NOx reduction system. Include access platforms, safety railings and ladders will be provided to access inspection, test and cleanout ports, obstruction lighting, and lightning protection system in accordance with Occupational Safety and Health Acto (OSHA) requirements. Provide obstruction marking and lighting for aviation safety in accordance with FAA AC 70/7460-1K.

5-3.6 Power Generation System.

Use condensing turbine-generators in a packaged configuration, complete with condenser, sized for steam. Rate boilers at the maximum combustion rate (MCR).

5-3.6.1 System Design.

Ensure the power generation system design includes the turbine, generator, oil system, hydraulic system, backup power, and operating controls.

5-3.6.2 Operating Conditions.

Ensure the turbine – generator operates over the broad range of combined heating plant system utility load and temperature requirements, if used.

5-3.6.3 Turbine.

Provide steam turbines that conform with ISO 14661 *g*eneral requirements. Where using cogeneration system that simultaneously supplies power, and heating or cooling, conform to ISO 26382:2010*.* Select the best steam turbine classification based upon economic analysis in accordance with DoD Instruction 7041.3. Use present value analysis and include the following cost elements:

- Capital costs; and
- Operating and maintenance costs (include equipment operating efficiencies).

Design turbine(s) as a complete package system mounted on bases for quick installation and alignment verification with steam extraction points at different pressures corresponding to different system temperatures based upon economic analysis. Design turbine to operate at a constant speed. Combine high pressure and intermediate pressure sections into a single casing to provide a compact system minimizing plant floor space. Low pressure section(s) are typically housed in a separate casing if not a single stage turbine. Provide DC backup power for critical lubrication systems.

5-3.6.4 Generator.

Provide a totally enclosed, air or hydrogen cooled, synchronous generator sized for continuous operation and directly connected to steam turbine. Use air cooling for generators up to 60 MW in capacity. Use hydrogen cooling for generators for over 60 MW in capacity. Provide on-site hydrogen generation system for hydrogen cooled generators.

Provide turning gear to thermally stabilize generators for a period of 24 hours or until the generator is cooled below 212 ^{o}F (100 ^{o}C), whichever is greater. The turning gear will start when the turbine speed drops to 100 rpm, then engage and rotate the turbine at a speed of 30 rpm to ensure an oil film is maintained in the journal bearings and to create turbulence in the cylinder to cool the cylinder and shaft uniformly.

5-3.7 Steam Condenser System.

5-3.7.1 Steam Dump.

Provide a steam dump capable of handling the following events: 1) turbine over-current protection device trip; 2) turbine failure; 3) continued furnace solid waste process at MCR regardless of turbine outage; or 4) other system failure. The steam dump will release steam until the plant can achieve an orderly shutdown or turbine operation can be restored.

5-3.7.2 Cooling Tower.

Design the condenser cooling tower in accordance with the weather data requirements of UFC 3-400-02 and NFPA 214. Size cooling towers to meet the turbine condenser(s) and other plant cooling loads requirements. Account for prevailing winds, proximity to existing or proposed transmission lines and facilities, and the boiler stack when siting cooling towers.

Provide cooling towers with fiberglass or concrete frame and film filled as appropriate for maximum wind conditions. Partition tower cells such that each cell can be operated independently of remaining cells. Conduct an on-site thermal performance test in accordance with the CTI ATC-105 standards to ensure installed tower(s) meet thermal performance requirements. Use high efficiency fill and drift eliminators. Size cooling towers to have a minimum 10 ^{o}F design approach between the cooling water outlet and the ambient wet bulb temperature at the design wet bulb temperature.

5-3.7.3 Circulating Pumps.

Provide separate primary and alternate circulating pumps for the turbine condenser(s) and separate primary and alternate water pumps for the other plant cooling loads.

5-3.7.4 Chemical Feed System.

Provide complete chemical feed system for cooling system circulating water to protect against corrosion and bio-growth.

5-3.7.5 Air Removal Equipment.

Provide air removal equipment for each condenser.

5-3.7.6 Surface Condenser.

Design condenser in accordance with Heat Exchange Institute (HEI) allowable stresses for tubes per ASME, and bypass headers in accordance with EPRI standards and codes. Provide a surface condenser with shell and tube exchanger. Equip the condenser with a minimum of two tube passes and divided water box. Provide an ejector assembly, atmospheric relief valve, and limit the inlet velocity to header to 200 to 300 feet per second (fps) (60 – 90 m/s). Extend the bypass headers are to extend along the entire tubes length and equip with the smallest diameter orifice. Provide impingement protection for tubes to also include dummy tubes.

5-3.7.7 Dump or Bypass Condenser.

Provide a dump or bypass condenser and use in conjunction with the surface condenser during periods of startup, shutdown, and turbine generator unavailability.

5-3.7.8 Condenser Hotwells.

Size the hotwell to contain all condensate produced in the condenser in a period of one minute under conditions of design load in accordance with HEI Standards for Steam Surface Condensers. Employ hotwell level controls with three level transmitters to maintain a normal level in the condenser hotwell. Controls will be dual redundant.

5-3.7.9 Blowdown Control and Treatment.

Provide automatic modulating blowdown control to maintain dissolved solids in accordance with recommended practices of ASME Consensus on Operating Practices for the Control of Feedwater and Boiler Water Quality in Modern Industrial Boilers. If economically justified, employ a boiler blowdown heat recovery system using a flash tank and heat exchanger.

5-3.7.10 Boiler Feed Pumps.

Provide one boiler feed pump per boiler. Size the pump for 125% of boiler steam capacity.

5-3.7.11 Feedwater Control System.

Provide a minimum of two (2) high pressure boiler feedwater pumps providing 200% of total design. Design the feedwater system to achieve the maximum flexibility for operations ranging from 33% MCR to peak facility operation. Utilize a boiler feed pump system driven by an electric motor, steam turbine drive, or combination of the two with an option for variable speed drive for the electric motor. The feedwater pump arrangement must be capable of providing the feedwater flow required for full capacity plant operation as well as providing partial flow to individual boilers if one or more boilers are shut down. The design must assure adequate NPSH is available to the boiler feed pumps during transient load conditions, including turbine trip at full load.

Rate pumps capacities to meet ASME code when pressure relief valves are open on high drum pressure.

Provide a three-element feedwater control system to include at a minimum: drum level transmitter, steam flow transmitter, feedwater flow transmitter, drum level controller, manual/automatic control station, feedwater control valve, steam flow element and feedwater flow element.

5-3.7.12 Condensate Pumps and Circulating Pumps.

Provide two motor driven, variable speed condensate pumps per boiler. Size each pump for 125% of boiler steam capacity. Provide bypass orifice at each pump.

Provide a minimum of two (2) circulating water pumps for condensing heat exchanger arrangement, each with a capacity equal to either unit MCR or facility MCR, as appropriate.

5-3.7.13 Miscellaneous Pumps.

Provide miscellaneous pumps and accessories as required by the final facility design. Provide 100% redundancy for all pumps. Include motors, couplings, coupling guards and baseplates for all pumps as applicable. Provide all special tools required for maintenance and installation of applicable pumps. Pump capacities to include a minimum of 10% margin, and a 20% margin for head, for all pumps, based on the final piping arrangement. Design pumps, as a minimum, in accordance with the manufacturer's standard for the service intended.

Perform a failure mode and effects analysis for the various pump categories as required. Additionally, provide a hierarchy according to which pump functions are grouped based on critical safety needs. Provide this during the design review. The results of this analysis shall indicate which functions require redundant pumps, priority circuitry, and back-up power supplies.

5-3.8 Water Supply, Makeup and Treatment.

5-3.8.1 Design.

Design domestic water supply, and makeup and treatment systems in accordance with UFC 3-401-01 and UFC 3-420-01*.*

5-3.8.2 Domestic Water Supply.

Obtain all facility domestic water (potable water) by connecting to the local utility supplier or through an on-site water well that is permitted, designed, and installed in accordance with local, State and Federal requirements. Provide all piping, valves, chambers, meters, and services to connect to the designated water supply source at the interface point. Treat water in accordance with UFC 3-230-02.

5-3.8.3 Water Treatment Equipment.

Provide a permanent water treatment system designed for continuous use. Design the water treatment system for automatic operation with minimal operator intervention. Include the option of providing a Reverse Osmosis (RO) unit, chemical-based treatment system, or combination of the two. The chemical-based treatment system is to include a dual-train demineralizer of the anion-cation type complete with regeneration equipment, piping, valves, and controls for treatment of public supply potable water, and industrial supply well water. Provide water treatment equipment to fulfill the following functions: boiler makeup water treatment; chemical feed systems; sampling systems; and, treated water storage.

Provide potable water for sanitary uses as required by applicable laws. Supply water for other facility needs from the following sources in the priority listed below:

- Blowdown from cooling towers (use for quench water for the bottom ash and dilution water for the scrubbers at a minimum);
- Harvested stormwater (as available);
- Industrial supply water (as available);
- De-chlorinated potable water; and
- Potable water (for selected process uses). Minimize to the greatest extent possible the need for potable water for non-sanitary usage.

5-3.8.4 Storage.

Store all harvested stormwater, industrial supply water, de-chlorinated potable water, and potable water in the facility recycle and reuse tank. Store cooling tower blowdown water in the facility’s wastewater tank prior to use at the facility.

5-3.8.5 Water Meters.

Install water meters to track water consumption (instantaneous and total) from all sources. Use electronic meters and track using the plant distributed control system. Comply with the local utility company’s metering requirements as well as the OUSD (AT&L) Utilities Metering Policy as detailed in the following website: (http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html) and DoDI 4170-11 Installation Energy Management.

5-3.8.6 Treatment.

Provide water treatment for boiler make-up water, cooling tower make-up water, and auxiliary cooling water. Treat water to equipment system manufacturer's requirements.

5-3.8.7 Water Storage Tanks.

At a minimum, provide a condensate storage tank, demineralized water storage tank, auxiliary cooling water head tank (if applicable), flue gas condensate tank (if applicable), raw water storage tank (if applicable), firefighting water storage tank, wastewater storage tank, and any other miscellaneous tanks necessary to the design must be provided.

5-3.8.8 Centralized Chemical Sampling System.

Provide a centralized chemical sampling station in order to provide information on chemical conditions in the feed, condensate, steam, and cooling tower systems. Continuously draw samples from defined points and analyze automatically.

Design so that each analyzers is capable of an indication at the local sample panel and in the control room. An indication of chemical conditions that are out of the acceptable range must be communicated via an annunciator in the control room. Design the local sample panel to accommodate the taking of grab samples.

5-3.8.9 De-mineralized Water System.

Provide two (2) full capacity skid-mounted operational demineralizers. Each demineralization must be capable of producing the required quantity and quality of make-up water for the facility feedwater-condensate water system.

Design the demineralizer system for push-button automatic operation. The demineralized water is to conform to the boiler and turbine manufacturer's requirements. In addition to boiler makeup, this system is required to provide makeup as necessary to other plant systems. Utilization of a RO system followed by electro deionization to provide boiler make-up water is acceptable.

5-3.8.10 Water Storage Tank (Fire).

Design and install the fire water storage tank and site main systems. Size the fire pump, water supply, and fire water storage tank systems to supply the minimum fire flow required by code.

5-3.8.11 Auxiliary Cooling Water System.

Design an auxiliary cooling tower capable of operation at full capacity with one closed cooling water pump to dissipate heat. Include sufficient cooling capacity to accommodate loads identified in the final design. Provide a chemical feed system.

5-3.9 Residue Hauling and Storage System.

Provide a complete furnished and installed residue conveying system for each boiler/furnace/steam generating unit. Provide a common conveyor system, consisting of primary and secondary conveyors, to transport residue from each unit to the ash management building. Provide an adequate means of redundancy that would prevent the shutdown of more than one boiler/furnace/steam generating unit if a system component must be taken out of service. The system proposed must be amenable to separate collection of APC residue (fly ash and spent salts of reaction) and bottom ash without requiring building modification.

5-3.9.1 Design Criteria.

Design the ash system for the quantity resulting from waste processing at the Contractor-specified ash density but no less than 100 lb/ft^3 (1602 kg/m^3) density with suitable margin for upset and peak conditions. Use a reasonable ash design density for volumetric sizing and conveyor and structural sizing. Design the system to start under fully loaded conditions assuming a two-hour interruption in the ash handling system.

Provide the quantity and compositions of residue ash expected to be produced at the facility from the furnace/boiler and APC systems and ensure that this residue ash is not considered hazardous based on applicable laws.

5-3.9.2 Bottom Ash Conveyors.

Provide two 100% capacity ash conveyors to remove the bottom ash from the boilers and convey the bottom ash and fly ash to the ash management building. Provide a grizzly scalper on each bottom ash conveyor as well as any other redundancy measures deemed necessary to keep the boilers in operation if an ash system component is taken out of service.

5-3.9.3 Fly Ash Conveyors.

Under normal operating conditions, the APC fly ash is combined with the bottom ash in the ash management building following the metals recovery system. Provide two 100% capacity conveyors to transfer the APC fly ash from the APC fly ash collection equipment to the ash management building. Include provisions for combining the APC fly ash with bypassed bottom ash if the metals recovery system is not operational.

5-3.9.4 Metal Recovery Conveyors and Storage.

Design ferrous and non-ferrous recovery and associated conveying and storage facilities to accommodate the waste throughput design rate.

5-3.9.5 Wet Residue Removal System.

Discharge residue from the grates, boiler and economizer hoppers, and siftings from under the grates for each unit into a pusher type residue discharger. Design equipment to be capable of using wastewater from the other facility operations. Provide the pusher type residue dischargers with a quench tank equipped with a hydraulically operated residue pusher. Discharge residue from the residue pushers directly into the residue pit or onto a series of conveyors and convey the residue to a residue building. Design all system components with housekeeping and safety in mind.

5-3.9.6 Residue Storage.

Include concrete, drainable pits in residue storage facility for placing residue containers or trucks during loading operations. Residue containers must be enclosed, watertight and dust-proof so as not to present a hazard to either plant personnel or the general public while residue is being loaded and transported to the landfill. Fully enclose the loading station. In general, design all residue loading and unloading systems to be dust free and designed to meet the general requirements for residue loadout established by U.S. EPA. In particular, no visible emissions of dust from any doorway, window, vent, louver, or other opening is allowed.

5-3.9.7 Residue Pit.

Design the residue pit for a minimum of five days' usable storage of residue for a 1,500 tons (1400 metric tons) per day (tpd) facility. Completely enclosed residue pit and all conveyors external to buildings with a filtered ventilation system. Do not connect the residue pit to any other structures in such a fashion as to enable dust to infiltrate to other plant parts.

5-3.9.8 Truck Loading Station.

Design the truck loading station with a 1.0% slope from the truck loading zone to the ash storage bunkers. Install four (4) ft. (122 cm) wide by four (4) in (10 cm) high speed bumps at the entrance and exit ramps. Supply the entrance and exit ramps bases with a trench drain, draining back to the building sumps, to capture any potential ash or water spillage. Place bollards on both the inside and outside of all truck door openings. Provide a reinforced push wall surrounding the bunker areas and extending to the truck entrance and exit doors with a minimum height of 14 ft. (4.2 m). Line the inside building perimeter, excluding the bunker areas, with a reinforced concrete wall at a minimum of two (2) ft. (61 cm) high by one (1) ft. (30.5 cm) thick.

5-3.9.9 Fly Ash Collection System.

Design the APC fly ash collection system to collect APC fly ash from the scrubber and baghouse, which may include spent lime reagent, carbon reagent, and collected salts. Provide two, 100% capacity, conveyors to transfer the APC fly ash from the APC fly ash collection equipment to the ash management building. Combine APC fly ash with bottom ash only after the bottom ash has passed through the metals recovery system. The fly ash handling system is not limited to screw conveyors, but must be a commercially proven design.

Collect APC fly ash from each APC system hopper with drag or screw conveyors. Convey fly ash to the residue pit, conveyor, or residue building after the point of ferrous metal recovery from bottom ash and then to a residue conditioner for disposal. Semi-dry reactors may incorporate air slides for conveying APC fly ash from the baghouse to the scrubber for fly ash reuse purposes. Utilize screw conveyors or drag conveyors for conveying APC fly ash to the APC fly ash conditioning system. Provide a completely dust-tight APC fly ash drag or screw conveyor area to prevent leakage of APC fly ash.

5-3.9.10 Ventilation System.

Include exhaust hoods at transfer points connecting to a central dust control system for all ash handling equipment within the ash management building. Connect this central dust control system to a wet scrubber or baghouse. Design the ash management building with a separate ventilation system designed to permit a minimum of two air changes per hour. Comply with current ASHRAE HVAC Applications Handbook ventilations standards.

5-3.9.11 Instruments and Controls.

Design the residue handling systems to be fully automatic between the furnace and the residue storage pit or residue building. Provide sensors with alarms for readout and recorded on the Distributed Control System (DCS) in the central control room for any system failure.

5-3.10 Control and Instrumentation.

5-3.10.1 Central Plant Controls.

Provide a central plant DCS with redundant processors and local area network with automatic switchover to enhance reliability of the control system. Plant controls are to be operated from the central plant control room, and include boiler, turbine, feedwater and condensate system, condensing system and water treatment system controls. Provide management control stations at strategic points in the plan for maintenance and redundant control requirements. Provide automated subsystems for the following:

- Each boiler train for steam production and air pollution control;
- Turbine and thermal cycle;
- Electrical substation;
- Emergency shut down; and
- Balance of plant controls.

Integrate asset management and maintenance activities into the central plant control. Asset management functions are to interoperate with the control system to plan maintenance operations. Use information from the plant instrumentation to perform statistic predictive maintenance. The following systems are to be handled locally or are automated systems.

5-3.10.1.1 Waste Handling Crane.

Crane control is maintained at a stationary operating station also called the crane pulpit. Provide voice communication between the control room and the crane pulpit. Provide video feeds covering the waste storage pit to the control room.

5-3.10.1.2 Residue Handling System.

Design the residue handling system between the furnace and the residue storage pit to be automatic. Design other residue handling systems for locally manual control. Operating status of all conveyors must be indicated in the control room. Install video feeds of all conveyor paths to the control room.

5-3.10.1.3 Waste water discharge

Design for local control.

5-3.10.1.4 Chemical addition systems

Design for automatic and locally controlled.

5-3.10.2 Control Room.

Provide a central plant control room and include DCS operator stations, DCS engineering station, and asset management station. Provide inter-facility start-up from the control room, with select systems started locally as detailed in previous sections. Ensure operators are able to supersede the automatic controls and operate the facility manually from the control room. Back up normal plant control systems and procedures by separate interlocks or safety systems designed to effect action in cases of emergency.

5-3.10.3 Control Pneumatics.

Provide separate controls for plant air and instrumentation air. Design air compressor system to provide plant air and instrument air for the facility. Equip plant air piping system with automated shutoff valves to non-essential headers in the event of a loss of primary compressed air. Install air dryers with the capability of being bypassed for maintenance without shutting down both compressors and associated accessories.

Provide redundant full capacity air compressors with aftercoolers. Provide separate stand-by redundant compressors sized for critical equipment operation. Compressors and compressor motors must be provided with manufacturer's standard offering control system which must load and unload the compressors during operation. Compressor operation must alternate between the two (2) compressors during normal operation. If one air compressor trips, the control system will automatically place the stand-by compressor in operation without low air pressure trip. Cover all couplings and drives with metal guards.

5-3.11 Fire Protection.

Design and construct the fire protection systems in accordance with UFC 3-600-01, and NFPA 101 and 850 as modified by UFC 3-600-01. Design and construct systems to prevent and control explosions in accordance with NFPA 69 at the tipping floor, waste storage pit, and material storage silos created by flammable concentrations of gases, vapors or dusts created by waste processes or hazardous waste not removed during the waste processing.

5-3.11.1 Fire Fighting Control Room.

Provide a self-contained firefighting control room adjacent to the plant control room. Locate the master fire alarm control panel, parallel displays of the plant closed circuit television (CCTV) system, and fire fighter telephone master console system, elevator status panels, and fan override controls in the control room.

5-3.11.2 Fire Fighter Telephone System.

Provide a fire fighter telephone system in the plant where fire fighter radios will not operate to enable two-way communications and in key areas as directed by the local fire authority having jurisdiction (AHJ). Use a common communication talk line system.

5-3.11.3 Interior Sprinkler System.

Provide all interior areas with sprinkler systems.

5-3.11.4 Exterior Sprinkler System.

Provide dry sprinkler system at all exterior areas with process equipment. Provide fire sprinkler system at cooling towers unless cooling towers are non-combustible.

5-3.11.5 Monitor Nozzles.

In addition to a dry pipe sprinkler system located over the pit and charging hopper parapet, provide local and remote operation of high capacity monitor nozzles. Locate monitor nozzles to facilitate ease of access by, and provide safe distance, for firefighting personnel. Space monitor nozzles to provide 100% coverage of the tipping and pit floors, and arrange to avoid inadvertent impact by the crane grapple. Protect monitor nozzle piping systems exposed to freezing temperatures from freezing.

5-3.11.6 Fire Fighting Water Storage.

Design the fire pump system to pressurize the fire water site main and take suction from the fire water storage tank. Size the fire pump, water supply, and fire water storage tank systems to provide fire water protection requirements for a 3-hour duration, or more. Arrange for the installation of at least two (2) fire water pumps unless a risk analysis eliminates the need for redundancy. Consider pump failure modes, electrical system failure modes, fire and explosion spread potential, life safety risk to fire fighters and plant personnel, environmental impact, pump maintenance requirements and local fire authority having jurisdiction requirements in the analysis. Where redundant pumps are used, one of the pumps must be isolated in a fireproof enclosure. Wire the redundant pump for a priority power from an emergency diesel generator or drive pump with a diesel engine.

5-3.11.7 Fire Alarm and Signaling Systems.

Provide fire alarm and Mass Notification Systems (MNS). Fire alarm systems must conform to NFPA 72 and UFC 3-600-01. MNS are to comply with UFC 4-021-01.

5-3.11.8 Smoke Relief Hatches.

Large emergency smoke relief hatches (solenoid release operated) are to be provided in the roof above the parapet-pit area.

5-3.11.9 Deflagration Venting.

Conduct a hazard analysis and provide deflagration venting systems in accordance with NFPA 68.

5-3.12 Water Pollution and Control Equipment.

5-3.12.1 Water Pollution Control Requirements.

Stormwater drainage and collection for all site areas to comply with all State requirements including all appropriate notifications and filings. Collect stormwater inside the site area discharged to a predetermined location. Utilize gasketed stormwater piping in areas subject to plant operations contamination and route to the facility wastewater treatment plant.

5-3.12.2 Process Waste Water Pollution Control Requirements.

Provide an onsite wastewater collection and treatment system to meet the wastewater discharge quality limit for the facility, including treatment of all process wastes, spent chemicals, backwash and rinse waters. Design facility wastewater system to maximize water reuse and reduce discharges to a minimum.

5-3.13 Heating Ventilation and Air Conditioning (HVAC) Systems.

Provide heating, ventilation, and air conditioning to remove dust, remove radiated process heat, control odor, minimize condensation, and provide a safe and comfortable working environment. Keep normally occupied areas such as the offices, control room, and crane operator control room at positive air pressure in relation to plant machinery and solid waste operation areas. Design and construct facility HVAC systems in accordance with UFC 3-401-01, UFC 3-410-01, UFC 3-410-04N (for Navy), and ACGIH Industrial Ventilation: A Manual of Recommended Practice, as appropriate for the facility area classifications.

Provide HVAC systems as indicated in the following sections. Where air conditioning is not provided, calculate ventilation rates for heat removal in summer conditions not to exceed 104 ^{o}F (40 ^{o}C) where practical. When 104 ^{o}F (40 ^{o}C) is exceeded, ensure all equipment upper operating temperatures are considered in the design. Limit forced air ventilation to not to exceed 60 air changes per hour. Preheat outside ventilation air to prevent freezing of piping and plant equipment as appropriate.

5-3.13.1 Refuse Receiving and Storage Building.

Design the refuse receiving and storage building ventilation to provide a minimum of 12 air changes per hour. Provide filters and scrubbers on exhaust air.

5-3.13.2 Boiler Building.

Design the boiler building for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of 30 air changes per hour below the burners and 15 air changes per hour above the burners. Provide multiple units. Source air through the refuse pit. Provide filters and scrubbers on exhaust air.

5-3.13.3 Control Room.

Design the control room for operating temperature between 72-76 ^{o}F (22-24 ^{o}C) cooling and 68-72 ^{o}F (20-22 ^{o}C) heating with relative humidity between 30 to 50%. Ventilation is to be per ASHRAE 62.1. Noise Criteria (NC) not to exceed 40. Provide two independent units for 100% redundancy. Control room air pressure to be positive to remainder of facility with filtration efficiency of 90% and ultraviolent (UV) sterilized.

5-3.13.4 Server Room.

Design the server room for operating temperature between 68-72 ^{o}F (20-22 ^{o}C) and relative humidity between 30 to 50%.

5-3.13.5 Crane Operator Control Room.

Design the crane operator control room for operating temperature between 72-78 ^{o}F (22-25 ^{o}C) cooling and 68-72 ^{o}F (20-22 ^{o}C) heating with relative humidity between 30 to 50%. Ventilation to be per ASHRAE 62.1. NC not to exceed 40. Provide two independent units for 100% redundancy. Control room air pressure to be positive to remainder of facility with filtration efficiency of 90% and UV sterilized. Provide a system with energy recovery units on exhaust air.

5-3.13.6 Steam Turbine Area.

Design the turbine area for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of 10 air changes per hour.

5-3.13.7 Administrative Offices.

Design the administrative offices for operating temperature between 74-78 ^{o}F (23-25 ^{o}C) cooling and 68-72 ^{o}F (20-22 ^{o}C) heating with relative humidity between 30 to 50%. Where administrative offices are included in the main plant facility, the air pressure is to be positive to remainder of facility with filtration efficiency of 90% and UV sterilized. Provide energy recovery units on exhaust air.

5-3.13.8 Air Pollution Control Building.

Design the area for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of 5 air changes per hour. Provide filters and scrubbers on exhaust air.

5-3.13.9 Ash Conveying Areas.

Design building for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of five (5) air changes per hour but not less than that required to prevent explosive dust accumulation. Provide filters and scrubbers on exhaust air.

5-3.13.10 Residue Management Building.

Design the building for processing and storing ash, ferrous and non-ferrous metals, and oversized materials. Size the Residue Management Building for five days storage for processing, separating, and storage of non-ferrous and ferrous metals; and four days storage of ash. Determine the Residue Management Building dimensions based on operating and space requirements.

5-3.14 Plumbing Systems.

Design plumbing systems in accordance with UFC 3-420-01.

5-3.15 Electrical Systems.

Design plant electrical system as a unit type system with the utility transformers connected solidly to the generator bus and switched with the generator. Design electrical systems in accordance with UFC 3-501-01.

5-3.15.1 Utility Interconnect.

Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

5-3.15.2 Synchronizing Switchgear.

Provide a substation on the facility site of a modern, fenced, low-profile design, complete with bus duct connection between generator switchgear and facility step-up transformer. Protect all the electrical equipment from electrical fault damage by protective relays. Design substation to operate over the range from import of full station auxiliary power requirement to export of full net plant real and reactive power capability to the transmission system while maintaining standard operating voltage limits on the facility buses.

5-3.15.3 Electrical Power Distribution System.

Provide a complete electrical system of medium-voltage, low-voltage, and DC power to all loads in the power plant under all service conditions including start-up, operation, failures, and shutdown. Plant medium and low voltage distribution system are to be grounded wye. Provide parallel medium voltage to low voltage unit substations for redundancy. Plant critical loads include the following:

- Fire pumps;
- Fire jockey pumps;
- Uninterruptable Power Supply(ies) (UPS);
- DC power system and battery chargers;
- Cooling water pumps;
- Hydraulic pumps;
- Critical lubrication systems;
- Elevators;
- Security systems;
- Distributed control system;
- Control and server room HVAC systems;
- Motor control center and switchgear HVAC systems;
- Critical instrumentation;
- Telecommunication systems;
- Aviation obstruction lighting;
- Perimeter security lighting; and
- Emergency and exit lighting.

Design the system with the following criteria:

5-3.15.3.1 DC System.

Provide a DC system, with UPS, for the plant DCS to provide for an orderly facility shutdown in the event of a loss of normal power. The DC power is to conform to the requirements of UFC 3-520-05.

5-3.15.3.2 Emergency Power System.

Provide an emergency power system for operating the plant critical loads in the event of a loss of normal power.

5-3.15.3.2.1 Uninterrupted Power System

Provide a UPS for the following critical loads: fire alarm system and MNS; telecommunications system; security systems; plant DCS; and critical instrumentation.

5-3.15.3.2.2 Generator

Provide natural or diesel gas generator(s) if natural gas is not available, sized to handle the plant critical loads and an N+1 redundancy. If using diesel gas generator(s), provide a minimum fuel storage for operating at full emergency power for five (5) days.

5-3.15.4 Lighting.

Conform to UFC 3-530-01 and National Electrical Contractors Association (NECA)/IESNA 502-2006.

5-3.15.5 Grounding/Lightning Protection System.

Conform to the following: IEEE C2, IEEE 142, NFPA 70, NFPA 780, and UFC 3-575-01.

5-3.15.6 Communications and Signal Systems.

Conform to UFC 3-580-01.

5-3.16 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

5-4 OPERATION AND MAINTENANCE.

5-4.1 Non-Performance.

Ensure non-performance and remedy clauses are included in the maintenance contract to address contractor non-conformance. Ensure liquidated damages address loss of power generation revenue and mission impacts.

5-4.2 Warranties.

Specific component warranties will vary with manufacturer. Arrange for a five (5) year extended warranty period after date of project acceptance for the following major equipment and sub-systems: scales, cranes, steam generating systems, APC systems, DCS system, CEM systems, turbine-generators, condensers, cooling towers, and feedwater-cooling tower pumps. Warranties are typically limited to repair or replace, at manufacturers' discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages.

5-4.3 Power Plant Operation.

Design plant so that each boiler/generator unit may be operated independently, and a single failure of mechanical equipment common to all boiler / generator units will not trip any operating boiler/generator unit.

The plant and each boiler/generator unit is to be fully dispatchable with automatic generation control (AGC) and capable of being dispatched from minimum to full load. The facility and each Unit will also be capable of cycling operation. The balance-of-plant design will not limit operation over the full range of site ambient conditions.

5-4.4 Maintenance Requirements.

Provide for and equip maintenance facilities with required tools and repair plant equipment. Organize the maintenance facility that is organized into defined work spaces. Provide hoists/monorails as required for the shop. Size maintenance area doors to accommodate expected maintained equipment sizes. Work spaces to include, at a minimum, a machine shop, hot work area, vehicle maintenance and storage garage, and painting work area with ventilation. Maintain critical spares as necessary to meet mission reliability/availability requirements.

5-4.5 Safety.

Comply to applicable provisions in 29 CFR 1910 and 29 CFR 1925, American Conference of Governmental Industrial Hygienists Threshold Limit Values and Biological Exposure Indices, and local/agency codes and requirements.

CHAPTER 6 DESIGN CRITERIA – LANDFILL GAS RECOVERY POWER PLANT

6-1 INTRODUCTION.

This chapter presents the planning, design, O&M requirements, and equipment calibration for renewable energy produced by landfill gas collection and processing systems.

6-1.1 Technology.

Use technology that utilizes waste gas (from landfills) to energy technology of low-grade, medium-grade, and high-grade landfill gas. Use resources and references specifically for a medium-grade landfill gas system.

6-1.2 Landfill Gas (LFG) To Energy.

Refer to USEPA for various applications for LFG to energy (http://www.epa.gov/lmop). USACE EM 200-1-22, as amended by Agency guidance, provides information on systems design to monitor, collect, transport, and treat LFG from landfills.

6-1.2.1 Land Fill Gas Overview.

Employ systems and technologies associated with analyzing, extraction, collection, processing, and treatment of LFG, produced by decomposing organic waste, and then converted into a useable energy source. Provide the aforementioned systems to have the capability to simultaneously lower the quantity of greenhouse gas emissions released into the atmosphere and nuisance odors.

6-1.2.2 Landfill Gas Systems Types.

Passive Collection Systems: Utilize passive collection systems for control of migrating gases through the use of vertical and horizontal wells, liners, vents with all applicable appurtenances.

Active Collection Systems: Utilize active collection systems for the collection of LFG by mechanical means to create a vacuum to influence the gases to a desired location through the use of blowers or vacuums, vertical and horizontal wells, vents, valve systems, controls and analyzers, and with all applicable appurtenances.

6-1.2.3 Landfill Gas Grades.

Determine landfill gas quality grade to produce based upon end use specifications.

6-1.2.3.1 Low-Grade.

Low-grade LFG requires only minimal processing to remove moisture and particulates and produces a low-grade fuel that may be adequate for the facility operational requirements.

6-1.2.3.2 Medium-Grade.

Providing medium-grade LFG requires increased level of processing to remove moisture, volatile organic compounds (VOC), siloxanes, and sulphur compounds. Medium-grade LFG is used for most heating applications and electricity generation.

6-1.2.3.3 High-Grade.

Processing LFG to a high-grade quality requires removing moisture, particulates, VOCs, sulphur compounds, siloxanes, halogenated compounds, carbon dioxide, nitrogen, and oxygen. Process LFG to high-grade when pipeline quality is desired.

6-2 PLANNING.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

6-2.1 Waste Type and Quality Site Assessment.

Overestimating available LFG resources is a common project pitfall. Perform site due diligence and conservatively estimate recoverable methane quantities and quality by using up to date computer simulation software.

6-2.1.1 Composition.

Confirm that landfill composition has sufficient organic material, such as yard waste, food waste and sewage waste, suitable for bacterial growth, and avoid hazardous wastes.

6-2.1.2 Moisture Content.

Evaluate the landfill moisture content because the moisture content is a major factor of methane generation. Provide important data such as weather conditions, initial waste moisture, liner design, leachate collection systems, and cover types. The optimum moisture content should be in the 50% to 60% range.

6-2.1.3 Temperature.

Analyze landfill temperature. Evaluate the landfill depth to predict temperature fluctuations in the landfill since deep landfills provide more stable temperatures whereas shallow landfills are affected by surface weather conditions causing greater fluctuations in temperature. Optimum temperature for aerobic decomposition is 130 ^{o}F to 160 ^{o}F (54-71 ^{o}C) and for anaerobic decomposition are 85 ^{o}F to 105 ^{o}F (29-40 ^{o}C).

6-2.1.4 pH.

Analyze the landfill pH as methane generation is maximized when the landfill pH is neutral. The pH is generally in the range of 6.5 to 8.0 during methane generation. Leachate pH range is expected between 5.0 and 9.0.

6-2.1.5 Waste Density and Particle Size.

Confirm the waste density, which is a factor of waste size and compaction techniques.

6-2.1.6 Waste Age.

Confirm the landfill age, since landfill gas generation is typically significant for 10-20 years. Landfills with an age greater than 20 years are less likely to produce large quantities of landfill gas.

6-2.1.7 Moisture Access.

Evaluate means of access for water entry into the landfill in order to calculate and predict moisture levels within the waste.

6-2.2 Landfill Gas Generation Modeling.

Scholl Canyon and EPA-600/R-05/047 LandGEM models are the preferred models for use by the U.S. EPA and USACE respectively. Use the Scholl Canyon Model (First Order Decay) to determine the amount of methane produced by calculating the amount of waste disposed each year and the amount time after the landfill is closed, which are the primary variables required. Use the LandGEM Model which modifies the Scholl Canyon Model by dividing the waste by a factor of 10.

Perform a pump test for landfill sites with a large potential of LFG quantities and recovery. The tests should consist of installing extraction wells, blowers, and monitoring probes to collect and analyze the gas composition. The test results must include LFG flow measurements, landfill pressures, and the final calculated LFG production rate.

6-2.3 Landfill Gas Quality.

The preferred LFG composition consists of 40-60% methane (CH_4) and the remainder mostly comprised of carbon dioxide (CO_2). Evaluate and design system based upon LFG quality and quantity. Adhere to the following quality criteria in the analysis:

6-2.3.1 Saturation Water (Water Vapor).

The preferred quantity of saturation water vapor within the LFG is 4-7% by LFG volume created.

6-2.3.2 Sulfur Compounds.

Process and filter LFG to keep sulfur compounds within acceptable limits set forth by the monitoring equipment's manufacturer's recommendations.

6-2.3.3 Siloxanes.

Process and filter LFG to keep siloxanes within acceptable limits set forth by the equipment manufacturer's recommendations.

6-2.3.4 Halogenated Compounds.

Process and filter LFG to keep halogenated compounds within acceptable limits set forth by the equipment manufacturer's recommendations.

6-2.3.5 Volatile Organic Compounds (VOCs).

Process and filter LFG to keep VOCs within acceptable limits set forth by the equipment manufacturer's recommendations.

6-2.4 Environmental Regulations and Restrictions.

6-2.4.1 Resource Conservation and Recovery Act (RCRA) Requirements.

Comply with RCRA requirements if LFG is emitted or if condensate is treated and disposed. Comply with:

- 40 CFR Part 258;
- 40 CFR Part 260;
- 40 CFR Part 261;
- 40 CFR Part 262; and
- 40 CFR Part 268.

6-2.4.2 Air Quality Regulations.

Comply with local Air Quality Board requirements.

6-2.4.3 National Ambient Air Quality Standards (NAAQS).

Comply with NAAQS standards.

6-2.4.4 Clean Air Act (CAA).

Comply with CAA, including:

- 40 CFR Part 60;
- 40 CFR Part 63;

- New Source Review (NSR) permitting;
- 40 CFR Part 70, Title V permitting; and
- Information collection authority used to implement greenhouse gas reporting program.

6-2.4.5 Water Quality Regulations.

Comply with Clean Water Act (CWA) regulations.

6-2.4.6 Solid Waste Disposal Regulations.

Comply with landfills RCRA requirements.

6-2.4.7 Other Restrictions and Requirements.

Consult with states and local authorities that may have adopted rules concerning LFG emissions and condensate disposal to ensure compliance with all applicable regulations. Monitor emissions and comply with personnel exposure threshold limits.

Comply with industry standards and equipment manufacturer specifications where codes do not govern specific equipment or system features.

6-2.4.8 Nuisance Odor.

Provide a design to efficiently collect LFG, without overpull, to minimize the gas release to the atmosphere causing nuisance odors. Hydrogen Sulphide is a trace compound found in LFG within a typical range of 100 parts per million (ppm).

6-2.4.9 Vegetation Stress.

Monitor signs of vegetation stress due to high levels of oxygen or other gases which indicate an imbalance in the system or possible loss of control components.

6-2.4.10 Potential Explosive Gas.

Use infrared LFG analyzers to monitor methane levels at the landfill perimeters and other structures on or adjacent to the landfill and to initiate alarms and safe shutdown procedures before the lower explosive limit (LEL) of methane in air (5%) is reached.

6-2.4.11 Greenhouse Gas Release.

The design must incorporate redundant equipment, redundant extraction methods and LFG destruction schemes, and control systems to prevent greenhouse gas release to the atmosphere.

6-2.5 Interconnect Studies.

Perform interconnect studies. Refer to Chapter 8 titled "UTILITY INTERCONNECTION" for guidance.

6-2.6 Permits.

Confirm all Federal, State, and local permitting requirements prior to the design and construction of a landfill gas to energy project.

6-2.6.1 Environmental Impact Statement.

Provide an Environmental Impact Statement (EIS) which is a required document describing how the human environmental quality is affected both positively and negatively. This document must discuss how the environment is affected and the environmental consequences associated with the project. Provide a list of required alternatives that are to be included in the document. Include the following in the EIS:

- All required air permits;
- Any required construction permits are required for new LFG projects under the NSR;
- All documentation regarding the Prevention of Significant Deterioration (PSD);
- Title V operating permit;
- A National Pollutant Discharge Elimination System (NPDES) permit which regulates point sources that discharge pollutants into United States waters and include separate permitting for storm water run-off associated with the landfill;
- Solid waste disposal permits as required for the project and as required by the local authorities; and
- Dredge and Fill permits as required to meet the CWA Section 404 which regulates the discharge of dredged or fill materials into the United States waters.

6-2.7 Cost Estimation / Analysis.

Cost analyses for landfill gas entail unique cost estimation requirements and parameters including waste tonnage estimation, landfill gas collection efficiency, greenhouse gas (GHG) emission reductions, annual fixed and variable O&M costs, and calculation of capital costs.

6-2.7.1 Waste Tonnage Estimation Methodology.

Use waste tonnage estimation methodology to predict the total quantity of LFG output for a landfill over a set period based on the amount of LFG produced each year versus the amount of waste added each year. The estimation must show the increasing and decreasing quantities of LFG produced over the landfill life in relation to the increasing and decreasing quantities of waste added each year.

6-2.7.2 LFG Collection Efficiency Estimation Methodology.

Use the LFG collection efficiency estimation methodology to determine the average amount of LFG collected in a year divided by the LFG generation that was modeled for that same year. The LFG flow composition is assumed will be 50% methane. The LFG collection and management systems efficiency is expected to be a minimum of 75%.

6-2.7.3 Greenhouse Gas Emission Reductions.

Comply with the CAA emission regulations and implement the greenhouse gas reporting program.

6-2.7.4 Capital Costs.

The capital cost associated with constructing an LFG to energy project are typically $1,000 per kilowatt of electricity produced.

6-2.8 Coordination.

Establish an institutional framework consisting of the major project stakeholders including government authorities, the landfill owner / operator, community groups, and energy sector companies. Review with the stakeholders the financial, environmental and energy plant operational issues. Perform a comprehensive stakeholder analysis to identify potential issues involving energy plant construction and operation. Establish agreements that resolve issues before the plans are made to build the plant.

6-3 DESIGN CRITERIA.

6-3.1 General Design Requirements.

Design landfill gas recovery systems to extract the landfill gas through a gas collection system of piping and wells. Design the condensate in the landfill piping to be collected and treated through a condensate collection and treatment system. Design a primarily active type system were gas in the collection piping is pulled by vacuum blower(s) to an extraction plant where the gas receives further treatment to remove contaminants and improve the gas quality and while the condensate entrained in the gas is separated and filtered out. Include gas conditioning and filtering prior to being, burned in a flare, burned in a boiler to produce heating, or burned in a generator that powers an alternator to produce electric energy. Consider site climate to determine if equipment should be enclosed in a structure.

6-3.1.1 Site Considerations.

Investigate the site to determine the landfill elevation at which the landfill collects waste, in relation to the surrounding grade. Consider the elevation at which the landfill collects waste, in relation to the surrounding grade, which can affect the quantity of LFG collected, gas released to the atmosphere, and migration of gases to surrounding areas. Design slopes around collected waste to be more gradual and less acute and not to exceed 25% (4 horizontal to 1 vertical unit) to provide increased collection, efficiency, decrease potential for oxygen overpull, and increase simplicity for cover construction and maintenance.

Provide service roads. Design the site to provide proper vehicle access for by service personnel and emergency vehicles. Use a perimeter fence with lockable and accessible gates, at a minimum, to secure facilities and remote pieces of equipment. Ensure access is available to fire hydrants or other fire protection features. Provide all necessary utilities, such as sanitary sewer, water, electricity, and telecommunications, required for plant operations. Refer to UFC 3-600-01 for additional guidance.

6-3.1.2 Hydro-geological Condition.

Investigate site hydro-geological conditions to assess off-site LFG migration to determine high and low permeability materials, depth of ground water, moisture content, and other geologic conditions. See Table 6-1 below for suggested parameters and test methods. USACE references are mandatory for U.S. Army. For other Agencies, comply with agency specific requirements.

Table 6-1 Parameters and Test Methods for Landfill Gas Migration

Parameters and Test Methods for Landfill Gas Off-Site Migration (Adapted from USACE EM 200-1-22 table 2-1)		
Parameter Tested:	**Collection Method:**	**Reference:**
Atterberg Limits	Soil Borings	ASTM D4318
Depth to Groundwater	Monitoring Wells	ASTM D4750
Grain Size and Porosity	Soil Borings	ASTM D422
Heterogeneity / Utility Trenches	Geophysical Investigations	USACE EM 1110-1-1804
Moisture Content	Soil Borings	ASTM D2216
Stratigraphy	Soil Borings	ASTM D2487 ASTM D2488 USACE EM 1110-1-1804
Vapor Phase Concentrations	LFG Monitoring Probes	EPA TO 14a

6-3.1.3 Landfill Cover Design.

Design cover to prevent intrusion of air into the waste. Design must consider the effects of changing barometric pressures. Design the cover to prevent air intrusion into the waste to prevent oxygen overpull. Refer to UFC 3-240-10A (for Army) for final cover design. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

6-3.1.4 Landfill Liner Design.

Refer to UFC 3-240-10A (for Army), for landfill liners design. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

6-3.1.5 Moisture Addition and Leachate Recirculation.

Introduce moisture to landfill or recirculate leachate as required to optimize LFG production by accelerating decomposition and to remove water soluble contaminants in the waste. Contaminants in the landfill can be removed by moisture percolating through the waste.

6-3.1.6 Oxygen Overpull.

Use monitoring equipment in the extraction well to assess the oxygen content in the LFG. The monitoring equipment must be capable of measuring the oxygen content to help determine oxygen overpull, locate possible leaks in the processing equipment, balance the wells to achieve the LFG quality desired, and to improve the extraction process efficiency. Oxygen levels should be less than 2.5% by volume.

6-3.1.7 Drilling Rig Access.

Provide adequate access, service roads, and space for the mobilization of drilling equipment and for drilling equipment usage when drilling LFG extraction wells.

6-3.2 Collection System Design.

Refer to USACE EM 1110-1-4016, or Agency specific guidance, for landfill gas collection system design.

6-3.2.1 Active Systems.

Design an active LFG collection system to consist of a blower system, extraction wells, a piping system with valves, flares, and electronic controls and meters. Use blowers to draw the LFG from the extraction wells through the piping system and delivered to the extraction plant where the gas is processed and combusted. Use an active system to capture and collect LFG.

6-3.2.2 Passive Systems.

Design a passive LFG collection system to consist of horizontal trenches filled with a coarse granular fill. Use passive systems only to supplement an active system and be used to prevent LFG from migrating out of the landfill to the surrounding soils or out to the atmosphere. Design passive systems to be located at the perimeter around the landfill and at shallow areas of the landfill.

6-3.2.3 Collection System.

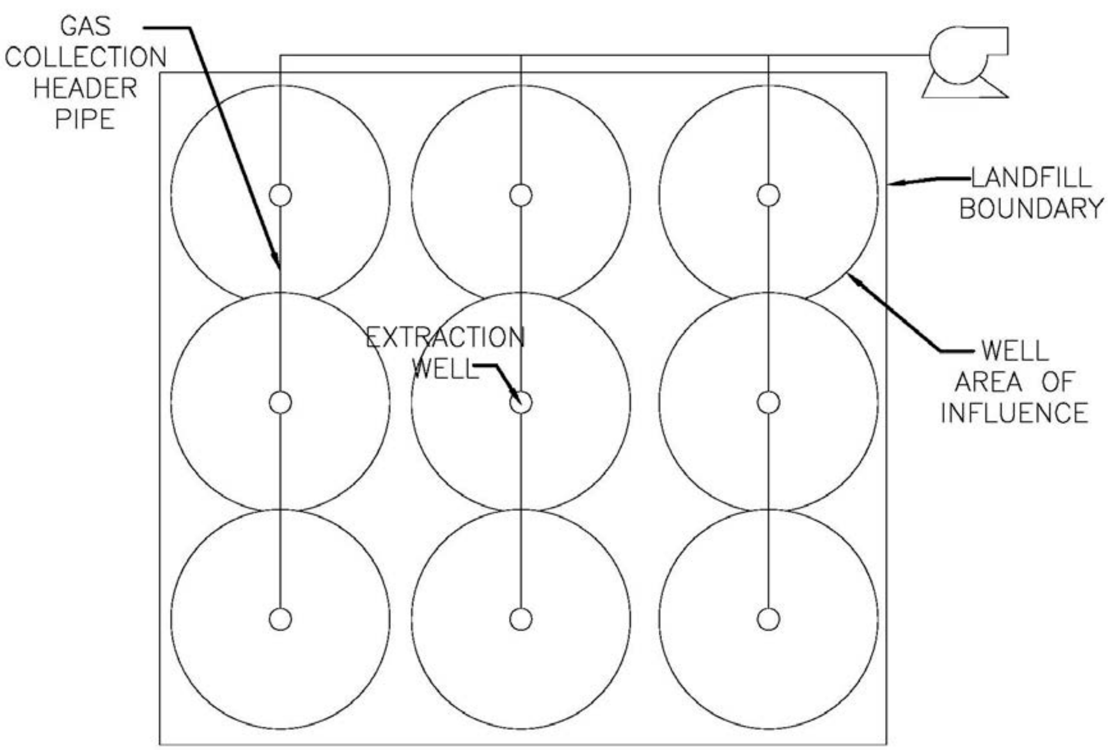
Collect landfill gas using a blanket collection system consisting of vertical extraction wells, and possibly with a combination of horizontal collection trenches. A blanket collection system consists of collecting LFG through a permeable layer of sand or gravel that is covered by an impermeable layer, a drainage layer, and a soil cover layer. A preferred permeable layer thickness is 1.0 ft. (30 cm) thick. Install a perforated pipe in the permeable layer connecting to a vent pipe. Space vent pipes 200 ft. (61 m) apart.

6-3.2.4 Vertical Extraction Wells.

Use vertical extraction wells primarily to extract LFG after landfill filling operations have been completed. Design vertical extraction wells to consist of perforated or slotted pipe that penetrate near the refuse bottom or near the saturated waste depth. The typical minimum depth of a landfill using vertical extraction wells is 40 ft. (12 m). Investigate the specific site confirm landfill depths and ensure a proper design.

Use the design procedures in USACE EM 200-1-22, or Agency specific guidance, and State regulatory requirements when determining the well spacing. Design vertical collection wells for 50 to 200 ft. (15-61m) spacing (Figure 6-1).

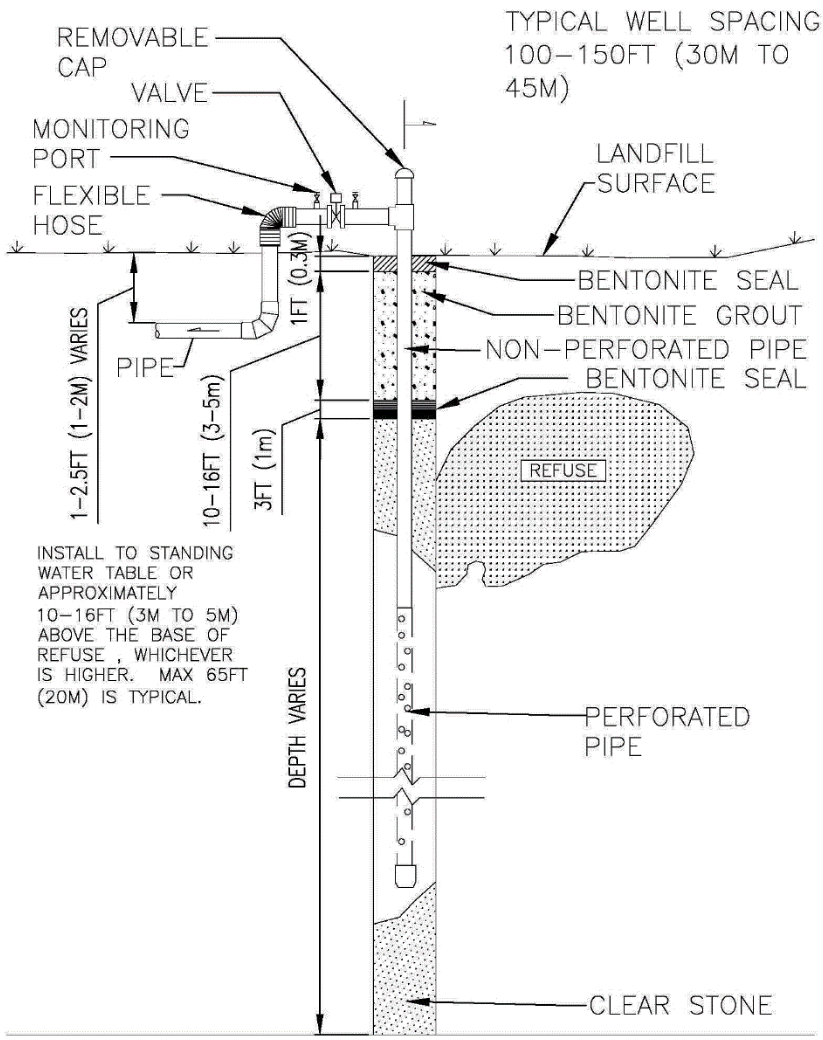
Figure 6-1 Well Spacing



6-3.2.5 Vertical Extraction Well Design.

Design a well to have a perforated pipe installed in the borehole center and then backfilled with an approved aggregate with a bentonite seal used to prevent air infiltration. Backfill the remaining borehole with soil. Analyze the LFG production rate and the radius of influence around a well to properly design the well system. The LFG recovery rate from a single well is expected to range from 10 – 50 cubic ft. per minute (cfm) (4.7- 23.6 l/s). The recommended design vacuum pressure for each extraction well is 10 – 25 in (25.4-63.5 cm) of water column (wc) to achieve higher LFG collection efficiency and to prevent a landfill fire or explosion. Where possible, design for higher efficiency operations to maximize the radius of influence while minimizing air (oxygen) intrusion into the landfill (Figure 6-2).

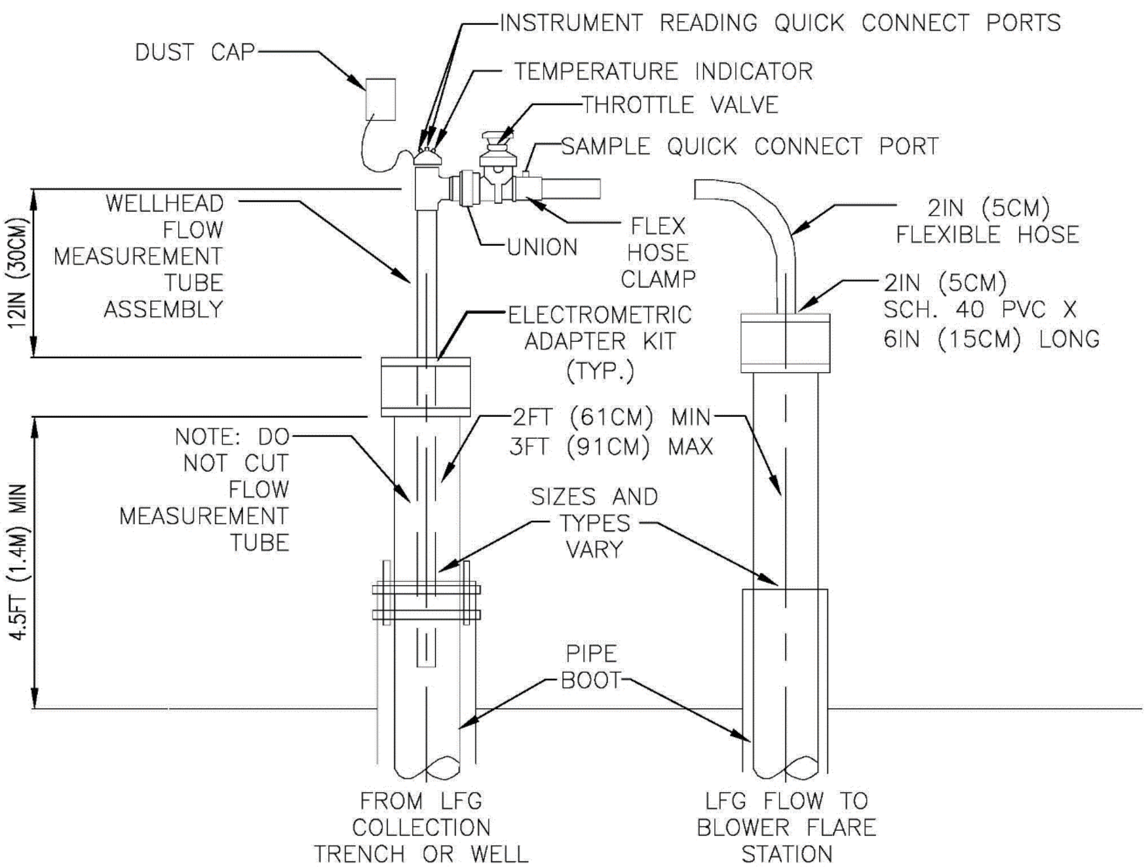
Figure 6-2 Typical Vertical Extraction Well



6-3.2.6 Vertical Extraction Well Heads.

Locate the well head assembly (Figure 6-3) above the landfill surface to allow for LFG sampling, measurement, adjustment, and inspection. Construct the well head assembly to incorporate a flow measurement tube, instrument connections, a sampling port, a control valve, a flexible hose, and a removable access at the perforated pipe top for inspection, maintenance, and leachate removal. Design pipe sleeves and boots for piping penetrating into extraction well. Size the control valve, or well head valve, to provide a high degree of control precision without over sizing valves. Preferred control valve types are butterfly and globe valves. Only use gate valves for isolation or on/off operation.

Figure 6-3 Well Head Assembly



6-3.2.7 Horizontal Collection Trenches.

Horizontal Collection Trenches. Use horizontal collection trench systems (Figure 6-4) for active landfills currently receiving waste or in shallow areas of the landfill. Use the horizontal trenches as part of the active type system. Limit passive type horizontal trenches to landfill perimeters only. Install the collection trenches in layers as the refuse is added (Figure 6-5).

Figure 6-4 Horizontal Collection Trench

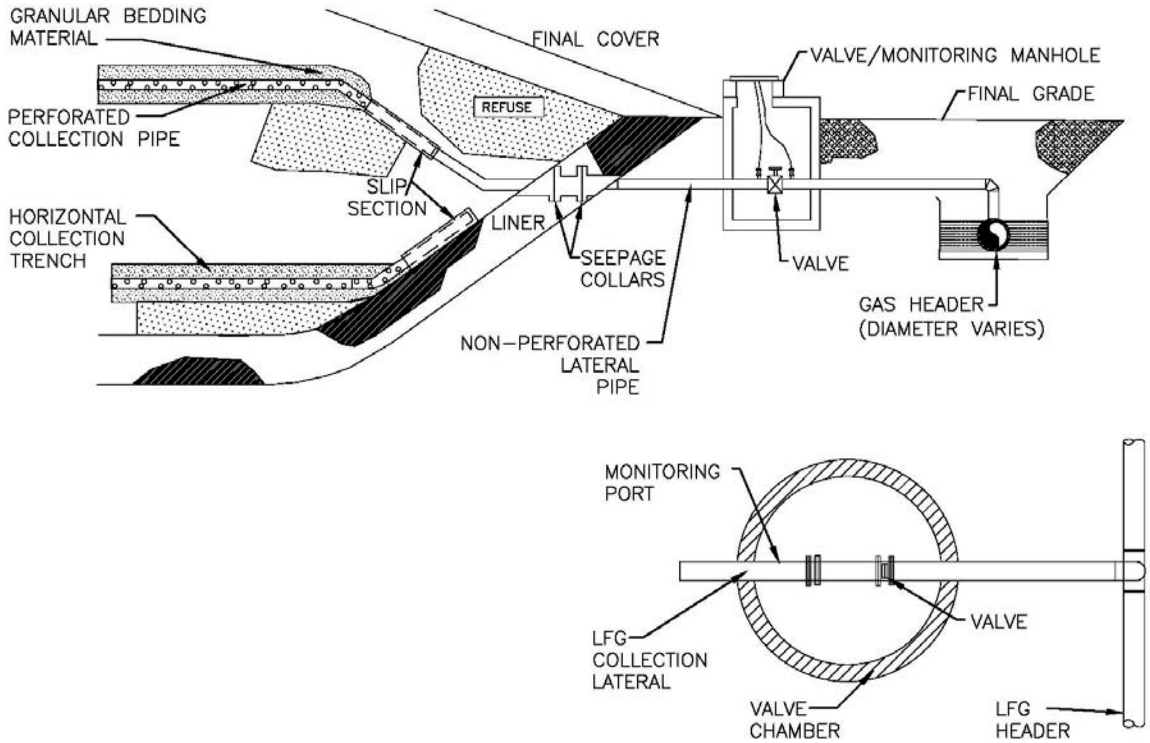
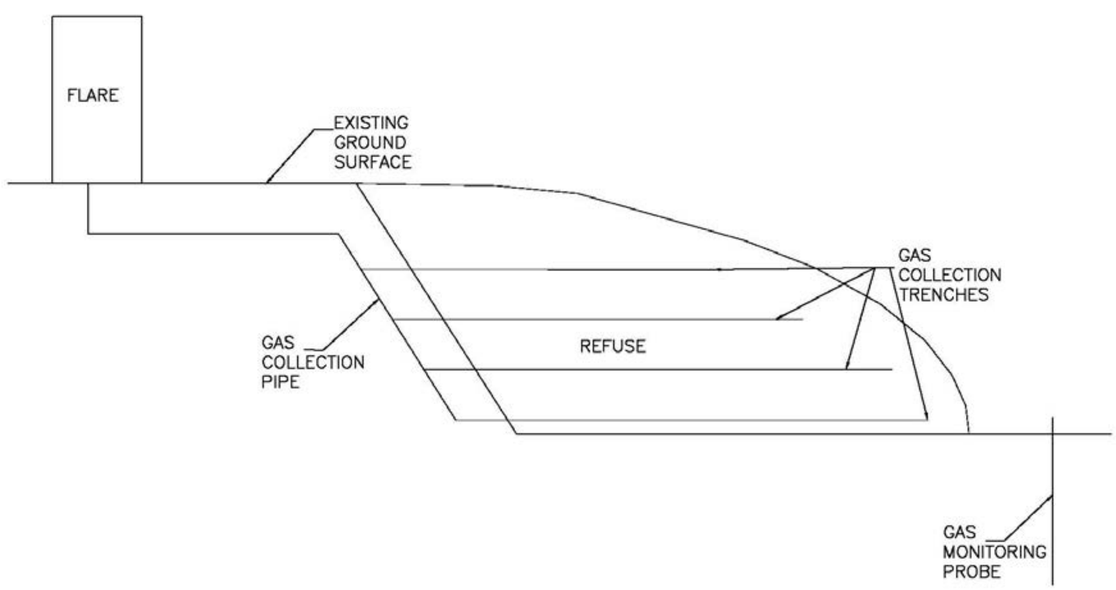


Figure 6-5 Horizontal Trench Layering



6-3.2.8 Horizontal Collection Trench Design and Construction

Refer to the design procedures in USACE EM 200-1-22 and State regulatory requirements when determining the well spacing. Space wells 200 ft. (61 m) apart.

Trench horizontal wells into the landfill using an approved aggregate bedding with a perforated pipe in the center of the trench. Backfill the trench with an approved aggregate. Apply a geotextile fabric on the trench top to prevent clogging. Use a bentonite seal to prevent air infiltration and back fill the trench with soil or waste. Construct the well head assembly similar to the configuration described for the vertical extraction well head.

6-3.2.9 LFG Collection Piping.

Design collection piping to transport LFG from the extraction wells, using blowers, to a burner or to a gas processing system prior to the end use equipment. Use a pipe header system to connect multiple extraction wells together. Design the LFG collection piping for below grade, wherever possible, to minimize condensate freezing and pipe clogging.

6-3.2.10 Header Configurations.

Take into account in the header configuration design, system components, landfill size and depth, types of waste, radius of influence, system friction losses in equipment and the subsurface components, and the extraction rate of LFG. Use one or more of the following three preferred methods for header configurations: (Figure 6-6).

6-3.2.10.1 Branch (Radial).

Design the branch header configuration to consist of a series of subheaders (branches) that connect to one main collection header. Use isolation valves to isolate individual branches for maintenance and service without shutting down large portions of the collection system.

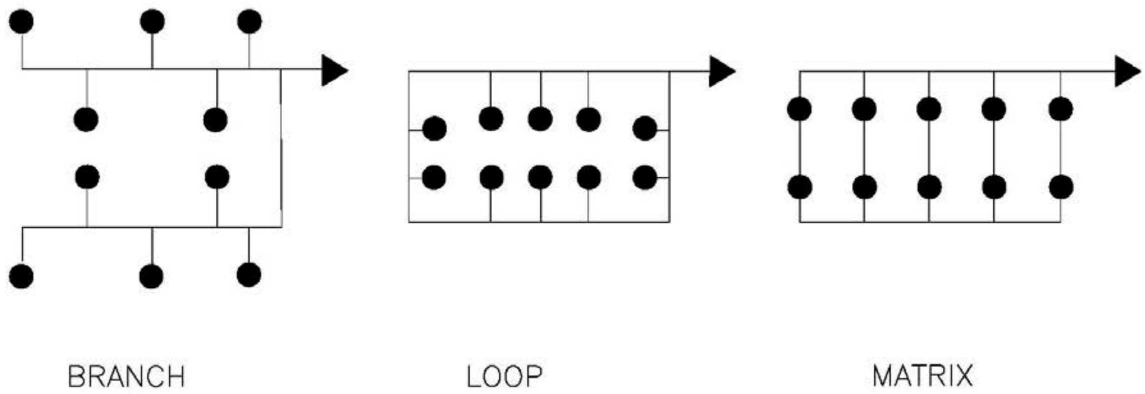
6-3.2.10.2 Loop.

Design the loop header configuration to consist of a main header that loops around the landfill with each well inside the loop connecting to the main header. Use isolation valves to shut down individual wells without shutting down major portions of the collection system. Ensure the design has adequate capacity to allow the LFG to flow in more than one direction.

6-3.2.10.3 Matrix (Herringbone).

Design the matrix header configuration to consist of a main header that loops around the landfill with the subheaders connected to the main header at both ends of the subheader. Connect the wells to the subheader that connect to the header. Use isolation valves to isolate individual subheaders for maintenance and service without shutting down large portions of the collection system. Ensure the design allows the LFG to have the capability to flow in more than one direction.

Figure 6-6 Typical Header Layouts



6-3.2.11 LFG Piping.

6-3.2.11.1 Sizing.

Size the piping system to have a frictional pressure drop, in the pipe, less than 10 in (25.4 cm) of water column with respect to the varying flow rates of LFG.

6-3.2.11.2 Header.

Slope the LFG header and subheader piping allow the condensate to adequately drain to a collection point and to prevent condensate collecting in pipes and potentially clogging the pipe. Provide 3- 5% slope in header and subheader piping. Design system to accommodate waste and soils settlement and account for settlement when determining pipe slopes.

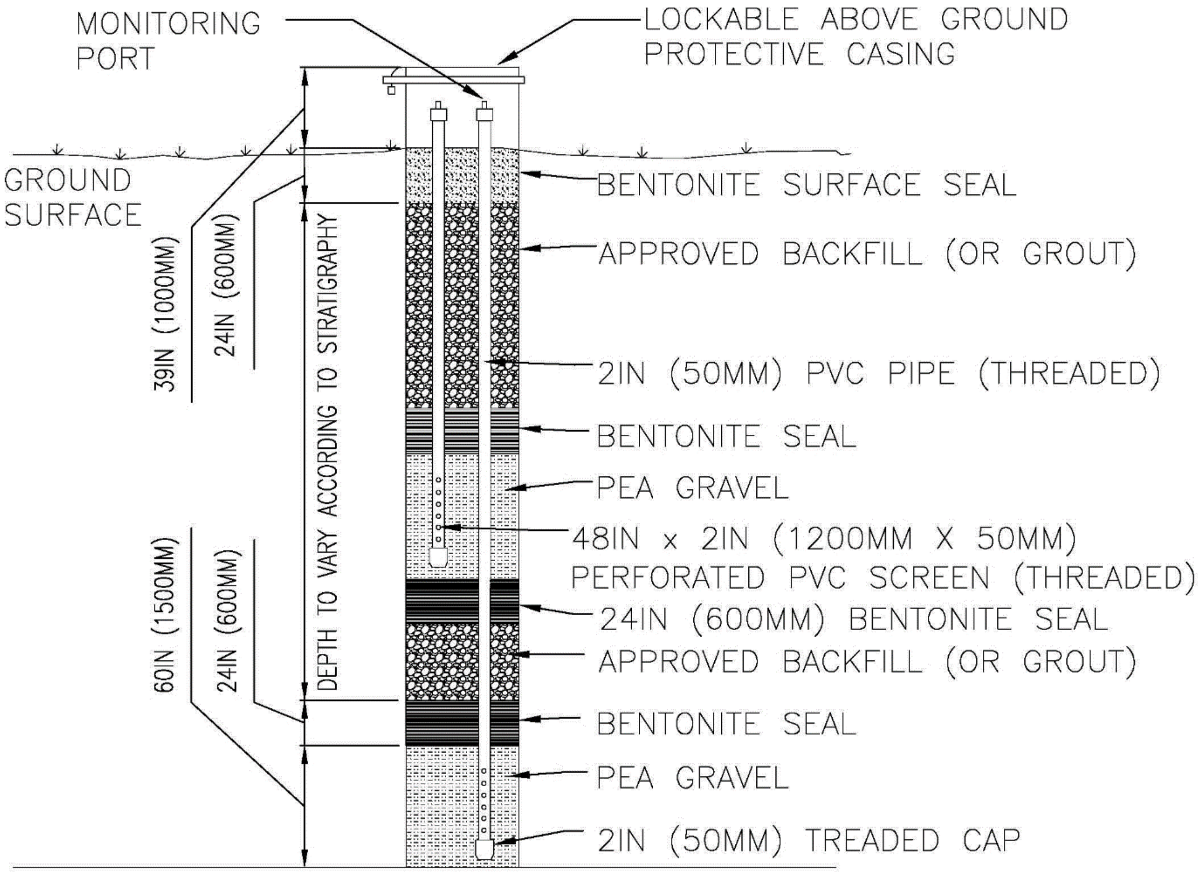
6-3.2.11.3 Materials.

Use polyvinyl chloride (PVC) or high density polyethylene (HDPE) pipe. HDPE is the preferred pipe type due its ability to withstand settlement damage and is less susceptible to damage from ultraviolet radiation than PVC.

6-3.2.11.4 Monitoring Probes.

Provide gas monitoring probes along the landfill perimeter to monitor LFG migration outside of the landfill and possible migration into adjacent structures. The preferred gas monitoring probe is a multilevel / multiple probe type to more accurately assess the migrating gases by defining the gas vertical profiles. Figure 6-7 illustrates a typical design of a multilevel / multiple gas probe.

Figure 6-7 Typical Gas Monitoring Probe Installation



6-3.3 Condensate Collection and Treatment System in LFG Collection Systems.

LFG condensate forms in the piping headers and subheaders. Design system to flow freely without blocking the pipe. Size the collection piping to allow for LFG and condensate to flow within the same pipe, and at times where the flow of LFG and the flow of condensate are in opposing directions. Provide for condensate collection low points. Provide air traps to avoid air intrusion into the waste. Use sump pumps to pump the condensate to a designated storage tank or treatment system for proper disposal or redistribution back into the landfill.

Provide for treatment and moisture / particulate filtering upstream of the blower to prevent damage to equipment and to ensure effective combustion at the flare. A condensate knockout system is the preferred type, to lower the velocity of LFG to allow an opportunity for the condensate to separate from the gas.

6-3.4 Extraction Plant.

Design an extraction plant consisting of equipment necessary to collect the LFG and primarily treat the LFG prior to being combusted for electricity generation or transmission.

6-3.4.1 Facility.

Design facility to effectively extract LFG from the landfill, remove condensate and particulates, combust the gas or divert the gas for electricity generation, and allow for adequate access and space for maintenance. Use blowers to create a negative pressure to extract LFG from the landfill and provide positive pressure to transport LFG to the flare where the gas is combusted, or for further treatment and use for electricity generation. Use flares to combust LFG for effective gas control and prevent LFG release to the atmosphere. Provide all controls, instrumentation, and monitoring equipment necessary for effective collection and processing of LFG.

6-3.4.2 Components.

6-3.4.2.1 Condensate Knockout and Particulate Removal.

Use a simple drum type condensate knockout system where low pressure centrifugal blowers are used for LFG extraction. Provide filters to remove particulates out of the LFG. Stainless steel or plastic mesh screen filters are preferred for particulate removal and added moisture removal.

6-3.4.2.2 Blowers.

Use centrifugal or positive displacement rotary lobe blowers recommended by USACE EM 200-1-22 or Agency guidance. Provide explosion proof blowers suitable for NFPA 70, Class I, Division I, Group D. Provide anti-corrosion protective coating for blower components in contact with landfill gas. Provide a full redundant unit for equipment maintenance and downtime as needed to avoid any potential health hazards. Design the blower system to take into account the LFG piping arrangement, sizes, flow rates of LFG, the pressure losses in the system piping and wells, the pressure losses in the system components, and all other system effects.

6-3.4.2.3 Gas Condenser (Refrigerated Dryer).

Use a gas condenser to further process the landfill gas by removing water vapor and organic impurities and to improve the combustion efficiency. Condensers utilizing a refrigerated system to cool the LFG to its dew point temperature to condense the water vapor out of the LFG stream are preferred. Use a refrigerated system that will bring the dew point for LFG down to 36 ^{o}– 38 ^{o}F. Use a gas condenser system that will remove impurities that are water soluble, such as halogens and H_2S, when water is condensed from the cooled LFG. Do not use systems containing chlorofluorocarbons refrigerants. Coordinate condenser LFG output quality and flow with any other LFG treatment technologies requirements that may be incorporated in the design, such as activated media. Provide a condensate drain and piping, as required by the equipment manufacturer, for condensate disposal.

6-3.4.3 Flare and Propane Feed.

Use a high temperature flare to combust the LFG when the processing plant is down or when a surplus of LFG is collected. Provide an oxygen content alarm to maintain safe flare operation and prevent oxygen intrusion into landfill and potential combustion. Select enclosed or candlestick flare based upon the approval authority requirements and project economics. Use flares that are self-supporting and designed for the wind and seismic conditions specific to the area where they will be installed. Comply with EPA Non-Methane Organic Compound Emission Guidelines.

6-3.4.4 Enclosed Flare.

The enclosed flare is preferred for methane and trace compounds combustion as these flares are considered more efficient at reduction of greenhouse gas emissions and typically provide more sensing and control options. The enclosed flare is also considered more visually pleasing as LFG combustion is not as noticeable as is with a candlestick flare.

6-3.4.5 Candlestick (Open) Flare.

Candlestick flares combust the waste gas at the flare top. Construct the flare of steel with a windbreaker and include a control outlet, flame arrestor, and propane ignition system. Use a flare with a shell comprised of steel and a refractory insulating material. Provide with flame arrestor, control valve, air damper and temperature and flame sensors, and controls. Consider using a purge blower to purge traces of LFG from the flare prior to ignition. Include a propane or natural gas pilot system. Design flare for a minimum retention time and temperature to allow for an effective and complete LFG combustion.

6-3.4.6 LFG Primary Treatment Plant.

Design the primary treatment plant to further process the LFG after the extraction plant and before use in electricity or heat generation. The treatment plant consists of equipment, aligned in series, for removing condensate, particulates, hydrogen sulfide, siloxanes, and halogenated compounds from LFG. Use economics evaluation and the desired fuel grade required for the end use to determine gas treatment requirements.

6-3.4.7 Facility.

Design the facility to ensure safe operation, a secure premises, proper maintenance space, and adequate separation of spaces to meet hazardous area classifications. Design the facility to have provisions for future expansion and installation of more equipment if expansion potential exists. Provide all buildings with gas monitoring probes to detect gas collecting around and underneath the building foundation.

At a minimum, construct a steel framed building with a roof and a concrete foundation. Design enclosed buildings, consisting of a roof, walls, and concrete foundation, as necessary to house the equipment type being utilized and support maintenance requirements. Separate electrical panels and equipment in enclosed buildings from any gas piping or other gas processing and conveying equipment. Provide a security fence surrounding the premises. Equip all enclosed buildings with an indoor air quality (IAQ) detection system with sensors, alarms, and interlocks to other safety devices and equipment such as mechanical ventilation and exhaust systems.

6-3.4.8 Components.

6-3.4.8.1 Blowers.

Add blowers, downstream from the extraction blowers, to increase the LFG pressure to overcome pressure losses in the treatment components.

6-3.4.8.2 After Cooler.

Use after coolers, following a blower, to lower the gas temperature as required by equipment downstream of the blower. Select after coolers to include a heat exchanger. Select an air cooled or refrigerant cooled machine based upon required equipment performance.

6-3.4.8.3 Pretreatment.

Pretreat or precondition the gas, prior to its end use, to prevent equipment inefficiencies, equipment damage, and frequent maintenance service.

6-3.4.8.4 Treatment Requirements.

Determine the expected final LFG fuel grade prior to selecting treatment equipment and technologies.

6-3.4.8.5 Treatment Technology.

Use treatment technologies that provide the proper conditioning and filtering required while requiring minimal maintenance and waste. Equipment utilizing a combination of technologies to remove multiple contaminants may be used.

6-3.4.8.6 Water Removal.

Use either refrigeration type technologies which employ heat exchangers, utilizing refrigerant or chilled water, or use a desiccant type system, which may use a silica type gel. A combination of systems may be employed to dry the air. Use a combination of condensate knockout tanks throughout the treatment system to further reduce the gas moisture content. Provide a condensate drain, as required by the equipment manufacturer, for condensate disposal.

6-3.4.8.7 Particulate Removal.

Use stainless steel mesh screens after the condensate knockout located in the LFG piping, and before the blower inlet. Use mesh screens to filter particles as small as 1.0 micron. Verify screens use are required prior to other treatment technologies and equipment, and select recommend micron size.

6-3.4.8.8 Foam Removal.

Use coalescing stainless steel mesh screens after the condensate knockout located in the LFG piping upstream of the blower. Provide a condensate drain, as required, for condensate disposal.

6-3.4.8.9 Siloxane Removal.

Use activated alumina, activated carbons, refrigeration type systems or a combination of these systems may be used to remove siloxane. The concentration range of siloxane after removal should be less than 100 parts per billion (ppb). Provide a condensate drain as required for condensate disposal.

6-3.4.8.10 Hydrogen Sulfide Removal.

Use an iron sponge to further reduce hydrogen sulfide. Provide a regeneration system as required by the equipment manufacturer. Provide a condensate drain, as required, for condensate disposal.

6-3.5 Condensate Collection and Treatment System in LFG Treatment Systems.

Treat collected condensate to local standards before final discharge.

6-3.5.1 Design Considerations.

Landfill gas typically contains water vapor. When the LFG is cooled, the water vapor in the gas stream will form droplets and the droplets combine to form condensate. The condensate quality from LFG depends on a number of factors from where the condensate originated. Condensate typically contains a number of volatile organic compounds (VOCs). The factors affecting the condensate quality are listed below:

- Waste type and nature;
- Age of waste;
- Climatic conditions;
- Moisture content within the landfill;
- Ambient temperatures and temperatures within the landfill;
- Landfill site configuration;
- Landfill overall size;
- Landfill covers and liners and their effectiveness; and
- Condensate production rate.

Estimate the condensate production rate by assuming the LFG is fully saturated and assuming that all the condensate will condense out of the LFG while it is cooled in the component cooling the gas. Size condensate piping for estimated condensate flow.

6-3.5.2 Condensate Piping.

The preferred condensate piping is HDPE type.

6-3.5.3 Condensate Pumps.

Use compressed air or electrical condensate pumps sized to accommodate the modeled condensate production rate.

6-3.5.4 Condensate Treatment System.

If allowed by local, State and Federal regulatory agency guidelines, drain generated condensate back into the landfill for processing. If the amount and / or characteristics of the condensate do not allow draining back into the landfill, determine and implement appropriate pretreatment measures before discharging into a local wastewater treatment system.

6-3.6 Power Generation Plant.

Internal combustion engines and gas turbines are the most common technologies for LFG energy generation. These technologies can be used individually or together maximizing the best and most efficient use of projected gas flow from the landfill over time.

6-3.6.1 Energy Conversion Technology.

Select the energy conversion technology based upon the developed electrical energy output as follows:

- 800 kilowatts (kW) to 3 megawatts (MW) – use internal combustion engines with multiple engines for 1 MW to 3 MW range unless gas turbines are determined to be the most effective / cost efficient;
- 5 MW or More – use gas turbine engines;
- Less than 250 kW – use microturbines.

6-3.7 Process Controls and Alarms.

Refer to EM 200-1-22 for landfill off-gas collection and treatment design requirements. Automated process controls are the preferred type. Provisions for the control points, at the minimum, must include:

- Flare and blower interlocks;
- Flare temperature;
- Pilot ignition status with blower operation sequence;
- Emergency fail-safe operation to isolate piping during power loss or outage;

- Pressure and flow measurements for each well;
- Pressure measurements for blower inlet and outlet;
- Thermal overload protection for blower motors;
- Vacuum relief valves or switches / blower shutdown;
- Facility IAQ monitoring/alarm (minimum of methane and hydrogen sulfide);
- Near surface emissions monitoring/alarm;
- Methane LEL monitoring and emergency shutdown;
- Condensate collection monitoring/alarm; and
- Power plant generation technology and switchgear status.

6-3.8 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

6-4 OPERATION AND MAINTENANCE.

6-4.1 Contract Based Operations and Maintenance.

Minimum plant O&M requirements for plant equipment and material are those necessary to meet warranty, compliance, and expected life expectancy requirements. Ensure that:

- All equipment O&M and warranty materials are collected and consolidated into a comprehensive O&M guide for review before plant operations start;
- O&M service contracts are in place to start after the warranty period and are based upon an operating life of 20 years;
- Contractor provides all plant operation and maintenance necessary for contract and environmental compliance; and
- Contractor compliance requirements include collecting and providing all recurring data collection and report generation necessary for permit(s) compliance.

See Appendix E for addition O&M guidance.

6-4.2 Safety.

Comply to applicable provisions in 29 CFR 1910 and 29 CFR 1925, American Conference of Governmental Industrial Hygienists Threshold Limit Values and Biological Exposure Indices, 40 CFR Part 60, Appendix A, and 40 CFR Part 63, Appendix A. and local/agency codes and requirements. Provide air monitoring for indoor air quality and outdoor ambient conditions. Provide near surface methane monitor to ensure proper plant extraction operations and take corrective actions if methane readings are more than 500 ppm above background.

6-4.2.1 Non-Performance.

Ensure non-performance and remedy clauses are in maintenance contract to address non-conformance. Ensure liquidated damages address loss of power generation revenue and mission impacts.

6-4.2.2 Warranties.

Specific component warranties will vary with manufacturer. Warranties are typically limited to repair or replace, at manufacturers' discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages.

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CHAPTER 7 DESIGN CRITERIA - GEOTHERMAL SYSTEMS

7-1 INTRODUCTION.

This chapter identifies typical applications and defines the data development requirements to establish design criteria for a geothermal power generation plant. Ground source heat pump technology is not consider utility level power generation technology and is not discussed in this UFC. Viable geothermal power production requires a geothermal resource with three attributes:

- Fluid – Water naturally existing in the geothermal reservoir is used to extract heat in quantities necessary to meet power production requirements;
- Heat – Earth's natural temperature which increases with depth. High grade resources vary based upon geographic locations. Geothermal power plants are 8-15% energy efficient, dictating using only higher quality geothermal resources; and
- Permeability – The working fluid's (water) ability to adequately move through the geothermal resource between the production and injection wells via natural or induced fractures.

7-1.1 Technology.

Select technology based on the available geothermal resource temperature and type – dry steam, wet steam, temperature, and technologies. Table 7-1 provides technology considerations for available geothermal resource. Geothermal plant economics is greatly affected by resource characteristics such as temperature, flow rate, and depth, drill rig availability, and plant cost.

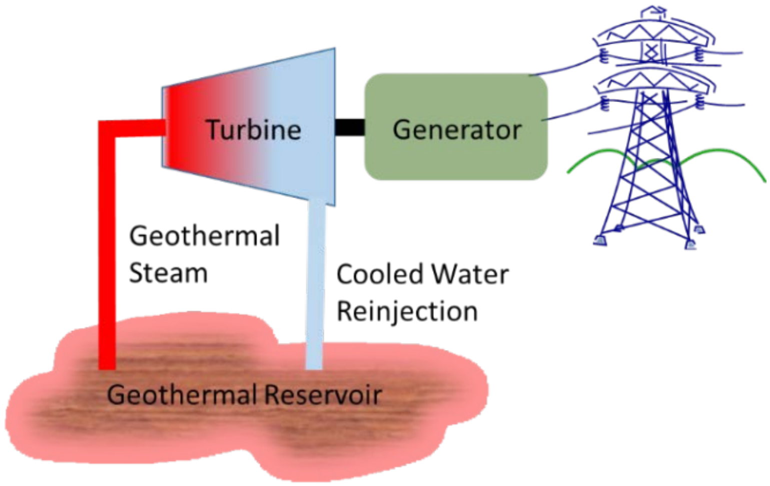
Table 7-1 Geothermal Resource Technologies

Resource Temperatures	Considerations for Use/Technologies
>400 °F (200°C) - High	Power generation – dry, flash, double flash, combination
300-400 °F (150-200°C) - Medium	Power generation – binary
<300°F (<150°C) - Low	Power generation – binary Direct use – processes, space heating, agriculture and aquaculture

7-1.1.1 Dry Steam Power Plants.

Use a dry steam power plant for a geothermal source producing high temperature steam, which does not contain water, to power the steam turbines. Inject spent geothermal fluid or low pressure steam back into the subsurface reservoir to continue the thermal cycle, as illustrated in Figure 7-1.

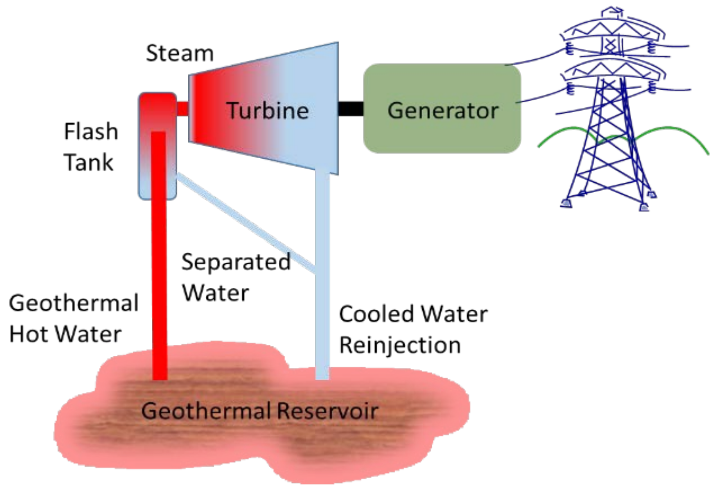
Figure 7-1 Dry Steam Power Plant



7-1.1.2 Flash Steam Power Plants.

Use a flash steam power plant when the geothermal source is high pressure hot water at the subsurface level. Design the system to flash high pressure / high temperature water into steam to power the turbines. Inject spent geothermal fluid or low pressure steam back into the subsurface reservoir to continue the thermal cycle, as illustrated in Figure 7-2. Evaluate binary generation economics using residual condensate.

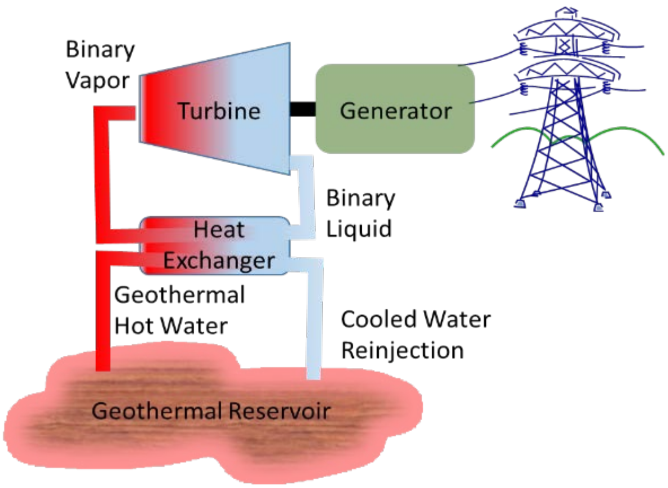
Figure 7-2 Flash Steam Power Plant



7-1.1.3 Binary Power Plants.

Use a binary power plant when the geothermal source has lower temperatures and in areas with sensitive environments. Design the binary power plant to have two separately piped, closed loop systems with pumps to move a working fluid and the geothermal fluid through a heat exchanger that will prevent the two fluids from coming into contact with one another. Select a working fluid that has a lower boiling point than water to allow it to vaporize into steam at lower temperatures. Inject spent geothermal fluid or low pressure steam back into the subsurface reservoir to continue the thermal cycle. Figure 7-3 illustrates Binary Power Plant.

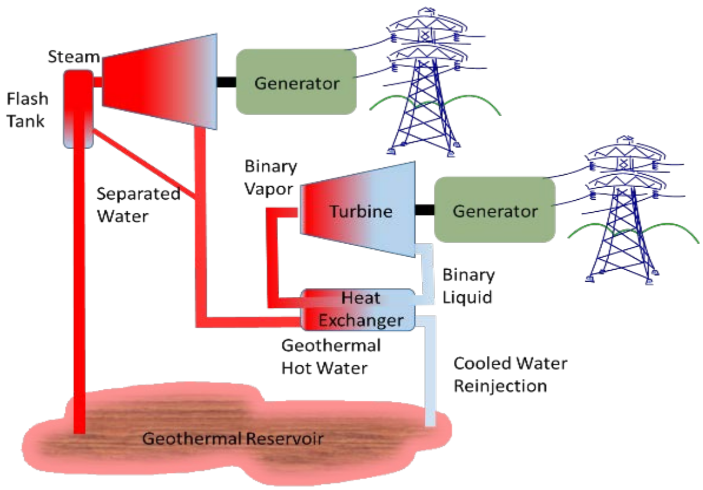
Figure 7-3 Binary Power Plant



7-1.1.4 Combination Flash and Binary Power Plants.

Use a combination flash and binary power plant when more than one geothermal source type is available at the location and sufficient residual thermal energy is available from the primary power cycle to economically use in a binary power plant. Figure 7-4 illustrates the application of a Combined Flash and Binary Power Plant.

Figure 7-4 Combination Flash and Binary Power Plants



7-1.1.5 Backpressure Plants.

Backpressure plants are not authorized. Back pressure plants discharge directly into the atmosphere and are less efficient than other plant types. Not re-injecting fluids limits the geothermal resource life and released fluids may have a chemical composition hazardous to the environment.

7-1.2 Geothermal Resource Types.

7-1.2.1 Conventional Hydrothermal.

Conventional hydrothermal resources are defined by level of development, and include:

- Conventional hydrothermal unproduced resource is a geothermal resource that has not been previously used;
- Conventional hydrothermal produced resource is a geothermal resource that has been previously used to support geothermal power plant(s); and
- Conventional hydrothermal expansion resource is an existing power plant and associated drilled areas.

7-1.2.2 Enhanced Geothermal.

Enhanced geothermal is a geothermal resource in sufficient temperature, but lacks water or permeability for sufficient geothermal fluid production for power production. Hydro-fracturing is used to create new and increase existing fractures to increase permeability in the geothermal reservoir. Surface or subsurface water is pumped through the more permeable geothermal reservoir to produce the necessary working fluid flow for power production in the power plants previously described for enhanced resource temperatures and pressures.

7-1.2.3 Other Geothermal Resources.

Other resource types include 1) geopressured system – high pressure water/gas reservoir which contain a gas (typically methane) and water/brine mix; and, 2) co-production – geothermal and hydrocarbon resource that uses high temperature fluids resulting from oil/gas field development.

7-1.2.4 Geopressured Systems.

Geopressured pilot plants utilizing the produced natural gas and the water’s thermal energy have been proven viable. Plant technologies included natural gas fired engines and binary geothermal plants. Spent geopressured fluids may be re-injected or processed for potable water and brines.

7-1.2.5 Co-production.

Water by-product is typically re-injected into the production strata. Before re-injection, the water volume and temperature may be sufficient for used in a closed loop binary plant.

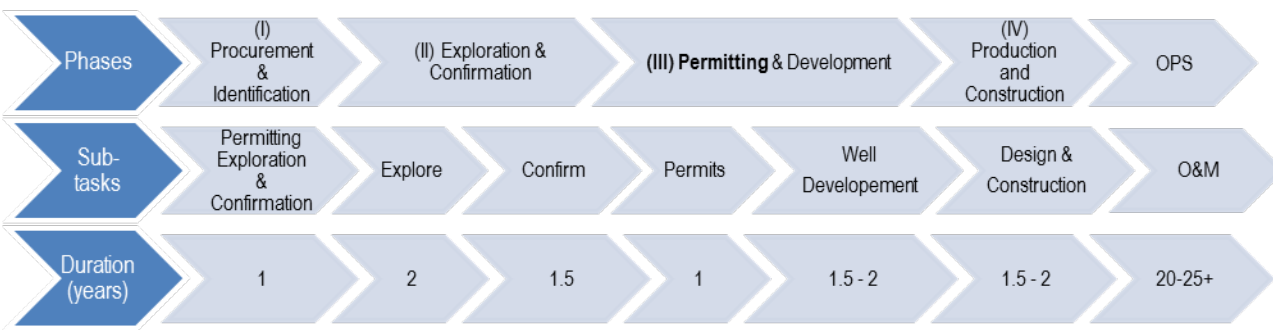
7-2 PLANNING.

32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil. Refer to paragraph entitled "COORDINATIONS" in Chapter 2 for required submission information.

7-2.1 Project Development Phases.

Consider using the Geothermal Energy Association four phase geothermal power project development timeline, listed below, for project development. These phases are described further in paragraphs 7-2.3 through 7-2.6. Figure 7-5 provides estimated planning timelines, by phase. Actual timelines are location and capacity specific. Some tasks may occur concurrently. Total project development timeline is typically 4-7 years.

Figure 7-5 Geothermal Project Planning Timeline



7-2.2 Geothermal Terms and Definitions.

The Geothermal Energy Association provides terms and definitions, by phase, at http://geo-energy.org/pdf/NewGeothermalTermsandDefinitions_January2011.pdf.

7-2.3 Phase I Resource Procurement and Identification.

This phase results in a Possible Resource Estimate and Possible Installed Capacity Estimate for the geothermal resource and the power plant. Review available data to determine evidence of geothermal potential in the desired area and what issues may arise in a procuring a geothermal plant. Refer to paragraph titled "COORDINATIONS" in Chapter 2.

7-2.3.1 Geothermal Assessment.

The highest risk for geothermal power production is finding a viable geothermal reservoir. Due diligence during Phase I is critical to reducing risk. Review information and literature pertaining to geological, hydrological, hot spring, thermal data, drilling data, active remote sensing (LIDAR, radar), passive remote sensing (multispectral, thermal, hyperspectral alteration mineralogy), and anecdotal information from local personnel. The U.S. Geological Survey contains maps, geochemical analyses, and geothermal activity information that are valuable resources. New evaluation techniques are being developed to find and assess ‘blind’, i.e. no surface indications, geothermal resources.

Once the site is defined, and before drilling initial test holes, perform geoscientific surveys / studies such as geochemical, geological, magnetotellurics, and geophysical tests, to minimize exploratory drilling costs.

7-2.3.2 Location Restrictions.

Preform initial power transmission analysis (availability, access, and capacity) to determine viable avenues to transmit power to the electrical grid. Perform initial infrastructure capabilities and restrictions, e.g. roads, water, power, bridges, communications. Use UFC 3-201-01 to evaluate existing site conditions and site development requirements.

7-2.3.3 Environmental Concerns.

Evaluate water, site, and air permitting requirements applicable to geothermal plant type. Begin initial discussions with local and State environmental organizations and local water/aquifer districts. Geothermal power generation plants do no burn fuel; however, they can emit trace amounts of nitrogen oxides, almost no sulfur dioxide or particulate matter, small amounts of carbon dioxide, and sometimes hydrogen sulfide, which is naturally present in many geothermal reservoirs. Other pollutants, such as mercury, may be present in trace amounts. Geothermal waters can be dangerous to humans and surrounding ecosystems as they contain varying concentrations of potentially toxic minerals and elements, and are extremely hot. However, geothermal waters are typically re-injected into the geothermal reservoir and do not contact surface ecosystems or drinking/irrigation aquifers.

7-2.3.4 Scaling and Corrosion.

Mineral scaling on or corrosion of equipment and piping are major operational concerns. Boiling point scaling may consist of calcium carbonate and metal sulfides; and, calcium carbonate and amorphous silica in surface equipment and re-injection wells scaling. Corrosion may include sulfide stress cracking in well piping; sulfuric acid corrosion at wellheads; hydrochloric and carbonic acids corrosion in surface and condensate pipeline; and, stress corrosion cracking in exchangers.

As hydrogen sulfide (H_2S) corrodes copper into Cu_2S, ensure surface electrical wiring and electronics are protected against a H_2S atmosphere, if present. Control humidity using sealed containers, coatings, sealants on wires, electronics, and control equipment, and clean air ventilation to reduce H_2S induced copper corrosion.

7-2.3.5 Scale and Corrosion Testing Requirements.

Perform water testing and hydrogeochemical model to determine expected corrosion or scaling mineral composition, and implement applicable countering means and methods. Perform mineral composition analysis on any accumulated scale before system cleaning and disposal operations. Perform the following water sample measurements as a minimum: pH, SiO_2, Na, K, Ca, Mg, Cl, SO_4, HCO_3/CO_3, and key trace elements Li, Rb, Cs, B, F, Al and Fe.

If site has environmental concerns, include As and Hg measurements. Test for the following gas sample measurements as a minimum: CO2, H_2S, NH_3, N_2, CH_4, H_2, Ar and O_2.

7-2.3.6 Recharge and Cooling Water.

Evaluate plant cooling water requirements, available source(s) (fresh, geothermal, effluent), and for adequate cooling water during planning phase. Table 7-2 provides median water use. Consider secondary use of rejected heat, such as space heating and agriculture. Consider sewage effluent as a geothermal reservoir recharge option. High temperature (400 ^{0}F / 200 ^{0}C) environments sterilize any residual organic material and this alternate disposal method eliminates waterway discharges.

Table 7-2 Median Water Use

Cooling Type	Technology	Median gal/MWh (l/MWh)
Tower	Dry Steam	1,796 (6799)
	Flash (freshwater)	10 (38)
	Flash (geothermal fluid)	2,583 (9778)
	Binary	3,600 (13627)
	EGS	4,784 (18109)
Dry	Flash	0 (0)
	Binary	135 (511)
	EGS	850 (3218)
Hybrid	Binary	221 (836)
	EGS	1,406 (5322)

7-2.3.7 Visual and Sound.

Geothermal power plants have minimal visual and noise impact once construction is complete. Cooling tower steam plumes are the most likely visual item noted. A plant's mechanical equipment may produce undesirable noise levels unless sound attenuation is specified. Specify overall plant maximum sound pressure (ex. 85 decibels at 1 m from enclosure) based upon local codes. Do not specify individual equipment sound pressures as reverberations and reflections compound individual sound pressures and may exceed specified decibel limit. Comply with UFC 3-450-01.

7-2.3.8 Subsidence.

Geothermal condensate re-injection minimizes subsidence caused by power generation. Tectonically active areas have naturally occurring subsidence. Document these natural movements in the planning and permitting documentation and measure local subsidence a minimum of every five years.

7-2.3.9 Induced Seismic Activity.

Geothermal reservoirs are typically located in areas of natural tectonic activity. The process of enhancing geothermal resources and reinjection may induce or increase frequency of micro-tremors. These micro-tremors are rarely the magnitude for humans to feel and are not in any general sense problematic for life or property surrounding the plant. Public awareness and mitigation planning is required to ensure community concerns are fully addressed early in the project timeline.

Perform initial screening, community outreach, baseline criteria and seismic monitoring, event hazard analysis, risk decision analysis for plant design, and risk-based mitigation plan for operations. Refer to paragraph entitled “GEOTHERMAL POWER GENERATION” in Appendix B for additional details on the recommended seven step protocol. Install a micro-earthquake monitoring system before production drilling to establish a seismic baseline and to monitor earthquake activity during operations.

7-2.3.10 Resource Evaluation.

Determine geothermal resource legal ownership as resource likely extends outside of installation boundaries. Establish legal rights to the geothermal resource before developing.

7-2.3.11 Power Agreements.

Coordinate with the local utility(ies) and transmission services provider(s), as well as the agency / installation involved on viability of obtaining power purchase agreements (PPA) and interconnection agreements for the proposed plant.

7-2.3.12 Planning Capital Expenditure.

For initial planning purposes, use the average plant capital expenditures for plants completed from 2011 to 2013 – $2.65 million/MW for flash plants, and $5.18 million/MW for binary plants – and escalate to mid-point of expected construction. Update costs at each phase as project requirements are further refined.

7-2.3.13 Phase I Findings.

Use Phase I findings to create an outstanding issues cost / risk / benefit matrix to support a project go / no-go decision before proceeding to Phase II.

7-2.4 Phase II Resource Exploration and Confirmation.

This phase results in a refined Possible Resource Estimate and refined Possible Installed Capacity Estimate for the geothermal resource and the power plant. Once site is validated under Phase I assessment, determine if site resources meet power generation requirements, transmission capabilities, and site development criteria.

7-2.4.1 Permit Applications.

Generate and submit appropriate permits for approval to drill resource development wells described under resource development. Coordinate with State and local environmental offices and water resource organizations.

7-2.4.2 Resource Capacity Analysis.

At the potential sites developed under Phase I, drill wells to gather site specific thermal data to refine resource location and to develop the Phase II geothermal *Possible Resource Capacity*. Drilling may be accomplished in a multi-step process to reduce costs: 1) drilling of shallow holes across suspect area to determine viable thermal gradients; if viable area found, then, 2) drilling of a ‘slim hole’ to validate thermal gradient; if a viable gradient is found, 3) extending the slim hole to penetrate the reservoir; and if a viable reservoir is found, 4) re-drilling the slim hole to full diameter production well or drilling new production sized well.

7-2.4.3 Transmission Development.

Initiate detailed utility transmission and interconnect requirements analysis and feasibility studies with grid owners. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

7-2.4.4 Phase II Findings.

Generate a *Possible Resource* capacity estimate and a *Possible Installed Capacity Estimate* specifically used for the financial evaluation for plant’s geothermal power production. Identify any initial potential project issues associated with local communities, transmission, sites, environmental, and any other applicable issue area.

Use Phase II findings create an outstanding issues cost/risk/benefit matrix to support a project go/no-go decision before proceeding to Phase III.

7-2.5 Phase III Permitting and Initial Development.

This phase results in a Delineated Resource Estimate and Delineated Installed Capacity Estimate for the geothermal resource and the power plant.

7-2.5.1 Permit Applications and Contracts.

Obtain applicable drill permit(s) for one full size production well. Start initial plant permit applications and Power Purchase Agreements (PPA). Developer to determine financing avenues to meet PPA requirements.

7-2.5.2 Resource Development.

The size and cost of a steam gathering system is affected by site topography, slope stability, steam field size and spread, and resource temperature and pressure. Locate production and injection well(s) to optimize reservoir recharge capacity. Injecting spent (cooled) geothermal liquid too close to a production well may locally cool the reservoir and subsequent production. Injecting spent geothermal liquid too far from the project well(s) may not sufficiently replenish the reservoir and steam pressure may decline.

Drill one full size production well with sufficient bottom hole temperature and flow rates for a commercial size geothermal well (3-5 MW gross equivalence). Drill one full size injection well capable of recharging the geothermal resource. Size production and injection well to allow the equivalent of at least 20% of proposed plant capacity. Use the production and injection well flow and thermal data to characterize the overall geothermal resource fluid flow and sustainable capacity.

7-2.5.3 Transmission Development.

Complete an interconnection feasibility Study and System Impact Study (SIS) to determine connection requirements. Request the utility to start the interconnection facility study to address the steps, equipment, and facilities required to connect to the grid. The developer shall submit the transmission service request to permit power transmission.

7-2.5.4 Phase III Findings.

Generate a *Delineated Resource Estimate* and a *Delineated Installed Capacity Estimate* specifically used to revise the Phase II financial evaluation for plant's geothermal power production. Identify any additional potential project issues associated with local communities, transmission, sites, environmental, and possible resolutions.

Use Phase III findings create an outstanding issues cost / risk / benefit matrix to support a project go / no-go decision to proceed with project approval, contactor selection and award, and before proceeding to Phase IV activities.

7-2.6 Phase IV Resource Production and Power Plant Construction.

This phase results in a *Confirmed Resource Estimate* and *Confirmed Installed Capacity Estimate* for the geothermal resource and the power plant. At Phase IV, activities shift primarily to selected contactor activities.

7-2.6.1 Resource Development.

The selected contractor finalizes plant design; begins production well(s) development; and plant construction starts.

7-2.6.2 Transmission Development.

Complete interconnect requirements analysis and feasibility studies. Obtain signed interconnection agreement with utility.

7-2.6.3 Permitting and Contracts.

Finalize PPA terms and conditions; plant construction permits approvals, and contract to design-build power plant, remaining production wells, steam gathering system, transmission lines, and remaining infrastructure to initial final design and construction.

7-2.6.4 Phase IV Findings.

Generate a *Confirmed Resource Estimate* and a *Confirmed Installed Capacity Estimate* specifically used for the financial evaluation for plant's geothermal power production. Identify any additional potential project issues associated with local communities, transmission, sites, environmental, and possible resolutions.

7-3 DESIGN CRITERIA.

7-3.1 General Design Requirements.

Comply with UFC 1-200-01. Geothermal power plant designs typically include:

- Site civil engineering;
- Well development;
- Steam enhancement and cleaning;
- Turbines;
- Condensing, gas ejection and cooling systems;
- Distributed control systems (DCS);
- Piping, valves and power island blowout preventer (BOP);
- Electric power generation and plant support systems;
- Electrical cabling, substation, and high voltage power interconnection; and
- Supporting structures consisting of turbine/generation building, black start generation, emission monitoring, gatehouse and security spaces, administrative and maintenance spaces, and fire pump house.

7-3.1.1 Layout.

The facility is to be designed with the concept of providing efficient operations and maintenance activities throughout the facility life. The design process must include a general configuration of all proposed buildings and structures, piping runs, wellheads, roads, parking and paved areas, as well as drainage features and any associated retention basins during site development / construction, and long term operation stages. Layout site to minimize footprint while protecting equipment and electrical systems from steam vetting to reduce equipment corrosion. If cost effective, consider redundant systems to allow O&M actions while maintaining operations.

The facility roadway system design must provide a traffic pattern allowing simultaneous traffic to both enter and exit the facility, and allow unencumbered travel of vehicles in both directions throughout the facility.

7-3.1.2 Materials.

Geothermal fluids are corrosive. All materials used will be selected for durability and longevity for their respective environments and in compliance with local architectural standards. As a minimum, the facility structure will be of concrete or steel construction with factory finished coating system steel exterior wall surfaces or architectural masonry. Use metal roofing, sloped for drainage. Exterior personnel doors will be galvanized insulated core steel with window lights and security systems, where appropriate. Overhead doors will be galvanized steel. Windows will be insulated double pane glass with insulated aluminum jambs. Floor finishes will be selected based upon safety and use.

All open grate working platforms, open grate stairs, ladders, ladder cages, and handrails at the exterior are to be galvanized steel coated after fabrication. Where steel components are exposed to corrosive materials, use coating systems that are specifically resistant to the corrosive materials.

7-3.2 Well Development.

Geothermal well development is very similar to oil / gas well development. Use drillers licensed for the location and have experience with large diameter geothermal wells. Size well casings for function (conductor, surface, intermediate, production), flow, and working pressure. Use static seals with no external energizing. Ensure the design accommodates casing expansion without restricting flow. The design shall allow installation before the casing cementing process to allow for alignment and casing reciprocation during cementing. Provide blowout prevention and other safety equipment as required for hazard classification. See “GEOTHERMAL POWER GENERATION” in Appendix B for drilling and materials best practices.

Specify pipe according to well conditions, fluid chemistry, and depth. Wells will have multiple casing materials; for example, two separate, 3 mi (5 km) deep, enhanced geothermal EGS wells have the following material characteristics, as shown in Table 73.

Table 7-3 Example EGS Well Material Design

Well Depth (km/mi)	Casing Schedule	Material	Depth (m/ft.)	Casing Length (m/ft.)	Hole Diameter (cm/in)	Casing Diameter (cm/in)
EGS#1 5 / 3.1	Conductor Pipe	Welded wall	24 / 79	24 / 79	91.4 / 36	76.2 / 30
	Surface Casing	Welded wall	381 / 955	381 / 955	71.1 / 28	55.8 / 22
	Intermediate Liner	K-55 Premium	1524 / 5000	1204 / 3950	50.8 / 20	40.6 / 16
	Production Casing	T-95 Premium	3999 / 13120	3999 / 13120	37.4 / 15	29.8 / 12
	Production Slotted Liner	K-55 Buttress	4999 / 16400	1061 / 3480	26.3 / 10-1/2	21.9 / 8-5/8
EGS#2 5 / 3.1	Conductor Pipe	Welded wall	30 / 98	30 / 98	106.6 / 42	91.4 / 36
	Surface Casing	Welded wall	381 / 1250	381 / 1250	81.2 / 32	71.1 / 28
	Intermediate Liner #1	K-55 Premium	1524 / 5000	1204 / 3950	66.0 / 26	55.8 / 22
	Intermediate Liner #2	K-55 Premium	3048 / 10000	1280 / 4200	50.8 / 20	40.6 / 16
	Production Casing	T-95 Premium	3999 / 13120	3999 / 13120	36.2 / 14-1/4	29.8 / 12
	Production Slotted Liner	K-55 Buttress	4999 / 16400	1061 / 3480	23.0 / 9	21.9 / 8-5/8

7-3.3 Steam Enhancement and Cleaning.

Evaluate geothermal fluid chemical characteristics and select equipment materials tailored to reduce corrosion characteristics. Evaluate and account for non-condensable gases (NCG) removal, such as hydrogen sulfide (H_2S) and carbon dioxide (CO_2). NCG reduces plant efficiencies due to equipment parasitic loads and NCG accumulation in the condenser leads to a higher turbine outlet pressure and a lower power output per unit of steam.

Use centrifugal or cyclone type steam separator designed for site specific geothermal fluids. Evaluate separator location to optimize plant performance and life cycle costs. Locations include adjacent to wells to reduce two phase liquid piping losses between the well and turbine, or near the turbines to reduce piping losses and allowing more brine to flash to steam.

7-3.4 Turbines.

Select turbines with materials specifically designed for site specific geothermal fluid, and to minimize and protect against dissolved gases, impurities, and water droplets corrosive effects.

7-3.4.1 Materials.

Require corrosion resistance treatment, such as Stellite alloy and induction treatment, to increase blade and turbine life.

7-3.4.2 Condensate Removal.

Require turbines have excessive condensate removal systems to reduce water droplet erosion.

7-3.4.3 Valves.

Require fast closing inlet valves for system emergency shutdown. Require low fouling or scaling valves to reduce potential closure failures.

7-3.4.4 Seals.

Evaluate and select shaft seals designed for simplicity, long life, and maintainability.

7-3.5 Condensing, Gas Ejection and Cooling Systems.

Use vacuum pump systems to extract NCG from the condenser to maintain condenser efficiency. Design H_2S systems to comply with location specific environmental, health and safety requirements and laws. Ensure sufficient contingency capacity is included in NCG systems. The amount and type of H_2S abatement required varies considerably and is dependent upon the reservoir characteristics. NCG concentration and the corresponding H_2S concentration may vary dramatically from reservoir to reservoir and from well to well within the same reservoir. H_2S removal systems include exhausting, thermal oxidation to covert to sulfur dioxide (SO_2), and solid (example iron) and liquid scavengers. Evaluate and select environmentally viable removal systems, including consumables and disposal costs, for best life cycle cost.

Evaluate air or water cooling / condensing system based upon environmental considerations, resource availability, and life cycle costs. Water-based cooling systems have higher heat transfer rates than dry air. Water based systems include direct contact condensers where both the cooling water and steam are combined and sprayed in the condenser; once through condensers using surface water source; and wet cooling towers. Dry type cooling towers have significantly less thermal rejection efficiency and water based systems. Use of dry type cooling towers will increase project costs by 10-20%, but may be only solution for sites with inadequate water supplies, strict water use regulations, or extremely low ambient conditions which causes water tower drift to freeze on surrounding surfaces and plants. Ensure the safety control and valve system prevents condenser backflow into the turbine.

7-3.5.1 Piping, Valves and Blowout Preventer.

Piping system designs must be robust to handle brine, two-phase liquids, steam, and entranced debris. Accommodate thermal expansion, condensate collection and disposal, slug flow, erosion from and elimination of entrained debris, and elevation induced pressure issues. Evaluate life cycle cost between use of corrosion resistant materials (stainless/alloys) or corrosion resistive coatings on lower cost carbon steel.

7-3.5.1.1 Two-Phase Fluids.

Minimize two-phase piping lengths to reduce pressure losses. Upslope two-phase piping design is not allowed as it encourages slugging. Evaluate brine line saturation pressure to ensure the brine will not flash into steam and create two-phase conditions.

7-3.5.1.2 Insulation.

Insulate piping to reduce thermal gradient and energy loss between the piped geothermal fluids and the ambient air.

7-3.5.1.3 Pipe Loading.

Evaluate gravity loads for piping on long slopes. Analysis of areas near support anchors is especially important to ensure pipe design strength is sufficient to resist buckling.

7-3.5.1.4 Valves.

Select valve for specific service (e.g. steam, brine, water). Valve designed to minimize seal and operations issues from deposits. Provide seats with upstream and downstream metal-to-metal seals. Provide adjustable packing glands. Provide an overpressure rupture disk, or similar, for over pressurization protection. Free passage design for minimum pressure drop and turbulence. Select body material and overlays, such as Stellite alloy, for corrosion protection.

7-3.5.1.5 Blowout Preventer.

Provide either an annular or a ram type blowout preventer, with accumulator operating system, selected for pipe size and pressure rating in accordance with State and Federal regulations.

7-3.5.1.6 Standards.

Comply with ASME B31.1, ASME B31.3, API Spec 6A and ANSI B16.34.

7-3.6 Pumps.

Select pumps for specific service: e.g. steam, brine, temperature, flow, and pressure.

7-3.7 Heat Exchangers.

Evaluate preheater and vaporizer heat exchanger layout for increased efficiency on binary plants. Select material for specific service conditions and working fluids.

7-3.8 Working Fluids (Organic Motive Fluids).

For binary plants, select organic motive fluid formulations to cost effectively maximize the plant power output for site specific thermodynamic characteristics.

7-3.9 Distributed Control System (DCS).

Install a Distributed Control System consisting of an open standards software with programmable logic controllers for expandability, self-diagnostics, and backup modules. Include data points monitoring flows, pressures and temperature changes, vibration, fluid levels, control valves status, and equipment status. Minimum human interface requirements include plant systems diagrams, trend graphs, control loop diagrams, alarm events with time stamping for fault analysis, and logic monitoring. H_2S corrodes copper; ensure mounted control component are sealed (NEMA 4X). Ensure sensors contacting geothermal fluid are stainless steel rated for the fluid's chemistry.

No direct communications with any DoD installation network is allowed unless system is certified through the DoD Information Assurance Certification and Accreditation Process and receive an Approval to Operate certificate. All Internet Connection Sharing (ICS) networks must be certified and have approval to operate regardless if they are connected the DoD NIPR network or not.

7-3.10 Electrical Systems.

7-3.10.1 General.

The electrical system for the plant will be a unit type system with the utility transformers connected solidly to the generator bus and switched with the generator.

7-3.10.2 Utility Interconnect.

Comply with the requirements of Chapter 8 of this UFC.

7-3.10.3 Generator.

Provide totally enclosed, synchronous generator sized for continuous operation directly connected to steam turbine. Generators up to 60 MW are to be air cooled. Coordinate output characteristics with ITO/RTO and local utility. Comply with UFC 3-540-01.

7-3.10.4 Synchronizing Switchgear.

Provide a substation on the facility site of a modern, fenced, low-profile design, and complete with bus duct connection between generator switchgear and facility step-up transformer. All the electrical equipment is to be protected from electrical fault damage by protective relays. The substation is to operate over the range from import of full station auxiliary power requirement to export of full net plant real and reactive power capability to the transmission system while maintaining standard operating voltage limits on the facility buses.

7-3.10.5 Plant Electrical System.

Provide a complete electrical system of medium-voltage, low-voltage, and DC power to all loads in the power plant under all service conditions including start-up, operation, failures, and shutdown. Provide unit substations with parallel step down transformers between the medium voltage and low voltage systems.

7-3.10.6 Plant Critical Loads.

Plant critical loads to operate off the low system include:

- Fire Pumps;
- Fire Jockey Pumps;
- Uninterruptable Power Supply(ies);
- DC Power System and Battery Chargers;
- Cooling Water Pumps;
- Hydraulic Pumps;
- Critical Lubrication Systems;
- Elevators; and
- Emergency Lighting.

7-3.10.7 DC System.

Provide a DC power system, with UPS, to provide for an orderly facility shutdown in the event of a loss of normal power. The DC power is to conform to the requirements of UFC 3-520-05.

7-3.10.8 Emergency Power System.

Provide an emergency power system for operating the plant critical loads in the event of a loss of normal power.

7-3.10.8.1 Uninterruptable Power Supply (UPS).

Provide a UPS system for the following critical loads:

- Fire alarm system;
- Mass notification system;
- Telecommunications system;
- Security systems;
- Plant distributed control system; and
- Critical instrumentation.

7-3.10.8.2 Generator.

Provide natural or diesel gas generator(s) if natural gas is not available, sized to handle the plant critical loads and an N+1 redundancy.

7-3.10.8.3 Transfer Switches.

Use automatic, bypass/isolation, overlapping neutral type transfer switches.

7-3.10.8.4 Fuel Storage.

If using diesel gas generator(s), provide a minimum fuel storage for operating at full emergency power for 5 days.

7-3.10.9 Lighting.

Lighting is to conform to UFC 3-530-01 and NECA/IESNA 502-2006.

7-3.10.10 Grounding/Lightning Protection System.

Grounding and lightning protection systems are to conform the following: IEEE C2, IEEE 142, NFPA 70, NFPA 780, and UFC 3-575-01.

7-3.10.11 Communications and Signal Systems.

Comply with UFC 3-580-01.

7-3.11 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

7-4 COMMISSIONING.

7-4.1 Commissioning.

Create and execute a commissioning plan for geothermal and supporting systems in accordance with manufacturer's recommendations. Demonstrate all routine and emergency operations, and start-up and recovery actions. Include the following systems/sub-components in the commissioning plan, as a minimum:

- Supply/Return: blowout preventer, pumps, valves, meters and controls, and emergency shutdown;
- Plant: heat exchanger, turbine, generator, condenser, NCG scrubber, cooling tower, water storage, water treatment, pumps, valves, meters and controls, and emergency shutdown; and
- Transmission: transformer, switches, meters, and controls.

7-4.2 Measurement and Verification (M&V).

Develop and execute a M&V plan to evaluate plant performance throughout the life of the plant. Include the following systems/sub-components in the M&V plan, as a minimum, to verify plant and subsystems are operating within design parameters:

- Supply and injection;
- Plant heat exchanger, turbine, generator, cooling tower, condenser; and
- Electrical transmission.

Ensure M&V report provides summary analysis showing design flows, operating parameters, energy production verses design model (guaranteed production); actions taken to correct findings, and future improvement recommendations.

7-4.2.1 First Year.

Complete a full M&V during plant startup and at the end of the first full year after the plant reaches full operational capability, but no later than the end of the warranty period to identify and document production / warranty issues. Review results verses stated objectives and take appropriate actions to resolve unsatisfactory conditions. Perform system components baseline measurements and verify against plant design and component operating parameters. Perform mass and energy analysis to verify modeled performance verses actual flows and energy production.

Ensure the M&V report provides summary analysis showing design flows, operating parameters, energy production verses design model (guaranteed production), actions taken to correct findings, and future improvement recommendations.

7-4.2.2 Annual Measurement and Verification.

Review previous M&V reports and perform an annual M&V to evaluate plant performance and trends verses model and contract requirements. Identify trends and areas of concern, generate corrective actions, and create / update future improvement plant recommendations.

7-5 OPERATIONS AND MAINTENANCE.

7-5.1 Operations and Maintenance.

Minimum plant O&M requirements for plant equipment and material are those necessary to meet warranty and life expectancy requirements. Ensure all equipment O&M and warranty materials are collected and consolidated into a comprehensive O&M guide for review before plant operations start. Ensure plant operations procedures include compliance requirements for data collection and report generation, e.g. injection reports, production reports, blowout preventer inspections, annual water resource management plan updates, and monitoring and preventive actions to address corrosion and scaling concerns.

7-5.2 Contract Based Operations and Maintenance.

In contractor owned / operated enterprises, payments are based upon power delivered ($/megawatt-hour). Plant operations to meet all applicable local, State, and Federal operating permits. Ensure the Contractor provides all plant operation and maintenance necessary for contract compliance; and the Contract requirements include collecting recurring data and report generation necessary for permit(s) compliance, e.g. injection reports, production reports, blowout preventer inspections, annual water resource management plan updates, and monitoring and preventive actions to address corrosion and scaling concerns.

7-5.3 Safety.

Comply to applicable provisions in 29 CFR 1910, 29 CFR 1925, and 29 CFR 1926, and local/agency codes and requirements.

7-5.3.1 Non-Performance.

Ensure non-performance and remedy clauses are in maintenance contract to address non-conformance. Ensure liquidated damages address loss of power generation revenue and mission impacts.

7-5.3.2 Warranties.

Specific component warranties will vary with manufacturer. Warranties are typically limited to repair or replace, at manufacturers’ discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages.

CHAPTER 8 UTILITY INTERCONNECTION

8-1 INTRODUCTION.

This chapter provides the requirements and general procedures for utility interconnection as well as describes processes for plant performance.

8-1.1 Federal Energy Regulatory Commission (FERC) Rules.

Comply with the applicable FERC rule / standard when connecting a generator to a transmission system. Coordinate with local transmission and interconnection services provider for specific procedures in accordance with the provider's pro forma Open Access Transmission Tariff.

8-1.1.1 Standardization of Generator Interconnection Agreements and Procedures.

This encompasses interconnections greater than 20 MW. For additional information, the latest issue of Order No. 2003 can be referenced herein: http://www.ferc.gov/industries/electric/indus-act/gi/stnd-gen.asp

8-1.1.2 Standardization of Small Generation Interconnection Agreements and Procedures.

This encompasses interconnections of 20 MW or less. For additional information, the latest issue of Order No. 2006 can be referenced herein: http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp

8-1.2 Non-FERC Standards.

Refer to the Interstate Renewable Energy Council's (IREC) interconnection standard for specific Level 4 procedures not subject to FERC. Comply with utility company current standards.

Comply with all the requirements of IEEE Std 1547. This standard addresses the interconnection technical and testing requirements necessary for electrical systems to operate under normal conditions without degradation. Prior to interconnection, provide proper documentation and certifications detailing all generation equipment, installation, operation, and maintenance compliance with IEEE Std 1547.

8-2 INTERCONNECTION REQUEST.

Contact the local transmission and interconnection services provider for the specific process to request interconnecting with the utility. The form requests information, such as project size, proposed point of interconnection, technical data and evidence of site control. A monetary deposit is usually associated with application request.

8-3 SYSTEM STUDY REQUIREMENTS.

After the initial interconnection request is submitted, it is appropriate for the transmission provider to perform a series of studies to ensure electrical power system safety and reliability by performing a feasibility study, system impact study, and facility study. Refer to IEEE Std 1547 for guidance on studies required based upon distributed generation and utility grid feeder characteristics.

8-3.1 Feasibility Study.

The feasibility study and scope will be based upon information set forth in interconnection request to transmission provider. The purpose of this study is to identify potential undesirable system impacts resulting from interconnection before additional studies are performed.

8-3.2 System Impact Study.

If any impact is identified from the feasibility study, a system impact study is then performed. The purpose of this study is to assess the impact of interconnection on the electrical system reliability, without any modifications.

8-3.2.1 Existing Infrastructure.

Maximize the use of existing infrastructure where appropriate in order to help minimize environmental and cultural impacts.

8-3.2.2 Planned System Modifications.

Consult the utility provider for any associated fees or additional studies required for planned system modifications needed for interconnection.

8-3.2.3 Load Flow Analysis.

Determine if the existing transmission facility is adequate to carry the additional generation reliably.

8-3.2.4 System Protection.

Refer to utility provider for specific requirements on types and models of equipment to ensure the proper operation, equipment compatibility, and stability of system.

8-3.2.5 Communications.

Consult with the utility provider for requirements of voice and data communications required for monitoring, recording, and transferring essential data.

8-3.2.6 Metering.

Refer to utility provider for functional specifications and design for the metering equipment. Comply with the local utility company's metering requirements as well as the OUSD (AT&L) Utilities Metering Policy as detailed in the following website http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html and DoDI 4170-11 Installation Energy Management.

8-3.2.7 Other Considerations.

In addition to utility provider specific considerations, consider system upgrade costs, system security, contingency, and generation type.

8-3.3 Facility Study.

The facility study is performed to determine specific equipment and necessary modifications required to complete the interconnection. Also, associated costs and schedule for installation or upgrades are developed.

8-4 CONNECTION OPTIONS.

The generation facility's physical connection to the utility provider's transmission system can be accomplished by one of two types: station type or line type connection. The particular connection type will be determined by installation's location within the transmission system. Select the connection type using life cycle cost analysis and discussions with utility provider. Once the connection typed is determined, the generation facility can constructed to operate in parallel with the utility provider or as a detached system.

8-4.1 Station Type Connection.

In a station type connection, the generation facility is connected to an existing substation with direct lines and circuit breakers. Proper design and coordination is necessary in determining amount of lines and corresponding circuit breakers. Comply with specific utility provider guidelines for connection design.

8-4.2 Line Type Connection.

In a line type connection, the generation facility is connected to an existing transmission line with new transmission lines and a new switching station. Comply with specific utility provider guidelines on switching station configuration and design.

8-4.3 Parallel / Non-Parallel Connection.

In parallel connection, the generation equipment is connected to the utility's system bus and is operating in parallel with the utility's electric system. Comply with specific utility provider guidelines on parallel generation connection accommodations.

In non-parallel connection, there is no simultaneous connection between the generation equipment and the utility's electric system. Use a transfer switching arrangement to allow load shifting between the two systems in an open, or non-parallel, mode.

8-5 DESIGN REQUIREMENTS AND CONSIDERATIONS.

The following requirements and considerations apply to parallel operation and synchronization to the transmission system.

8-5.1 Voltage Requirements.

Design generation equipment to operate within the utility provider's established threshold.

8-5.2 Power Factor Requirements.

Coordinate with the utility provider on specific lagging/leading power factor ranges required at the interconnection point. If required by utility provider, consideration of supplying reactive power must be taken when in parallel connection to maintain desired power factor range.

8-5.3 Power Quality Requirements.

Comply with the following power quality requirements.

8-5.3.1 Voltage Flicker.

Generation equipment is not to cause voltage flicker exceeding the term limits specified in IEEE Std 1453.

8-5.3.2 Harmonic Distortion.

Comply with harmonic limits specified in the most recent revision of IEEE Std 519.

8-5.3.3 Communication Interference.

The total communication interference not to exceed the levels specified in IEEE Std 519.

8-5.4 Frequency Requirements.

When connecting to the utility, frequency deviations may be expected and can effect an entire interconnection. The system operating frequency to operate at the utility provider system nominal frequency range.

8-5.5 Abnormal Frequency Operation.

Provide frequency sensing equipment required to protect all generation equipment and facility during abnormal frequency operation.

8-5.6 Generator Step Up (GSU) Transformer Configuration.

Comply with the utility provider's specific protection, metering and operating requirements for parallel generation.

8-5.7 Induction Generator Unique Requirements.

Installing capacitors for reactive power supply at or near an induction generator can significantly increase self-excitation. During planning and design, verify the need by a system analysis. Refer to TSWEG TP-2 for additional information if power factor correction is considered.

8-5.7.1 Low Voltage Ride Through (LVRT) and Low Frequency Ride Through (LFRT).

Comply with IEEE Standard 1547. Voltage and frequency stability analysis studies system oscillations and is required when adding distributed generation into a system. Stable voltage and frequencies are primary concerns for transmission systems; therefore, this study must be performed prior to design completion because modifications of the proposed system may be required. The drop in voltage caused by reactive power deficiencies in the system are a severe concern. Generator rotor angle instability is also a cause of voltage instability. The most extreme instability is complete voltage collapse. Sudden changes in generation or load may result in system frequencies deviating from their normal ranges.

LVRT and LFRT Analysis involve the study of a distributed generation system's ability to continue after faults or disturbances in the system require wind turbines, PV systems, or small generators to drop off the system. Some generators use electricity to generate a magnetic field in order to function. If the voltage drops, these generators will drop off line. Synchronous machines will slip their frequency if the stator voltage drops significantly. If additional generation or load trips due to voltage or frequency disturbance, it has a potential to amplify the disturbance when more and more units rapidly fall off the line. This analysis determines which units will drop off, and if they will remain off or automatically restart. If the analyses show an issue, an engineered solution has to be designed to dampen or modulate voltage / frequency disturbances. Design renewable generation plants with LVRT and LFRT capability and adhere to applicable ISO / RTO standards or criteria. Coordinate with the utility provider in determining required clearing times.

8-5.8 System Grounding.

Comply with the requirements of IEEE Std 142.

8-5.9 Transient Stability.

Coordinate with the utility provider for specific criteria related to generator transient stability performance.

8-5.10 Excitation Control.

The excitation control system response ratio to conform to the latest edition requirements of ANSI Standard C50.13. Conform to applicable utility provider requirements.

8-5.11 Speed Governing.

Comply with the requirements of UFC 3-540-01 for generator speed governing systems.

8-5.12 Automatic Generation Control.

Coordinate with the utility provider for specific guidance and provisions.

8-5.13 Black Start Capability.

Depending upon the geographic location and other considerations, the utility provider may request generator black start capability in the event of a blackout. Coordinate with the utility provider for black start requirements.

8-5.14 Sub-Synchronous Torsional Interactions or Resonance.

Conform to the utility provider guidance and appropriate controls to eliminate damaging torsional oscillations resulting from voltage variations.

8-5.15 Metering.

All utility metering equipment shall conform to IEEE Std 1547. Refer to utility provider for specific metering, SCADA and communications requirements. Coordinate with the Base Operating Support (BOS) group for specific activity requirements or preferences and obtain approval from the AHJ for communication systems that enable remote access.

8-5.16 Transmission Line Design.

Transmission line design shall conform to the requirements in UFC 3-550-01. Determine the interconnection point and construct new transmission lines in accordance with utility provider criteria.

8-5.17 Protective Devices and Coordination.

All utility grade protective devices to conform to ANSI/IEEE Std C37.90. Prior to implementation, obtain utility provider approval for the selective coordination of overcurrent protective devices. Refer to IEEE Std 242 for guidance concerning coordinated power system protection.

8-5.17.1 Special Considerations.

Discuss with and determine the utility provider's specific protective devices specifications and installation requirements. Ensure protective relays are able to sense ground faults and automatic reclosing protection conforms to IEEE Std C37.60. Coordinate specific transformer zero sequence impedance requirements and generator under-frequency protection with NERC mandated automatic load shedding protection settings.

8-6 SUBSTATION EQUIPMENT.

Refer to IEEE Std 1613 for specific regulations governing the installation of substation equipment. If substation is utility-owned, obtain pertinent design information of utility-owned equipment to facilitate requirements for downstream equipment.

8-7 SCADA REQUIREMENTS.

8-7.1 General Requirements.

Refer to 18 CFR Part 35 and utility provider for general SCADA requirements and procedures. In addition, refer to applicable DoD directives concerning information assurance requirements for intelligence community (IC) systems. SCADA is to be equipped to monitor and report the location of a fault in any panel in a solar PV system.

8-7.1.1 Hardware.

Refer to utility provider guidance on approved interface equipment, communication, and hardware requirements for remote terminal unit (RTU) installations.

8-7.1.2 Revenue Metering Data.

Coordinate revenue metering requirements with the utility provider regarding interconnection-specific data.

8-7.2 Data Requirements.

Coordinate with the utility provider on determination of data and control points assignment / list and requirements. The RTU contains input/output functions to handle analog and digital data.

8-7.3 Supervisory Control Requirements.

Coordinate with the utility provider on requirements regarding supervisory control capability and responsibility.

8-8 TRANSMISSION OPERATIONAL REQUIREMENTS.

Coordinate the transmission operational requirements with utility provider based upon NERC and applicable RTO / ISO reliability standards. These requirements will be factors for interconnection including, but not limited to, in-service coordination, NERC registration, normal operating voltage schedule, and planned outage schedule.

APPENDIX A REFERENCES

A-1 FEDERAL

http://www.archives.gov/federal-register/

10 USC Part 2667, Leases: Non-Excess Property of Military Departments and Defense Agencies

10 CFR Part 436, Federal Energy Management and Planning Programs

18 CFR Part 35, Interconnection for Wind Energy

29 CFR 1910 Occupational Safety and Health Standards

29 CFR 1910 Subpart D, Walking Working Surfaces

29 CFR 1910 Subpart I, Personal Protective Equipment

29 CFR 1910.269(g), Fall Protection for Power Generation Industry

29 CFR 1925 Safety and Health Standards for Federal Service Contracts

29 CFR 1926 Safety and Health Regulations for Construction

29 CFR 1926 Subpart E, Personal Protective and Life Saving Equipment

29 CFR 1926 Subpart M, Fall Protection

32 CFR Part 211, Mission Compatibility Evaluation Process

40 CFR Part 60, Standards of Performance for New Stationary Sources

40 CFR Part 60.51c, Definitions

40 CFR Part 61, National Emissions Standards for Hazardous Air Pollutants

40 CFR Part 70, State Operating Permit Programs

40 CFR Part 71, Federal Operating Permit Programs

40 CFR Part 77, Excess Emissions

40 CFR Part 81, Designation of Areas for Air Quality Planning Purposes

40 CFR Part 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices

40 CFR Part 266-273, Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities - Standards for

Universal Waste Management

49 USC Part 44718, Structures Interfering with Air Commerce

50 CFR Part 13, General Permit Procedures

50 CFR Part 17, Endangered and Threatened Wildlife and Plants

E.O. 13327, Federal Real Property Asset Management

FEDERAL AVIATION ADMINISTRATION

http://www.faa.gov/

FAA AC 70/7460-1K, Obstruction Marking and Lighting

FAA Form 7460-1, Notice of Proposed Construction or Alteration

National Oceanographic and Atmospheric Administration (NOAA)

https://www.ncdc.noaa.gov/data-access/severe-weather

Severe Weather Data

NATIONAL RENEWABLE ENERGY LABORATORY

http://www.nrel.gov/analysis/tech_size.html

Land Use by System Technology

http://www.nrel.gov/docs/fy15osti/62566.pdf;

Making Sustainable Energy Choices

http://www.nrel.gov/analysis/tech_footprint.html

Useful Life

http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html

Distributed Generation Renewable Energy Estimate of Costs

http://www.nrel.gov/docs/fy13osti/56266.pdf

Land Based Wind Turbine Systems Installed Capital Costs

U.S. ENVIRONMENTAL PROTECTION AGENCY

http://cfpub.epa.gov/ols/catalog/catalog_lookup.cfm

EPA-600/R-05/047, Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide

EPA TO 14a, Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography

LFG Energy Project Development Handbook

https://www3.epa.gov/lmop/publications-tools/handbook.html

U.S. DEPARTMENT OF ENERGY

http://apps2.eere.energy.gov/wind/windexchange/what_is_wind.asp

WINDExchange

http://apps2.eere.energy.gov/wind/windexchange/wind_maps.asp

Utility-Scale Land-Based 80-Meter Wind Maps

U.S. ENERGY INFORMATION ADMINISTATON

http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b

Table 6.7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, January 2013-August 2015

http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015

A-2 DEPARTMENT OF DEFENSE

AIR FORCE

http://www.e-publishing.af.mil/

AFI 32-7006, Environmental Program in Foreign Countries

ARMY

http://armypubs.army.mil/epubs

USACE EM 200-1-22, Environmental Quality, Landfill Gas Collection and Treatment Systems

USACE ETL 1110-3-412, Engineering and Design: Transformer Application Guidance

USACE EM 200-1-22, Landfill Gas Collection and Treatment Systems

USACE EM 1110-1-1804, Geotechnical Investigations

USACE EM 1110-1-4016, Landfill Off-Gas Collection and Treatment Systems

DEPARTMENT OF DEFENSE (DOD)

http://www.defense.gov/resources/

DoDI 4170.11, Installation Energy Management

DoDI 4270.5, Military Construction

DoDI 7041.3, Economic Analysis for Decision Making

DoDI 8500.01, Cybersecurity

DoDI 8510.01, Risk Management Framework for DoD Information Technology

JOINT SERVICE

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, DoD Building Code (General Building Requirements)

UFC 3-201-01, Civil Engineering

UFC 3-230-02, Operation and Maintenance: Water Supply Systems

UFC 3-240-05A, Solid Waste Incineration

UFC 3-240-10A, Sanitary Landfill

UFC 3-260-01, Airfield and Heliport Planning and Design

UFC 3-301-01, Structural Engineering

UFC 3-400-02, Design: Engineering Weather Data

UFC 3-401-01, Mechanical Engineering

UFC 3-410-01, Heating, Ventilating, and Air Conditioning Systems

UFC 3-410-04N, Industrial Ventilation

UFC 3-420-01, Plumbing Systems

UFC 3-430-02FA, Central Steam Boiler Plants

UFC 3-430-03, Air Pollution Control Systems for Boiler and Incinerators

UFC 3-440-01, Facility-Scale Renewable Energy Systems

UFC 3-440-05N, Tropical Engineering

UFC 3-450-01, Noise and Vibration Control

UFC 3-501-01, Electrical Engineering

UFC 3-510-01, Foreign Voltages and Frequencies Guide

UFC 3-520-01, Interior Electrical Systems

UFC 3-520-05, Stationary Battery Areas

UFC 3-530-01, Design: Interior and Exterior Lighting and Controls

UFC 3-540-01, Engine-Driven Generator Systems for Backup Power Applications

UFC 3-550-01, Exterior Electrical Power Distribution

UFC 3-560-01, Electrical Safety, O&M

UFC 3-575-01, Lightning and Static Electricity Protection Systems

UFC 3-580-01, Telecommunications Building Cabling Systems Planning and Design

UFC 3-600-01, Fire Protection Engineering for Facilities

UFC 3-730-01, Programming Cost Estimates for Military Construction

UFC 3-740-05, Handbook: Construction Cost Estimating

UFC 4-010-01, DoD Minimum Antiterrorism Standards for Buildings

UFC 4-010-02, DoD Minimum Antiterrorism Standoff Distances for Buildings

UFC 4-020-01, DoD Security Engineering Facilities Planning Manual

UFC 4-021-01, Design and O&M: Mass Notification Systems

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE (ASD) FOR ENERGY, INSTALLATIONS, AND ENVIRONMENT (OUSD (AT&L))

http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html

OFFICE OF THE UNDER SECRETARY OF DEFENSE (OSD) FOR ACQUISITION, TECHNOLOGY, AND LOGISTICS (OUSD (AT&L))

Utilities Metering Policy, April 16, 2013

NATURAL RESOURCES DEFENSE COUNCIL | DEPARTMENT OF DEFENSE

http://www.acq.osd.mil/dodsc/library/Siting_Renewable_Energy_Primer_5SEP13_FINAL_WEB.pdf

Working with the Department of Defense: Siting Renewable Energy Development

A-3 INDUSTRY

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

http://www.acgih.org/Store/

ACGIH Industrial Ventilation: A Manual of Recommended Practice

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.ansi.org/

ANSI B16.34, Valves

ANSI C2, National Electrical Safety Code

ANSI C37.90, Standard for Relays and Relay Systems Associated with Electric Power Apparatus

ANSI C50.13, American National Standard Requirements for Cylindrical Rotor Synchronous Generators

ANSI Z359, Fall Protection Code

ANSI 60, Drinking Water Treatment Chemicals – Health Effects

AMERICAN PETROLEUM INSTITUTE (API)

http://www.americanpetroleuminstitute.com/

API Spec 6A, Wellhead and Christmas Trees

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

http://www.asce.org/

ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

http://www.techstreet.com/ashrae?ashrae_auth_token=

ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality

ASHRAE Handbook - HVAC Applications

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

http://www.asme.org/

ASME B30.2, Overhead and Gantry Cranes (Top Running Bridge, Single, or Multiple Girder, Top Running Trolley Hoist)

ASME B31.1, Power Piping

ASME B31.3, Process Piping

ASME Boiler and Pressure Vessel Code

ASME PTC 6, Steam Turbines

AMERICAN SOCIETY FOR TESTING AND MATERIALS INTERNATIONAL (ASTM)

http://www.astm.org/Standard/standards-and-publications.html

ASTM D2216, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D422, Standard Test Method for Particle-Size Analysis of Soils

ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

ASTM D4750, Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)

AMERICAN WIND ENERGY ASSOCIATION (AWEA)

http://www.awea.org/

ASCE/AWEA RP 2011, Recommended Practice Compliance Large Land-based Wind-Turbine Support Structures 2011

AWEA O&M RP, O&M Recommended Practices

COOLING TECHNOLOGY INSTITUTE (CTI)

http://www.cti.org/pub/cticode.shtml

CTI ATC-105, Acceptance Test Code for Water-Cooling Towers

HEAT EXCHANGE INSTITUTE (HEI)

http://www.heatexchange.org/

Standards for Steam Surface Condensers

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

http://ieee.org/

ANSI/IEEE Std C37.90, IEEE Standard for Relays and Relay Systems Associated With Electric Power Apparatus

IEEE C2, National Electrical Safety Code (NESC)

IEEE Std 142, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

IEEE Std 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

IEEE Std 519, IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems

IEEE Std 1069, IEEE Recommended Practice for Precipitator and Baghouse Hopper Heating Systems

IEEE Std 1453, IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

IEEE Std 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std 1613, IEEE Standard Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations

IEEE Std C37.60, IEEE/IEC High-Voltage Switchgear and Controlgear – Part 111: Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems up to 38 kV

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

http://www.iec.ch/

IEC 61215, Crystalline Silicon Terrestrial Photovoltaic (PV) Modules – Design Qualifications and Type Approval

IEC 61400, Wind Turbine Generator Systems

IEC 61400-1, Design Requirements

IEC 61400-3, Design Requirements for Offshore Wind Turbines

IEC 61400-3-2, Design Requirements for Floating Offshore Wind Turbines

IEC 61400-4, Design Requirements for Wind Turbine Gearboxes

IEC 61400-5, Wind Turbine Rotor Blades

IEC 61400-11, Acoustic Noise Measurement Techniques

IEC 61400-12, Wind Turbine Power Performance Testing

IEC 61400-13, Measurement of Mechanical Loads

IEC 61400-14, Declaration of Apparent Sound Power Level and Tonality Values

IEC 61400-21, Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines

IEC 61400-22, Conformity Testing and Certification

IEC 61400-23, Full-Scale Structural Testing of Rotor Blades

IEC 61400-24, Lightning Protection

IEC 61400-25, Communication Protocol

IEC 61400 26, Time Based Availability for Wind Turbines

IEC 61400-27, Electrical Simulation Models for Wind Power Generation

IEC 61646, Thin-Film Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

IEC 62727, Photovoltaic Systems - Specification for Solar Trackers

IEC 61724, Photovoltaic System Performance Monitoring - Guidelines for Measurement, Data Exchange and Analysis

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

http://www.iso.org

ISO 14661, Thermal Turbines for Industrial Applications (Steam Turbines, Gas Expansion Turbines) -- General Requirements

ISO 26382, Cogeneration systems -- Technical Declarations for Planning, Evaluation and Procurement

ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IESNA)

http://www.ies.org/

The Lighting Handbook: Reference and Application

NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION (NECA)

http://www.necanet.org/neca-store/publications

NECA/IESNA 502-2006, Standard for Installing Industrial Lighting Systems

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

http://nfpa.org/

NFPA 1, Fire Code

NFPA 68, Standard on Explosion Protection by Deflagration Venting

NFPA 70, National Electrical Code

NFPA 72, National Fire Alarm and Signaling Code

NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

NFPA 214, Standard-on-Water-Cooling-Towers

NFPA 780, Standard for the Installation of Lightning Protection Systems

NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

http://www.nist.gov/publication-portal.cfm

NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION (NERC)

http://www.nerc.com/pa/stand/Pages/ReliabilityStandardsUnitedStates.aspx?jurisdiction=United States

BAL, Resource and Demand Balancing

CIP, Critical Infrastructure Protection

COM, Communications

EOP, Emergency Preparedness and Operations

FAC, Facilities Design, Connections, and Maintenance

INT, Interchange Scheduling and Coordination

IRO, Interconnection Reliability Operations and Coordination

MOD, Modeling, Data, and Analysis

PER, Personnel Performance, Training, and Qualifications

PRC, Protection and Control

TOP, Transmission Operations

TLP, Transmission Planning

VAR, Voltage and Reactive

UNDERWRITER'S LABORATORIES (UL)

http://www.ul.com/

UL 98, Enclosed and Dead-Front Switches

UL 98B, Outline of Investigation for Enclosed and Dead-Front Switches for Use in Photovoltaic Systems

UL 1703, Standard for Flat-Plate Photovoltaic Modules and Panels

UL 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources

UL 4703, Standard for Photovoltaic Wire

A-4 MISCELLANEOUS

BRITISH COLUMBIA MINISTRY OF ENVIRONMENT (BCME)

http://www.env.gov.bc.ca/epd/codes/landfill_gas/

Landfill Gas Management Facilities Design Guidelines

DATABASE OF STATE INCENTIVES FOR RENEWABLES & EFFICIENCY

http://www.dsireusa.org/

State Interconnection Policies

A-4.1 Service Reachback Contacts

ARMY:

USACE Reachback Operations Center (UROC);

Email: UROC@usace.army.mil or UROC@usace.army.smil.mil

NIPR website: https://uroc.usace.army.mil

SIPR website: http://uroc.usace.army.smil.mil

NAVY/MARINE CORPS:

NAVFAC Pacific (PACOM AOR)

https://portal.navfac.navy.mil/portal/page/portal/navfacpac/ce

NAVFAC Atlantic (Atlantic AORs)

NFCEL_CE_Reachback@navy.mil

Phone:

Comm: (757) 322-8302

AIR FORCE:

AFCEC Reachback Center

Email: AFCEC.RBC@us.af.mil

Phone: DSN (312) 523-6995

Comm: (850) 283-6995

A-4.2 Independent System Operators (ISOs)/Regional Transmission Organizations (RTOs)

ISO/RTO COUNCIL.

http://www.isorto.org

United States

California ISO

www.caiso.com

Electric Reliability Council of Texas

www.ercot.com

ISO New England

www.iso-ne.com

MISO

www.misoenergy.org

New York Independent System Operator

www.nyiso.com

PJM Interconnection

www.pjm.com

Southwest Power Pool

www.spp.org

Canada

Alberta Electric System Operator

www.aeso.ca

INDEPENDENT ELECTRICITY SYSTEM OPERATOR (IESO).

www.ieso.ca

APPENDIX B BEST PRACTICES AND REFERENCE INFORMATION

B-1 BEST INDUSTRY PRACTICES.

B-1.1 Solar Power Generation.

Solar Energy Industry Association website, http://seia.org provides information on best practices.

B-1.2 Wind Power Generation.

American Wind Energy Association website, http://www.awea.org provides information on best practices.

Additional best practices:

B-1.2.1 Site selection:

- Average wind speeds above 6 m/s (13.5 mph)
- Coordination with utility company for capacity, connections, and connection costs
- Site access constraints
- Investment (funding) approach

B-1.2.2 Environmental:

- Visual aspect and impact on important public viewpoints.
- Proximity to dwellings due to noise, shadow flicker, visual domination and reflected light.
- Ecology to include protected species found in the area either seasonally or year round. May require an Environmental Management Plan during construction and operation.
- Presence of archaeological and historical heritage artifacts may affect acceptability of a site.
- Impact on close recreational areas should be considered.
- Baseline hydrological assessment, where considered appropriate.
- Use a three step approach, 1) preliminary site assessment; 2) detail assessment requirements from local planning authority; 3) detailed assessment execution.
- Site selection discussion and rationale:
- Visual and landscape assessment. Create “zone of visual influence.” Consider sun motion and reflections.

- Noise assessment. Characterize current background noise level and provide sound level predictions.

B-1.2.3 Dialogue.

- Initial discussion and coordination with local planning authorities to identify and address potential issues to address.
- Communications plan for local planning authority and community awareness, and feedback.
- Create economic impact details, short (construction) and long (maintenance) impacts, and renewable energy impact.

B-1.2.4 Technical.

- Telecommunications. Existing systems may be affected. Coordinate with owners.
- Air Traffic. Local air traffic authorities must be consulted.
- Secured Areas: Proximities to restricted security areas should be evaluated.
- Testing. Local planning authority permission for and use of anemometers for detailed wind measurements at favorable sites. Duration of not less than 6 months and in some cases more than 1 year.
- Existing Land Uses. Discussions with landowner for best integration between land use and wind farm to include locations and access roads.
- Ground Conditions. Examine if construction areas and access is feasible. Investigate previous land uses and infrastructure for incompatibility.
- Site Access. Consult local authorities on impact of large and heavy goods movement over public and private roads and what improvements are required. Sharp turns and steep gradients may limit materials access.
- Electrical Connection. Connection to the grid can vary significantly by site. The local utility company can give information about likely connection points and connection costs.
- Draft Project Design. Create draft design showing potential number and size of turbines for use during initial project consultations.
- Safety. Assessment on tower integrity verses intended site; layout to avoid shadow flicker on roadways.

- Electrical Connections. Addressing land use and environmental impact of new transmission lines should run parallel with the wind farm development.

B-1.2.5 Operations.

- Complaint System. Owner has formal system for recording and addressing concerns.
- Accessibility: Owner/owner representative is accessible to the public for issues and status updates.

B-1.2.6 Decommissioning.

- Decommissioning. Initial site planning assessment to address decommissioning and site restoration.

B-1.3 Waste to Energy Power Plant.

The Energy Recovery Council website, www.wte.org, provides information on benefits of waste to energy plants.

B-1.4 Landfill Gas Power Generation.

The Environmental Protection Agency Landfill Methane Outreach Program, (http://www.epa.gov/lmop/index.html), provides best practices presentations and LFG project development guidance.

B-1.5 Geothermal Power Generation.

The Geothermal Energy Association website, http://geo-energy.org, provides information on best practices: http://geo-energy.org/reports/Geothermal%20Best%20Practices%20Publication%20Final%20CL188154847.pdf

B-1.6 Utility Interconnections.

Contact ISO/RTO Council members (http://www.isorto.org/pages/home) for North American Independent System Operators/Regional Transmission Organization requirements and best practices.

B-1.7 Policies and Incentives.

The Database of State Incentives for Renewables & Efficiency (DSIRE®) website (http://www.dsireusa.org/) provides a convenient summary of renewable energy policies and incentives.

General Federal and State “regulatory roadmap” flow charts are available for reference only at OpenEI (http://en.openei.org/wiki/Main_Page). Use of reference materials does not relieve designer from compliance with current laws and policies.

APPENDIX C PROJECT PLANNING CHECKLISTS

C-1 INTRODUCTION.

Use/adapt the example project questionnaire from the U.S. Department of Energy FEMP Guidance Developing *Renewable Energy Projects Larger than 10 MWs at Federal Facilities* to assist project planning.

- http://www1.eere.energy.gov/femp/pdfs/large-scalereguide.pdf

For geothermal projects, adapt the *Geothermal Regulator Roadmap* to create project development checklist or use commercial the following project development checklist, based upon project phase.

- http://en.openei.org/wiki/RAPID/Roadmap/Geo

C-2 GEOTHERMAL POWER DEVELOPMENT CHECKLIST.

Summarized from www.geo-energy.org terms and definitions.

Phase I – Resource Procurement and Identification	
Resource Development - meet at least two of the following criteria; and	
Y/N	Literature Survey Complete
Y/N	Geologic Mapping Completed, Geophysical and Geochemical Sample Sites Identified
Y/N	Geochemical and geophysical surveys in progress
Transmission Development - complete the following criteria; and	
Y/N	Internal transmission analysis complete
External Development - complete all of the following criteria to be considered Phase I.	
Y/N	Land or lease acquired
Y/N	Permitting process for exploration drilling (TGH, slim holes) underway

A completed Phase I level project will have two capacity estimates: a Possible Resource Estimate (estimated total subsurface geothermal resource energy value) and a, Possible Install Capacity Estimate (estimated installed capacity, in MW).

Phase II – Resource Exploration and Confirmation	
Resource Development - meet at least one of the following criteria; and	
Y/N	Temperature Gradient Holes (TGH) Drilled
Y/N	Slim Hole Drilled
Y/N	One Full Size Discovery Well Drilled
Transmission Development - meet at least one of the following criteria; and	
Y/N	Interconnection application submitted and queue position established
Y/N	Transmission feasibility studies underway
External Development - complete at least one of the following criteria to be considered Phase II.	
Y/N	Permit for Slim Hole Drilling Applied for or Approved
Y/N	Permit for Production Well Drilling Applied for or Approved

A completed Phase II level project will have two refined capacity estimates: a Possible Resource Estimate; and a, Possible Install Capacity Estimate.

Phase III – Permitting and Initial Development	
Resource Development - meet at least two of the following criteria; and	
Y/N	At least one full size production well drilled and operational
Y/N	At least one full size injection well drilled and operational
Y/N	Reservoir characterization completed and sustainable reservoir capacity determined
Transmission Development - meet at least two of the following criteria; and	
Y/N	Interconnection feasibility study complete
Y/N	System impact study (SIS) underway or complete
Y/N	Interconnection facility study underway
Y/N	Transmission Service Request Submitted (if appropriate)
External Development - complete at least two of the following criteria to be considered Phase III.	
Y/N	Plant permit application complete or in process
Y/N	Power purchase agreement secured or in negotiation
Y/N	Financing secured, or being secured, for portion of project construction

A completed Phase III level project has two refined capacity estimates: a Delineated Resource Estimate and a Delineated Install Capacity Estimate.

Phase IV – Resource Production and Power Plant Construction	
Resource Development - meet at least two of the following criteria; and	
Y/N	Majority of plant equipment on order
Y/N	Plant construction underway
Y/N	Production and injection drilling underway. 50% of geothermal resource confirmed.
Transmission Development - meet at least two of the following criteria; and	
Y/N	Interconnection Agreement Signed
Y/N	Transmission System Service Request studies completed
External Development - complete all of the following criteria to be considered Phase IV.	
Y/N	Plant permit(s) approved
Y/N	EPC contract signed
Y/N	PPA secured

A completed Phase IV level project have two refined capacity estimates: a Confirmed Resource Estimate and a Confirmed Install Capacity Estimate.

APPENDIX D PROJECT DESIGN PLANNING

D-1 INTRODUCTION.

Address areas and tailor as applicable for energy source.

D-1.1 Physical Space Requirements.

- Operation and maintenance space.
- Cooling system space.
- Fuel storage space.
- Ventilation (cooling air intake and exhaust).
- Electrical panels, transfer switches, control panel spaces.
- Exhaust system space and silencer location.
- Starting system (electrical/air start).
- Collection piping and infrastructure.
- Transmission infrastructure.
- Site access.

D-1.2 Power Rating.

- Design to power requirement.

D-1.3 Start Times.

- Maximum time to start and be ready to assume load, including black start and emergency application, and procedures.

D-1.4 Emissions.

- Exhaust gas composition and particulate limits.
- Condensates and ash.
- Noise. Equipment and total plant.
- Thermal (air/water).
- Odors.
- Visual vapors (steam, water).

D-2 ELECTRICAL.

D-2.1 Generator and Inverter.

- Electrical load (kVA) – facility loads plus loads e.g. fans, fuel pumps, lighting, and battery charging.
- Motor starting kVA.
- Nonlinear loads and effect on generator rating.
- Power factor.
- Turbine/engine-generator application – single set / parallel.
- Frequency bandwidth (steady state).
- Frequency regulation maximum – no load to full load.
- Voltage regulation – no load to full load.
- Voltage bandwidth – steady state.
- Frequency – 50/60 Hz.
- Voltage – output volts.
- Phases – 3 phase, wye / delta, single phase.
- Max step load increase – kVA.
- Transient recovery time – seconds (voltage and frequency).
- Maximum voltage deviation (transient).
- Maximum frequency deviation – Hz.

D-2.2 Protection.

- Subtransient reactance – percent (minimum).
- Switchgear/breaker size, location, characteristics, enclosure.

D-2.3 Automatic Transfer Switch.

- Sizing, controls, transfer options.
- Coordination of ground fault protection (four-pole/three pole).
- In-phase protection for large motors downstream of transfer switch.
- Define sequence of operation "Upon loss of normal power…" Define load shedding, motor starting sequence, if required, multiple generator operation, method of return to normal power (time delays).

D-2.4 Starting System and Operation Controls.

- Black start requirements.
- System operational controls and emergency shutdown.

D-2.5 Additional Circuits

- Pumps, pumps, heaters, piping heat-trace, cooling towers, cranes, conveyors, cathodic protection.

D-2.6 Grounding.

- System Grounding.
  - Grounding Electrode System.
  - Bonding.
  - Ground Fault Protection.
  - Transient Voltage Surge Suppression.
- Equipment Grounding.
  - Component Grounding.
  - Electronic Equipment Grounding.
- Generator grounding - ungrounded, solidly-grounded, impedance-grounded.
- Substation Grounding
  - Safety Criteria and Exposure Mechanisms.
  - Soil Parameters.
  - Surfacing.
  - System Parameters.
  - Ground Grid Design.
  - Fence Grounding.
- Static and Lightning Protection Grounding.
- Testing Criteria and Methodology.

D-2.7 Lighting.

- Normal lighting.
- Emergency lighting.
- Outdoor enclosure lighting (access for controls).

D-2.8 Communications.

- Equipment authority to operate certificates.

D-3 MECHANICAL.

D-3.1 Engine.

- Installation elevation above sea level (derating).
- Maximum speed (rpm).
- Fuel consumption/flow.
- Starting system.
- Ambient temperature extremes (HVAC, derating).
- Vibration limitations.
- Ancillary equipment.

D-3.2 Fuel System.

- Fuel level controls.
- Fuel transfer pump.
- Supply line/return line routing.
- Pressure.
- Flow (CFM, tons/hour, GPM).

D-3.3 Lube-Oil System.

- Integral to equipment.
- External to equipment.
- Space and provision for changing the oil.

D-3.4 Governor.

- Type.
- Frequency bandwidth (steady state).
- Frequency regulation maximum – No load to full load.

D-3.5 Cooling.

- Heat exchanger location (local/remote).
- Cooling system design (local/remote heat exchanger)

- Maximum summer outdoor temperature (ambient).
- Minimum winter outdoor temperature (ambient).
- Cooling medium (e.g., glycol/water, raw water).

D-3.6 Plant Climate Control.

- Cooling capacity.
- Maximum summer indoor temperature.
- Minimum winter indoor temperature.
- Heating capacity.

D-3.7 Generator Controls.

D-3.8 Exhaust System.

- Insulated / non-insulated.
- Silencer.
- Scrubbers.
- Penetration.
- Exhaust considerations: flappers, gooseneck, bird-screen, rain shields.

D-3.9 Sound Limitations

- OSHA, State, City Ordinances, Post/Base regulations.
- Mechanical noise mitigation (interior/exterior). Baseline monitoring.
- Combustion-air intake noise mitigation (interior/exterior).
- Exhaust noise mitigation (exterior).
- Posting of signage - Hearing Protection Required.

D-3.10 Safety.

- Guarding of mechanical hazards.
- Posting of signage for equipment which may auto-start.
- Insulation of hot equipment.
- Enclosure of electrical hazards.
- Fall protection.

D-4 CIVIL/STRUCTURAL.

- Seismic zone design compliance. Baseline monitoring.
- Vibration isolation.
- Foundation, house-keeping pads.
- Wind turbine site and structure, ASCE/AWEA RP2011, Chapter 9.

D-5 ARCHITECTURAL.

- Code and compatibility compliance.
- Bird nesting prevention.
- Climate specific corrosion resistance materials.

APPENDIX E O&M CRITERIA AND TIMING

E-1 MAINTENANCE CATEGORIES.

Maintenance falls under two categories, preventive maintenance, and predictive maintenance.

E-1.1 Preventive Maintenance.

Preventive, or time-based, maintenance is based upon equipment manufacturer's recommendations; supplemented by local knowledge.

E-1.2 Predictive Maintenance.

Predictive, or condition-based, maintenance activities are based upon feedback analysis from sensors placed on or in the equipment. The goal of predictive maintenance is to allow for advanced parts ordering, scheduling work, and planning for the repair-refurbish activities. An effective predictive maintenance program will minimize unplanned outages and maximize equipment power generation. A predictive maintenance program for critical components will dramatically reduce the threat of sudden and unexpected failures in these components, and the overall system.

E-2 O&M CRITERIA

Base O&M upon specific site requirements, available resources, and installed equipment. Obtain equipment specific training and certifications, such as those provided by manufactures or a nationally accredited program, for personnel maintaining systems. Use equipment manufacturer's recommended O&M guidelines and the following information to assist in developing O&M practices for applicable energy systems. Table E-1 provides a sample checklist.

E-2.1 Solar PV.

Use *Solar Access to Public Capital (SAPC) Working Group Best Practices in PV System Operations and Maintenance* Version 1.0, March 2015, as a reference for the O&M program (http://www.nrel.gov/docs/fy15osti/63235.pdf).

Table E-1 Sample Solar PV O&M Procedures

MAINTENANCE PROCEDURES	General Inspection	
Required Maintenance Actions	**Frequency**	**Crew Size**
Perform regular system monitoring, review system reports, respond to system alarms, and re **Travis McLeod, P.E.** Vice President port system failures based on severity level.	Daily	1
Check for insect and rodent infestation.	Monthly	1
Clean all equipment items from dust buildup.	Monthly	1
Clean all debris.	Quarterly	1
Ensure roof penetrations are watertight.	Semi-annual	2
Check for new vegetation growth or other shade items.	Semi-annual	1
Check for ground erosion near footings.	Semi-annual	1
Confirm proper signage is in place.	Semi-annual	1
Confirm electrical enclosures are secured and accessible to authorized personnel only.	Semi-annual	1
Check for corrosion on enclosures and mounting system.	Semi-annual	1
Check for low hanging wiring.	Semi-annual	1
Check for animal infestation.	Semi-annual	1
Perform site visits.	Semi-annual	2
Check all the system conduits, junction boxes, and connections for damage.	Semi-annual	2

MAINTENANCE PROCEDURES	PV Modules	
Required Maintenance Actions	**Frequency**	**Crew Size**
Inspect for defects such as delamination, broken glass, burn marks, cracking, and discoloration.	Semi-annual	2
Clean PV modules using demineralized water.	Semi-annual	2
Check for loose or exposed wiring.	Semi-annual	2
Test voltage / current through wires and PV modules.	Semi-annual	2
Check for shading by trees, objects, facilities around modules.	Semi-annual	1
Inspect components for moisture.	Annual	2

MAINTENANCE PROCEDURES	Mounting System/Support Structure	
Required Maintenance Actions	**Frequency**	**Crew Size**
Check array structure mechanical security.	Quarterly	2
Inspect for defects such as corrosion, missing or broken clips/bolts, rust, and corrosion.	Semi-annual	2
Check integrity of all penetrations.	Semi-annual	2
Grease actuator gears and filling hydraulic fluid on track components, if applicable.	Semi-annual	2
Make seasonal tilt adjustments, if applicable.	Semi-annual	2
Check proper alignment on tracking components, if applicable.	Semi-annual	2

MAINTENANCE PROCEDURES	Combiner Box	
Required Maintenance Actions	**Frequency**	**Crew Size**
Re-torque all connections. Repair or replace the cabling, if applicable.	Semi-annual	1
Check for debris and water intrusion inside of enclosure.	Annual	1
Check status of breakers/fuses.	Annual	1
Check for switch blockage or obstruction. Clean switch contacts.	Annual	1

MAINTENANCE PROCEDURES	Disconnect Switch	
Required Maintenance Actions	**Frequency**	**Crew Size**
Perform visual inspection.	Bi-annual	1
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	Annual	2
Verify operation of mechanical interlocks.	Annual	2
Inspect and dress current carrying contacts in accordance with manufacturer's recommendations.	Annual	2
Perform insulation resistance test using a megohmeter of each critical load switch.	Annual	2
Perform contact resistance test on each critical load switch.	Annual	2
Perform thermal imaging of modules, inverters, and combiner boxes while under resistive load.	Annual	1
Repair enclosure rust spots and paint if needed.	3 years	1
Inspect the base and mounting for loose bolts and insecure or inadequate support and tighten.	3 years	1
Clean and inspect ventilators, replace as needed.	3 years	1
Check bolts on the buses and splices for manufacturer's recommended torque.	3 years	2
Inspect insulators for chipped or broken porcelain, excessive dirt film, and tracking; clean as necessary; replace broken insulators; tighten base and cap bolts.	3 years	2
Verify space heater operation or operate continuously to overcome thermostat malfunction.	3 years	2
Ensure the main switch blades are proper seated in the contacts; operate the switch several times and see that blades are properly aligned to engage contacts; clean contact surfaces if corroded; lubricate; tighten bolts and screws.	3 years	2
Check pressure springs in contact and hinge and replace, if not adequate; replace flexible shunts, if frayed.	3 years	2
Confirm that blade latches, where provided, are engaged; check latches for proper engaging and holding blade against opening force. See that stops are in place and tight.	3 years	2
Check for condition, alignment, and proper operation of arc chutes and interrupter device.	3 years	2
Adjust mechanism and linkage for adequate contact	3 years	2

closure and over travel; lubricate.		
Check and tighten bolts, screws, and locknuts; see that rods, levers, and cranks are in serviceable condition and repair as necessary; lubricate pivot points and bearings.	3 years	2
Check gears and bearings; flush out oil or grease and re-lubricate.	3 years	2
Check motor operation and Megger®; check adjustment of brake.	3 years	2
Check condition of contacts and refinish with fine file if burned or corroded; check contact springs, operating rods, and levers; check closing and opening positions with respect to main switch contacts, travel, or motor mechanism.	3 years	2
Check functional test of door and interlocks for proper sequence.	3 years	2
Lubricate switch disconnect studs and finger clusters (if drawout type) unless manufacturer's instruction says otherwise.	3 years	2
Clean and inspect cable terminations and connections for surface tracking; check connections for correct tightness.	3 years	2
Check calibration of meters (if applicable).	3 years	2
Check fuse clips for adequate spring pressure and proper fuse rating.	3 years	2
Check base and operating handle ground connections; see that ground cable is not broken.	3 years	2
Evaluate and make necessary repairs on potential, current, and control transformers.	3 years	2
Confirm that switch operating hot sticks are in good condition and are kept in a dry place; inspect hot sticks for damage and deterioration; discard suspect switch operating hot sticks; test hot sticks per requirements under FIST Volume 4-1B, section 25.	3 years	2
Review equipment ratings.	5 years	1

MAINTENANCE PROCEDURES	Inverter	
Required Maintenance Actions	**Frequency**	**Crew Size**
Verify proper operation of cooling fan. Remove debris from fan and filter.	Monthly	1
Conduct visual inspection (interior and exterior)	Quarterly	1
Inspect heat sink for debris. Check for debris and water intrusion inside enclosure.	Semi-annual	1
Re-torque all connections. Inspect all connections and replace damaged wiring.	Semi-annual	1
Inspect enclosure door seal and replace, if damaged.	Semi-annual	1
Verify installed software is current.	Annual	1

E-2.2 Wind Power Generation.

Use AWEA *Operations and Maintenance Recommended Practices*.[1] This manual presents recommendations for gearboxes, generators, rotors/blades, towers, data collection and reporting, balance of plant, warranty, and condition monitoring. Use ASCE/AWEA RP2011, Chapter 10, for structure inspection criteria.

E-2.3 Waste to Energy Power Plant.

Require builder to provide equipment manufacturers' recommended operation and maintenance practices for installed equipment. Use recommended operation and maintenance practices to generate O&M checklist and frequency. See Chapter 6 for typical waste to energy power plant equipment.

E-2.4 Landfill Gas Power Generation.

Require builder to provide equipment manufacturers' recommended operation and maintenance practices for installed equipment. Use equipment manufacturers' recommended practices to generate O&M procedures and frequency checklist for installed equipment.

Recommended documentation may include:

[1] http://www.awea.org/oandm

- Daily reading and log sheets;
- Individual extraction well logs
  - Individual monitoring probe logs
  - Regulatory monitoring data logs
  - Generator operation parameters
- Records of gas or electricity sold;
- Maintenance schedules per manufacturer's recommendation and frequency;
- Record of maintenance performed and parts used;
- Consumables, lubricant and chemicals used; and
- Equipment calibration records.

E-2.5 Geothermal Power Generation.

Require builder to provide equipment manufacturers' recommended operation and maintenance practices for installed equipment. Use equipment manufacturers' recommended practices to generate O&M procedures and frequency checklist for installed equipment. Installed equipment may include:

- Blowout preventer(s);
- Separator(s);
- Valves;
- Pipe lines; steam/brine supply and re-injection system;
- Heat exchanger including pre-heater, vaporizer and recuperator exchanger;
- Turbine and accessories;
- Generator and accessories;
- Condenser;
- Auxiliary systems (e.g. compressors, pumps, HVAC, fire, cooling systems, drainage systems, detecting systems);
- Control system(s);
- Electrical components (e.g. switch gears, bus bars, transmission lines); and
- Emergency stand by diesel generator.

Table E-2 provides a sample inspection checklist:

Table E-2 Sample Geothermal O&M Checklist

Daily
• Check for system warnings, correct and clear as necessary.
• Check generator, turbines, gearbox, pipes, feed pump and oil pumps for vibrations, noise or oil leaks, repaired as necessary
• Check/record power output and compare against design/historical for trend
• Adjust the settings to operate within set parameters
Weekly
• Record flows and power output, and compare against design point values. Adjust/bleed condenser air to operate within set parameters.
• Check oil levels; fill as necessary. Replace oil as manufacturer's recommended frequency.
• Verify proper operation of control valves.
• Inspect for vibrations of turbine, generator gearbox and feed pump.
• Check valve shafts and feed pump mechanical seal for leaks.
Monthly
• Check valve shafts and pump seals for leaks.
• Check the oil ring in the bearing housings visually.
• Check battery(s)
• Check for hot spots in the power and control cabinets
• Clean strainers
• Replace filter elements
• Grease all motors and couplings according to manufacturer's instructions.
Semi-Annual
• Perform monthly inspection actions.
• Tighten all construction bolts.
• Check for leaks (use a leak detector).
• Verify tightness of all power terminals and cables.
• Grease all electrical motors and couplings.
• Change gearbox oil check oil, perform oil analysis.
Annual
• Perform 6-month inspection actions.
• Check feed pumps shut-off pressure.
• Perform equipment maintenance as required by manufacturer.
• Check turbine/gearbox alignments, correct if required.
• Replace oil in lubrication system(s).
• Check for leaks.
• Calibrate gages and transducers.

• Check/repair contractors.
• Replace filters in the hydraulic block.
• Check/adjust lubrication systems.

Two Years
• Perform annual inspection.
• Perform internal turbine inspection
• Test pump performance; check and repair feed pumps mechanical seals.
• Perform manufacturer’s generator and gearbox preventive maintenance.
• Visual inspect supply and re-injection pipe, exchangers, for scaling/pitting; repair as necessary.

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APPENDIX F COST PLANNING

F-1 CREST

NREL website provides the comprehensive renewable energy 'Cost of Renewable Energy Spreadsheet Tool' (CREST) for solar, wind, and geothermal renewable energy systems. Models are located at https://financere.nrel.gov/finance/content/crest-cost-energy-models. Use these models for preliminary project evaluations.

F-1.1 Landfill Gas

For landfill gas projects, perform simple payback analysis.

F-1.2 Geothermal

For geothermal projects, use Table F-1 planning factors, or more current, if available, in project payback analysis.

Table F-1 Example 50 MW Geothermal Power Plant Planning Factors

Phase	Subfactors	Installed Cost*
Field Work and Power Plant Planning Factor		$3-5,000+ / kW
Example 50MW Plant	Resource Identification	<1% of total cost, ~ $14/kW
	Resource Evaluation	8% of total cost, ~ $300/kW
	Test Well	5% of total cost, ~ $169/kW
	Production Wells	38% of total cost, ~ $1,376/kW
	Plant Construction	49% of total cost, ~ $1,800/kW
Operations and Maintenance Planning Factor		$0.01-0.03 / kWh

*Installed costs is highly dependent upon drilling costs, which, in turn, is affected by drilling activity supporting oil and gas exploration, especially shale fracking, as it uses the same type drilling equipment.

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APPENDIX G GLOSSARY

G-1 ACRONYMS

AC	alternating current
ACI	Activated Carbon Injection
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
AWEA	American Wind Energy Association
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
AFI	Air Force Instruction
AGC	Automatic Generation Control
AHJ	Authority Having Jurisdiction
APC	Air Pollution Control
BACT	Best Available Control Technology
BOP	Blowout Preventer
BOS	Base Operating Support
BTU	British thermal units
C	Celsius
CAA	Clean Air Act
CCTV	closed circuit television
CEMS	Continuous Emission Monitoring System
cf	cubic foot
CFM	cubic feet per minute
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CO_2	carbon dioxide
CSAMT	Controlled Source Audio-Frequency Magnetotellurics
CTI	Cooling Technology Institute
CWA	Clean Water Act
cy	cubic yard(s)
DC	direct current
DCS	Distributed Control System
DOE	Department of Energy
DSIRE	Database of State Incentives for Renewables & Efficiencies
EA	Environmental Assessment
ECIP	Energy Conservation Investment Program
EG	Emissions Guidelines
EGS	Enhanced Geothermal System
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency
EERE	Energy Efficient Renewable Energy

EPRI	Electric Power Research Institute
EPACT	Energy Policy Act
ESPC	Energy Savings Performance Contract
EUL	Enhanced Use Lease
F	Fahrenheit
FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FEMP	Federal Energy Management Program
fps	feet per second
ft.	foot/feet
ft^2	square foot/feet
ft^3	cubic foot/feet
H_2S	hydrogen sulfide
HAWT	Horizontal Axis Wind Turbine
HCl	hydrogen chloride
HF	hydrogen fluoride
HEI	Heat Exchange Institute
HDPE	high density polyethylene
HVAC	Heating, ventilation, and air conditioning
GHG	Greenhouse Gas
GSU	generator setup
IAQ	indoor air quality
ICS	internet connection sharing
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	intermediate pressure
ISO/RTO	Independent Systems Operators/Regional Transmission Operators
IREC	Interstate Renewable Energy Council
ICS-CERT	Industrial Control Systems Cyber Emergency Response Team
in	inch(es)
IP	Induced Polarization
ISO	Independent System Operators
kg	kilogram
kJ	kilojoule
km	kilometer
kW	kilowatt
kWh	kilowatt-hour
lb	pound
LCOE	Levelized Cost Of Energy
LEL	Lower Explosive Limit
LFG	Landfill Gas
LIDAR	Light Detection and Ranging
l/s	liters per second
LFRT	low frequency ride through
LVRT	low voltage ride through
m	meter
m^2	square meter

m^3	cubic meter
mi	mile
MCR	Maximum Combustion Rate
M&V	Measurement & Verification
MJ	megajoule
MNS	Mass Notification System
MPa	megapascal
mph	miles per hour
m/s	meters per second
MSW	Municipal Solid Waste
MSW-DST	Municipal Solid Waste Decision Support Tool
MT	magnetotellurics
MTR	Military Training Route
MW	megawatt
MWh	megawatt-hour
NC	Noise Criteria
NCG	non-condensable gases
NAAQS	National Ambient Air Quality Standards
NFPA	National Fire Protection Act
NECA	National Electrical Contractors Association
NERC	North American Electric Reliability Corporation
NREL	National Renewable Energy Laboratory
NPSH	Net Positive Suction Head
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	ammonia
NOx	nitrous oxide
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NSPS	New Source Performance Standards
NSR	New Source Review
NTEP	National Type Evaluation Program
O_2	oxygen
OSD	Office of te Secretary of Defense
OSHA	Occupational Safety and Health Acto
OEBGD	Overseas Environmental Baseline Guidance Document
O&M	Operations and Maintenance
ϕ	phase
PAC	Powered Activated Carbon
pH	measure of acidity or basicity of an aqueous solution
PPA	Power Purchase Agreement
ppb	parts per billion
ppm	parts per million
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PTC	Production Tax Credits
PV	photovoltaic
PVC	polyvinyl chloride

RCRA	Resource Conservation and Recovery Act
REC	Renewable Energy Credit
REO	Renewable Energy Optimization
RO	reverse osmosis
rpm	rotations per minute
RPG	Renewable Power Generation
RPS	Renewable Portfolio Standards
RTI	Research Triangle Institute
RTU	Remote Terminal Unit
s	second
SCADA	Supervisory Control and Data Acquisition
SCR	Selective Catalytic Reduction
SGHAT	Solar Glare Hazard Analysis Tool
SIS	System Impact Study
SNCR	Selective Non-catalyst Reduction
SO_2	sulfur dioxide
SP	Self-Potential
sq	square
TDEM	Time Domain Electromagnetics
tpd	tons per day
TSWEG	Tri-Service Electrical Working Group
UESC	Utility Energy Service Contract
UFC	Unified Facilities Criteria
UPS	uninterruptable power supply
UV	ultraviolet
V	volt(s)
VAWT	Vertical Axis Wind Turbine
VES	Vertical Sounding
VOC	volatile organic compound
wc	water column
WTE	waste to energy
yd^3	cubic yard

G-2 DEFINITIONS OF TERMS

3D Seismic Tomography: Uses seismic waves produced by explosives or vibrators to produce a 3D image. Common in oil and gas industries.

Aeromagnetics: Detects subsurface magnetic fields from aerial flights. Detects demagnetization from low temperature geothermal alteration. Much of US already surveyed.

Controlled Source Audio-Frequency Magnetotellurics (CSAMT): Similar to MT, but uses a man-made signal source. CSAMT has significantly less depth range than MT, at less than two miles (1.6 km).

DC Resistivity, Electrical Resistivity, Schlumberger, Vertical Sounding (VES): Uses electrical currents to measure resistivity/conductivity. Effective depth is proportional to distance between electrodes.

Energy Resilience: The ability to prepare for and recover from energy disruptions that impact mission assurance on military installations.

E-Scan: Proprietary DC method.

Gravity: Measures gravitational field to determine subsurface rock density.

Induced Polarization (IP): Uses direct current residual conductivity measurements. May be difficult to interpret.

Magnetotellurics (MT): Measures subsurface electricity created by naturally occurring magnetic fields. Indirectly detects temperature and permeability patterns. Can measure several miles deep and can be used to develop 3D images.

Paleomagnetics: Laboratory based measurement of magnetic field variations (rotation) in rock samples to determine crust dilations use to predict possible geothermal.

Time Domain Electromagnetics (TDEM or TEM): Uses manmade magnetic field to determine subsurface conductivity. TDEM has less distortion than other electrode based techniques.

Self-Potential (SP): Uses electrodes to measure natural subsurface electrical potentials. Useful when shallow groundwater flow is of interest

Synthetic Aperture Radar (InSAR): Uses changes in data from two separate flights, on two different dates, to detect subsidence or inflation between flight dates. Changes may indicate volume changes caused by reservoir pumping, or cooling of rock.

UFC 3-550-01
1 September, 2016
Change 3, 01 November 2019

UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR ELECTRICAL POWER DISTRIBUTION

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-550-01
1 September, 2016
Change 3, 01 November 2019

UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR ELECTRICAL POWER DISTRIBUTION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	23 Mar 2017	Removed reference to IEEE C57.12.22 and updated reference to IEEE C57.12.34 in section 3-5.1 and Appendix A references.
2	13 Mar 2019	Section 1-3 and Appendix A revised for cybersecurity requirements. Section 1-4 Cybersecurity added. Added the clarification Notes to section 2-2, 3-4, 3-5.1, 3-6.1, and Appendix A. Section 3-5 Pad-mounted transformer revised Section 3-10.9 Sectionalizer added. Section 3-10.10. Ground Connections revised. Section 3.11.6 Locating Underground Structures revised. Revised section 3-14.2.1. Appendix A added references to IEEE Guides mitigating bird and wildlife-related power interruptions.
3	01 Nov 2019	Added Environmental Severity Classification and humidity design requirements and updated corrosion prevention requirements in 1-3.1, Appendix A and Appendix D.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *General Building Requirements*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: 3-550-01, *Exterior Electrical Power Distribution*

Superseding: UFC 3-550-01, *Exterior Electrical Power Distribution*, dated Feb 3, 2010, including Change 1, dated Jul 1, 2012.

Description: This UFC 3-550-01 provides design guidance for the design of exterior distribution systems.

Reasons for Document:

- Provide technical requirements.
- Incorporate new and revised industry standards.

Impact: There are negligible cost impacts associated with this UFC. However, the following benefits should be realized.

- Standardized guidance has been prepared to assist engineers with unique installation requirements.
- Exterior electrical equipment design criteria are specified to ensure that a reliable installation is realized.

Unification Issues:

The Air Force has the following noted exceptions:

- Paragraph 3-11.5.1 Permits use of pad-mounted sectionalizing cabinets instead of manholes.
- Paragraph 3-11.5.2 Prohibits T splices and Y splices on any MV system.
- Paragraph 3-11.5.5 Does not permit manholes in aircraft aprons.

The Navy has the following noted exceptions:

- Paragraph 3-2.3 Requires 600V insulated neutral conductor in pole riser and ductbanks.
- Paragraph 3-7 Requires switchgear to be SF-6 gas or high fire point liquid insulated.
- Paragraph 3-11.8 Does not permit concentric neutral conductors in ductbanks.
- Paragraph 3-11.8 Requires EPR insulation for MV cables.

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FIGURES

CHAPTER 1 GENERAL

1-1 PURPOSE.

This UFC provides policy and guidance for design criteria and standards for electrical power and distribution systems. The information provided here must be utilized by electrical engineers in the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP) and must serve as the minimum electrical design requirements. It is applicable to the traditional electrical services customary for Design-Bid-Build construction contracts and for Design-Build construction contracts. Project conditions may dictate the need for a design that exceeds these minimum requirements.

UFC 3-501-01 provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-550-01 for exterior electrical system requirements. Refer to UFC 3-501-01 for design analysis, calculation, and drawing requirements.

1-2 APPLICABILITY.

The design criteria and standards contained within are the minimum requirements acceptable for military installations for efficiency, economy, durability, maintainability, and reliability of electrical power supply and distribution systems. The criteria and standards herein are not intended to be retroactively mandatory.

1-2.1 NFPA 70 and IEEE C2.

Comply with the requirements of NFPA 70 and IEEE C2. Generally, IEEE C2 is the basis for UFC 3-550-01 and NFPA 70 is the basis for UFC 3-520-01. However, there are exceptions to which standard applies to each UFC, including:

- Systems covered by other UFCs, such as airfield lighting and shore power systems.
- Exterior circuits such as lighting and service entrance (overhead and underground), which are covered by NFPA 70.

For medium voltage applications, feeder conductor sizing is permitted to be determined by qualified persons under engineering supervision as defined by NFPA 70 Article 215.2 (B) (3), *Supervised Installations*.

1-2.2 Additional References.

Comply with UFC 3-560-01 for electrical safety requirements applicable to the installation and operation of electrical systems.

Comply with UFC 4-010-01 and UFC 4-020-01 for security requirements related to exterior electrical distribution systems.

1-2.3 Exclusions.

Onsite generation is not addressed by this UFC.

1-3 GENERAL BUILDING REQUIREMENTS.

2\ Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, physical security, cybersecurity, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFC and government criteria referenced therein.

1-3.1 \3\ Environmental Severity and Humid Locations.

In corrosive and humid environments, provide design detailing, and use materials, systems, components, and coatings that are durable and minimize the need for preventative and corrective maintenance over the expected service life of the component or system. UFC 1-200-01, section titled "Corrosion Prone Locations" identifies corrosive environments and humid locations requiring special attention. UFC 1-200-01, section titled "Requirements for Corrosion Prone Locations" provides examples of necessary actions. To determine Environmental Severity Classifications (ESC) for specific project locations refer to UFC 1-200-01 Appendix titled "Environmental Severity Classifications (ESC) for DoD Locations". /3/

1-4 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

Cybersecurity is implemented to mitigate vulnerabilities to all DoD real property facility-related control systems to a level that is acceptable to the System Owner and Authorizing Official. UFC 4-010-06 provides requirements for integrating cybersecurity into the design and construction of control systems. /**2**/

1-5 CRITERIA WAIVER PROCESS.

The criteria waiver process is provided in MIL-STD 3007.

1-6 REFERENCES.

Codes and standards are referenced throughout this UFC. The publication date of the code or standard is not routinely included with the document identification throughout the text of the document. In general, the latest issuance of a code or standard has been assumed for use. Refer to Appendix A to determine the publication date of the codes and standards referenced in this UFC.

1-7 UTILITY-OWNED AND OPERATED DISTRIBUTION SYSTEMS ON FEDERAL PROPERTY.

This UFC does not apply to:

- Utility-owned and operated distribution systems with right-of-way or easements on Federal property.
- Military installations that have privatized their electrical distribution system.

CHAPTER 2 ELECTRICAL POWER REQUIREMENTS

2-1 ELECTRICAL POWER REQUIREMENTS: GENERAL.

Virtually all military bases have an existing overhead and underground distribution system that has been in service for many years. As part of any new design project, review the existing design with base personnel to determine which existing features should not be duplicated in future designs. Address design preferences with responsible engineering and operations personnel as part of the system design analysis.

2-2 SELECTION OF PRIMARY VOLTAGE.

NEMA C84.1 establishes typical voltages and voltage ranges for 60 Hz systems.

Facilities located outside of the United States must also comply with the applicable host nation standards; refer to UFC 1-202-01 and UFC 3-510-01 Foreign Voltage and Frequencies Guide (inactive), for additional information.

2-3 DESIGN FOR MAINTENANCE.

Design primary distribution system equipment installations with future periodic maintenance as a principal consideration. Equipment must be capable of removal from service while minimizing the outage time of affected facilities and missions. Looped and alternate feed designs are essential to allow periodic maintenance.

Provide maintenance criteria with the design analysis as part of the basis for the design as specified in UFC 3-501-01.

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CHAPTER 3 DESIGN CRITERIA

3-1 MAIN AND UTILIZATION ELECTRIC SUPPLY STATIONS.

For all main and electric supply stations/substations, comply with the requirements of IEEE C2 Part 1, *Rules for the Installation and Maintenance of Electric Supply Stations and Equipment*, as follows:

- Electric Supply Stations are defined as stations that transform the energy level (voltage) for further bulk distribution at medium voltage levels.
- Comply with the requirements of NFPA 70 for the low voltage equipment in a main or electric supply station (equipment that is being served from a Utilization Electric Supply Station).

3-1.1 Main Electric Supply Stations.

The main electric supply station is the installation/utility interface point where further transmission, distribution and utilization of electrical power, the monitoring and control of such power or equipment and the protection of electrical equipment or systems usually becomes the sole responsibility of the Government or their contracted representatives. Coordinate the design of new stations, or modifications to existing stations with the supplying utility and with any other suppliers or users of power supplied through the station.

3-1.2 Utilization Electric Supply Stations.

Utilization Electric Supply Stations are defined as equipment such as pole or pad-mounted transformers, secondary unit substations, or primary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use. Some examples of Utilization Electric Supply Stations are station service transformers (serving low voltage equipment in a Main Electric Supply Station), a lighting transformer (serving equipment for a roadway lighting system), a pole or pad-mounted transformer (serving a building), or a secondary unit substation (serving piers and wharfs electrical systems)

3-2 GENERAL ELECTRICAL REQUIREMENTS.

Refer to Appendix C for Best Practices-General Electrical Power Requirements.

3-2.1 Industry Standards.

Overhead systems – comply with the requirements of IEEE C2 Part 2, *Safety Rules for the Installation and Maintenance of Overhead Electric Supply and Communication Lines*.

Underground systems – comply with the requirements of IEEE C2 Part 3*, Safety Rules for the Installation and Maintenance of Underground Electric Supply and Communication Lines*.

3-2.2 Arc Flash Analysis Criteria.

Refer to UFC 3-560-01 Section 1-4.1.1 for arc-flash criteria and the delineation points between IEEE C2 and NFPA 70E conformance requirements.

3-2.3 System Design.

Design new primary distribution systems as four wire, multi-grounded systems that are wye connected at the source transformer. Provide a system grounded neutral conductor throughout the system. Provide a bare conductor for the neutral on overhead systems.

Note: For the Navy, provide a neutral that is a 600 volt insulated conductor for pole riser and underground systems.

When a project is limited to connecting to an existing three wire system and the primary electrical characteristics are established and defined, continuation of the existing system is permitted with the following requirements:

- For extensions from underground structures, provide a four wire extension. Bond the grounded neutral conductor at each end of the extension to the applicable grounding electrode systems.
- For extensions from overhead pole lines, provide a four wire extension. Bond the grounded neutral conductor at each end of the extension to the applicable grounding electrode systems.

Note: Design of the extensions as four wire systems does not change any circuit classifications. It provides an extended grounding electrode system to facilitate any future circuit conversions to four wire systems.

3-2.4 Pad-Mounted Equipment.

Provide pad-mounted equipment foundation pads and ensure a minimum of 10 ft (3 m) clear workspace in front of pad-mounted equipment for hot stick work. Orient equipment so that adjacent equipment will not interfere with the clear workspace. Provide bollards in areas where equipment is subject to vehicular damage.

3-3 PRIMARY UNIT SUBSTATIONS.

Provide primary unit substations to distribute underground medium voltage circuits. Comply with the following industry standards as applicable for the specified configuration:

- IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Basis – Preferred Ratings and Related Required Capabilities*.
- IEEE C37.46, *High Voltage Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnection Switches*.

- IEEE C37.121, *Switchgear – Unit Substations Requirements*.
- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.
- IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

3-4 SECONDARY UNIT SUBSTATIONS.

Provide secondary unit substations when secondary currents exceed 3,000 amperes at 1,000 volts and below. Comply with the following industry standards as applicable for the specified configuration:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE 57.12.50, *Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase, and 15 to 500 kVA Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 120-600 Volts*.
- IEEE 57.12.51, *Ventilated Dry-Type Power Transformers, 501 kVA and larger, Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 208Y/120 to 4160 Volts*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.01, *General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.91, *Test Code for Dry-Type Distribution and Power Transformers*.
- IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.

- IEEE C57.124, *Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers*.

3-5 PAD-MOUNTED DISTRIBUTION TRANSFORMERS.

3-5.1 Reference Criteria.

Comply with the following industry standards:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- **1**\\IEEE C57.12.34, *Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers, 10 MVA and Smaller High-Voltage, 34.5 kV Nominal System Voltage and Below; Low-Voltage, 15 kV Nominal System Voltage and Below*. /**1**/
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.

3-5.2 Configuration.

Use dead-front construction for pad-mounted transformers unless not available within system parameters.

Three-phase pad-mounted transformers must be loop-feed capable with 6 bushings. Provide two-position, oil-immersed, load break switches that are appropriate for the application. If the transformer might be used as part of a loop-feed design, provide three switches to permit closed transition loop feed and sectionalizing. If the transformer will be installed at the end of a radial supply with no intention of future loop feed capability, provide a single on-off switch. Provide a spare conduit in the high voltage section extending 5 ft (1.5 m) out from the transformer pad.

3-5.3 Size and Secondary Voltage.

Do not use pad-mounted transformers with secondary currents exceeding 3,000 amperes because of the size and quantity of secondary conductors. Transformers rated above 1,000 kVA serving 208Y/120 volt loads and above 2,500 kVA serving 480Y/277 volt loads must be in a secondary unit substation configuration.

Minimize double transformations to reduce energy consumption and to minimize items of equipment. Provide two \2\liquid/2/-filled pad-mounted transformers in lieu of one 480Y/277 volt service if the required 208Y/120 volt load using dry-type transformers exceeds 40 percent of the 480 volt service transformer capability. Connect equipment at the highest available voltage to minimize the capital cost and energy losses of transformation equipment.

3-5.4 Winding Configuration.

Provide \2\step-down/2/ delta-wye \2\grounded connections and step-up grounded wye-wye/2/ connections for three phase systems.

3-5.5 Surge Protection.

Provide bushing-mounted elbow type arresters at the ends of all radials and in normally open locations in loops. Provide arresters for all voltage levels above 5 kV.

3-5.6 Drawing Details.

When using a pad-mounted transformer, select the applicable pad-mounted transformer detail in AutoCAD or PDF format from: http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf , supply the missing data, and incorporate that detail onto the contract drawings. Pad-mounted transformer details are contained in the UFGS 26 27 14.00 20 Electricity Metering file. These drawing details represent typical situations but may not meet all requirements. Modify transformer details as required to indicate the actual requirements for each particular installation.

In rare cases when “live front construction” is required due to equipment ratings (available system fault current values), obtain approval from the Authority Having Jurisdiction (AHJ), as defined in UFC 1-200-01. Do not use the pad-mounted transformer details to show secondary unit substations.

3-6 MEDIUM VOLTAGE SWITCHGEAR.

3-6.1 Metal-Clad Switchgear.

Metal-clad switchgear can include either SF6 or vacuum style breakers and must consist of a single section or multiple section line-up of NEMA 1 or NEMA 3R enclosures. Either walk-in or non-walk-in construction can be provided. Medium voltage metal-clad switchgear can be provided as unit substation construction or as stand-alone switchgear. The sections must contain the breakers and the necessary accessory components. The equipment must be factory-assembled (except for necessary shipping splits) and be operationally checked before shipment. As an electrical safety consideration, provide a remote racking mechanism to rack breakers in and out. As an electrical safety consideration, provide ground ball studs on the load side of each circuit breaker to allow for connection of temporary grounding sets.

Comply with the following industry standards:

- IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*.
- IEEE C37.121, *Switchgear – Unit Substations Requirements*.

- IEEE C37.04, *Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*.
- IEEE C37.20.2, *Metal-Clad Switchgear*.
- IEEE C37.90, *Relays and Relay Systems Associated with Electric Power Apparatus*.

3-6.2 Metal-Enclosed Switchgear.

Do not use metal-enclosed switchgear. Instead, use either a vacuum fault interrupter (VFI) in a unit substation configuration or pad-mounted switchgear.

3-6.3 Circuit Breaker Operation Design.

Provide batteries with battery charger for dc opening and closing of circuit breakers. Do not use ac or capacitor control methods.

3-7 PAD-MOUNTED SWITCHGEAR (SWITCHES).

For the Navy, utilize multi-way pad-mounted switchgear when switching, isolation, or electrical protection is required. Specify SF6 gas or high fire point liquid (non-temperature dependent) insulation technology and vacuum bottle interruption technology. Specify dead front construction with stainless steel tanks and operator full size viewing windows for each switching way. Specify three position (On/Off/Ground) switch ways for all new construction. For switch replacements when existing switching arrangement is On/Off/Tie, a similar arrangement without ground position is permissible. Specify switch design which incorporates operating handles on the opposite side of the tank from the cable entrance bushings, terminations and cables. Specify 600 ampere dead break connectors with 200 ampere interface bushings for each switch way. Coordinate with the Activity and include ground fault circuit indicators in accordance with the base design standard. Air-insulated (fused or non-fused) technology is not permitted. Comply with the following industry standards:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C37.60, *Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV*.
- IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

For the Army and Air Force, air-insulated and fused switches can be used in either a live-front or dead-front configuration. Do not use air-insulated switches in corrosive and high humidity areas as defined in UFC 3-501-01 unless the installation experience for the installed location confirms that switch corrosion and tracking is not a problem.

3-8 PAD-MOUNTED SECTIONALIZING TERMINATION CABINETS.

Apply pad-mounted sectionalizing termination cabinets only when switching, isolation, or electrical protection for the downstream circuit is not required or anticipated. Sectionalizing termination cabinets can be used instead of in-line splices in manholes or for minor loads that do not warrant the expense of pad-mounted switchgear. Sectionalizing cabinets are available up to 35 kV. Provide low profile sectionalizing termination cabinets when the conductor size is 4/0 AWG or smaller. Coordinate with the Activity and include ground fault circuit indicators in accordance with the base design standard.

3-9 CAPACITORS.

3-9.1 Application.

Do not use capacitors unless they are needed for power factor correction or to minimize line losses. Verify the need by a system analysis; the analysis must consider the potential adverse effects of transients caused by capacitor switching. Refer to TSEWG TP-2: *Capacitors for Power Factor Correction*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 for additional information if power factor correction is considered.

Underground distribution has more capacitance than equivalent overhead distribution. When converting from overhead distribution to underground distribution, provide pad-mounted capacitors on a distribution system only if supported by the design analysis. Do not automatically replace existing pole-mounted capacitors with equivalent pad-mounted capacitors.

3-9.2 Disconnect Design.

For safety purposes, include an oil switch disconnect with pole-mounted capacitors.

3-10 OVERHEAD POWER DISTRIBUTION.

Design overhead lines to IEEE C2 Grade B construction complying with the following:

a. Limit the initial loaded conductor tension to a maximum of 50% of the conductor rated breaking strength. Lesser tensions are usually applicable and generally more preferred. Utility distribution line design is generally in the range of 25% to 35% of the rated breaking strength.

b. Provide clearance requirements using final sag values in conformance with IEEE C2 Part 2.

c. Limit the maximum design tensions for any conductors to 4,750 pounds (2,154 kg). Base all clearance values on the following maximum conductor temperatures.

- Copper phase conductors – 167 degrees F (75 degrees C).

- Aluminum/aluminum alloy phase conductors – 194 degrees F (90 degrees C).
- Neutral conductors for multi-phase circuits – 120 degrees F (49 degrees C).
- The maximum conductor temperature for single-phase neutral conductors is identical to the phase conductors.

Match the existing base construction methods. Match those construction methods used by the local utility when directed. Where new overhead distribution is required, route the overhead distribution along roadways and other major topographical features; the poles must be accessible for future maintenance or work. Coordinate pole locations with land-use planning to ensure that new poles do not interfere with future facility plans.

3-10.1 Drawing Details.

Use NAVFAC pole details OH-1.1 through OH-41. NAVFAC pole details are available in Adobe PDF format and in AutoCAD format http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf. In situations where an applicable pole detail has not been developed, provide new detail drawings as required. For designer developed details, provide a level of detail equivalent to NAVFAC pole details and include material requirements. Refer to UFC 3-501-01 for additional pole detail requirements.

3-10.2 Pole Types.

Use solid wood poles for electric distribution lines. Concrete or steel poles may be justified for medium-voltage distribution circuits where wood poles do not provide adequate strength, or where climatic conditions cause wood poles to deteriorate rapidly. Do not use laminated wood poles for electric distribution lines.

3-10.3 Conductors.

Due to the increasing technology improvements with aluminum conductors and connectors, and the economic disadvantage of providing copper conductors, provide aluminum conductor steel reinforced (ACSR) or aluminum alloys for new overhead lines and extensions of existing lines. Do not use ACSR conductors in corrosive and high humidity areas. For corrosive and high humidity areas, provide Type ACSS conductors.

Except for grounding systems, the use of copper conductors is prohibited without specific approval and documentation by the applicable local engineering authority. The local engineering authority is defined by the following:

- For the Navy, the Facilities Engineering Command (FEC) organization's chief engineer has the authority to use copper product for their applicable jurisdiction.

- For the Army, the Installation Department of Public Works Chief Engineer has the authority to use copper product for their applicable jurisdiction if documented in the planning process and the design analysis.

- For the Air Force, the Base Civil Engineer has the authority to exercise the criteria option of copper product for their applicable jurisdiction if documented in the planning process and the design analysis.

3-10.4 Pole-Mounted Transformers.

3-10.4.1 Maximum kVA Rating.

Provide pad-mounted transformers rather than pole-mounted transformers for new three-phase installations larger than 75 kVA.

Limit pole-mounted transformer sizes (except for projects involving system conversions to a different operating voltage) as follows:

- Three-phase installations – limited to three 25 kVA transformers or smaller.
- Single-phase installations – limited to one 75 kVA transformer or smaller.

3-10.4.2 Configuration.

Use only single phase transformers for pole-mounted installations. For single phase installations and when banking single phase transformers for three phase applications, apply phase-to-neutral primary connections unless installed on three wire distribution systems.

Do not use self-protected transformers. Self-protected transformers have internal primary fuses that must be replaced by experienced personnel.

3-10.4.3 Mounting and Location.

Do not use pole-platform mounting (two-pole structure or H-frame).

Aerially mounted installations might supply several buildings. When that is the case, install the transformers at the pole location closest to the building with the greatest load. Secondary wiring should drop directly to the buildings served, if the span does not exceed 125 feet; otherwise, intermediate poles are required.

3-10.5 Pole-Top Switches.

Pole top switches are installed at important system locations to allow either isolation of the downstream circuit or cross-connection to a different circuit. Where ground operated, gang type, three phase, air break switches are used with non-insulated operator handles, provide a metal plate or grate at ground level for the operator to stand on when operating the switch. Connect the metal plate or grate to the pole ground conductor as well as through a braided conductor connection to the switch handle mechanism. Include a provision for locking ground accessible switch handles in the open and closed position.

Single-pole knife blade switches and copper barrels inside distribution cutouts are only acceptable for use in locations where frequent switching is not expected.

3-10.6 Surge Arresters.

Provide surge arresters on the line side of:

- Pole mounted transformers.
- Overhead to underground terminal poles.
- All “normally open” switch ways of pad-mounted sectionalizing switches connected to and served from overhead lines.
- Underground primary metering installations connected to and served from overhead lines.

Provide surge arresters on the line and load sides of:

- Gang operated airbreak switches on overhead lines.
- Primary metering applications on overhead lines.
- Recloser/sectionalizer applications on overhead lines.

3-10.7 Fuse Protection.

Provide IEEE C37.41 rated backup current limiting fuses in series with Type K expulsion fuses on systems that are:

- Greater than 15 kV.
- 15 kV and lower that have available fault currents equal to or greater than 7,000 asymmetrical amperes.

Note: Existing systems should continue to use the expulsion fuse link type that represents the standard for that system.

3-10.8 Automatic Circuit Reclosing.

Do not provide automatic circuit reclosing on underground distribution circuits. \2\

3-10.9 Sectionalizer.

Comply with IEEE C37.63. Use sectionalizer as a not load break switch in conjunction with an upstream recloser or circuit breaker. It counts the interruptions created by a recloser during a fault sequence. On a preset count, the sectionalizer trips during the dead time of the upstream recloser and isolates the faulty network section.

Note: Sectionalizer with a separate Controller requires an auxiliary power source. Sectionalizer with an integral electronic control incorporates electronic logic and trip circuits which are controlled and powered by current transformers. /2/

3-10.10 Ground Connections.

\2\ All pole mounted equipment and metallic frames must have two connections to the multi-grounded system neutral conductor. /2/ Keep ground wires straight and short. Minimize bends in all ground connections.

3-11 UNDERGROUND ELECTRICAL SYSTEMS.

3-11.1 Underground Distribution General Criteria.

3-11.1.1 Locations.

Provide underground distribution as follows:

- In areas where the primary distribution is already underground.
- In locations where overhead distribution is operationally hazardous, such as within airfield clearance zones.
- As required to supply pad-mounted equipment and transformers.
- Near electronics or munitions facilities that have clearance requirements for overhead power lines.
- Near piers and loading areas where overhead cranes operate.
- In congested industrial areas.
- In areas where storm and hurricanes or typhoons can damage overhead distribution.

3-11.1.2 Conductor Type.

Due to the increasing technology improvements with aluminum conductors and connectors and the economic disadvantage of providing copper conductors, provide aluminum conductors for new underground lines and extensions of existing circuits. This includes all new medium voltage system designs that do not require interface (splicing copper to aluminum in underground structures) with existing copper infrastructure. Provide only copper grounding electrode systems. The use of copper conductors is authorized for extensions of existing systems in which the use of aluminum results in technical limitations, such as:

- Maintaining required circuit ampacity, including derating associated with number of circuits in a common ductbank or burial depth.

- Maintaining base infrastructure capacity, including feeder cross-tie capability.
- Conduit size. All phases are required to be installed in the same conduit.
- Undersized or congested structures necessitating tape splices of aluminum cable to existing copper cable. *Note: If adequate space exists for the use of improved technology "heat shrink or cold shrink" splices, or if proper aluminum to copper compression connectors designed for the natural offset of size difference between the conductor materials is available as a standard manufactured product, provide the copper to aluminum cable extension*.

Approval of copper conductors is authorized as follows:

- For the Navy, the Facilities Engineering Command (FEC) organization's chief engineer has the authority to use copper product for applications within their applicable jurisdiction, in addition to the above authorized use for extensions.
- For the Army, the Installation Department of Public Works Chief Engineer has the authority to use copper product, in addition to the above authorized use for extensions, within their applicable jurisdiction if documented in the planning process and the design analysis.
- For the Air Force, the Base Civil Engineer has the authority to exercise the criteria option of copper product, in addition to the above authorized use for extensions, within their applicable jurisdiction if documented in the planning process and the design analysis.

3-11.1.3 Routing.

Do not route primary underground utilities under buildings. Do not route systems greater than 600 volts under buildings except as a direct service entrance to a single interior transformer.

3-11.1.4 Marking and Labeling.

Tag all underground cables in all accessible locations such as in manholes, transformers, switches and switchgear. Install a detectable locator tape above all buried underground circuits. Marking must meet the base utility standards.

3-11.2 Ductbanks.

The definition of the terms ductbank, conduit, and duct are often confused. Within this UFC, a ductbank consists of two or more conduits (or ducts) routed together in a common excavation with or without concrete encasement.

3-11.2.1 Conduit Size.

Minimum conduit sizes must be as follows:

- Provide concrete encasement for primary distribution conduits between underground structures, and between underground structures and associated equipment, except in locations where soil conditions prohibit a stable environment. With approval of the Activity, utilize directional boring where conditions are not conducive to concrete-encased ductbanks.

  Primary Distribution Conduits (along main run and on laterals between underground structures and associated equipment) – size as needed to satisfy conduit fill and jam ratio criteria for the selected conductor size and voltage class, with 5 in (127 mm) minimum. For primary distribution conduits serving Navy dockside utilities, provide 6 in (155 mm) minimum.

  Secondary Distribution Conduits (Low Voltage) – size as needed to satisfy conduit fill and jam ratio criteria for the selected conductor size, with 4 in (103 mm) minimum for conductor sizes 500 kcmil and larger. In this case, secondary distribution conduits refer to the low voltage conduit routing from the distribution transformer to the service entrance equipment. This requirement does not apply to street lighting circuits, secondary supplies to housing, or secondary circuits originating from an interior panel.

- Telecommunication Conduits – 4 in (103 mm) for main telecommunications circuits.

  Specialty telecommunications circuits, such as cable television or alarm circuits, can select conduit sizes as needed for the application.

  Example: a cable television circuit might only require a 2 in (52 mm) conduit stubbed out to a fiberglass composite handhole.

3-11.2.2 Installation.

- Use Type EB Schedule 20 PVC conduits (minimum thickness) for conduits installed in concrete encasement. Provide at least 3 in (75 mm) of concrete encasement.
- Use Schedule 40 PVC conduit (minimum thickness) for conduits that are not installed in concrete encasement.
- Install all phase conductors and neutral conductor, if applicable, in the same conduit for three-phase circuits and delta-connected single-phase circuits. *Note: some utilities install each phase conductor in a separate conduit. This practice is not authorized*.
- Bury conduit at a minimum depth of 18 in (450 mm) below grade. Conduits must be 24 in (600 mm) minimum depth under roads and

pavement, and for voltages between 22 kV and 40 kV. Apply conductor ampacity derating when exceeding the NFPA 70 maximum burial depths.

- Provide 3 in (75 mm) clearance between conduits utilizing interlocking plastic spacers.
- For primary distribution circuits, provide spare conduits such that at least 1/3 of the ductbank contains empty conduits with a minimum of at least one spare conduit.
- For secondary distribution circuits on the secondary side of distribution transformers, provide one spare conduit.
- Include pull wires (pull string or pull rope) in all spare ducts.
- Provide a transition from Type EB conduit to Schedule 40 PVC conduit before emerging from underground.
- Use directional boring or jack-and-bore techniques for routing conduit(s) under existing pavement for roadways, aircraft aprons, runways and taxiways. Directional boring can be used for other locations where excavation can adversely affect daily operations.

  Note: Comply with Appendix B for the use of directional boring for conduit installations.
- For permafrost locations, use ductbank installation methods that are the standard for the base, post, or local utility.

3-11.3 Direct Buried Wiring Methods.

The term direct buried wiring refers to the direct burial of conductors without any conduit or concrete encasement. Comply with IEEE C2 for all direct burial systems.

3-11.3.1 Authorized Locations.

With approval of the Activity, direct buried wiring methods for low or medium voltage systems may be allowed for specific applications such as:

- Special applications in remote or extremely controlled areas. Examples of such applications could be ranges or range facilities, renewable energy projects such as wind farms or bulk photovoltaic (PV) facilities provided for the purpose of supplementing system demand loading.
- Housing projects utilizing residential type distribution principles of single-phase, pad-mounted transformer designs and single-phase distribution principles for balanced three phase system loading.
- Bulk power transfer (feeder) from point to point crossing remote or controlled real estate which will revert to public utility ownership and maintenance upon completion.

Direct buried wiring methods are not authorized for any application which constitutes a part of the base utility core distribution infrastructure.

3-11.3.2 Conductor Type.

All approved direct burial medium voltage systems can utilize concentric neutral underground distribution cable design instead of the typical Type MV tape-shielded conductor design utilizing a separate 600 volt insulated neutral conductor.

3-11.3.3 Crossing of Paved Areas.

Provide a spare conduit system with associated enclosures for direct buried systems under all streets, roads, and parking areas to provide for future maintenance capability without having to disrupt pavements. Provide minimum Schedule 40 PVC extending 5 feet on each side and capped for future use.

For crossing existing paved areas, the directional boring technology referenced in the paragraph titled Directional Boring, also applies for installation of the direct buried system.

3-11.4 Directional Boring.

Directional boring (DB) is a trenchless technology method to install high density polyethylene electrical (HDPE) conduit used for underground electrical distribution systems.

3-11.4.1 Authorized Locations.

Do not select DB methods as an installation means in lieu of concrete encasement or other approved jack-and-sleeve techniques, based solely on cost. Concrete encasement and jack-and-sleeve techniques always provide the best means to protect conduit and conductors; therefore, DB is authorized only for crossing under the following:

- Roads.
- Parking lots.
- Airfield aprons, taxiways, or runways (not airfield lighting circuits due to counterpoise requirements).
- Bodies of water.
- Environmentally sensitive areas with appropriate federal, state, and local government approval.
- Historical preservation areas with appropriate federal, state, and local government approval.

DB is also authorized for locations where earth setting has caused shearing of conduits. Document this basis for selection of DB as part of the design analysis.

3-11.4.2 Limitations.

DB is applicable to medium-voltage (MV) underground distribution systems between 1000 volts (V) and 34.5 kilovolts (kV) (nominal) and all low-voltage distribution systems (less than 1000 V). It is not applicable to airfield lighting circuits. Use of DB techniques to install electrical conduit distribution for voltages greater than 34.5 kV (nominal) is prohibited.

Refer to Appendix B regarding depth of DB. The depth can be less if a detailed survey is performed and documented before starting boring.

3-11.5 Underground Structures (Manholes and Handholes).

3-11.5.1 General Requirements.

Provide separate power and communication manholes. When power and communication duct lines follow the same route, use a common trench and locate power and communication manholes in close proximity to one another and staggered. Use manholes for main duct runs and wherever shielded medium voltage cable is installed. For the Air Force, pad-mounted sectionalizing termination cabinets can be used instead of manholes for locations that do not have multiple feeders.

Handholes can only be used for airfield lighting circuits, for other non-shielded medium voltage circuits, and for low-voltage and communication lines.

3-11.5.2 Equipment Prohibited Inside Manholes.

The following equipment is prohibited inside underground structures:

- Load junctions.
- Separable splices (bolt-T connections).
- T-splices and Y-splices on systems rated for greater than 15 kV.
- For the Air Force, T-splices and Y-splices on all medium voltage systems.
- Power distribution equipment, including transformers and switches.

3-11.5.3 Splice Locations.

All in-line splices must be in underground structures. Do not use handholes for splicing shielded power cables.

3-11.5.4 Fireproofing.

Individually fireproof medium voltage cables in all underground structures.

3-11.5.5 Design Loading.

Specify H20 highway loading for most locations. Structures subject to aircraft loading must be indicated to the Contractor. Design decks and covers subject to aircraft loadings per FAA AC-150/5320-6 except as follows:

- Design covers for 100,000 lb (45,000 kg) wheel loads with 250 psi (1.72 MPa) tire pressure.
- For spans of less than 2 ft (0.6 m) in the least direction, use a uniform live load of 325 psi (2.24 MPa).
- For spans of 2 ft (0.6 m) or greater in the least direction, the design must be based on the number of wheels which will fit the span. Use wheel loads of 75,000 lb (34,000 kg) each.

Note: For the Air Force, do not install electrical manholes in aprons. Maintain a distance of 50 ft (15 m) from the edge of paving, 50 ft (15 m) from any hydrant lateral control pit, and 200 ft (60 m) from a fueling point for all manholes.

3-11.5.6 Manhole Size.

Determine the size of power manholes by the number of circuits, voltage ratings and splicing requirements of the cables within. Provide manholes that are a minimum 6.5 ft (2 m) deep. For circuits rated above 15 kV, provide manholes that are a minimum of 9 ft by 12 ft (2.8 m by 3.7 m) in interior size. Provide cable racks in all new manholes. When reworking cables in existing manholes, provide racks for new cables. Route cable installations inside manholes along those walls providing the longest route and the maximum spare cable lengths.

Size communications manholes for equipment and splices contained, including future projections. Manholes must accommodate racking of splice closure of largest multi-pair cable while keeping cable bending radii greater than 10 times cable diameter.

3-11.5.7 Manhole Drawing Details.

Provide manhole foldout details or exploded views for all multiple-circuit primary systems and all primary systems requiring splices. Indicate the entrance of all conduits and the routing of all conductors in the manholes. Manhole details are available in AutoCAD or Adobe PDF format at http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf .

3-11.6 Locating Underground Structures.

Provide where \2\any of three the following conditions exists:

- Where/2/ splices are required,
- \2\Where/2/ duct lines change direction \2\unless the field manufactured longsweep bends having a minimum radius of 25 feet (7.6 m) can be used for a change of direction of more than 5 degrees, either horizontally or vertically, using

a combination of curved and straight sections with the maximum manufactured curved sections of no more than 30 degrees,

- Within/2/ 100 ft (30 m) of every riser pole, pad mounted transformer, or unit substation unless a calculation is provided to justify a greater distance. The distance must not exceed 200 ft (60 m).

Separation on straight runs must not exceed 400 ft (120 m). In situations where greater separation is desired and this greater separation is not prohibited by either excessive pulling tension or site requirements, separation of up to 600 ft (180 m) is permitted.

3-11.7 Pull Boxes.

Pull boxes are used for electric circuits supplying low-voltage electric loads which require conductors no larger than 1/0 AWG and no more than one 2-inch (52 mm) conduit entrance at each side. Wherever larger conduits are installed, use handholes or manholes. Do not use pull boxes in areas subject to vehicular traffic.

3-11.8 Medium Voltage Cable.

Comply with NEMA WC 74 and select type MV (105°C) aluminum or copper based on the specific applications as defined in Para. 3-11.1. Provide a 600 volt insulated neutral when required. For the Army and Air Force, concentric neutral conductors are also authorized.

Comply with the following:

- Cable Jacket – PVC or polyethylene jacket suitable for wet conditions.
- Insulation Type – Provide ethylene propylene rubber (EPR). For the Army and Air Force, cross-linked polyethylene is also authorized. Do not use paper insulated lead covered (PILC) for new installations.
- Insulation Level – Provide a 100% minimum insulation level for all circuits classified as multi-grounded (4 wire systems throughout the entire circuit). Provide a 133% insulation level for all other classification of circuits.
- Cable Shields – Use copper-tape shielded cables and ensure minimum bending radii of 12 times the overall cable diameter. Use copper-wire shielded cables only where existing manholes are utilized and the minimum cable bending radii of tape shielded cables cannot be realized. Refer to NEMA WC 74 for cable bending radii.
- Number of Conductors – Use single conductor cable as a general rule. Three conductor cable may be used only when splicing to existing three conductor cable.

3-12 CONCRETE FOR UNDERGROUND ELECTRICAL SYSTEMS.

Concrete for encasement of underground ducts must be 3000 psi (20 MPa), minimum 28-day compressive strength. Concrete associated with electrical work for other than encasement of underground ducts must be 4000 psi (30 MPa), minimum 28-day compressive strength unless specified otherwise.

3-13 HOUSING DISTRIBUTION.

Comply with the following requirements for electrical distribution to housing units:

- Serve single dwelling units, duplexes and quadraplexes in housing areas by single-phase, 240/120V transformers.
- Serve no more than 6 dwelling units; 4 duplexes; or 2 quadraplexes per transformer.
- Minimum conductor size from the transformer to the service entrance equipment should be 3/0 copper in underground conduit.
- Provide a maximum length of 220 ft (67 m) for the service lateral conductors from the distribution transformer to the service entrance device (or meter base).
- Design the distribution system such that the available fault current at the service equipment is less than 10,000 amperes.

Where an underground 3-phase circuit is used to feed single-phase transformers, provide a separate 3-phase pad-mounted switch or sectionalizing cabinet with a radial supply to the single-phase transformers.

3-14 DISTRIBUTION SYSTEM GROUNDING.

Comply with the requirements of IEEE C2 Section 9, *Grounding Methods for Electric Supply and Communication Facilities*, for distribution system grounding (medium voltage systems classified as multi-grounded, single point grounded at source transformer either solidly or with grounding resistors, and ungrounded).

Design in accordance with IEEE Std 80 main electric supply stations and all supply stations consisting of equipment for the purpose of transforming the voltage level for further bulk distribution. Complete measurements of the station grounding system prior to inter-connection with other systems and prior to station energization to assure the limits of step and touch potentials as required by IEEE Std 80 have been attained.

3-14.1 Separation of Grounding Conductors.

Comply with the requirement for separation of grounding conductors between classes of equipment operating in excess of 750 volts and below 750 volts for the design of all facilities. The exception for connecting the different classes of equipment "to a sufficiently heavy ground bus or system ground cable that is well connected to ground at more than one place" is the Government's engineering basis for interconnecting the different classes of equipment connected to existing systems.

Note: The predominant classification of existing Government medium voltage systems is a classification of something other than multi-grounded. For designs on new systems or existing systems classified as multi-grounded, the standard grounding detail of a 4/0 ground ring and interconnecting ground rods on utilization electric supply stations may be omitted and replaced with a simpler system complying with the requirements of IEEE C2 Section 9.

3-14.2 Materials and Special Requirements.

3-14.2.1 Ground Rods.

Comply with IEEE C2 Section 9 for ground rod composition, minimum spacing requirements and connections except provide ground rods with minimum dimensions of 10 ft (3.0 m) in length and ¾ inch (17 mm) in diameter. Provide copper-clad steel, solid copper, or stainless steel ground rods. Sectional ground rods are permitted. All connections to ground rods below ground level must be by exothermic weld connection or with a high compression connection using a hydraulic or electric compression tool to provide the correct circumferential pressure. Accessible connections above ground level and in test wells can be accomplished by clamping. Pole–butt plates and wire wraps recognized by IEEE C2 Section 9 are not authorized as grounding electrodes.

Spacing for driving additional grounds must be a minimum of \2\6 ft (1.8 m)/2/. Bond these driven electrodes together with a minimum of 4 AWG soft drawn bare copper wire buried to a depth of at least 12 in (300 mm).

3-14.2.2 Ground Rings.

Comply with the requirements of NFPA 70 Section 250 for ground rings. If the system is not classified as multi-grounded, utilization electric supply stations, switchgear, and sectionalizing cabinets require a 4/0 bare copper ground ring with a minimum of four ground rods for three phase service. Single phase service installations can be modified to minimum 1/0 copper and two ground rods for the ground ring. Test wells are permitted on specific applications as required.

If metal bollards are installed and are within 8 feet of the pad-mounted equipment, bond each bollard to the ground ring.

3-14.3 Low Voltage Grounding Interface With Utilization Electric Supply Stations.

For design purposes, the secondary terminals of the utilization electric supply station are the demarcation point between IEEE C2 and NFPA 70. The transition between the grounded neutral conductor (functioning as a neutral and a grounding conductor per IEEE C2) and the grounded conductor (functioning as a neutral conductor only per NFPA 70) must be at the "service point" as defined by UFC 3-501-01 Chapter 2.

- The service point for low-voltage conductors from utilization electric supply stations containing no secondary overcurrent protection device is defined as the line side terminals for the facility service equipment.
- The service point for utilization electric supply stations containing an overcurrent protection device is at the main breaker on the secondary side of the utilization electric supply station. This is the transition point from IEEE C2 to NFPA 70 grounding where the service main bonding jumper is located.

3-14.4 Grounding Requirements – Fences.

Ground metal fences for electrical equipment in accordance with IEEE C2 Section 9.

Other metal fences that are electrically continuous with metal posts extending at least 24 inches (610 mm) into the ground require no additional grounding unless specifically required by other criteria.

3-14.4.1 Ordnance Facilities.

Ordnance facilities or locations where ordnance and explosives are handled and stored require special protective measures. Refer to the following service-specific criteria for grounding of metal fences near these facilities:

- NAVSEA OP-5, *Volume 1, Ammunition and Explosives Ashore*.
- AFMAN 91-201, *Explosive Safety Standards*.
- AFMAN 91-118, *Safety Design and Evaluation Criteria for Nuclear Weapon Systems*.
- Department of the Army Pamphlet 385-64, *Ammunition and Explosives Safety Standards*.

3-14.4.2 Plastic Coated Fencing.

Plastic coated fencing is prohibited for fences that require grounding.

3-15 METERING.

Provide metering in accordance with UFC 3-520-01.

3-16 EXTERIOR SITE LIGHTING.

Provide exterior lighting in accordance with UFC 3-530-01.

3-17 CATHODIC PROTECTION SYSTEMS.

Provide cathodic protection in accordance with UFC 3-570-01.

3-18 ENVIRONMENTAL CONSIDERATIONS.

Consider oil spill containment for substation transformers. Containment is not authorized for pad-mounted oil-filled distribution transformers and switches.

Do not use askarel-insulated and nonflammable, fluid-insulated transformers because of environmental concerns as to their insulation liquid.

3-19 FIRE PROTECTION CONSIDERATIONS.

Provide fire protection and specify installation location for oil-filled equipment in accordance with UFC 3-600-01.

Oil-filled transformers using mineral oil can only be used outdoors. Less-flammable liquid (fire point of not less than 300 degrees C (575 degrees F)) transformers may be used either outdoors or indoors.

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APPENDIX A REFERENCES

Note: The most recent edition of referenced publications applies, unless otherwise specified.

DEPARTMENT OF DEFENSE

AFMAN 91-118, *Safety Design and Evaluation Criteria for Nuclear Weapon Systems*.

AFMAN 91-201, *Explosive Safety Standards*.

Department of the Army Pamphlet 385-64, *Ammunition and Explosives Safety Standards*.

NAVSEA OP-5, Volume 1, *Ammunition and Explosives Ashore*.

IEEE

www.ieee.org

IEEE C2, *National Electrical Safety Code*.

IEEE C37.04, *Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*.

IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*.

IEEE C37.20.2, *Metal-Clad Switchgear*.

IEEE C37.41, *Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories*.

IEEE C37.46, *High Voltage Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnection Switches*.

IEEE C37.60, *Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV*.

IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

IEEE C37.90, *Relays and Relay Systems Associated with Electric Power Apparatus*.

IEEE C37.121, *Switchgear – Unit Substations Requirements*.

IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.

IEEE C57.12.01, *General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings*.

IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.

1\IEEE C57.12.34, *Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers, 10 MVA and Smaller; High-Voltage, 34.5 kV Nominal System Voltage and Below; Low-Voltage, 15 kV Nominal System Voltage and Below*. /**1**/

IEEE C57.12.50, *Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase, and 15 to 500 kVA Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 120-600 Volts*.

IEEE C57.12.51, *Ventilated Dry-Type Power Transformers, 501 kVA and larger, Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 208Y/120 to 4160 Volts*.

IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.

IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.

IEEE C57.12.91, *Test Code for Dry-Type Distribution and Power Transformers*.

IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.

IEEE C57.98, *Guide for Transformer Impulse Tests*.

IEEE C57.124, *Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers*.

IEEE 80, *IEEE Guide for Safety in AC Substation Grounding*.

\2\IEEE 1651, *IEEE Guide for Reducing Bird-related Outages.*

IEEE 1656, *IEEE Guide for Testing the Electrical, Mechanical, and Durability Performance of Wildlife Protective Devices on Overhead Power Distribution Systems Rated Up to 38 kilovolts.* /2/

NATIONAL ELECTRICAL MANUFACTURERS' ASSOCIATION

www.nema.org

NEMA C84.1, *Electric Power Systems and Equipment-Voltage Ratings (60 Hz)*.

NEMA WC 74, 5-*46 KV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*.

NEMA TC7, *Smooth-Wall Coilable Polyethylene Electrical Plastic Conduit*.

NETA MTS, *Maintenance Testing Specifications*.

NFPA NATIONAL FIRE PROTECTION ASSOCIATION

www.nfpa.org

NFPA 70, *National Electrical Code*.

NFPA 70B, *Electrical Equipment Maintenance*.

NFPA 70E, *Standard for Electrical Safety in the Workplace*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

3\ UFC 1-200-01, *DoD Building Code (General Building Requirements)*. /**3**/

UFC 3-260-01, *Airfield and Heliport Planning and Design*.

UFC 3-501-01, *Electrical Engineering*.

\1\/1/UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls*.

UFC 3-560-01, *O & M: Electrical Safety*.

UFC 3-570-01, *Cathodic Protection.*

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*.

UFC 3-600-01, *Fire Protection Engineering for Facilities*.

UFC 4-010-01, *DoD Minimum Anti-Terrorism Standards for Buildings*.

2\ UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*. /**2**/

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*.

UFC 4-211-01, *Aircraft Maintenance Hangars*.

UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*.

MISCELLANEOUS REFERENCES

ASTM D2447, Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter.

FAA Advisory Circular 150/5320-6, Airport Pavement Design and Evaluation.

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APPENDIX B DIRECTIONAL BORING

B-1 CONDUIT TYPE.

Provide smoothwall HDPE conduit, approved/listed for directional boring, approved/listed for electrical system installations, and minimum Schedule 80 meeting ASTM D2447/F2160/NEMA TC-7 (latest editions).

Note: Install HDPE conduit below freeze lines and in no case can the conduit be installed less than the minimum depths noted below.

B-1.1 Conduit Design – 1,000 Volts to 34,500 Volts.

Provide a minimum size HDPE conduit of 5 inches (130 mm) for distribution voltages greater than 1,000 V and less than 34.5 kV (nominal). Do not exceed 30 percent conduit fill.

Install HDPE conduit with a minimum ground cover of:

- 120 inches (3 m) in non-pavement-covered areas.
- 48 inches (1.2 m) in pavement-covered areas.

B-1.2 Conduit Design – Less Than 1,000 Volts.

Provide a minimum size HDPE conduit of 4 inches (100 mm) for distribution voltages less than 1,000 V. Do not exceed 35 percent conduit fill.

Install HDPE conduit with a minimum ground cover of 48 inches (1.2 m) in pavement- or non-pavement-covered areas.

B-1.3 Conduit Design – Branch Circuit Wiring Less Than 600 Volts.

Provide a minimum size HDPE conduit for branch circuit wiring less than 600 V that is determined by calculation, addressing, as a minimum, branch circuit conductor size, maximum allowable pulling tension, and maximum 5 percent voltage drop. Do not exceed 40 percent conduit fill.

Install HDPE conduit with a minimum ground cover of 24 inches (610 mm) min pavement- or non-pavement-covered areas.

B-2 INSTALLATION METHODS.

The use of specific conductor or insulation types for either high- or low-voltage installations is not mandated here. However, the combination of a chosen conductor and insulation type may not meet the requirements for the installation methods required in the following paragraphs where length, depth, and routing of the directional bore conduit may require an alternative conductor material and/or insulation type (i.e., maximum pulling tensions are different for aluminum and copper conductors).

B-2.1 Ampacity.

If the directional bored portion of the cable run is more than 25 percent of the total run length, evaluate and document the conductor derated ampacity in accordance with NFPA 70 Article 310.60 (C) (2).

B-2.2 Installation.

Water-jetting is not permitted. Use drilling fluids for DB methods that are approved by federal, state, and local codes and authorized for use by the BCE.

Pre-installed cable-in-conduit is not permitted. Install the conduit(s) immediately after the conduit hole is completed.

B-2.3 Allowable Pulling Tension.

B-2.3.1 Distance.

There is no restriction on DB distances provided the allowable pulling tension of the conduit and installed conductors are not exceeded, conductor splices are not within the conduit, and maximum ampacity of conductors due to depth derating is not exceeded.

B-2.3.2 Calculation Requirements.

A registered Professional Engineer (PE) must calculate pulling tension requirements for each directional bore, taking into consideration the HDPE conduit(s) size and type, bend radius, elevation changes, vertical and horizontal path deviations, installed electrical conductor size and type, and any conductor ampacity derating due to depth of HDPE conduit. The electrical contractor must provide certification of compliance with the PE's design requirements.

The professional engineering design process must include consideration of tensile forces and bend radii created during the installation so that allowable limits are not exceeded. Allowable tensile forces must be determined by a PE, including accounting for the conduit's allowable bend radius to prevent ovalization and kinking from installation. Do not exceed 5 percent ovalization of the conduit.

B-2.4 Termination into Equipment Pads.

Terminate HDPE conduits into concrete-pad-mounted electrical equipment from either a pavement or non-pavement transitional area as indicated in Figures B-1 through B-5. Route and terminate HDPE or rigid conduit within the concrete pad such that no conductor exiting the conduit is bent past the vertical plane formed with the equipment pad when routed to conductor terminations and with approved insulated bushings (Figure B-1).

Figure B-1 HDPE or Rigid Conduit Electrical Equipment Transition

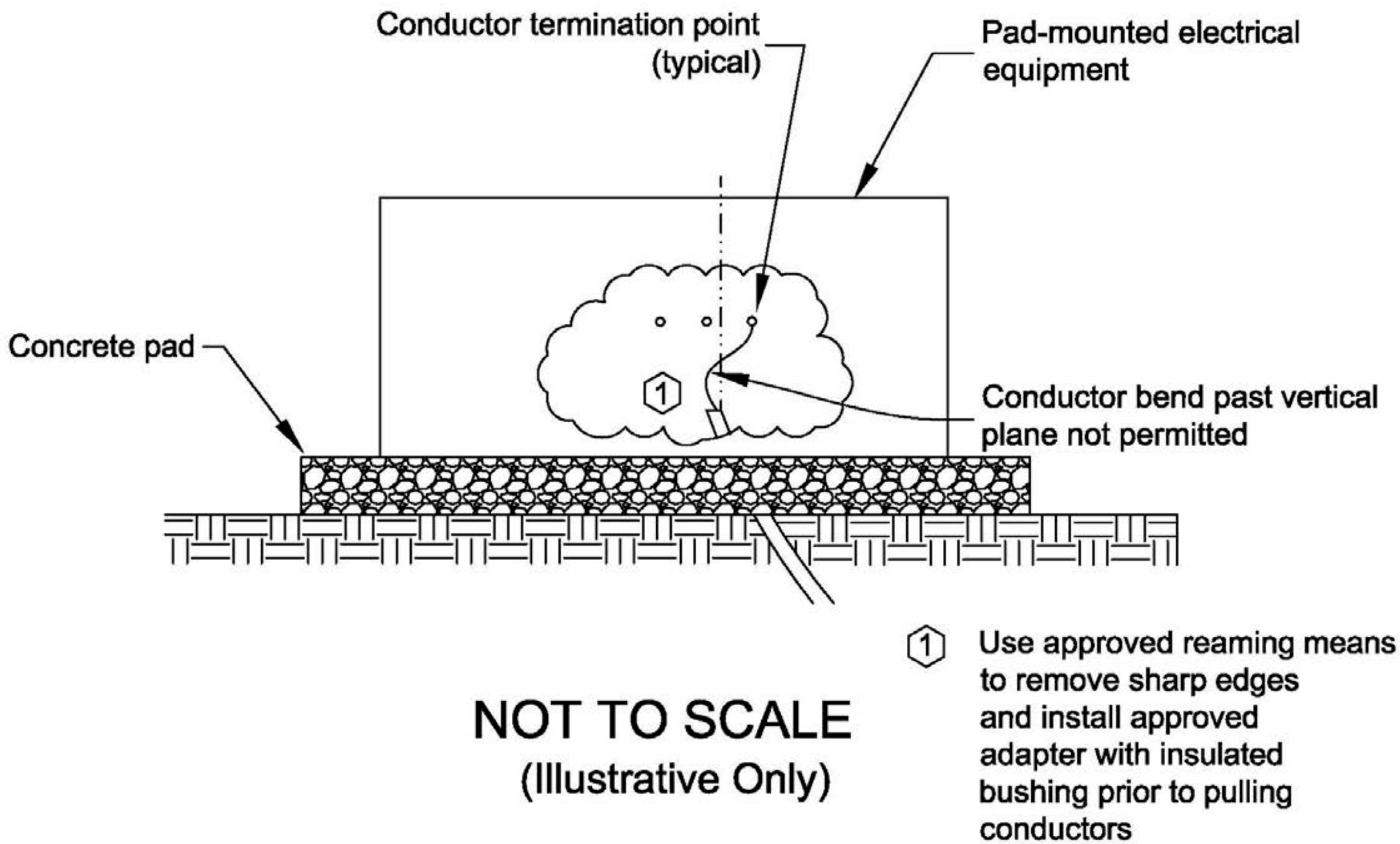


Figure B-2 Pavement Covered Area to Electrical Equipment Transition – Rigid Conduit (45˚–90˚)

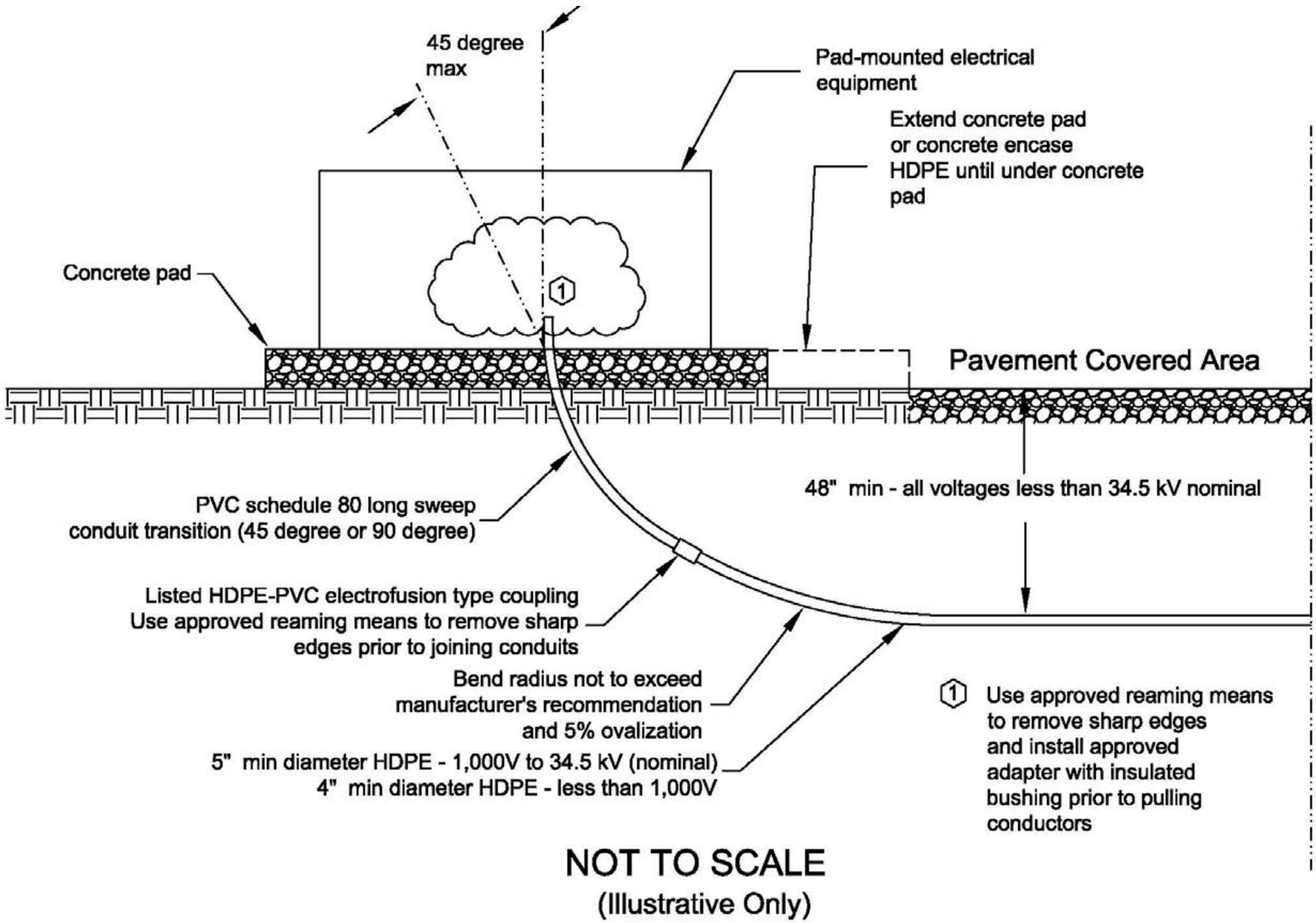


Figure B-3 Pavement Covered Area to Electrical Equipment Transition – HDPE Conduit (20˚–45˚)

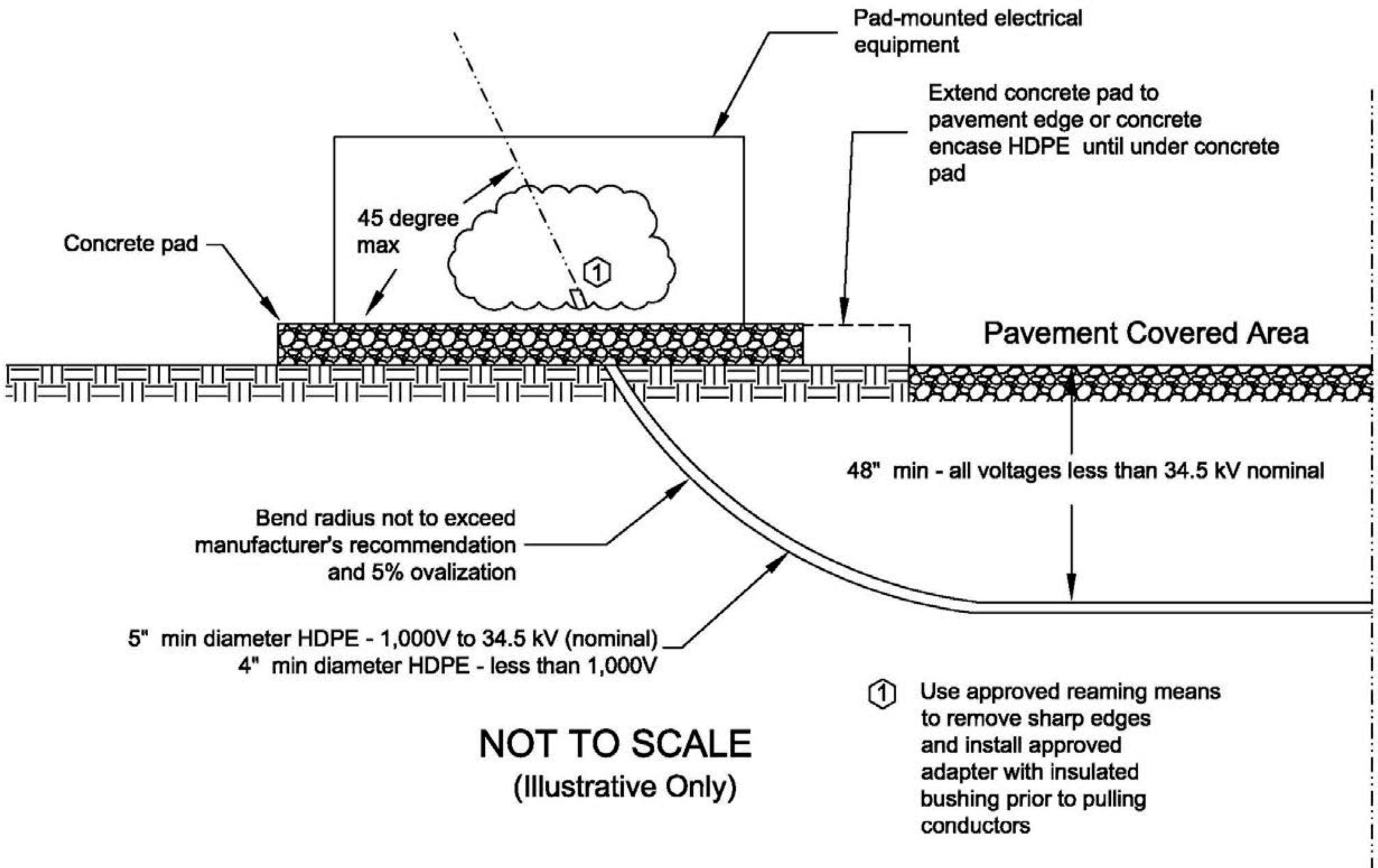


Figure B-4 Non-Pavement Covered Area to Electrical Equipment Transition – Rigid Conduit (45˚–90˚)

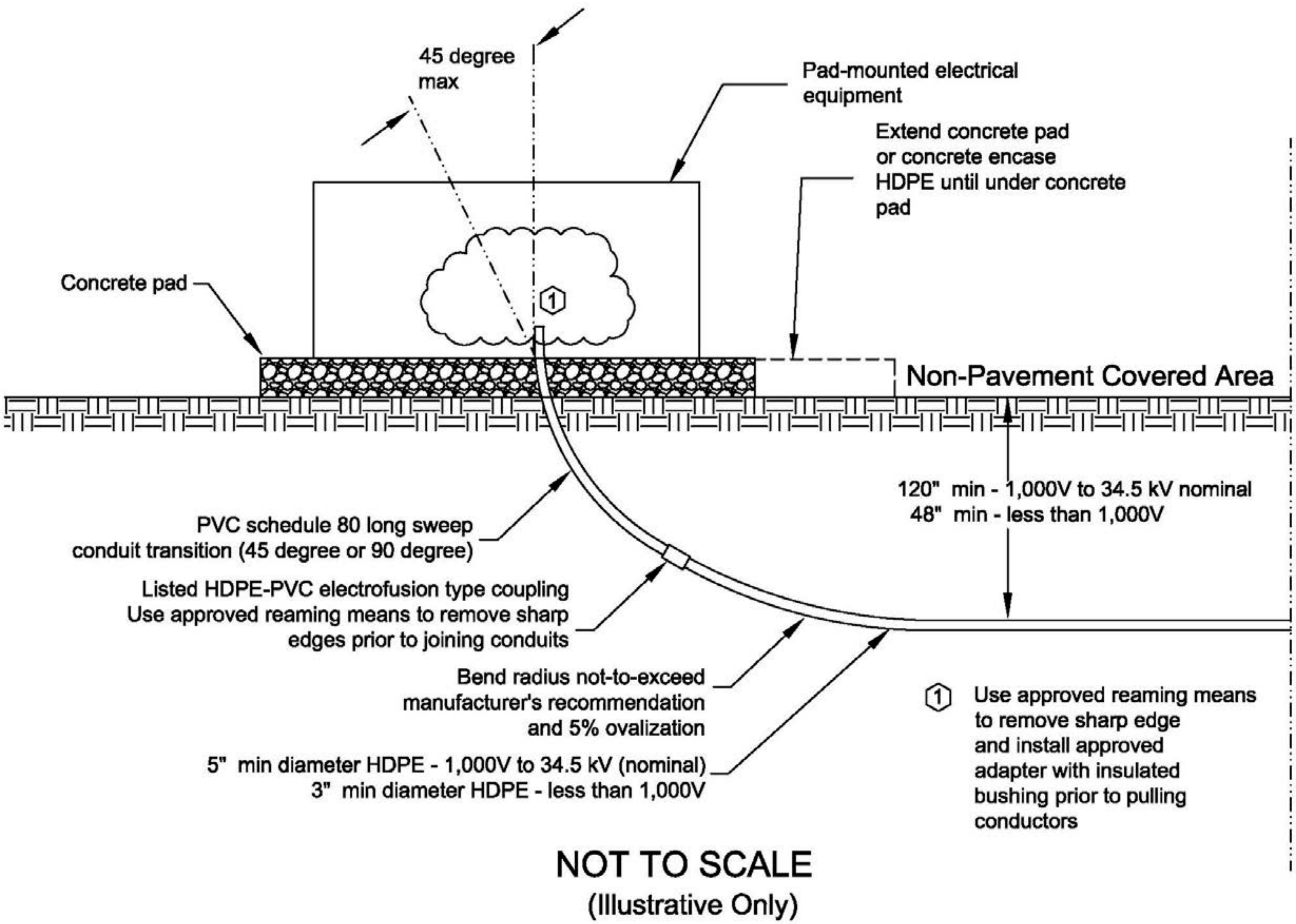
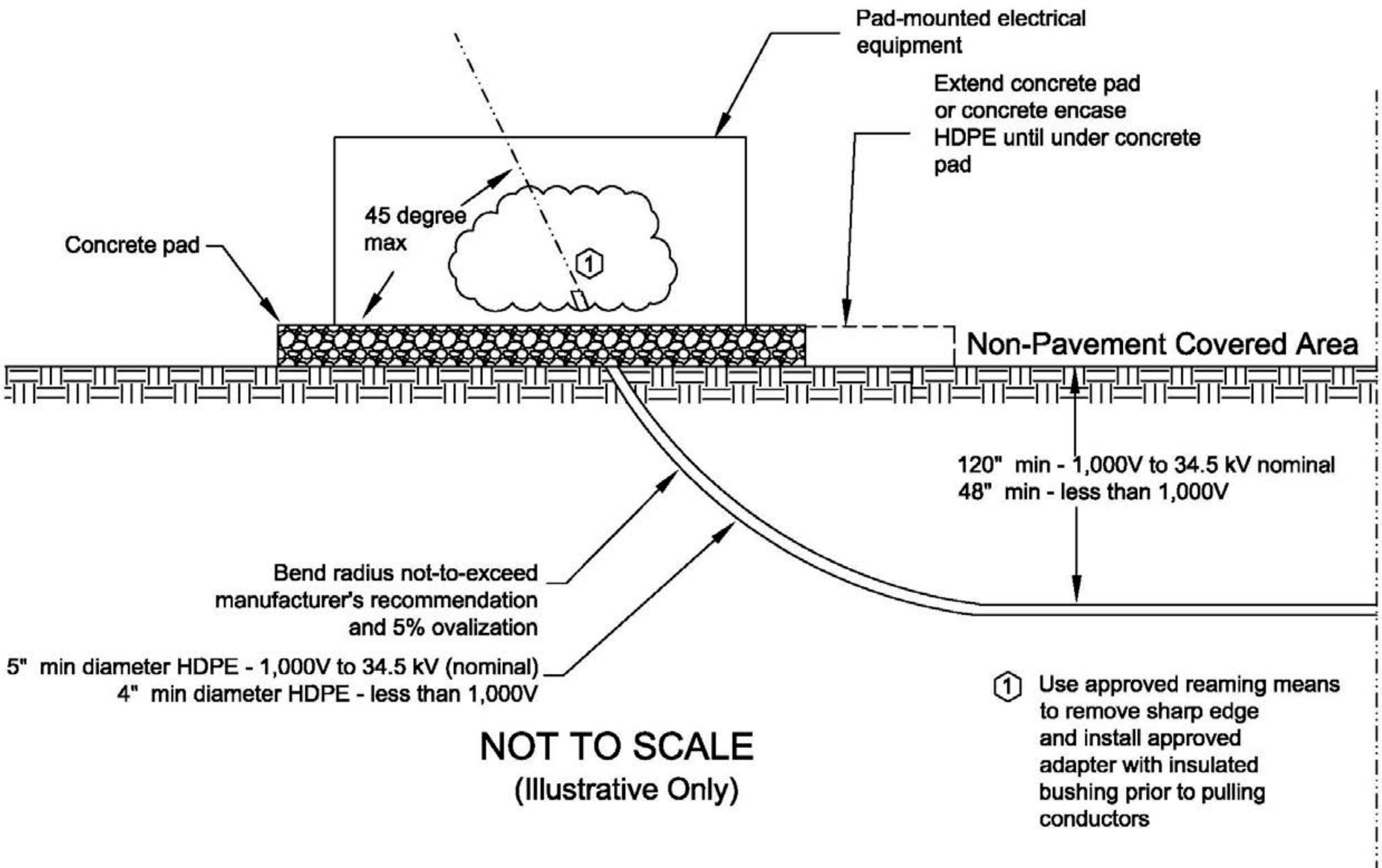


Figure B-5 Non-Pavement Covered Area to Electrical Equipment Transition – HDPE Conduit (20˚–45˚)



B-2.5 Multiple Conduits and Wiring Methods.

B-2.5.1 Installation.

Multiple HDPE conduits are permitted to be pulled through each bore. Designs requiring multiple conduits to accommodate parallel conductor installations must comply with NFPA 70 grounding and wiring methods requirements. As an example, one set of paralleled conductor requirements is illustrated in the following excerpt from NFPA 70, Article \2\310.10.(H)(2)/2/, which states:

> *"The paralleled conductors in each phase, polarity, neutral, \2\grounded circuit conductor, equipment grounding conductor, or equipment bonding jumper/2/ shall comply with all of the following:*
> *(1) Be the same length*
> *(2)\2\ Consist of/2/ the same conductor material*
> *(3) Be the same size in circular mil area*
> *(4) Have the same insulation type*
> *(5) Be terminated in the same manner*"

Thus, using DB methods to comply with (1) from the NFPA 70 excerpt, as well as other requirements, may not be possible, especially for long boring distances. NFPA 70 has other requirements for paralleled conductor installations that must also be considered when designing for these types of installations.

Note: Any deviations from NFPA 70 requirements must be approved by the AHJ.

B-2.5.2 Ampacity.

If the directional bored portion of the cable run is more than 25 percent of the total run length, evaluate and document the conductor derated ampacity in accordance with NFPA 70 Article 310.60 (C) (2).

B-2.6 Joining Methods.

Butt and electrofusion joining means are the only joining methods approved for HDPE conduit installations. Complete installations by persons certified in the process and in accordance with the manufacturer's procedures.

B-2.7 Transition from HDPE to PVC.

Make the transition from HDPE to PVC using only electrofusion coupling means with approved and listed materials. Perform coupling installation by persons certified on the equipment and process.

Complete coupling between HDPE and concrete-encased duct banks from pavement or non-pavement transitional areas as indicated in Figures B-6 and B-7. Perform the transition from HDPE to concrete manholes from pavement or non-pavement transitional areas as indicated in Figures B-8 and B-9.

Figure B-6 HDPE-to-PVC Pavement Covered Area Concrete Ductbank Transition

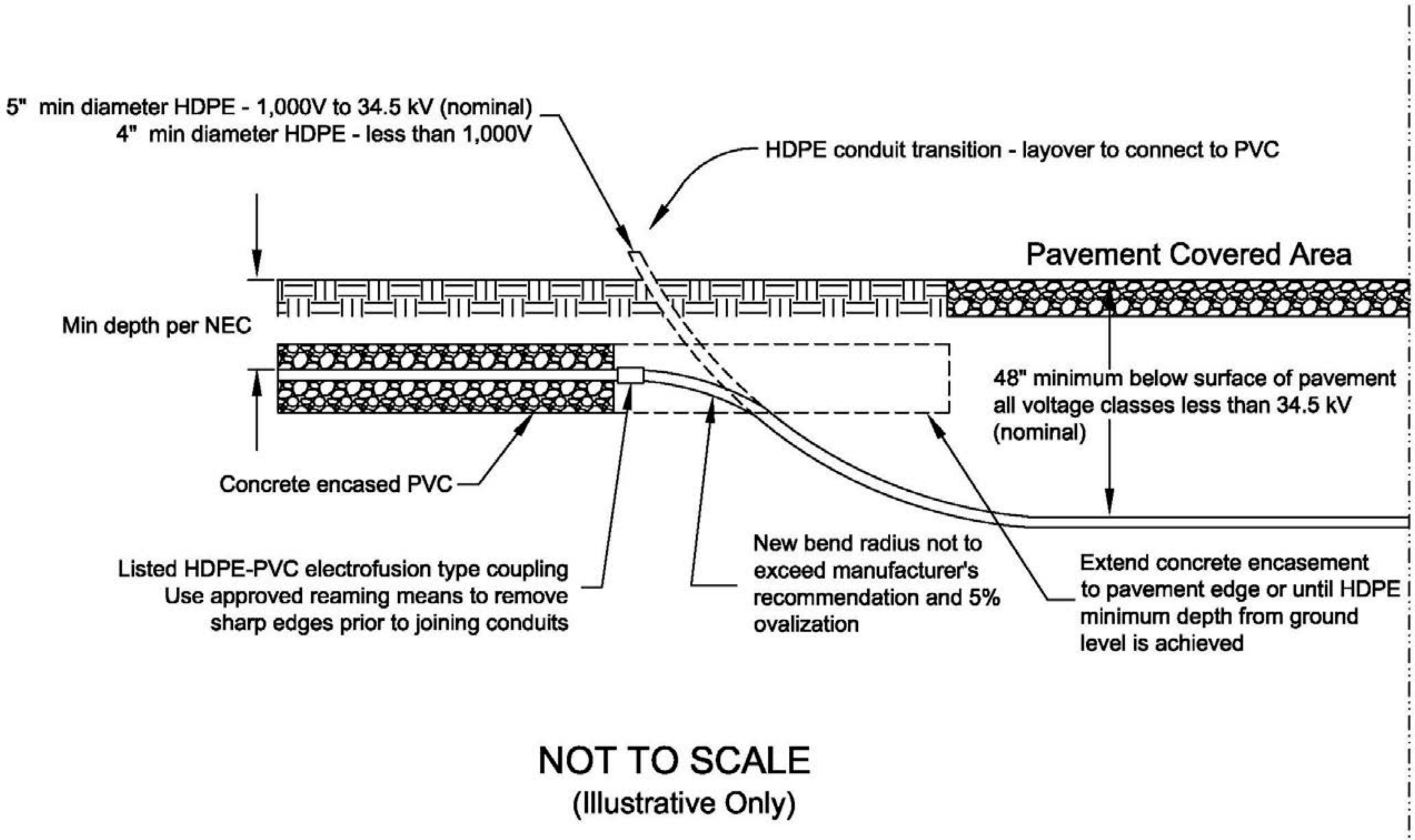


Figure B-7 HDPE-to-PVC Non-Pavement Covered Area Concrete Ductbank Transition

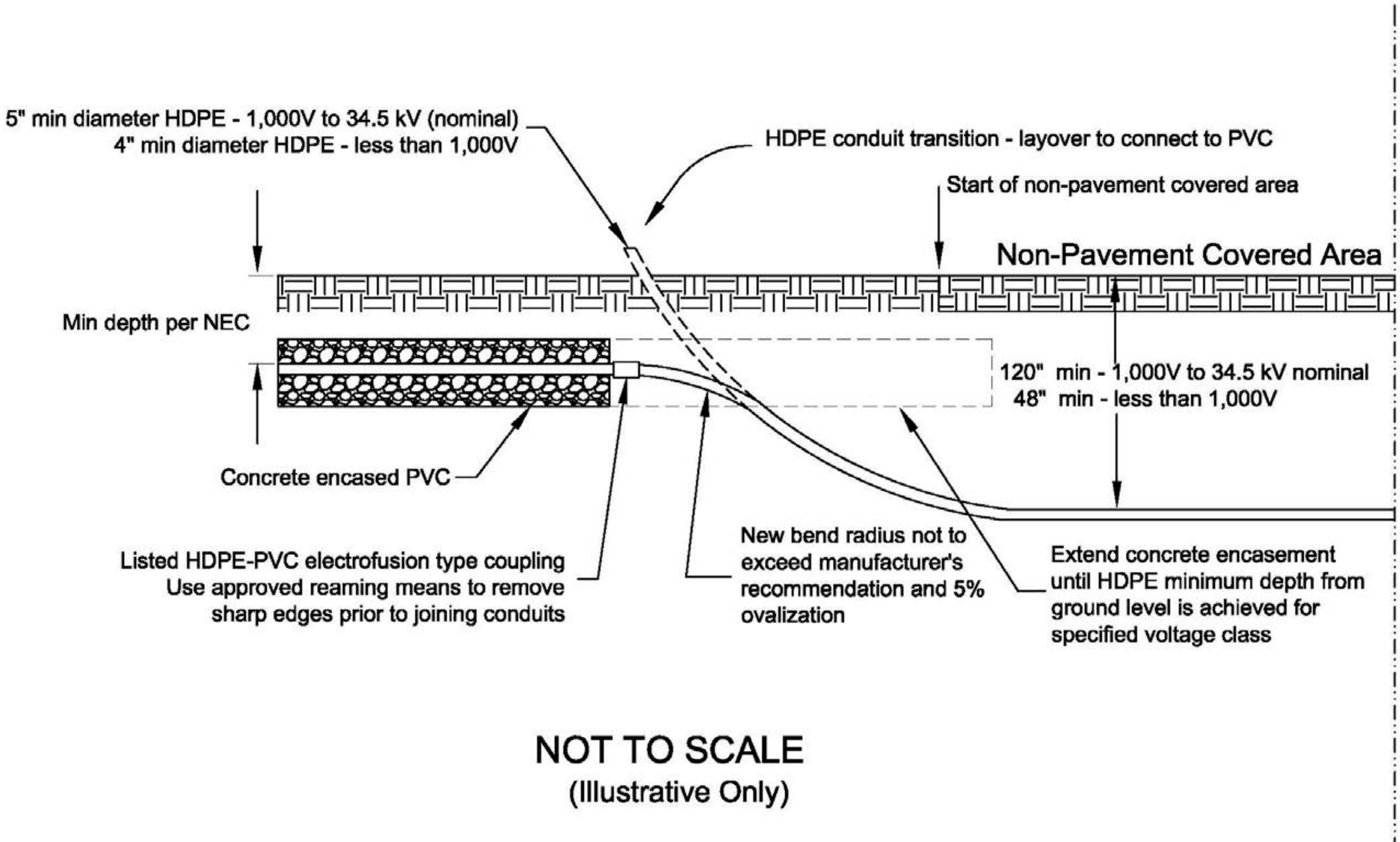


Figure B-8 HDPE-to-Manhole Pavement Covered Area Transition

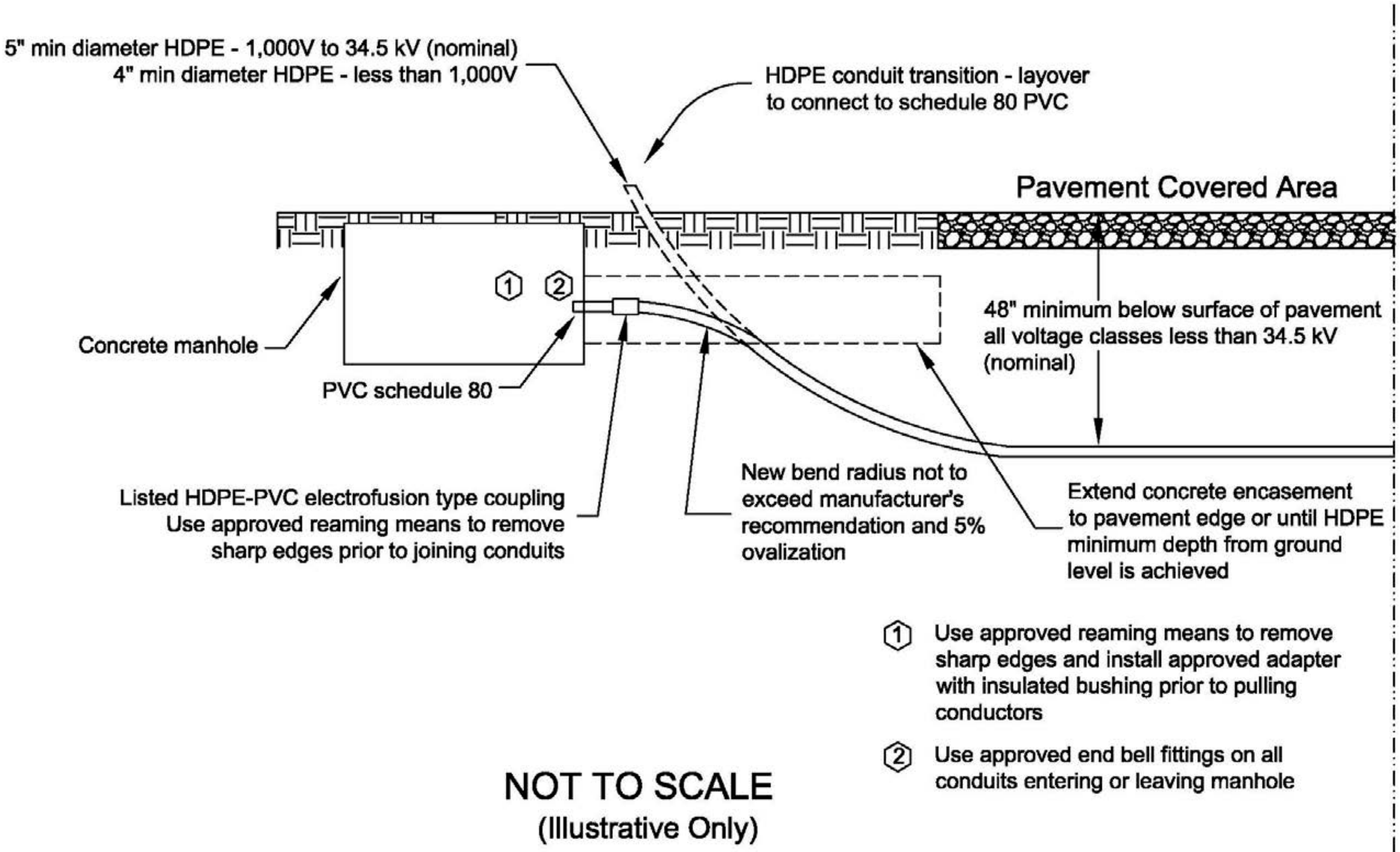
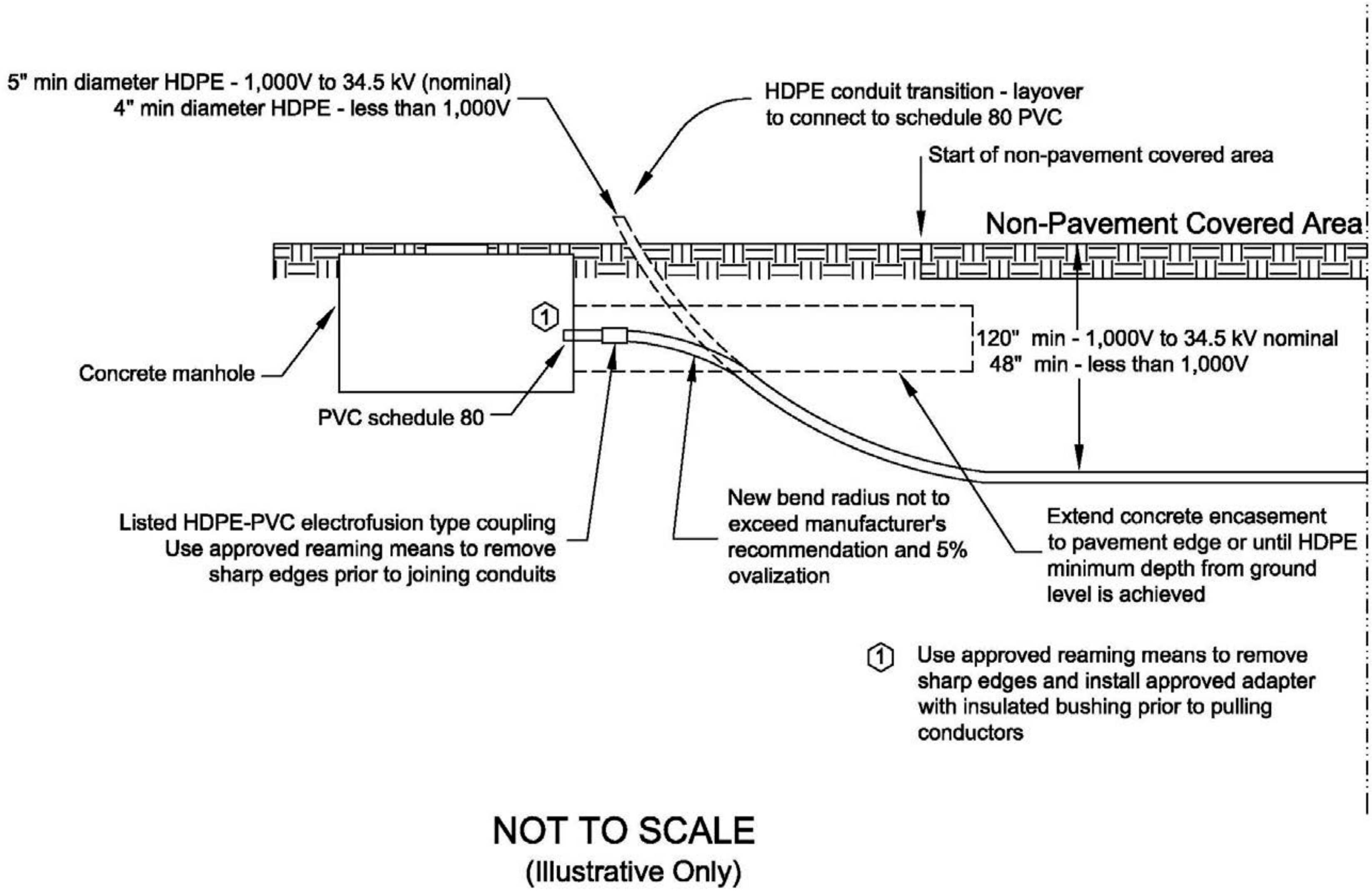


Figure B-9 HDPE-to-Manhole Pavement Covered Area Transition



B-3 DOCUMENTATION.

Record the location and depth of DB-installed HDPE electrical conduit on applicable as-built drawings. Use Global Positioning System (GPS) recording means with “resource grade” accuracy to record HDPE conduit bore path. Record GPS coordinates at intervals not to exceed 50 feet (15 m) along the bore path. Provide this information, along with the size of conduit, number of conductors, conductor size, and insulation type, to the appropriate base civil engineering office for incorporation into the GeoBase database.

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APPENDIX C BEST PRACTICES – GENERAL ELECTRICAL POWER REQUIREMENTS

C-1 EXTERIOR SYSTEM DESIGN.

Consider the following general criteria as part of any exterior electrical system design:

- Looped versus radial primary distribution. The alternate supply capability of a looped system for primary distribution system feeders can enable the system to continue operation even with a failed conductor. Evaluate design changes to the existing system to ensure that the potential impact of conductor failure is minimized.
- Cross-tie (alternate supply) capability. The ability to remove a feeder supply from service while ensuring continuity of power is essential for a reliable and maintainable design. Feeder cross-tie capability should be provided near the beginning of the feeder (to reduce voltage drop) and at key points downstream (to provide alternate supply capability for a portion of the feeder). Address cross-tie capability and how it is improved in the design analysis.
- Mission essential facilities. These facilities require additional consideration for the exterior electrical system design. Even if the facility is equipped with standby generation, minimize single points of failure in the exterior electrical system design. Provide redundant power supplies to the facility fed from different feeders, if multiple feeders are available.
- Communication. Determine communication requirements for the system, including SCADA, security, access, metering, and breaker control. Include security requirements as an input to the electrical system design criteria.
- Safety. Include electrical safety as a design consideration. Equipment selection, redundancy, installation approach, and how the equipment can be removed from service can all affect equipment and personnel safety.
- Reliability and maintenance. NFPA 70B, NETA MTS, and the manufacturers' documents provide periodic maintenance criteria applicable to exterior electrical equipment. Consider maintenance requirements in the specification of equipment and in the installation design of the equipment. As an example, a single manhole located near a substation should not contain the cables for all base feeders; in this example, the design should install multiple manholes with fewer distribution feeders located inside each manhole.

C-2 METERING.

Coordinate metering, system design, protection, electrical coordination, load requirements, and short circuit limitations with the local utility. If the supply station/substation is owned by the utility, obtain sufficient design information for the utility-owned equipment to help establish design requirements for downstream equipment.

Coordinate revenue metering requirements with the local utility. Provide a government-owned revenue meter for the supply station/substation even when the local utility meters the incoming supply.

C-3 DEMARCATION.

Clearly define the point of demarcation between the utility-owned system and the government owned equipment. Define ownership for the incoming utility supply lines if there are any shared equipment, such as overhead distribution with utility and government-owned lines sharing the same power poles.

C-4 SUBSTATIONS AND SWITCHING STATIONS.

Use or modify existing substations unless a new substation is required for capacity or unique requirements. Aging substations will often require complete replacement.

Design a main electric supply station/substation for reliability of service and maintenance. Address the following in the design analysis for the supply station/substation:

- Formal design. Substations require a formal design. Address the structure and foundation design, lightning protection, manholes and vaults, grounding, lighting, protective relaying, and the other electrical items listed below.
- Dual substation transformers. Coordinate with the utility to provide separate utility feeders, if available. The transformers should be sized so that either transformer and incoming supply line can carry the entire substation peak demand, including load increase projections for the next 10 years.
- Voltage regulation. Either transformer load-tap changing (LTC) transformers or separate voltage regulators are acceptable. Separate voltage regulators, wherever installed, must be provided with bypass and disconnect switches.
- Circuit breaker or circuit switcher on each substation transformer primary side for local isolation of the incoming supply. For substations with overhead bus structure, include a load-break or non-load break switch as an additional isolation device.
- Circuit breaker on each substation transformer secondary side. This is typically the main breaker to the substation switchgear. For substations with overhead bus structure, include a load-break or non-load break switch as an additional isolation device.

- Separate switchgear for each transformer with cross-tie capability between switchgear. Provide spare breakers and evaluate the need for additional distribution system feeders.
- Electronic protective relays to allow circuit protection, monitoring, and event recording.
- Station class surge arresters.
- SCADA controls. If remote SCADA control is included, provide dedicated fiber-optic lines between the facility and the desired control location. Obtain approval from the AHJ for communication systems that enable remote access.
- Connections between the transformer secondary and the main circuit breaker. Preferred connection methods include cables in conduit or cable trays. Busway transitions are discouraged, but if they are used, it must be labeled for the application by Underwriter’s Laboratories, or equivalent; designed for outdoor service, including a stainless steel housing and hardware for corrosion control; rated and braced for the maximum expected continuous current and short circuit current; designed to control condensation and its effects; and designed to allow access for periodic inspection following the NETA MTS guidance.

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APPENDIX D GLOSSARY

D-1 ACRONYMS

AC	Alternating Current
ACSR	Aluminum Conductor Steel-Reinforced
ACSS	Aluminum Conductor Steel Supported
A/E	Architect/Engineer
AFCEC	Air Force Civil Engineer Center
AHJ	Authority Having Jurisdiction
AL	Aluminum
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
UFC	Unified Facilities Criteria
BCE	Base Civil Engineer
BIL	Basic Insulation Level
CT	Current Transformer
CU	Copper
DB	Directional Boring
DDC	Direct Digital Control
DIA	Diameter
DoD	Department of Defense
EMCS	Energy Management and Control System
3\\ ESC	Environmental Severity Classification /**3**/
ESS	Electric Supply Station
Degrees F	Degrees Fahrenheit
fc	Footcandles

ft	Feet (or Foot)
ft^2	Foot Squared
GPS	Global Positioning System
HDPE	High Density Polyethylene Electrical
HQUSACE	Headquarters, US Army Corps of Engineers
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
Hz	Hertz
IEEE	formerly Institute of Electrical and Electronic Engineers
in	Inch
kcmil	Thousand circular mils
kg	Kilograms
kV	Kilovolts
kVA	Kilo-Volt-Ampere
kVAR	Kilo-Volt-Ampere-Reactive
kW	Kilowatts
lb	Pound
LTC	Load-Tap Changing
m	Meter
m^2	Meter Squared
Max	Maximum
Min	Minimum
mm	Millimeter
MPa	Mega-Pascals
MTS	Maintenance Testing Specifications

MVA	Mega-Volt-Ampere
NAVFAC	Naval Facilities Engineering Command
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
OH	Overhead
O&M	Operation and Maintenance
PE	Professional Engineer
psi	Pounds per square inch
PILC	Paper Insulated Lead Covered
PPE	Personal Protective Clothing
PT	Potential Transformer
PVC	Polyvinyl Chloride
RFP	Request for Proposal
SCADA	System Control and Data Acquisition
SF6	Sodium Hexafluoride
TSEWG	Tri-Service Electrical Working Group
UESS	Utilization Electric Supply Station
UL	Underwriters Laboratories
UFC	Unified Facilities Criteria
V	Volt
VA	Volt-Amp
VFI	Vacuum Fault Interrupter
W	Watt

W/ft^2	Watts per Foot Squared
W/m^2	Watts per Meter Squared

D-2 DEFINITION OF TERMS

Activity: With respect to this UFC, approval is provided by the following:

- For the Air Force, this is the Base Civil Engineer.
- For the Navy, this is the Public Works Officer.
- For the Army, this is the Installation Director of Public Works.

Contractor: Person(s) doing actual construction portion of a project.

Corrosive Area: An area identified by the Technical Reviewing Authority as requiring special equipment corrosion mitigation methods. **3**\ Corrosive areas include locations with an Environmental Severity Classification (ESC) of C3, C4, and C5. See UFC 1-200-01 for determination of ESC for project locations. /**3**/

Designer of Record: The engineer responsible for the actual preparation of the construction documents.

Main Electric Supply Station: A main electric supply station is also referred to as a “switching station” and does not have power transformers to transform from the utility transmission voltage to a lower distribution voltage. The main electric supply station is the installation/utility interface point where further transmission, distribution and utilization of electrical power, the monitoring and control of such power or equipment and the protection of electrical equipment or systems usually becomes the sole responsibility of the Government or their contracted representatives.

Main Electric Supply Substation: A main electric supply station that also transforms the energy level (voltage) for further bulk distribution at medium voltage levels. A main electric supply substation includes power (substation) transformers.

Facility Core Distribution Infrastructure: System components that constitute a part of the base infrastructure system that are required to provide electrical service to multiple users.

Low Voltage System: An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage System: An electrical system having a maximum RMS ac voltage of 1,000 volts to 34.5 kV. Some documents such as NEMA C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Primary Distribution: A system of alternating-current distribution for supplying the primary of distribution transformers from the generating station or substation distribution buses. Primary distribution can be supplied either overhead or underground and includes all associated equipment.

Project Manager: Engineer charged with the administration of the project.

Secondary Distribution: An alternating-current system that connects the secondaries of distribution transformers to the consumers' services. A secondary distribution is typically operating at low voltage, but could be operating at medium voltage.

Service: The conductors and equipment for delivering electrical energy from the serving utility or Government-owned system to the wiring system of the premises served.

Site Electrical Utilities: Site Electrical Utilities are the primary electric power distribution to the facilities and other electrical loads, all exterior lighting not attached to the building; and all telecommunication services (fiber optic, copper cable, CATV, etc.) required by the Facilities.

Switching Station: refer to Main Electric Supply Station.

Utilization Electric Supply Station: Equipment such as pole or pad-mounted transformers or secondary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use.

UNIFIED FACILITIES CRITERIA (UFC)

RESILIENT INSTALLATION MICROGRID DESIGN

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UNIFIED FACILITIES CRITERIA (UFC)

RESILIENT INSTALLATION MICROGRID DESIGN

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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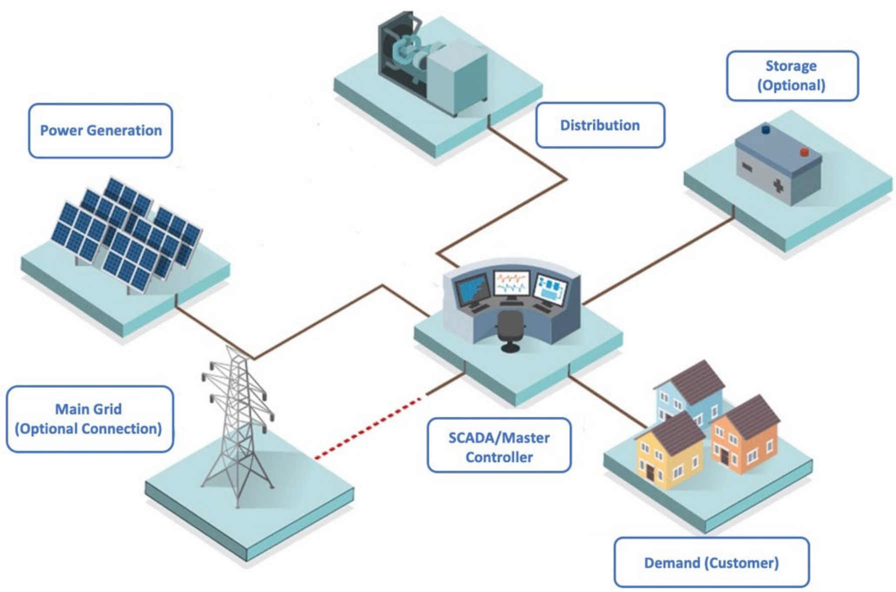
CHAPTER 1 INTRODUCTION

1-1 GENERAL.

The primary objective of networked standby power systems (e.g., microgrids) is to deliver resilient, ride-through power to installation operations during extended contingencies resulting from commercial service failure, natural disaster, or cyber-attack. Microgrid systems deliver contingency power to loads inside a facility, a facility cluster, several facilities on a feeder(s), across a substation(s), or an entire installation campus. Islanded operation is a fundamental characteristic of all microgrid designs governed by this document. A microgrid's primary benefit is its ability, as a bounded system, to disconnect from the commercial grid during an emergency and deliver resilient, ride-through power with optimized off-grid endurance. Figure 1-1 shows components of a microgrid.

Figure 1-1 Components of a Microgrid

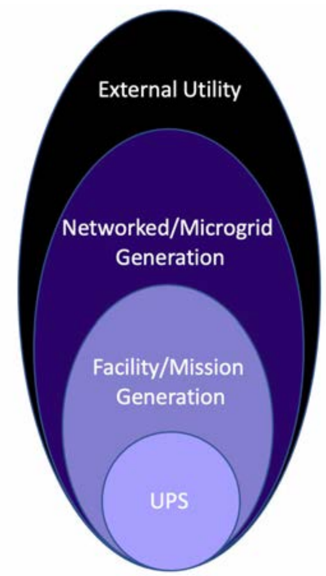


1-2 BACKGROUND.

Facility-dedicated backup power architectures represent DoD's de-facto approach to backing up mission loads during commercial power outages, in accordance with UFC 3-540-01. This approach has several noteworthy advantages: relative simplicity of operation (mission-dedicated generation supports specific mission loads), clear demarcation of real property ownership, and limited ambiguity of sustainment cost share (a tenant or mission owner generally maintains that facility's backup generator). However, such load-dedicated standby power solutions can be ill-suited to carry critical operations over extended periods of time (each load is completely dependent on its mated facility generator, and increasing redundancy at each load requires additional infrastructure at each load). Further, such solutions offer limited ability to interconnect and leverage large renewable energy systems (or exploit their sustainability and economic benefit), as modestly sized facility generators may be subject to extremely high ramp rates, load-following conditions, and power quality variability when networked with large renewable systems. Finally, cyber-securing each of the IP-addressable assets and controllers in a facility dedicated standby environment is generally costlier and laborious than securing a single, large, centralized utility monitoring and control system.

Microgrids and networked standby power systems deliver a complementary solution supporting a layered framework for contingency power (see Figure 1-2). Using this approach, each layer of contingency power relieves the power system in the layer below. Accordingly, when the microgrid is active, mission-dedicated assets are relieved by the network, allowing the installation to maintain a more unified and resilient standby power posture.

Figure 1-2 Layered Approach to Contingency Power



Multi-Layered Approach to Contingency Power

1-3 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) provides criteria on installation microgrid design requirements, performance metrics to inform design, sequence of operations, commissioning and validation, and sustainment. Design tenets and criteria contained herein are intended to ensure resilient, robust, and standardized solutions based on performance-based criteria and best design practices.

1-4 APPLICABILITY.

This UFC is applicable to all networked “islandable” standby power systems (systems capable of isolating and operating independently from the external grid). Compliance with this UFC is mandatory for the planning, design, construction, and commissioning of networked standby power systems, including microgrids for facilities and installations, regardless of funding source. This UFC also applies to overseas facilities, considering mission objectives and Host Nation standards, to the greatest extent practicable. This criteria addresses both prime and continuous power application under islanded and grid-connected conditions of operation. This guidance does not forego adherence to prevailing guidance for stationery engine-drive power systems as stated in UFC 3-540-01. Whenever unique conditions and problems are not specifically addressed by this UFC, use the applicable referenced industry standards and other documents for design guidance.

Per DoD Instruction 4270.5, the design criteria of this UFC does not apply to privatized housing or to projects acquired through a real property exchange agreement. This guidance is not applicable or intended to address mobility power system or mobile generation solutions. This UFC is not applicable to individual facility or load-dedicated standby power systems.

1-5 MICROGRID POINTS OF CONTACT BY SERVICE.

For any DoD project involving networked standby power or microgrid design, the relevant agency for each service must be contacted as soon as possible. Information, design support, system modeling, and other assistance is available from the following organizations:

- **Army**: US Army Corps of Engineers (USACE)
- **Navy and Marine Corps**: Naval Facilities Engineering Systems Command (NAVFAC), HQ NAVFAC Utilities, Washington Navy Yard
- **Air Force and Space Force**: Air Force Civil Engineer Center (AFCEC), Operations Director, Tyndall AFB

1-6 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-7 ENERGY RESILIENCE.

All energy systems must be planned, designed, acquired, constructed, and maintained in accordance with Title 10, U.S.C., Section 2911(a), DoD Instruction 4170.11, and as required by individual Service and Defense Agency policies on energy resilience.

Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond and recover rapidly from high-impact, low-probability disruptions (including events resulting from climate change) impacting mission readiness per DoDD 4715.21. It is determined by the ability of a system to anticipate, resist, absorb, respond, adapt, and recover from disturbances such as natural disasters, terrorism, cyber-attack, or other significant and adverse impacts.

1-8 OWNERSHIP AND SUSTAINMENT.

To determine if a microgrid is a viable and sustainable solution, mission and public works personnel should review the installation master plan, energy plan, existing resilience posture, and commercial utility historical service performance including System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) metrics per IEEE 1366 (an example of these metrics is given in Table D-1). Microgrids should be evaluated against alternative resilience enhancement solutions that reduce reliance on external commercial systems, improve resilience score, operational based readiness, and minimize lifecycle sustainment cost. When evaluating resilience enhancement options, refer to official policy and guidance provided by the appropriate military service.

Since microgrids primarily address resilience and mission assurance metrics, mission and public works personnel need to be consulted to determine 1) if a microgrid is an appropriate approach to advance these metrics, 2) ownership of the microgrid, 3) and capacity to operate and sustain a dedicated microgrid system. Real property and cybersecurity ownership, appropriate accreditation authority, and cyber-sustainment strategy must be identified.

1-9 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy. All information systems connected to, or with software loaded onto, DoD information grids must receive an interim or full authorization to operate/test prior to connection in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

1-10 TOPOLOGY.

Microgrids are generally classified with respect to their sources and architecture. All installation microgrids are composed of energy sources, loads, one or more points of common coupling (PCCs), electrical distribution, switchgear, and secure controls (Figure 1-1). Specific microgrid topology is based on a distributed or central-plant architecture. Distributed microgrid architectures are composed of geographically disparate distributed energy resources (DERs) networked across the distribution system using secure controls and communications. Alternatively, central plant-based microgrids include co-located, generally large DER (for example, reciprocating internal combustion engines) to deliver power to the load, but generally with greater reliance on the distribution system. Regardless of architecture, type of DER, or configuration, all interconnected DER assets are subject to anti-islanding, mandatory minimum voltage ride-through, and under/over-voltage trip time safety requirements per IEEE 1547.8 when the microgrid is connected to the external grid. Inverter-based DER may only interconnect to the islanded microgrid once the inverter has detected that the distribution has been energized by dispatchable (firm) DER (as listed under the Predictable Electrical Output column in Table 1-1).

1-10.1 Distributed Systems.

Distributed systems network discrete sources located throughout the microgrid boundary. Sources can be a combination of existing sources such as facility-level DERs or new microgrid-dedicated DERs. Distributed control points, switchgear, fiber network infrastructure, and the human machine interface (HMI) are the backbone of a distributed control system. While more communications intensive, distributed generation solutions offer the advantage of leveraging existing capital asset investments at many installations. See service-specific informing references in APPENDIX I.

The building block of a distributed energy microgrid's functionality is the facility generator's switchgear, which is generally sited near facilities with emergency generators (Figure 1-3). The microgrid architecture incorporates dedicated paralleling switchgear, breaker protection, and updated device protection settings to allow facility-level DERs to parallel and energize an islanded distribution feeder.

Figure 1-3 Distributed Generation Architecture

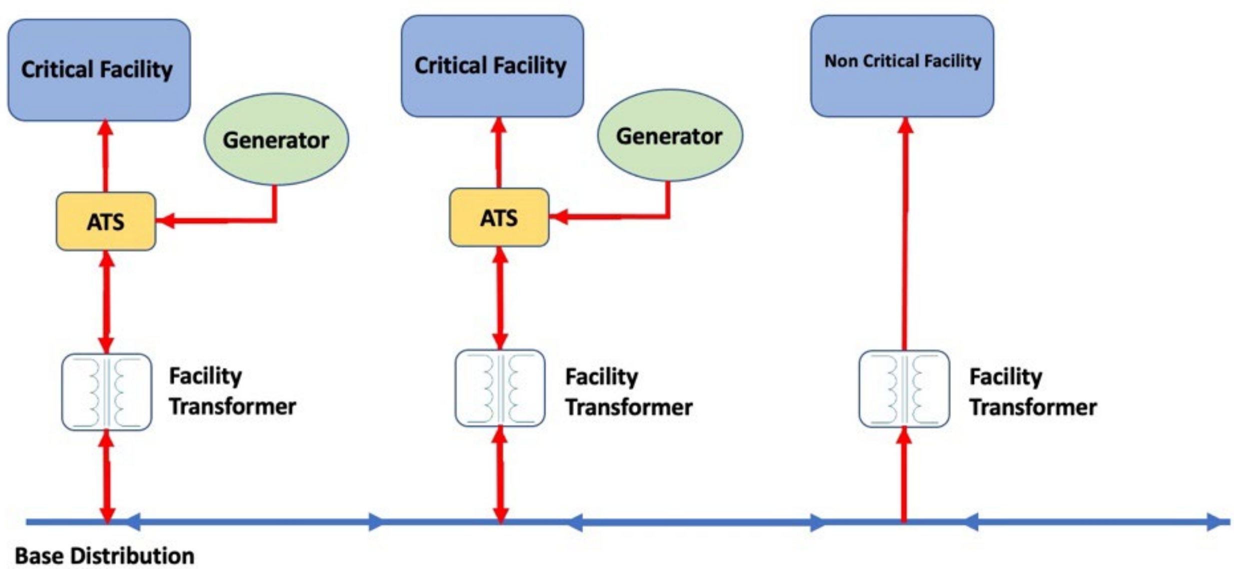
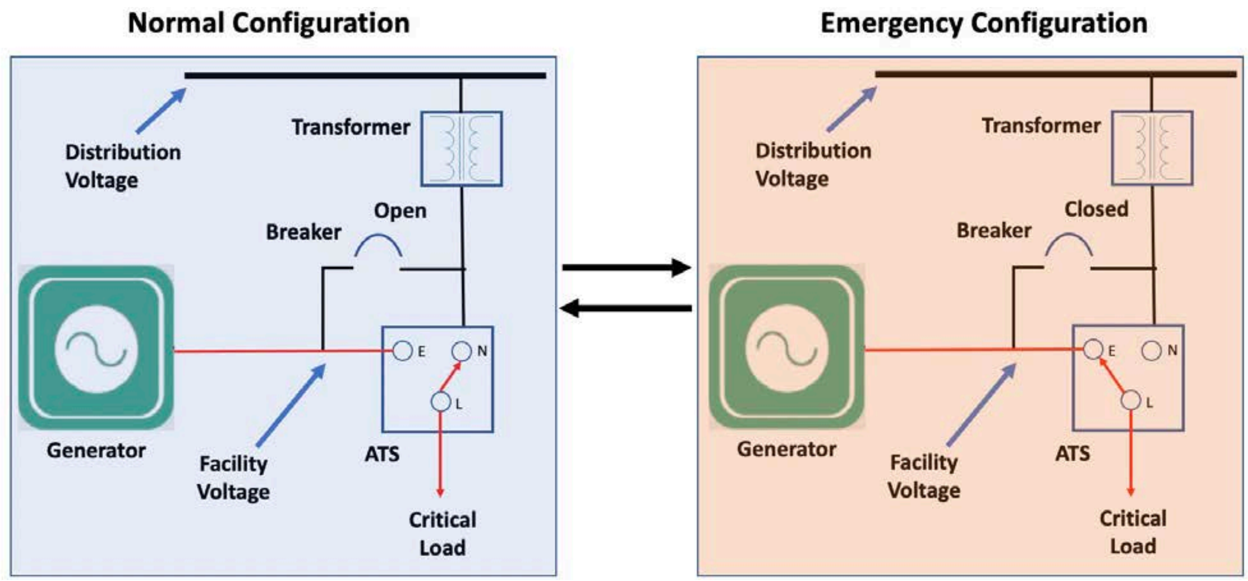


Figure 1-4 shows normal and emergency switchgear configurations across the ATS allowing increased functionality, beyond simply isolating a given facility and its generator from the distribution system. The emergency configuration is used to network each standby generator inside the microgrid boundary to a common bus using existing galvanic isolating devices. The bus is energized by the distributed generator fleet (much like discrete power plants supporting a utility's commercial transmission system, albeit at smaller scale).

Figure 1-4 Normal and Emergency Switchgear Configuration Across ATS



As soon as external grid power is lost, facility-level DERs come online. Many of these facility-level DERs are standard emergency generators associated with specific loads.

The DERs operate autonomously per UFC 3-501-01 (Electrical Engineering) and UFC 3-550-01 (Exterior Electrical Power Distribution), and tend to be out of phase with each other. When the interconnection point is opened and the installation is disconnected from the external grid, the DERs must first synchronize before forming a microgrid. DERs must operate "in phase" as they are connected (this is also true of the renewable resources that are subsequently networked to the microgrid). A reference frequency is selected from the DERs and the remaining DERs synchronize to this reference. The synchronization process repeats when the external grid is restored and the microgrid prepares to reconnect at the PCC. In this case, however, the microgrid DERs (in unison) use the external grid frequency as the reference when synchronizing to the utility.

An important benefit to this approach is that it leverages DoD's existing fleet of fuel-based generation. Infrastructure already specified in current design guidance can be applied to support a distributed microgrid, with paralleling switchgear and modification in engine governor controls. Since many facility-level DERs require dedicated paralleling gear and updated protection settings, it is advisable and prudent to network larger DERs with significant remaining service life and appropriate generator and emissions certification (for example, larger than 250kW, prime/continuous rated Tier 4).

1-10.2 Central Plant Systems.

Central-plant based systems employ a central generating plant, often including RICE units, combined heat and power, co-generation, or other configurations, with co-located DER (e.g., turbines, reciprocating engine, gas-fired, fuel-fired, or fuel oil-fired generators). While generally more dependent on distribution system, these solutions are typically more efficient when backing up large base loads. Additionally, central plant systems can typically tolerate greater contributions and variability of renewable energy generation without energy storage.

1-10.3 Fuel-Based, Dispatchable (Firm) Generation.

These are assets that deliver “firm” dispatchable power and include turbines, diesel, propane, or natural gas generators. Fuel and gas-based generation (including facility-dedicated standby systems) are dispatchable. These systems are typically capable of black start, grid-forming operation, and load following.

These systems are frequently sited on DoD installations with automatic transfer or automatic distribution switches (to support dedicated standby operation following loss of service) and are capable of operation without an energized distribution system or microgrid signal. These assets are generally capable of black start operation (when the distribution bus is not energized) and can be networked within an islanded distribution grid (sometimes requiring engine governor modification). These DERs can be permitted for standby, prime, or continuous application (emergency operation, unlimited hours at variable load, or unlimited hours at a constant load, respectively).

1-10.4 Inverter-Based Generation.

Contributions from inverter-based and renewable DERs may defer fuel resources and extend off-grid operational endurance in an extended emergency. The electrical output of these DERs is delivered in direct current (DC), requiring one or more inverters to interface with installation distribution. Because these systems rely on differing inverters at their output, their degree of visibility, controllability, and flexibility to support the microgrid design intent can vary significantly. Inverter based generation is subject to UL 1741 per UFC 3-540-08. Additional tolerance (capacity) factors should be included when generation is intermittent or non-dispatchable.

Higher interconnection of inverter-based assets on small microgrids can often necessitate increased firm, dispatchable generation with reserve capacity to manage source intermittency, islanded load variability, non-linear loads, inductive and motor start loads, and other high-VAR load requirements.

1-11 ENERGY RESOURCE CLASSIFICATION GUIDE.

Table 1-1 provides DER attributes and common applications to inform design. For clarity, the table column categories are explained below:

- Primary power: the primary energy resource, used to reliably meet largest portion of load – can be replaced with utility
- Base load power: the ability to provide base load power is highly variable, depending on the size of loads served
- Load following: the DER follows the load and can adjust power output to amount of power needed
- Power quality correcting: also referred to as improve power quality
- Inverter based system: systems may include inverters that convert power from DC to AC
- Predictable electrical output: may also be referred to as firm or availability of power when needed
- Grid forming DER now includes all DERs listed under Predictable Electrical Output column of Table 1-1

1-12 PROGRAMMING.

Primary Category Codes for microgrid resilience and backup power projects include 81109, 81110, 81160, etc. Revisions to this UFC will include additional category codes for networked standby power projects.

1-13 GLOSSARY.

APPENDIX G contains acronyms, abbreviations, and terms.

1-14 REFERENCES.

APPENDIX H contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

Table 1-1 DER Attributes

	Climate Change	Predictable Electrical Output	Inverter Based System	Standby Power	Black Start (Dispatchable)	Primary Power	Base Load Power	Load Following	Power Quality Correcting
Turbine or Engine-Driven (Low Speed)	⊘	✓	⊘	✓	✓	✓	✓	⊘	△
Engine-Driven and RICE (High Speed)	⊘	✓	⊘	✓	✓	✓	✓	✓	△
Facility Level, Stand-alone Engine-drive[8]	⊘	✓	⊘	✓	✓	△ [5]	△	✓	△
(Natural) Gas-Fired	✓	✓	⊘	✓	✓	✓	✓	△ [4]	△
PV	✓	⊘	✓	△ [1]	⊘ [1]	△ [1]	△ [1]	⊘	△
Wind Turbine	✓	⊘	⊘	△ [2]	⊘	△ [2]	△ [2]	⊘	△
Fuel Cell (High Temp)	✓	✓	✓	✓	△ [3]	⊘ [7]	✓	⊘	△
Fuel Cell (Low Temp)	✓	△	✓	△	△ [3]	⊘ [7]	△ [3]	⊘	△
BESS/UPS	✓	✓	✓	✓ [6]	△ [3]	⊘ [7]	△ [3]	✓	✓
Flywheel (FESS)	✓	✓	⊘	✓ [6]	△ [3]	⊘ [7]	⊘	✓	✓
Symbol Key		✓ = Yes, ideal △ = Possible, with caution ⊘ = No							
Caution Notes December 28, 2022		[1] subject to availability allowed by weather conditions [2] subject to wind conditions; min speed must be met & max (lockout) speed not exceeded [3] battery storage must be charged [4] only for microturbines [5] facility-level dedicated generators are typically permitted for backup only [6] instant backup power – rapid ride-through [7] energy storage must first be charged by another resource, but can still serve significant loads [8] UFC 3-540-01							

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CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 MINIMUM DESIGN REQUIREMENTS.

To be in compliance with the criteria prescribed herein, the design must:

a. Be capable of islanding with ability to network (or parallel) more than one disparate source of generation per UFC 3-540-01

b. Be a Bounded System with autonomous generation, distribution, controls, and Human-Machine Interface (HMI)

c. Include Black Start[1] Capability: Be capable of grid-independent black start with a minimum of one grid-forming DER[2]

d. Contain sufficient generating sources, stored form of energy, and reserve capacity[3] to meet the peak critical load within the system boundary with off-grid endurance not less than the duration of time required by mission and service policy (independent of renewable energy sources)

e. Include System Balancing: Contain Grid-Independent ability to energize critical loads and optimize load factor

f. Include fail-safe ability that resorts to load-dedicated (or pre-microgrid) operation following electrical system, communication, or other network disruption

g. Have risk management framework process initiated. This may include a Cybersecurity Authorization to Operate (ATO) by a DoD Approving Official (AO)

h. Use technology that is commercial, warrantied, and supports permanent infrastructure improvement. This UFC does is not intended to govern research, development, demonstration, emerging practice, or developmental technology.

The following considerations represent recommended best practice and should be included as scope and funding of a project allows:

- Redundant networked sources of generation
- Energy storage
- Bi-directional soft, “blinkless” transition

[1] Black start is starting a microgrid system after unplanned grid failure with no energized generation resources.
[2] Energy Resilience Readiness Exercise (ERRE) tests the operational capabilities of microgrids to support mission operations in the absence of normal utility power.
[3] Reserve capacity is the uncommitted, immediately-available generation capacity on the network, accounting for islanded load variability, non-linear loads, motor start, and other high-VAR, inductive, and nonlinear load requirements.

- Grid connected support, with capability for demand response, and ancillary services such as frequency support, voltage management, and black start
- Redundant (min 2) grid forming assets
- Redundant (min 2) HMI Visualization HMI Front-Ends
- Redundant (min 2) Independent Black Start Sources
- Load Shedding Capability
- Be capable of re-synchronization and soft (seamless) transition back to the external grid

2-2 PERFORMANCE REQUIREMENTS.

Agency policy, mission needs, and installation requirements should inform the performance requirement, which then informs the basis of design and, subsequently, the acquisition. All installation microgrids must include the following elements: energy sources, loads, one or more PCCs, electrical distribution and switchgear, and secure controls. The following requirements listed in paragraphs 2-2.1 to 2-2.4 are also mandatory.

2-2.1 Autonomous Operation.

A microgrid must be capable of providing power independently of all external power and communication networks. In this respect, microgrids are autonomous. However, the degree to which a microgrid is configured to automatically enter into its active states of operation following an outage must be carefully considered based on mission Continuity of Operations (CONOPS) and personnel requirements. Degree of automation can vary from having a required "human in the loop" input command between each system configuration and operational state, to fully automated systems that are "Always Sensing" systems with no required user intervention between each system state.

2-2.2 Safety and Grounding.

Because the systems often integrate generation on the load side of facility transformers and operate independently from the external grid, designs may require dedicated or modified grounding during certain conditions of operation. Special design consideration must be given to islanded operational states requiring dedicated grounding and protection configurations per AFMAN 32-1065. Prior to integrating microgrids into existing installation systems, evaluate if:

- existing installation distribution equipment and switchgear are integrated;
- dedicated or modified grounding during certain conditions of operation are required;
- any islanded operational states require dedicated grounding or updated protections at any location.

2-2.2.1 Safety and Arc Flash.

Designs often include system simulation or modeling to update arc flash and safety protections and identify issues with equipment duty ratings that require upgrading or replacing existing equipment, or increases in arc flash that require mitigation and protective device coordination. Any analysis developed or updated must be performed in the prevailing modeling environment used by public works and the local utility. The model must be updated per NFPA 70E by a qualified engineer. All updated model files should remain the property of the government.

2-2.2.2 System Grounding.

Grounding needs specific attention when the microgrid is designed. Grounding configuration must be assessed during all conditions of the microgrid, including all operational modes and all temporary modes that may conceivably exist during microgrid formation and disconnect. Grounding systems are required although equipment may be disconnected from the main power but remain live at different points. Careful analysis, including modeling, is required for both the grid connected and islanded modes (and all configurations between) to protect equipment and personnel during fault conditions.

2-2.2.3 Fault Protection.

Specific attention must be given to islanded fault protection. When connected to the utility grid, the distribution system is capable of delivering the necessary short circuit system performance based on protective relay settings at substations. When the distribution is energized in islanded mode, system inrush current may cause deviation in islanded voltage and frequency triggering generator under speed protection or other DER protections. Short-circuit characteristics of the networked sources may not consistently produce sufficient current to be detected using existing protection settings; allowing faults to be undetected and potentially cause system damage. Consequently, the grid-connected protection configuration (before a microgrid is implemented) may not offer adequate fault protection. The design must include updated protection settings at system and device level to isolate or clear faults to prevent damage to equipment and loads. Analysis of the system protection architecture includes system simulation or modeling prior to final design approval. In some cases, protective device coordination studies are performed as part of design and updated during construction. Refer to APPENDIX E for additional performance metric and safety information.

2-2.3 Cybersecurity and Risk Management Framework.

Designers must refer to UFC 4-010-06 for all microgrid designs as the primary resource for planning cybersecurity protocols in advance of acquisition. Within DoD, each agency has an AO who determines the “Authority To Operate (ATO)” based on risk, and approves the final implementation (representing minimized, well-managed risk). Based on the organizational mission and details of the control system, the System Owner and AO determine impact levels (LOW, MODERATE, or HIGH) for the control system. The Designer of Record must coordinate with the relevant service-specific authorities and ensure that the DoD approved evaluation processes and risk management framework for cyber security concerns are addressed.

When Applying Risk Management Framework to Microgrid Controls Systems, the network boundary should include all control points and IP-addressable assets constructed as part of, or controlled by, the microgrid system. Facility control systems are not information technology (IT) systems; they should not use standard IT system approaches and not be connected to public systems, especially internet systems, and not have remote access. (no access outside of defined and approved system architecture network boundary).

2-2.4 Utility Management Control System (UMCS) Integration.

System design must demonstrate minimum interoperability with existing (or planned) UMCS, specifically any data required from UMCS as part of microgrid operation or information from microgrid system to UMCS for display or other purposes. Interoperability may support aspects of microgrid design including communication with, or control of, primary assets of the Utility Control Systems (UCS) as described in UFC 3-470-01.

CHAPTER 3 PERFORMANCE METRICS

Consistent with OSD Metrics and Standards for Energy Resilience at Military Installations (2021), the microgrid performance-based design process must identify performance metrics and goals to inform the basis of design. This includes the following metrics described in this chapter.

3-1 OFF-GRID SYSTEM ENDURANCE.

Off-grid endurance is a primary performance metric that must be used to inform system design and must be identified in the basis of design. This refers to the total duration the microgrid can carry the peak critical load without the return of commercial power or refueling service (i.e. islanding duration). Regardless of what level of off-grid endurance is targeted, the final design must provide a total amount of onsite stored form of energy (fuel, gas, compressed gas, electrical energy, etc.) that meets the target.

This target metric must be informed by prevailing DoD service policy and mission assurance requirements. Traditional standby generation design practices have targeted 72 hours of system endurance for all critical loads served by the network. UFC 3-540-01 includes a requirement of 7 days of onsite fuel storage capacity, with a provision for confirmed delivery of sources. OSD Metrics and Standards for Energy Resilience at Military Installations promotes a 14 day target for mission loads. DoDD 3020.26 includes language to ensure performance of Mission Essential Functions during any emergency for a period of up to 30 days or "until normal operation can be resumed”.

3-2 PEAK CRITICAL LOAD SERVED.

The design must have the capacity to support the peak load demand of critical systems when they are engaged in normal and peak mission activity (along with any non-critical loads that are incidental or non-segregable). Analysis of mission load profile during times of normal and peak mission activity must be conducted to verify adequate generation as well as load following capacity is available.

The load analysis must give specific consideration to step loads, highly nonlinear loads, motor and high-VAR inductive loads, as well as projected and actual or tested requirements in island mode. Load analysis must be conducted for both grid-connected and island modes.

3-3 LOAD SHEDDING.

Load shedding is the capacity of the design to shed load to maximize endurance of higher priority mission operations. The engineering analysis must include options for active load management and load shedding maximize off-grid endurance of mission loads. The load shedding plan must consider mission dependency criteria and installation load restoration plan to support the level of energy resilience required for the microgrid’s essential facilities (see Table 4-2). Load shedding can be implemented by sequential restoration at substation breakers or via under frequency load shedding. For cases with nominal non-critical loads (or that are not easily segregable), designers must assess the tradeoff between incorporating additional load-shedding switchgear against the marginal cost of additional generation and system capacity required to support those loads.

3-4 RESTORATION TIME AND SOFT TRANSITION.

The microgrid system is responsible for transitioning to islanded power following a commercial power outage, as well as transition back to external power following commercial system restoration. Restoration time to supply power to all critical loads in the network is an important performance factor. This includes the time required for the system to island at all points of interconnection, parallel and synchronize generation, and deliver power to the designated critical load(s) in accordance with mission and installation circuit priority. This can range from soft transitions with instant “blinkless” power to the critical loads, to seconds or minutes (see Figure 4-3).

While not an explicit criteria requirement, designers must consider any specific operational needs or loads that may require soft transition both to and from islanded operation.

3-5 OPTIMIZED DER LOAD FACTOR.

Optimize DER load factor to the extent to which the design minimizes low load factor operation of individual DER assets including operation of assets in a reserve capacity. This includes minimized operation of fuel-based generation operating at low load factor, load banks, and other operational inefficiencies. Optimizing target DER load factor improves off-grid endurance and economizes system operation by preferring lowest-cost form of generation, renewable generation assets, and energy storage. Designers must assess the tradeoff between larger DERs (associated with more attractive capital and operational cost per unit output) against smaller DERs (as a network, can support system requirement at higher load factor).

3-6 ENERGY SURETY AND REDUNDANCY.

Redundancy is the allowance for failure or loss of at least one significant generation network DER and still serve the peak critical load requirement.[1] The aggregate generation capacity of the network must meet or exceed the maximum peak critical load based on the load analysis. The degree of required redundancy in the network must correspond with the resilience requirement of the load. See load designations in Figure 4-3.

3-7 DEGREE OF RENEWABLE ENERGY CONTRIBUTION.

Designs with greater contributions of power produced by climate-friendly technologies offer more sustainable operation and advance DoD climate impact goals. Though not firm or dispatchable forms of generation, renewable DER sources reduce or defer fuel

[1] This degree of redundancy may not be viable for large-scale projects, peaking plants, or designs primarily targeting grid support (often comprising very large DER systems).

use or energy storage discharge to deliver greater off-grid endurance. Systems exclusively using renewable generation sources must verify sufficient available storage and black start performance to manage islanded resilience requirements as well as climate goals.

3-8 OPERATIONAL VISIBILITY AND GRAPHICAL INTERFACE.

Designers must include the graphical human-machine interface (HMI) that conspicuously illustrates system state, operational parameters and condition of major components, available reserve fuel and other forms of stored energy, position of major switchgear components, and flow of power within the system boundary. The HMI should be intuitive and interactive for system operators. Interface elements shall conform to accepted power system industry standards per IEEE 1826. The HMI must include dedicated uninterruptible power supply (UPS) of no less than 2 hours to accommodate operation during changes in operational state.

3-9 EXPANDABILITY AND RECONFIGURABILITY.

System design needs to accommodate load growth or mission expansion with minimal design reconfiguration, reprogramming, and recurring engineering costs. Scalable designs can accommodate mission growth by expanding the number of network sources, the size and location of the addressable load, and reconfigure/reprioritize load without significant re-design, retrofit or replacement of capital assets (distribution switchgear, motor controllers, substation equipment, etc.). All design modification and expansion must accommodate and adhere to installation configuration management protocols. Designs with looped distribution, multi-terminal switches, and bypass of DERs and switchgear (to minimize impact of equipment maintenance and testing) should also be considered. A MILCON is valid for five years; expansion after that five-year period requires a new MILCON. Should a new project require modification or expansion of the microgrid, then that activity must fund all required upgrade to the system, including any additional generation, to maintain operational functionality. Perform studies to determine if a microgrid is appropriate. For bases with existing microgrids, study to determine if new construction requires a new microgrid or if it can be integrated to an existing microgrid as an expansion.

3-10 GRID-CONNECTED AND ECONOMIC APPLICATIONS.

The degree to which the design allows for grid-connected operation or applications supporting economic incentives including demand response, load curtailment, grid-support services, or other ancillary arrangements that improve lifecycle payback. The lifecycle value of these design attributes is a function of site location, degree to which the region is energy constrained, nature of existing power purchase agreements, and commercial utility needs.

3-11 POWER QUALITY.

Power quality is a significant consideration for islanded microgrids. Because microgrids energize smaller systems than commercial grids (and generally operate with less reserve generation capacity), loads can be impacted by ramping effects from large renewable systems, power system transients, and other power quality events. Transients resulting from normal operations such as switching, renewable energy variability, and transformer inrush currents must be managed to avoid equipment damage. The design must accommodate large motor starting and other nonlinear and reactive power events during islanded operation. Grid modeling and short-circuit analysis is generally required at sites with: low short-circuit ratio, substantial dynamic power system considerations, other power quality challenges, or where required by the commercial utility operator. Microgrid systems are now capable of following the load and provide power to the systems needed.

CHAPTER 4 PLANNING, DESIGN AND ACQUISITION

4-1 MICROGRID PERFORMANCE-BASED PLANNING AND DESIGN.

Planning and design must be informed by performance criteria. Performance-based acquisition uses performance criteria, rather than prescriptive criteria, to inform planning, design, and acquisition (for example, total amount and duration of load to be supported rather than prescribing the number and size of DERs, switches.) Such a performance-informed approach allows the DoD to assure salient service policy and installation requirements are fully reflected in the project from inception, without being unnecessarily prescriptive as to the type or form of generation solutions, size, or controls in advance of acquisition.

For USAF projects, AFMAN 32-1062 specifies USAF approval process of generators for prime power, cogeneration, or microgrid applications. Air Force Civil Engineer Center/Operating Directorate (AFCEC/CO) must coordinate on all government funded microgrids, and AFCEC Energy Directorate (AFCEC/CN) must coordinate on all third party funded microgrids. Commissioning should include all items needed on hand for O&M/Repair such as spares/repair parts/supplies/special tools/special test equipment. Develop a configuration management plan and implementation of procedures for controlling changes to the design baseline over time.

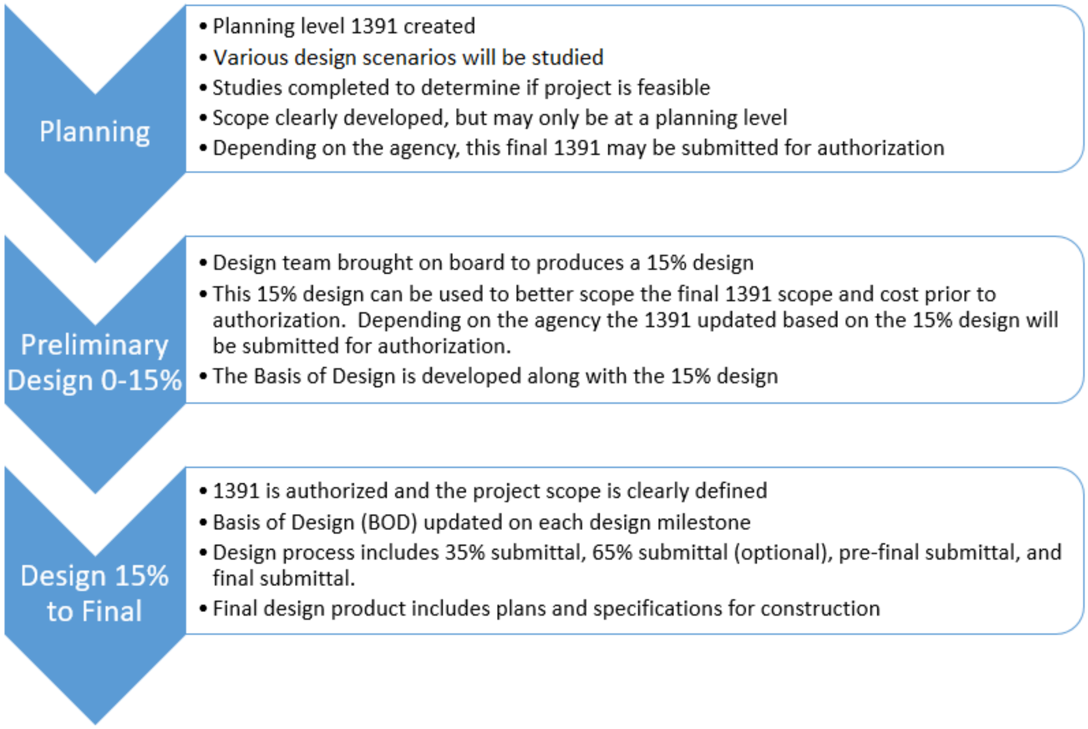
4-1.1 Performance-Based Planning and Design Process.

The planning and design process includes identifying and applying salient organizational policies, including application of DoD energy resilience policy and directives (e.g., DoDI 4170.11) as defined by 10 USC 2911, climate goals, and UFGS/UFC criteria early in the concept development. Refer to Figure 4-1 for the microgrid design progression. Planning includes:

- Defining objectives
- Defining scope
- Assessment of options
- Condition assessment
- Other operational requirements

All design activities must consult the Public Works/Public Works Officer (PW/PWO) office and utility operations to ensure all equipment selection, specification, documentation requirements, HMIs, software configuration, sequence of operations, operational visibility, and other elements aligns with mission and installation operation and protocol.

Figure 4-1 The Microgrid Design Progression



4-1.2 Checklist for Compiling a Planning DD1391.

DoD uses DD Form 1391 to support funding requests for military construction projects to Congress. The form is used to record the installation's program in relation to personnel strengths, real property improvements, mission and functions. A sample DD1391 is provided in paragraph D-2.1. Reference annual planning guidance for the Energy Resilience and Conservation Investment Program (ERCIP) issued by Office of the Secretary of Defense (OSD) for the latest DD-1391 format and required information with respect to ERCIP submissions. ERCIP submissions from all components are evaluated annually for funding and need to contain required information in prescribed format.

4-1.3 Methods of Procurement.

Microgrid systems can be acquired either directly through installation resilience resources such as DoD MILCON, ERCIP, and Intergovernmental Service Agreement (IGSA), or under alternative third-party financed arrangements such options include Energy Savings Performance Contracts (ESPC), Power Purchase Agreements (PPAs), Utility Energy Service Contract (UESC), Utility Privatization (UP), or as part of in-kind consideration with a public utility or independent power provider for leased military sites. Resources required to support system O&M and testing throughout the system lifecycle should be identified and microgrid performance should be recorded as required by each Service.

4-1.4 Construction Sequencing.

The designer must include sequence of construction. Schedule coordination with ongoing operations is critical, particularly for cut-in/tie-in work and equipment upgrade and swap out. Construction activities can be coordinated with normal maintenance shutdowns and affected component Commands for acceptable outage times.

Additionally, the sequence of construction needs to be considered. For example, if a high-penetration level of PV renewable energy is to be installed with a battery energy storage system (BESS), it is best to install the BESS first, to manage power stability prior to installing of the PV system.

4-2 PLANNING AND MODELING (0-10%).

Planning and modeling determines feasibility and viability of a networked standby power solution. Mission needs and lifecycle costs (capital and operational) are considered. Options for a combination of energy sources, to include renewable energy and energy storage options must be investigated at the start of any microgrid project (often referred to as techno-economic analysis). Mission requirement, service policy, and prevailing DoD guidance must inform the early design.

The planning phase must also identify existing power system models (for example, Easypower, ETAP, SKM, and PSCAD) and include scope to reflect all changes and impacts from the microgrid project.

The conceptual design should include the following elements. Refer to Sections 4-2.1.1-4-2.1.11 for further details on each element.

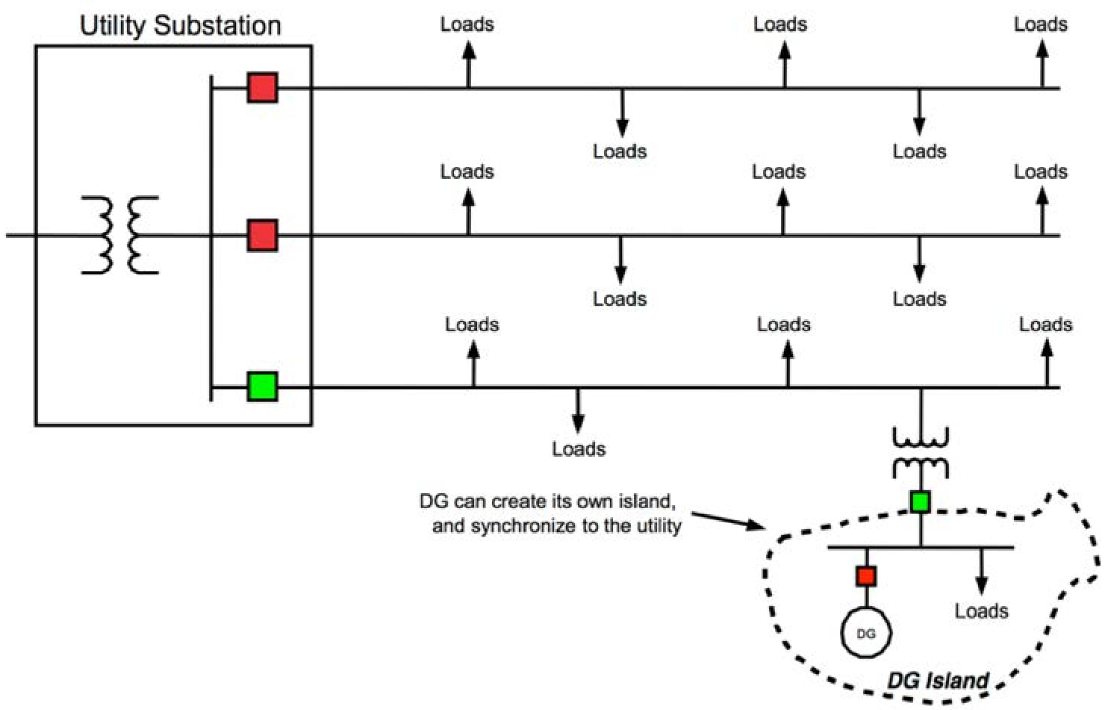
- Defining system boundary (based on stakeholders and mission commands with elevated security requirements)
- Identification of critical loads to support with microgrid
- Identification of mission owners, system owner, and cybersecurity accreditation authority (UFC 4-010-06 is the primary resource for planning cybersecurity)
- Identification of areas requiring electrical system modeling or updating
- Feasibility and constructability of alternatives
- Utility interconnection application and studies
- Compiling draft layout and list of systems components
- Complete cost estimation and cost-benefit analysis

4-2.1 Conceptual Design Elements.

4-2.1.1 Defining System Boundary.

The system boundary must be defined based on mission need, infrastructure configuration, and operational requirement (see Figure 4-2). A system boundary is determined based on mission requirements, existing power generation and distribution infrastructure, ease of electrical isolation (based on the one-line diagram), deficiencies in resilience related to the electrical supply to loads, and optimization of new and existing and DER sources, power distribution, and supporting fuel supply.

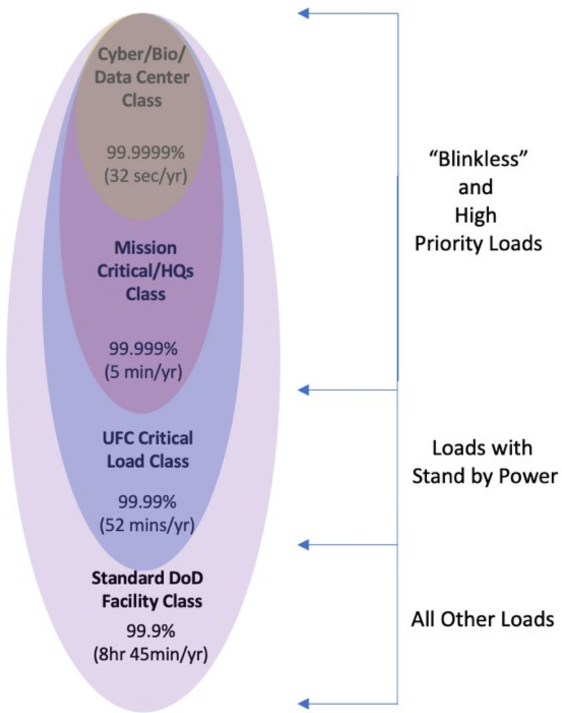
Figure 4-2 Microgrid Boundary



4-2.1.2 Identifying Critical Loads.

During the conceptual design phase, critical loads need to be identified. Designers must consult with the affected mission owners to define requirements, associated dependencies, and critical loads that, if lost, will ultimately lead to a failure of an identified mission-critical system. A notional example of load designations based on allowable annual outage duration is shown in Figure 4-3.

Figure 4-3 Load Class Designations and Annual Down Time



Identification and prioritizing of critical loads is informed by the mission. Buildings, systems, and other critical elements required to support the mission elements must be identified. The following are characteristics of microgrid critical assets and systems:

- Time Basis: Loads should be identified as to how long after power outage they are needed (uninterruptible, seconds, minutes, hours, days, and weeks). Also, how long must load be supplied each day?
- Load Requirements: Full load, peak load, average load, or minimum load need to be subdivided into critical and non-critical loads. Can control systems be used to drop non-critical loads?

During the iterative stakeholder process, the designers must tailor microgrid performance to meet mission requirements according to each of the performance metrics in CHAPTER 3.

Certain critical loads may already have load-specific generation that cannot be interconnected to the microgrid for technical or mission reasons. Under these conditions, designers can proceed with a system designed to relieve mission-dedicated generation without controlling or interconnecting load-dedicated generator(s). Under this scenario, the local facility's Automatic Transfer Switch (ATS) system identifies energized distribution (due to normal grid or microgrid operation) and refrains from switching to emergency position. In this way, the local facility generator serves as an additional level of redundancy for that facility above and beyond what is delivered by the microgrid (see Figure 1-2).

4-2.1.3 Power System Modeling and Microgrid Design Modeling.

DoD is required to use analytical tools when evaluating energy resilience measures, such as microgrids, that are accurate and effective in projecting the costs and performance of such measures (10 U.S.C. 2911). Two types of models are used to inform microgrid planning: Microgrid Design Modeling and Power System Modeling. Refer to Table 4-1. APPENDIX B provides an assessment of available microgrid design tools relative to these requirements to aid designers in picking the best tool for the installation. As microgrid design tools continue to evolve, APPENDIX B will be updated.

Microgrid design modeling is instrumental to inform planning. This modeling employs microgrid design tools (see Table 4-1) to produce a techno-economic analysis of optimal DER type and size based on energy resource costs, impacts of interdependent design decisions, attractive economic or lifecycle solutions, and other performance factors necessary to interpret the design space and evaluate the tradeoff of alternatives. Microgrid design tools account for mission requirements and distributed energy resources' performance to facilitate defining conceptual designs. It allows installations to understand the design space and evaluate the cost and performance of alternatives.

Power system modeling determines grid maximum short circuit available and performance of the power system by calculating short-circuit analysis. Small, isolated grids with higher penetration of power-electronic-based DER typically operate at lower short-circuit ratio (SCR) performance. A grid's SCR performance is bounded by the theoretical conditions of 1) an infinitely stiff bus behaving as an ideal voltage source with zero impedance, such that any attempt to change the voltage produces an infinite supply of current, maintaining a constant voltage, or 2) a weak bus where it is easy to change the voltage by sourcing small amounts of current.

Table 4-1 Microgrid Modeling Tools Vs Power System Analysis Tools

	Microgrid Modeling Tools	Power System Analysis Tools
Focus Area	Technology Tradeoff and Economic Analysis of DER	Power System Stability and Operation Performance
Components Sized or Designed	Turbine-Drive DER, Engine or Gas-Driven DER, Renewable DER, Storage-Based DER, etc.	Protective Device Selection, Time-current curves, Relays, and ArcFlash Reduction Maintenance Settings, etc.
Output	Techno-economic Alternatives of Microgrid Concepts and Lifecycle Costs	Short Circuit, Arc-Flash, load-flow, or Grid stability analysis
Supports	Planning (0-10%)	Modeling and Detailed Design (10-100%)
Notable Examples	Listed in APPENDIX B	SKM, Easy Power, ETAP and PSCAD.

4-2.1.4 Constructability, Feasibility, and Site Constraints.

Microgrid implementation will consist of installing controls, adding switches, realigning supported loads to high priority feeders, and changing operational procedures. Planned modifications and infrastructure improvements to the distribution system must be integrated and leveraged during conceptual design. Designers must specify candidate load centers and design options, and provide alternative options (for example, centralized or distributed generation solutions) to support maximum critical load given current operational conditions, practices, and CONOPS.

The following site constraints or restrictions raise unique issues for microgrid design projects and careful consideration must be taken:

- Footprint and environmental permitting issues associated with one or more microgrid DERS and energy-storage locations. Often it is attractive to centralize any new generating capacity near substations and to use larger generators because cost per unit capacity is lower.
- Site space, permit, and climate factors associated with renewable energy: this includes site operational issues, such as mission conflicts with wind turbine operation. Planners must reference the prevailing design guidance for facility-scale renewable assets (UFC 3-440-01) and utility-scale renewable assets (UFC 3-540-08).
- Building code issues
- Restrictions on commercial power procurement agreement with local electric utility and options available to modify the service contract: includes options available to cost share (capital cost or maintenance cost)

- Other challenges aligning infrastructure with microgrid operation
- Fire protection offsets, especially for further addition of battery storage (UFC 3-600-01)

4-2.1.5 Facility Classification.

Prioritization of facility loads must be informed by their mission profile, installation's emergency response plan, installation energy and water plan, and established/identified deficiencies (interrelationships and dependencies of those loads must be confirmed). See Table 4-2. Additional documents to be reviewed include the Critical Infrastructure Program, Mission Assurance Program, and Mission Dependency Index.

Table 4-2 Facility Designation in Microgrid System

Facility Designation	Microgrid Supported Conditions	Examples
Microgrid Essential Facilities	Supported under all modes of operation	Facilities meeting criteria of UFC 3-540-01, or with other significant mission-dependence
Microgrid Supported Facilities	Served by microgrid under most conditions, can be shed during extended grid events	Facilities meeting criteria of UFC 3-540-01, or with other significant mission-dependence (HQ, command and control, data or communication centers)
Microgrid Discretionary Facilities	Can be served by microgrid, located within system boundary	Discretionary facilities not consistently requiring secure power for the entirety of an outage event
Non-Microgrid Facilities	Are not located within system boundary	Facilities that do not have an elevated stand-by power requirement

4-2.1.6 Load Analysis & AMI Data.

The microgrid must support the peak-load demand of mission critical systems. A load analysis is necessary to size system components and develop an informed load shedding capability schedule. Essential loads to be served by the microgrid and optional loads, as defined by facility categories in Table 4-2, must be identified during the engineering analysis.

The highest resolution energy consumption data must be used and must include load variation due to season, mission operational tempo, and other major impacts to load profile. For many sites, high-fidelity load data is stored in digital relay devices, or is reported via Smartgrid or UMCS enterprise systems. At other locations, AMI meter data is most accessible. Realistic estimates of real world data, with reasoning provided will inform the design and critical engineering decisions. If AMI data is available, the difference between total base load and AMI metered load can be used to estimate and create a load curve for the remaining loads. Additional techniques that may be used to determine this include the following:

- Refine estimates by studying the available load curves based on season, time of day, day of the week, holiday, workload, outside temperature, and operating information and discuss the requirements with building and system owners (AMI, with gaps estimated.)
- For certain building types, such as office buildings, typical load information for the building design and use may be available.
- For some large, non-critical loads, it may be possible to make a rough estimate by dropping the load and seeing how much the closest upstream meter moves.
- For critical loads with existing emergency generators, the generator output during past utility outages is a good indicator of load that must be supported by the new microgrid.

4-2.1.6.1 Peak Loads.

The microgrid must support the peak-load demand of critical systems when they are engaged in normal mission activity. The engineering analysis must include options for managing loads, including loads in critical buildings that are not mission critical. Simpler design and operations can often be realized by backing up an entire load center should a facility or load center contain non-segregable critical and non-critical loads.

4-2.1.6.2 Thermal and Non-Electrical Loads.

During analysis, the designers must give special consideration to thermal and other non-electrical requirements, including heating, cooling, industrial loads, mechanical loads, pollution-abatement systems, or other specialty functions. Startup requirements of these loads, associated in-rush or motor start needs, and other non-linear load requirements must be specifically addressed if such systems are to be supported by the microgrid during islanded operation.

Other areas to consider for thermal and non-electrical load analysis include:

- Magnitude of real (Watts) and reactive (Vars) power for each phase and total
- Apparent power in VAs for each phase and total
- Power factor for each phase and average
- Averages of energy in kWh and reactive
- Rated capacities of infrastructure
- Seasonal effects of temperature and usage
- Derating factors for equipment

- Theoretical additional load information

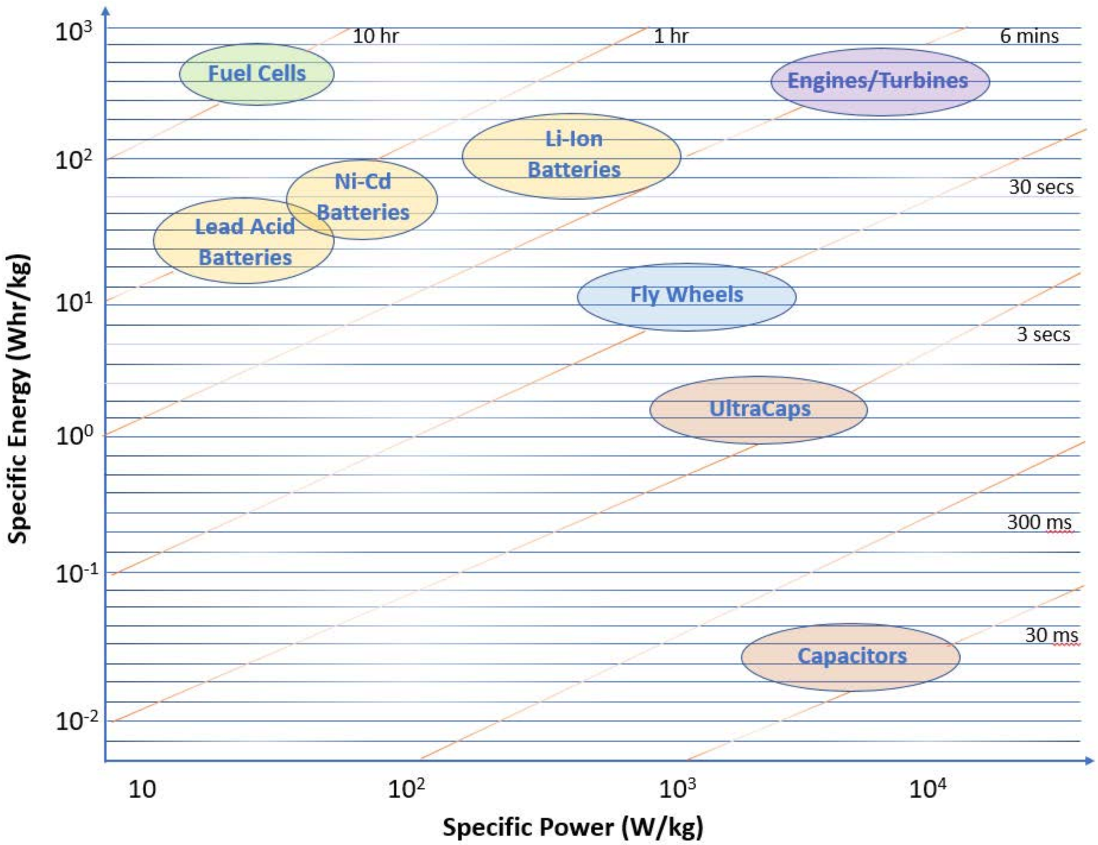
4-2.1.7 Integrating Storage-Based DER.

Integrating energy storage technology can enable many additional use cases for microgrids. Figure 4-4 provides performance attributes of different energy storage technologies. Electrical energy storage can be considered if the design must support any of the following performance requirements:

- Blinkless transition to or from external grid power
- Rapid load restoration, UPS-grade support
- Rapid load-following
- Facilitate very high percentages of renewable utilization
- Firming Renewable DER Output (for example, solar "smoothing")
- Minimizing unnecessary spinning reserve and fuel-based generation
- Active power quality support
- Supporting demand response, peak-shaving or other grid services

Should energy storage be deemed prudent, designers must define the applications, operational states, and scenarios the storage will support. This allows both appropriate type of storage (Figure 4-4), sizing of the storage system (and inverter), how the system should manage State of Charge (SOC), and rate of charge/discharge (greater discharge “C-rates” generally result in less cycle efficiency for electrochemical-based storage systems).

Figure 4-4 Specific Energy vs. Specific Power for Storage DER Assets



4-2.1.8 Candidate Evaluation Study.

The following considerations must be taken into account:

- Installation master plan and development plan with projected load growth
- Mission impact, allowable downtime, and required restoration time: facility or load ratings on the site depending on criticality
- Sample critical facilities list
- Available reports, energy audits, and studies
- Available historical data and studies regarding outages and potential natural disasters
- Documentation of frequency, duration, and magnitude of outages at target locations, existing CONOPS during outages, and operational capability gaps to improve or automate the CONOPS
- Existing electrical site loads and load profile

- Utility maps, one-line drawings, substation configuration, other electrical infrastructure information
- Generator lists
- Communications diagrams, network diagrams, and fiber diagrams
- Site drawings with significant buildings and features identified
- Site electrical load information (by buildings and equipment)
- Smart meter or AMI data, if available
- Load shedding, facility, and installation/utility restoration plans

4-2.1.9 Ability to Support Critical Facility Loads.

Microgrid candidate designs must be evaluated based on their ability to maximize the amount of critical load served. Design options serving greater amounts of critical load within project cost are considered more favorably. Facilities are characterized based on their level of service during microgrid operation. For each facility supported by the microgrid, NFPA 110 describes a Standard Classification of Emergency Power for Emergency and Standby Power Systems including:

- Installation, maintenance, operation, and testing requirements as they pertain to the performance of the emergency power supply system (EPSS).
- Class - minimum time, in hours, for which the EPSS is designed to operate at its rated load without being refueled or recharged.
- Type - maximum time that the EPSS will permit the load terminals of the transfer switch to be without acceptable electrical power.
- Level - two levels of equipment installation, performance, and maintenance.

4-2.1.10 Availability of Existing Infrastructure.

Candidate microgrid designs that leverage more existing capital assets are considered more favorably than candidate solutions that require significant replacement or upgrade and additional capital investment. The design must ensure existing infrastructure is adequate to support all operational conditions required by the microgrid.

4-2.1.11 Cost Estimate.

At the conceptual design phase, a cost estimate may be completed with a mix of vendor information and standard cost-estimating data. For specific high-cost elements (such as generators, energy storage systems, transformers, and renewable energy systems), designers must request preliminary vendor budget pricing information on the specific high-cost equipment being planned. The vendor is typically supplied with system performance specifications (as opposed to a detailed design specification), and will typically provide the cost of a component(s) with allowance for installation, specification descriptions, and estimated delivery schedule. The budget information is non-binding and the budget must include an allowance for potential changes or unknowns. DD1391 has percentages assigned for these unknowns. Designers will also be responsible for identifying items such as management overhead, permits, and contingency. For cost estimating, refer to DoD Area Cost Factors by region.

Designers must update cost estimates throughout the design process. The cost estimate from the 10-15% design is more relevant to the authorization for funding than the initial planning estimate. Service-specific preferences and "buy American" clauses are key components of estimates. Refer to UFC 3-740-05 Section 8-2.2 and the Federal Acquisition Regulation (FAR) for further information on the "buy American" clause.

Local personnel or the relevant DoD agency can provide assistance with adjustment factors. See UFC 3-701-01 and UFC 3-730-01.

4-3 PRELIMINARY DESIGN (10-15%)

The preliminary design advances the conceptual design by considering feasibility of integrating existing infrastructure, equipment and control system requirements governed by installation standardization efforts, "constructability" of proposed infrastructure, developing modes of operation and performance metrics, and location/available footprint needs of new assets. The purpose of the preliminary design is for the government to produce a performance-driven scope of work and inform performance-based acquisition to produce a detailed design.

4-3.1 Preliminary Design Elements.

4-3.1.1 Detailed Load Analysis.

This includes higher fidelity load estimating, and power system analysis per UFC 3-501 and incorporates the following:

- AMI system, 15-minute metered data, feeder loading data, or some form of continuous output (if available)[1].
- Loads for non-metered facilities and equipment: the difference between total base load and AMI metered load can be used to estimate loads.
- Available load curves based on season, time of day, day of the week, holiday, workload, outside temperature, and operating information.
- Load specific information from facility engineers, onsite personnel, or system owners.
- Facility-dedicated generator loading data (this data may not represent normal facility loading if generator testing typically occurs during non-

[1] Existing generation should be taken into account when analyzing load data to ensure that the gross load is determined and not net load.

business or non-mission hours; therefore, it is important to run these generators under full emergency operations load simulating a grid outage when retrieving loading data).

4-3.1.2 Defining Storage Assets.

The below table (Table 4-3) is intended to aid planners and designers in reviewing the realities of energy storage options, prior to acquisition. Some options included for context are emerging or nascent technologies that are not currently available as commercial-off-the-shelf (COTS), or are infrequently used. Values assigned in the columns are estimated for the benefit of planners. All listed technologies are subject to individual considerations, for example, the lithium ion battery requires reliable air conditioning, due to the fire threat at high temperatures.

Table 4-3 Energy Storage-based DER (as of January 2023)

DER Type	Availability (COTS)	Hazardous Material Waste (EOL)	Energy Density	DoD History as Permanent Infrastructure	Lifecycle (Years)	Greenhouse Gas Emissions	Energy Time Provided Prior to Recharging
Fossil Fuel	Yes	State-Dependent	High	Yes	N/A	Yes	N/A
Iron Flow (BESS)	No	No	Low	No	25	No	Up to 12 Hours
Lead Acid	Yes	Yes	High	Yes	3-12	No	2 Hours
Lithium Ion	Yes	Yes	High	No	10	No	Up to 4 Hours
Compressed Air	No	No	Low	No	30	No	TBD
Fly Wheel (FESS)	Yes	No	Low	Yes	20	No	30 Minutes
Pumped Hydro	Yes	No	Low	Yes	>40	No	Up to 12 Hours
Super Capacitor	No	TBD	High	No	10-20	No	TBD
Hydrogen	No	No	TBD	No	N/A	No	N/A

4-3.1.3 Identifying Infrastructure Gaps and Deficiencies.

Infrastructure deficiencies and gaps must be identified prior to implementation of the networked system. This may include:

- Addressing areas in need of infrastructure improvement including additional generation, distribution capacity, or fiber communication capacity.
- Identifying mechanically inoperative breakers and switchgear that is not normally engaged.

- Recapitalization or other integration of legacy infrastructure to meet performance standards.

4-3.1.4 Continuity of Operation (CONOPS).

The basis of design must be informed by mission CONOPS requirements. This includes microgrid (or microgrid operator's) islanding, restoration sequence, and load shedding decisions. These design requirements must be reflected in the operating procedures and are the basis for programming the control system. During design development, designers must specify operating procedures and the exact behavior of individual equipment and control elements.

4-4 DETAILED (ENGINEERING) DESIGN.

The detailed design is the final design product of the performance-based acquisition. It specifies every aspect of construction, device type and interconnection, programming, cabling, wiring, and fiber. This is the engineering level specification that would be furnished to a bid-build contractor. The detailed design must include the following:

- Description of how all generation sources are integrated and configured into the network to best deliver firm, reliable power to the critical loads per UFC 3-410-02 and UFC 3-470-01.
- Devices: List of devices, device IDs, device attributes including type, model, location, dimension, rating, interconnection type and attribute (e.g., black start, grid-forming, droop-controlled, grid-following), software/firmware version, and communication protocols.
- Pathways and Conduits: List of utility conduits, fiber pathways, cable type/length, capacities, etc.
- Schematics and Diagrams: Device schematics, network diagrams, wiring diagrams, flow diagram, trenching plans, site designations, equipment specification, cut sheets, etc.
- States of Operation: A complete listing of each state of operation, order of events under each state. For each state of operation, the exact commands and actions taken by each asset/device/component and the expected result of all other devices in the system. This must include load restoration and load shedding sequences.
- Device Isolation: Description of generation bypass and other device isolation, loaded testing, step loading with planning for oversizing generation or ensuring loads can be added, removed, or segregated in manageable increments.
- Configuration management plan and implemental of procedures for controlling changes to the design baseline over time.
- Nonstandard hardware components needed on hand for O&M/Repair including spares, repair parts and supplies, tools, test equipment, etc.

- Equipment/System Documentation: In-depth operational training material for addressing step-by-step microgrid operation for each system condition and state of operation, common troubleshooting and maintenance procedures. This must include material to identify anomalous operation, and troubleshooting, vendor contact, and warranty information.

4-4.1 Aligning Microgrid Operation with Existing Infrastructure.

Microgrids leverage existing capital infrastructure with new power system assets and controls. Consequently, many design solutions may involve nontrivial levels of effort to validate proper operation of existing electrical systems, require specialized reprogramming of existing systems to support microgrid functionality intent, or involve other hardware or software costs. For new facilities to be “microgrid-ready”, construction must include paralleling switchgear at the point of electrical service as well as the following attributes for inverters.

- Programmable output capable of accepting an external control signal from the master controller (in some cases, inverter oversizing might be prudent to support both reactive power and planned real power needs)
- Adjustable inverter trip levels and clearing times
- Ability to network control signals from Microgrid master controller
- Logical output curtailment from Microgrid master controller
- Extended voltage and frequency operating ranges
- 4-quadrant operation and control (for new construction with battery-based storage)

4-4.2 Aligning Generation Sources for Islanded Operation.

Islanded operation requires black start generation to energize the islanded distribution, along with sufficient additional generation capacity to support full critical load.

4-4.3 Aligning Renewable Systems for Islanded Operation.

When interconnecting renewable sources of power to the installation power system, the inverter-based device must adhere to IEEE1547 Clause 8, including Anti-islanding and Ride-through requirements. During islanded operation, both grid-following and grid-forming sources can support islanded operation provided at least one black start, grid-forming asset is available in the islanded system. Systems solely containing renewable sources and energy storage must maintain sufficient state of charge (SOC) operating margins to ensure mission assurance posture should commercial power be lost when renewable power is unavailable.

4-4.4 Aligning Controls and Switchgear for Islanded Operation.

All control systems and switchgear whose operation is required during black start operation must be fitted with a UPS (this is particularly applicable to switchgear that is not typically operated from a dead bus condition).

4-4.5 Aligning Switches and Transformers.

Devices that are normally configured for the flow of power in one direction must be certified by the manufacturer for bi-directional operation without negative impact to the life expectancy or warranty of the equipment.

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CHAPTER 5 COMMISIONING AND PERFORMANCE VALIDATION

The microgrid commissioning (or recommissioning) and testing planning must be received and approved by the government and independently supervised, verified, and certified by the government as fully functional. Microgrid commissioning ensures that:

- Each subsystem operates as designed
- The interconnected system operates in every state of operation as designed
- Design supports contingency of operations and installation emergency response plan
- The system meets each of the performance metrics used to inform design

The commissioning phase not only validates system operation using target performance metrics, but also identifies troubleshooting procedures that must inform training plan documents that facilitate efficient sustainment and operation. The commissioning phase is generally the most effective time to diagnose areas of improper operation of legacy capital assets, devices, and alignment of existing infrastructure components. Equally important, sequential operation of device assets and system-level commissioning allows designers to further optimize controls, device and relay settings, and device logic to achieve or exceed the respective performance targets. An independent, third-party validator is advisable during system commissioning. The validator must approve the system commissioning plan and validate fielded operational performance in accordance with each of the stated operational states, performance objectives, and metrics.

The commissioning phase includes the following steps:

- Commissioning plan
- Device/component level commissioning
- System-level commissioning

5-1 COMMISSIONING PLAN.

During system design, a detailed commissioning plan must be developed in parallel based on each operational state the system is designed to support (with a detailed sequence of operations for each scenario). The sequence of operations must state device configuration and expected result for each step of the test and record configuration of switchgear, device load factor, and indication of unexpected or anomalous operation. Load banks or energy storage devices can be integrated into the testing process to avoid unnecessary impact to active facilities that do not need to be disrupted for the early part of the testing procedure. An energy storage system may be used as a load rather than a load bank. Final system testing must demonstrate the system's ability to support actual targeted mission loads.

The commissioning plan must clearly identify performance metrics (see CHAPTER 3) and thresholds to be achieved for every operational state under test. Measurement and verification of all performance objectives must be explicitly stated in the commissioning plan. Commissioning must include all items needed on hand for O&M/Repair such as spares/repair parts/supplies/special tools/special test equipment. Develop a configuration management plan and implementation of procedures for controlling changes to the design baseline over time.

5-2 DEVICE/COMPONENT LEVEL COMMISSIONING.

Each device and subsystem component must be independently tested prior to system commissioning. The project construction plan generally includes equipment and software acceptance testing for each subsystem commissioning. Site staff must receive training before these stages and be involved in these processes as part of their training.

This includes start-up of each device using standard vendor (local) control to verify proper operation prior to interconnection with network (remote) control assets or other network equipment. Subsequent phases of device level commissioning must address remote operation of devices, verification that remote device operation is reflected and controlled at the master control location, as well as validation of device settings, timing, controls, paralleling, and protections. In some cases, testing of two or more microgrid elements prior to interconnection with the whole microgrid/grid is prudent (e.g., protection devices and islanded DERs). Each component of the commissioning must be designed to best simulate real world operations, under fully loaded conditions. This is especially critical during system-level commissioning.

5-3 SYSTEM-LEVEL COMMISSIONING.

Upon completion of component testing, system-level commissioning verifies the full system's capacity to react to an unplanned outage. This includes:

- Synchronize all of the local sources of power,
- Reenergizing critical loads in the appropriate sequence of restoration,
- Optimized load factor and operational endurance,
- Transition back to commercial power.

Close coordination with the commercial utility is encouraged to facilitate disconnection/reconnection to the external power system, as well as validate that the system meets all the technical requirements of the interconnection agreement. Commissioning must include all items needed on hand for O&M/Repair such as spares/repair parts/supplies/special tools/special test equipment.

5-3.1 Identify Software/Hardware Configuration Changes

System-level commissioning may identify software or hardware configurations needing further attention including switching operations, device timing, communications or fiber functionality, inter-device coordination and protection settings, or devices requiring independent power to and other. During commissioning, breakers, switches, or other substation or facility equipment may require dedicated UPS, modification in set point, timing, or other re-programming to facilitate off-grid operation.

5-3.2 Validate Operational State

Each operational state of the system must be independently validated during commissioning including black start, microgrid formation, generator paralleling and islanded inverter-based device interconnection, supporting variable load states, ability to support load after during loss of generation or communications, fail safe operation, and safe reconnection back to commercial power. To the extent possible, metrics and targets must be assigned to each phase of the commissioning to quantify operational improvement resulting from microgrid operation, as well as to validate performance goals associated with the ERCIP Program and other DoD Installation Energy Resilience Policy.

A critical aspect of system commissioning is to operate in conditions as faithfully as normal installation conditions as possible. While device and initial system commissioning can take place during off-peak times (to minimize impact to business operations), microgrid performance cannot be fully validated until the system is exercised in a manner faithfully reproducing an unplanned utility outage under full load (with no ancillary connections or external sources of power). Utility system managers and facility engineers must work with tenants and mission stakeholders to facilitate such a “real world” microgrid system commissioning. This may include testing under normal loading, during normal business hours, etc. In some cases, mobile or other alternative contingency generation can be temporarily sited should testing and commissioning render existing stand by power systems inoperable.

5-3.3 Periodic Reverification Testing

There must be periodic reverification testing at intervals prescribed by the Operations and Maintenance Test plan, typically three to five years. System performance reverification and testing is performed by a qualified testing organization such as an AFCEC/COM (CEMIRT) type organization or by an approved commissioning contractor.

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CHAPTER 6 SEQUENCE OF OPERATIONS

6-1 STATES OF OPERATION.

Islanding and reconnection to the commercial utility must be performed safely and seamlessly to the priority loads. The microgrid controller must support the elements of power system interoperability per IEEE 2030 and is responsible for each state transition, each associated sequence of operation, and visualization of the distribution system and generation asset output under all conditions. The following items are typical microgrid states of operation (some alternatives are possible for systems with adjustable droop-type controls, closed-loop fast-feedback controls, PMUs or other devices):

- Normal operation (grid-connected, standby)
- Isolation from external utility (islanding)
- Microgrid formation (soft transition or black start)
- Islanded operation (optimized operation for resilience and endurance)
- Re-synchronization back to external utility (soft transition only)
- Testing and diagnostic mode (supports regularly scheduled loaded testing, device testing, and troubleshooting)

There are two primary scenarios for totally disconnecting from the grid: emergency disconnect (unplanned disconnect as the result of grid failure) and planned disconnect. This is done in anticipation of an impending failure or for business reasons, such as operation as part of a Voluntary Protection Program (VPP) in support of the local utility.

An example of how the system can manage these operations is provided in UFC 3-540-08, Chapter 8. This reference covers information related to utility relations and financial incentives.

6-1.1 Normal Operation (Grid-Connected, Standby).

This is the normal state of operation. The system remains in standby and awaits a grid event to notify a human operator or take autonomous action.

6-1.2 Isolation from External Utility.

Upon unscheduled loss of utility power, all facility loads are lost[1], renewable generation systems disconnect, and the system controller begins a timer (based on a programmable time delay parameter). Should stable utility power resume within this period, no action is taken. If the utility power is not restored within the programmed time, the operator or system commits to entering islanded operation and issues a command

[1] Blinkless designs running parallel with the external grid may not lose power during islanding (paragraph 3-4).

to open the interconnecting breaker(s) or recloser(s) at the point(s) of common coupling (PCCs), and system boundaries are established (IEEE 1547 Clause 8).

6-1.3 Microgrid Formation.

All microgrid systems must be capable of black start (reenergizing the microgrid island after unplanned grid failure with no energized generation resources). Because there is no utility reference, the resources must be able to define their own reference frequency and synchronize all resources uniformly to the reference. A start-up command is sent to black-start generators under microgrid control that are not dedicated to facilities (regardless of magnitude of connected load prior to the outage). The first networked generator to reach the rated voltage and frequency connects (provides power) to the distribution bus, and operates under synchronous control mode (subsequent generators and inverter-based systems joining the network operate in droop control mode). For microgrid designs with fully distributed, agent-based control, this generator (and its local controller) can be designated as the master controller by the rest of the controllers (this avoids having a predetermined master control point which could be a single point of failure should its generator or communications be lost during start up). Under this logic, each of the subsequent generators' voltage, frequency and phase are matched to the master/bus voltage, frequency, and phase before their respective paralleling breakers close to the bus. As previously mentioned, controls and switchgear whose operation is required for black start should be fitted with UPS (this is particularly applicable to switchgear that is not typically operated from a dead bus condition).

If the system is responsible for supporting facilities with dedicated backup generators, the automatic transfer switch (ATS) at each facility generator detects loss of power on its normal side and transfers to emergency (generator) position and each facility generator starts (see Figure 1-4). Once all facility generators have restored their respective loads, the microgrid closes its breaker between the emergency side of the ATS and the secondary side the facility transformer to allow the facility generator to feed the transformer and outside distribution system. Once the ATS determines its normal side is energized with stable voltage, it switches back to its normal position to allow the facility generators to energize the distribution system, depending on the relevant topology. Once all generators are online, paralleled, and the master controller is defined, breakers at the facility loads are closed to the bus in a predefined sequence corresponding to the installation's facility load restoration plan. The system monitors system load as these breakers are closed and issues a stop command once it determines that the load has reached a level corresponding to the N+1 generator redundancy target (i.e. should any generator fail to maintain load or be e-stopped, the system still maintains the energized network at that load level). The system never commits the generator network to a higher load than this, unless specifically commanded by a human user.

6-1.3.1 High-Speed and Low-Speed Controls and Operation.

Microgrids manage every aspect of the power system including islanding, paralleling, interconnection, system protection, load following, and renewable energy management.

Microgrid control takes place at two levels: high-speed controls and low-speed controls. The two levels of microgrid control are comparable to an individual controlling a modern automobile (the driver sends comparatively slow commands to the vehicle, while the vehicle control system responds accordingly by issuing commands to internal vehicle systems at much faster response times).

6-1.3.1.1 High-Speed Control Functions.

First, the phase and frequency is set by a master source controller, and is followed by the other generators to synchronize systems using high-speed, sub-cycle generator controllers. These device-level, high-speed controllers and governors manage voltage and frequency output and other high-speed parameters relating to electrical power stability. These are used to synchronize and measure electrical magnitude and phase angle of electricity as well as to synchronize time and coordinate the distributed power sources prior to merging.

6-1.3.1.2 Low-Speed Control Functions.

While the high-speed system is programmed to verify that all the prime movers on the system are synchronized, it may not monitor operational set points, load factors and power output. These attributes are optimized by a low-speed control supervisory controller, which manages distributed control points over slower communications. Given a specific operational scenario, the system issues commands to generator controllers and energy storage for each asset to compensate for renewable energy output fluctuation, load variation, demand response programs, etc. A microgrid system’s low speed control is also responsible for:

- Management of renewable energy system output
- Management of energy storage
- Optimization of fossil fuel based generation load factors
- Dynamic load following
- Optimization of network efficiency and endurance

6-1.4 Islanded Operation for Resilience and Endurance.

Once the full load is served, the microgrid can optimize operation by 1) Managing load factor of paralleled generation 2) Paralleling inverter-based generation devices, and 3) Shedding discretionary loads to increase system endurance.

The system begins to optimize load factor at each generator unit and shuts off units if the load can be supported with fewer units running (at higher load factors). Should each of the running units be operating below a threshold load factor (for example, 50 percent), one generator is commanded to shut down to increase load factor of the remaining units. Conversely, should each of the running units be operating over a threshold load factor (for example, 80 percent), an additional DER or energy storage service is engaged in reserve to rapidly ramp up in case a load spike occurs during this time.

By this time, inverter based (renewable) assets have sensed the energized system and begin to provide renewable power (for example, PV) or stored energy (for example, 4-quadrant energy storage devices) to the network, thereby deferring the amount of power the generator fleet must deliver.

The microgrid master controller continuously iterates the full network optimization based on the changes in load, renewable energy availability, state of charge of storage devices, and status of generator/fuel availability. Finally, the system may open breakers to discretionary loads to meet system endurance targets during extended utility outages. Load shedding actions may be triggered based on pre-determined thresholds including remaining fuel levels, devices state(s) of charge, or projected remaining overall system endurance.

6-1.5 Re-Synchronization Back to External Utility (Soft Transition Only).

Once the system detects utility power has returned on the primary side of the PCC, it waits a predefined period of time to determine if the utility is stable and begins the process to soft transition back to commercial power. Because the microgrid's signal will likely be out of phase with the utility, the system phase locks the utility's phase with the microgrid by waiting for the microgrid signal's phase to align with the incoming utility signal's phase, synchronizes the systems and closes the substation breaker.

Loads not supported by the microgrid are slowly added, sequentially; the objective is to maintain a steady escalation of power and avoid a disturbance that trips the breakers. Once all loads are online, the microgrid issues shut down commands to its networked generator fleet.

6-1.6 Testing and Diagnostic Mode.

The microgrid system must be tested periodically verify proper operational capability. Testing must be monthly or quarterly (as often as the mission allows) to verify working order of the equipment and system. Testing can incorporate emergency generator testing and can allow sources to be tested under load while mitigating unnecessary facility outages associated with moving to and from generator power. Refer to paragraph 7-2 for further information on testing.

6-2 UTILITY CONSIDERATIONS.

See UFC 3-540-08, Chapter 8 for information related to utility relations and financial incentives. An example of such utility incentives can be found at California Public Utilities Commission Rule 21.

6-2.1 Utility Interconnection and Secure Islanding.

A properly designed microgrid can become a resource during normal operations to self-manage power consumption and cost, independent of the commercial utility provider. Installation personnel can also use the microgrid to negotiate alternative rate structures with the utility in exchange for cooperation in managing the grid loads. Some commercial utilities have significant limitations with respect to interconnection agreements, including limitations on: power export, operating in parallel with the external grid, device isolation/lock out requirements, etc. Early discussion with the commercial power provider must be part of the preliminary background data gathering. Bases are encouraged to use any available Utility Company Fast Track / Pre-Application processes, whenever possible.

Designers must coordinate with the local commercial power utility to identify microgrid performance and interconnection requirements relating to islanding, protection, and paralleling (if permitted by the grid operator). Depending on the nature of the site and prevailing utility contractual arrangements, technical discussions may be necessary to address system operation when grid-connected. Discussions must include options for regularly scheduled demand reduction, power export, and paralleling with the utility if possible. When this is not possible, “hard transitions” to islanded operation could be necessary, and even then, utility operators may allow “soft transitions” to utility power by having the site remain on microgrid power following phase-lock resynchronization to the grid. This approach allows load to be gradually shifted back to the commercial power system, once it is restored and stable.

When developing the microgrid project, it is prudent to perform energy audits of the loads within the microgrid boundary in order to identify opportunities to reduce load, thereby reducing microgrid size and cost. Communication with the local electric utility should include the process for adding future electrical load within the microgrid boundary as operations move from current fossil-fueled operations to carbon-free energy supply. As noted above, it is critical to involve utility representatives early in the design process to discuss tariff interactions, policy guardrails, and the interconnection process, which can be lengthy given the potential size and complexity of these projects. For example, Southern California Edison (SCE) Account Managers in SCE’s Business Customer Division helps manage interconnection process and provides information related to available incentive programs.

6-2.2 Commercial Utility Relations.

Establishing a microgrid can significantly change the business relationship between the military installation and commercial utility. If the installation uses a standard large service rate-structure contract, the microgrid can be used to manage energy and reduce the installation’s cost under its existing agreement. Additionally, the opportunity exists to coordinate the microgrid with commercial utility’s operation; in such cases, the commercial utility may offer a modified rate schedule in exchange for a benefit. The commercial utility may be able to invest in the project capital or operating cost budget.

The Federal Energy Regulatory Commission establishes reserve requirements for utilities. Many utilities will offer alternative rate structures with incentives to customers if the customers can help reduce the need for utility investment in reserve resources (which are expensive and produce little or no revenue).

Curtailable Service: In exchange for rate benefits, the customer agrees to reduce power usage according to a mutually agreed upon schedule. Distributed System Generation (DSG): In exchange for benefits, the customer agrees to bring generators online at the request of the utility. There are limits on the amount of power that must be provided by the customer and the customer has the right to refuse under certain circumstances.

All networked devices and systems must be in compliance with IEEE 1547 Chapter 8 requirements. Inverter based devices must comply with UL 1741.

Special design attention must be given to cases requiring accommodation of the following:

- Paralleling with the commercial utility grid (if permitted by the grid operator)
- Interconnection of “blinkless” devices intended to continually parallel with the utility in order to provide soft transition in and out of islanded operation
- Special operational needs and requirements of grid operators of smaller utility systems that may allow wider grid operating ranges involving customized calibration and field validation of controls, protection, and isolation.

CHAPTER 7 OPERATIONS AND SUSTAINMENT CONSIDERATIONS

Long-term, user-friendly, and sustainable operation is the primary consideration of all aspects of design, commissioning, training, and transitioning of the microgrid system. While automation and device-integrated controls represent valuable opportunities to improve mission resilience and system efficiency, such capabilities must be integrated into the system transparently, intuitively, and easily managed by installation public works personnel. Systems must have the capacity to operate safely, securely, and logically with maximized operational visibility over the lifecycle. For Army, Navy and Air Force, microgrids that support mission critical facilities must support a mission of 14 days (or more days during unscheduled electric power outages). Note that Air Force microgrids require a 7-day fuel plan but that is not intended to state that USAF policy is to island for 7 days. A 7-day fuel plan is designed so that all USAF generators have a plan to operate beyond their local storage requirement. Other areas of consideration may include the following:

- Automated operation and restoration sequences consistent with installation and mission CONOPS
- Provisions for testing including testing under load (as well as use of load banks)
- Testing controls
- Startup and RE integration sequence
- Integration with existing or planned supervisory control and data system/ industrial control system (SCADA/ICS) based grid operation
- Real time user visibility to operational metrics
- HMI based user accessibility
- Standardized ICS configuration management for streamlined operation
- Cyber sustainment and re-configurability

7-1 SYSTEM TRAINING.

To successfully transition a complex microgrid system from design to operation, personnel training is critical. Implement training using information acquired during the detailed engineering design phase.

The training material and strategy must be customized to the specific installation and complexity of the microgrid system. Additional roles and responsibilities may be added including: CIO and cybersecurity hygiene, ICS maintenance, operation of HMI, and SCADA familiarity, etc. Separate training regiments must be considered and developed for each role/responsibility (public works officers, CIO, operators, maintenance personnel).

Specific personnel needs must be determined based on lessons learned during commissioning, as well as interviews with key personnel to account for current operations, focus areas, and roles. Training material and strategy must be updated appropriately to reflect system improvements and modifications.

7-2 PERIODIC OPERATIONAL TESTING.

Periodic testing of the microgrid system provides higher confidence in generator readiness and familiarity by operators during times of need. Testing can be monthly or quarterly to verify working order of the equipment and system. At a minimum, the system must be tested for black start annually (this can be coordinated with DoD's Energy Resilience Readiness Exercises). If facility-level DERs are part of the microgrid, testing must be coordinated with facility generator testing per UFC 3-540-01. Generator assets must be tested in accordance with maintenance intervals and procedures as prescribed by the manufacturers. Load banks must only be used where no alternative exists to test the system under load without unacceptable mission disruption.

Testing must include operating generation under variable load factors and with reduced mission disruption or hard transition to end users (moving to and from generator power). This can be facilitated by operating the system in parallel with the external grid or redirecting power via looped distribution systems. This will also test the microgrid's ability to island and black start all supported mission loads without external grid support (per DoD Framework for Planning and Executing Black Start Exercises). Testing under real world mission and load conditions is strongly recommended.

Microgrid performance results (as required by each service) must be kept on file with annual reporting of the overall system status to the office of responsibility for system certification.

APPENDIX A MICROGRID BACKGROUND INFORMATION

A-1 MICROGRIDS AND DOD INSTALLATION ENERGY POLICY.

Microgrids and Networked standby solutions advance 3 broad areas of DoD installation policy; 1) Mission Resilience and Off-Grid Endurance, 2) Increased Utilization of Renewable Energy Systems, and 3) Consolidated Cybersecurity within Defined Network Boundaries with Defense in Depth.

A-1.1 Executive Orders

EO 14057 sets high standards for many items, including the use of renewable energy in federal buildings; 30 percent of the electrical energy consumed by federal agencies must be renewable by fiscal year 2025 and each year thereafter (note the goal is an aggregate and does not apply to each building individually). Microgrids are an effective means of using renewable energy during grid power outage situations. By effectively using microgrid resources (hardware, control systems, and software), the penetration of renewable energy may be increased during normal operation.

A-2 LOAD CHARACTERIZATION USING AMI DATA.

Load information is used to determine microgrid resources needed and for designing the microgrid system. During the initial study, the feasibility load analysis can be challenging. An AMI system, which is increasingly used, can provide detailed data. However, for specific loads, AMI data may not be available. During the feasibility study, designers must estimate load with sufficient confidence process using available information. If confidence is acceptable, designers may proceed with feasibility knowing that higher-fidelity data may inform preliminary design. Alternatively, designers may choose to pause, selectively install AMI equipment, and gather additional data before readdressing the load analysis problem.

Areas to consider for thermal and non-electrical load analysis include:

- Magnitude of Real (Watts) and Reactive (Vars) power for each phase and total
- Apparent Power in VAs for each phase and Total
- Prevalence of volatile, high-ramp rate loads, or other load following requirements
- Prevalence of Specialty or Industrial loads with motor start requirements or potential for Phase imbalance impact
- Power Factor for each phase and average
- Averages of Energy in kWh and Reactive
- Rated capacities of infrastructure
- Seasonal effects of temperature and usage

- Derating factors for equipment
- Theoretical additional load information

APPENDIX B ANALYSIS AND DESIGN MODELING TOOLS

B-1 ANALYSIS TOOLS.

Power System and Utility Modeling may include the following:

- Short Circuit Analysis: Calculates the maximum available fault current at each bus in the system
- Arc-Flash Analysis: Determines the duration, amount of energy released, and minimum distance required to protect an individual from an arc-flash
- Load Flow Analysis: Provides magnitude and phase angle of the voltage at each bus and the real and reactive power in each feeder; analysis includes generators, transformers, and renewable resources
- Voltage Profile Analysis: Load-flow analysis is used to develop voltage profiles for each scenario; this is particularly important when renewable resources are included in the system as rapid output swings may introduce instability in the system; instabilities that may not be a problem for a large utility grid may be an issue for a microgrid
- Coordination Studies: Determines the proper time versus current settings for medium-voltage relays based on feeder cables, transformer inrush current, generator size, and time-current setting of other equipment; objectives include devising relay settings to be tolerant to normal events such as inrush currents and still provide maximum protection from failure (fault) events, and having downstream circuit breakers clear first, thus compartmentalizing the outage to the smallest subsystem

Additional considerations are as listed:

- Analyzing Allowable Contribution of inverter-based power generation assets
- Grid tolerance and Grid Characterization and Modeling (if installation determines highly stressed grid or high RE penetration)

B-2 MICROGRID DESIGN MODELING TOOLS.

In accordance with Section 2911 of Title 10, DoD is required to use tools that are accurate and effective in projecting the costs and performance of potential microgrids. This appendix serves to define those requirements and provide a list of tools currently meeting these requirements, which may be used in developing microgrid projects and assessing alternatives. As microgrid design tools continue to evolve, this Appendix will be updated every three years.

Microgrid design tools are used to create conceptual designs at approximately the 10% to 20% design level and provide estimates for system performance and life cycle costs. They are used by the government to consider design alternatives, project cost estimates, establish RFP requirements, and assess alternative designs. Private sector engineering firms use them in combination with utility design tools to develop 100% designs.

B-2.1 Modeling Tool Requirements.

Section 2911 requires DoD to use tools to design and assess microgrid options. Tools must:

- Provide an accurate projection of the costs and performance of the energy resilience measure being analyzed,
- Produce resulting data that is understandable and usable,
- Consistent with standards and analytical tools commonly applied by the Department of Energy and by commercial industry,
- Adaptable to accommodate a rapidly changing technological environment,
- Peer reviewed for quality and precision,
- Measured against the highest level of development for such tools.

The following provides an assessment of available microgrid design tools relative to these requirements. Only microgrid design tools that meet Section 2911 of Title 10 requirements should be used to develop conceptual designs for DoD installation microgrids, assess cost and performance tradeoffs, and establish the requirements for future proposals for detailed designs. From the tools that meet Section 2911 requirements, installations should select one based on the design issues relevant for their installation.

B-2.1.1 Costs Requirements.

Accurate projection of costs requires the following information on finances, DER costs, and utility tariffs:

- Finances: Transparent analysis period, inflation, and discount rates are required to ensure lifecycle financial calculations are accurate and meet projects’ requirements and current financial conditions.
- DER Costs: Transparent assumptions on the capitol and O&M costs of all DERs being modeled that are consistent with industry practices and that can be modified to account for changing technologies.
- Utility Tariffs: Ability to accurate model utility tariff structure used by installations. Factors to consider include energy costs, demand charges, and time of use rates as needed.

B-2.1.2 Performance Requirements.

Accurate projection of performance requires the following information on installation energy loads and DER performance:

- Energy Load: The installations total and critical load at a resolution of one hour or less for an entire year is used to calculate the system's performance.
- DER Performance: Renewable and conventional DER performance is modeled using transparent techniques that are consistent with industry practices and can be updated to account for changing technologies.

B-2.1.3 Peer Review Requirement.

The model has been peer reviewed through publication in scientific or engineering journals.

B-2.2 Tools Reviewed.

Recent reviews[1,2,3] of existing software solutions and tools developed through DoD funding led to the consideration of the following conceptual design tools:

1. **DER-CAM** (Distributed Energy Resources Customer Adoption Model) is a decision support tool that can find optimal distributed energy resource (DER) investments for multi-energy microgrids developed and supported by Lawrence Berkeley National Laboratory (https://gridintegration.lbl.gov/der-cam). DER-CAM is publicly available and free to use.
2. **DER-VET** (https://www.der-vet.com/) developed and supported by the Electric Power Research Institute, is a free, publicly accessible, open-source platform that can optimize the value of distributed energy resources (DER) based on their technical merits and constraints for microgrids. It determines optimal size, duration, and other characteristics for maximizing benefits based on site conditions and the value that can be extracted from targeted use cases.
3. **ERA** (Energy Resilience Assessment) is a tool designed and supported by MIT Lincoln Laboratory that assists installations and missions to explore alternative microgrid technology solutions for meeting critical power requirements. It performs a system analysis of alternatives based on life

[1] Microgrid Analysis Tools Summary, https://www.nrel.gov/docs/fy18osti/70578.pdf
[2] A review of microgrid development in the United States – A decade of progress on policies, demonstrations, controls, and software tools, Applied Energy, Volume 228
[3] Assessment of Existing Capabilities and Future Needs for Designing Networked Microgrids, SAND2019-2436

cycle cost and ability to meet the critical load. It is a web-based tool that requires a DoD Common Access Card to access.

4. **HOMER** is a microgrid design software tool originally developed at the National Renewable Energy Laboratory and enhanced and distributed by HOMER Energy (https://www.homerenergy.com/products/pro/index.html). It provides simulations of grid-connected microgrid systems that combine traditionally generated and renewable power, storage, and load management. Access to the tool requires a licensing fee.

5. **MDT** (Microgrid Design Toolkit) is a free decision support software tool (https://energy.sandia.gov/download-sandias-microgrid-design-toolkit-mdt/) designed and supported by Sandia National Laboratory for microgrid designers in the early stages of the design process. The software employs powerful search algorithms to identify and characterize the trade space of alternative microgrid design decisions in terms of user-defined objectives.

6. **MicrogridUP** is a recently developed tool by National Rural Electric Cooperative Association (NRECA) (https://microgridup.org). It leverages DOE-developed solutions to lower microgrid planning costs to DoD by developing a repeatable microgrid planning framework that simplifies the process of planning for the integration of assets with legacy infrastructure. The tool is publicly available at no cost.

7. **NPS Tool** was developed by the Naval Post Graduate School (NPS) and the University of Wisconsin - Milwaukee (https://microgrid.nsetti.nps.edu/). A simple API is currently available and a microgrid simulation tool is under development. The tool is sponsored by Navy Shore Energy Technology Transition and Integration and Energy System Technology Evaluation and Program Office of Naval Research.

8. **REopt** was developed and supported by the National Renewable Energy Laboratory (https://reopt.nrel.gov/) and is a free decision support platform that evaluates how renewable energy and storage can be incorporated alongside conventional generation in grid-connected microgrids to meet critical loads at the lowest life cycle cost. REopt optimizes a microgrid system’s DERs to provide ongoing economic savings and extend site survivability during outages.

9. **XENDEE** provides a microgrid design support system (https://xendee.com/) that implements a physically based economic tool that couples financial optimization with detailed electrical power system analysis to verify resilience and financial viability. XENDEE provides support through a subscription-based service for initial feasibility studies through balance of system engineering analysis.

10. **HelioScope** is an industry leading software platform for designing high-performance solar arrays. Folsom Labs developed HelioScope, an advanced solar PV design tool.

11. **Resilience and Cost Assessment Tool** was developed by NAVFAC EXWC, creating resilience and cost models implemented with a corresponding methodology, “Resilience Assessment of Islanded Renewable Energy Microgrids.” The methodology generates the resilience and cost trade space for a site specific location. This tool enables more informed decisions on microgrids by being able to choose the microgrid architecture that provides the most cost effective resilience. The Naval Post Graduate School adapted the models to a web-based object-oriented design API incorporating the initial methodology. The tool’s development was sponsored by Navy Shore Energy Technology Transition and Integration, and Energy System Technology Evaluation and Program Office of Naval Research.

Table B-1 provides an assessment of these microgrid design tools with respect to costs of use, evaluating system performance, and peer review.

Table B-1 Microgrid Design Tools & Section 2911 Requirement Status

	Costs	Performance	Peer Review
DER-CAM	Yes	Yes	Yes
DER-VET	Yes	Yes	Yes
ERA	No	No	No
HOMER	Yes	Yes	Yes
MDT	Yes	Yes	Yes
MicrogridUp[1]	Yes	Yes	No
NPS Tool[2]	No	No	Yes
REopt	Yes	Yes	Yes
XENDEE	Yes	Yes	Yes

[1] A peer review article on MicrogridUP tool will be published in 2023.

[2] NPS plans to expand their tools capabilities to meet Section 2911 performance and cost requirements over the next few years.

The DER-CAM, DER-VET, HOMER, MDT, MicrogridUP, Reopt, and Xendee all meet Section 2911 requirements and may be used by DoD for the component of conceptual design shown under Table 4-1 to establish performance and costs options, and compare alternative opportunities. Neither ERA nor the NPS Tool meet the statutory requirements and should not be used for microgrid design work. Other tools that can demonstrate they meet these performance requirements may also be used.

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APPENDIX C CYBERSECURITY FOR MICROGRIDS

Appendix C discusses cybersecurity as it pertains to microgrids.

The design must include strategies to assure that a cyber-attack on the grid does not also compromise the microgrid. Microgrid control design must follow the published UFC 4-010-06 for Cybersecurity of Facility-Related Control Systems. The current approach relies on a more holistic strategy of building security in, not bolting it on.

Based on the organizational mission and details of the control system, the System Owner and Authorizing Official (AO) determines impact levels (LOW, MODERATE, or HIGH) for the control system per UFC 4-010-06.

C-1 APPLYING RISK MANAGEMENT FRAMEWORK TO MICROGRID CONTROLS SYSTEMS

All microgrid control system designs must follow the Risk Management Framework (RMF) which details how risk management is applied to DoD information systems. As defined by the National Institute of Standard and Technology (NIST), the RMF is "the process of managing risks to organizational operations (including mission, functions, image, reputation), organizational assets, individuals, other organizations, and the Nation, resulting from the operation of an information system, and includes: (i) the conduct of a risk assessment; (ii) the implementation of a risk mitigation strategy; and (iii) employment techniques and procedures for the continuous monitoring of the security state of the information system."

Within DoD, each agency has an AO who determines the "Authority To Operate (ATO)" based on risk, and approves the final implementation (representing minimized, well-managed risk). When applying RMF to microgrid controls systems, the network boundary should include all control points and IP-addressable assets constructed as part of, or controlled by, the microgrid system.

Facility control systems are not information technology (IT) systems; they should not use standard IT system approaches and should not be connected to public systems, especially internet systems, and should not have remote access. The public internet system is one path for cyber-attack.

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APPENDIX D LESSONS LEARNED AND EXAMPLES

D-1 LESSONS LEARNED.

D-1.1 Acquisition Lessons Learned.

Since microgrids cannot be procured as a single system, efficacy and competence of the final product is a function of systems integration. To the extent possible, acquisition should be "full and open" and based on "best value" with appropriate weight on performance metrics, technical approach, and past experience.

D-1.2 Design Lessons Learned.

At the preliminary design phase, performance metrics should be used to inform best-value design acquisition for both Design-Build and Design-Bid-Build. The government should seek detail regarding expected performance metrics and the level of detail of controls design needed prior to issuance of construction contract. Typically, government contracts don’t include specific language requiring exact sequence of operation and expected outcome of each action and reaction of all equipment. As such, ensure that it is done in the request for proposal stage.

D-1.3 Operations Lessons Learned.

D-1.3.1 Power Critical Communications Nodes and Servers.

A number of critical communications nodes and servers lacked sufficient or functional UPS and generation backup power systems resulting in widespread NIPR (Non-Classified Internet Protocol Router) and SIPR (Secure Internet Protocol Router) outages. Power and SIPR outages at Command Centers would have significantly degraded operations in the event of an urgent task. Connect these nodes to the microgrid, add local backup power systems with enough capacity to bridge transition times as needed, and re-test.

D-1.3.2 Identify UPS Maintenance Contract.

No standardized maintenance contract exists to support UPS units on the installation, and the party responsible for funding and overseeing maintenance is often unclear. Identify a plan to obtain a site-wide UPS maintenance contract outlining clear roles and responsibilities.

D-1.3.3 Preserve Copper Landlines.

Copper landlines are still the primary voice backbone for some bases and is a reliable system. Ensure personnel are aware that these services will function during a power outage.

D-1.3.4 Update Critical Facility Lists.

A prioritized critical facility list was unavailable during the exercise, delaying responses to important facilities. Create a list and review it with all mission owners, support services, and installation leadership.

D-1.3.5 Resolve Nuisance Fire Alarms.

Address nuisance fire alarm issues to prevent significant disruptions to missions and to ensure that critical resources are available to respond to real emergencies.

D-1.3.6 Conduct a Long-duration Test for the Entire Installation.

Conduct a long-duration (ideally multi-day) installation-wide outage to demonstrate refueling, and to fully evaluate communications interdependencies and backup power systems for facilities not connected to the microgrid. A commercial cellular communications outage inject would also be useful to ensure bases are prepared for an unplanned, long-duration, regional power outage.

D-1.3.7 Integrate Findings into the Installation Energy Plan.

Integrate lessons learned from the microgrid test into drafting the base Installation Energy Plan.

D-1.3.8 Create Preemptive Warning Prior to Non-critical Generation Shutdown.

Ensure microgrid operators have preemptive flags alerting them of an impending problem with generation units that is not critical (e.g., Tier 4 emissions) and develop a procedure to override during outage conditions.

D-1.3.9 Train Sufficient Microgrid Operators.

Ensure there are enough trained microgrid operators for continuity of operations in the event of a long-duration outage scenario.

D-1.3.10 Improve Microgrid Power Control System.

Consider the development of an automated procedure to bring the entire installation online in the event that sufficient generation capacity exists. Continue to mature the PCS software and document lessons-learned.

D-1.3.11 Evaluate the Advanced Metering Infrastructure (AMI) and SCADA system.

This will determine if additional benefit can be gained by connecting legacy infrastructure into the new microgrid system. Leveraging all utility equipment into the microgrid system could greatly strengthen capability.

D-1.3.12 Improve Microgrid Power Quality.

Address power quality concerns with the microgrid, both through distribution system devices (e.g., battery energy storage systems and capacitors) and at the local level, and continue to engage with mission owners that have expressed concerns to increase their confidence to operate this equipment in a future exercise.

D-1.3.13 Document Microgrid Lessons Learned.

Consider the development of a living microgrid lessons-learned document that can be shared broadly across DoD.

D-2 PROJECT EXAMPLES.

D-2.1 Sample of DD1391.

<table>
<tr><td colspan="2">1. COMPONENT
ARMY/NAVY/USAF</td><td colspan="4">FACILITY ENERGY IMPROVEMENTS</td><td>2. DATE 11 Jan 2022</td></tr>
<tr><td colspan="3">3. INSTALLATION AND LOCATION</td><td colspan="4">4. PROJECT TITLE:
Energy Security Microgrid for Critical Facilities</td></tr>
<tr><td>5. PROGRAM ELEMENT
ECIP</td><td colspan="2">6. CATEGORY CODE
Multiple</td><td colspan="2">7. PROJECT NUMBER
P-123</td><td colspan="2">8. PROJECT COST ($000)</td></tr>
<tr><td colspan="7">9. COST ESTIMATES</td></tr>
<tr><td colspan="3">ITEM</td><td>U/M</td><td>QUANTITY</td><td>UNIT COST</td><td>COST ($000)</td></tr>
<tr><td colspan="3">Energy Security/Microgrid
Natural Gas Generation (Capacity)
Diesel Generation (Capacity)
Energy Storage (Capacity)
Building for Generation plus Interconnection Equipment
Loads & Control
System Integrator & Controller
Cyber security equipment, testing, and upgrades</td><td>
EA
EA
EA
EA
LS
LS
LS</td><td></td><td></td><td></td></tr>
<tr><td colspan="3"><u>MATERIAL AND LABOR SUB-TOTAL</u>
General Provisions (25%)
Contingency (5%)
<u>SUB-TOTAL</u>
SIOH (5.7%)
<u>TOTAL PROJECT COST</u>
Engineering Design (4%)
<u>TOTAL FUNDING COST</u></td><td></td><td></td><td></td><td></td></tr>
</table>

<u>10. DESCRIPTION OF PROPOSED CONSTRUCTION:</u>

<u>Executive Summary of Project Benefits</u>:

- ✓ Financial – The project has a payback of 25 years depending on the use and application of the microgrid. Energy cost savings were identified through demand response programs with the local utility and the value of energy security was analyzed and savings were determined by NREL
- ✓ Energy Savings – The benefits to the project go beyond energy savings as the project will demonstrate a never before achieved capability for installation wide renewable integration in a microgrid.
- ✓ Goals – This project will achieve Campaign Plan goal for energy independence by as well as meet many challenges from the DoD to achieve energy security.
- ✓ Energy Security – This project will provide energy security to all critical facilities with the use of renewable energy, energy storage, and convention fuel. This microgrid will power hundreds of buildings on the mission critical side.
- ✓ Synergistic Effect – This project will integrate many technologies such as renewable energy, direct digital controls, industrial control systems, energy storage, advanced metering, and SCADA. This microgrid project is designed to be scalable to accommodate future mission critical facilities added to the installation.

Table D-1 below shows San Diego Gas and Electric (SDG&E) Reliability Numbers. This calculation assumes a higher probability of large duration outages for the bases then has been historically observed. The future probability of outages is expected to increase but the magnitude of any reliability change is unknown. Between 2001 and 2010 for SDG&E, the average annual outage interruption per customer was approximately 1h and 45 minutes, and the average annual number of interruptions per customer was 0.7.

Table D-1 Example SAIDI/SAIFI Reliability Numbers

CRITERIA	SAIDI	SAIFI
Including CPUC Major Events (2010)	89.77	0.863
Excluding CPUC Major Events (2010)	67.74	0.543
10-Year Average (2001-2010) Including CPUC Major Events	105.59	0.691
10-Year Average (2001-2010) Excluding CPUC Major Events	64.09	0.596

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APPENDIX E DEMAND RESPONSE

Once changes are incorporated in the commercial utility agreements, the installation can autonomously take the following actions described in E-1 through E-3.

E-1 CONTROL OF DEMAND CHARGES.

There are multiple technologies that may be used for demand response, demand reduction, including load management, energy storage, and the use of renewable and non-renewable energy sources. Microgrid designers need to consider how the design of a microgrid could be used to reduce demand or load shifting.

E-2 POWER FACTOR CORRECTION.

Electrical systems include loads that are not purely resistive. More complex energy uses, such as motors, may cause phase misalignment of voltage and current. Apparent power does not equal true power. The misalignment, called Reactive Power, is measured in units of Volt- amp reactive. Utilities may charge the installation for a power factor that is less than their established rate structure (typically 0.90 leading or lagging). Microgrid designs may typically include control systems to correct power factor. The interconnecting utility will require the project to meet certain reactive power.

The interconnecting utility will require the project to meet certain reactive power requirements at the point of interconnection. Per FERC Order No. 827, a DG project must achieve a gross dynamic reactive power requirement of at least 0.95 leading through 0.95 lagging utilizing only the dynamic reactive power capability of the planned inverters and dynamic reactive power compensation equipment installed at the substation (e.g., STATCOM). This requirement should be assumed to be applicable over a voltage range of 0.95 pu through 1.05 pu at the high side of the substation. Check with utility for rate considerations for a 0.95 +/- 0.05 power factor.

E-3 CONTRACT REVISION.

In cooperation with the local utility and by negotiating a new contract, the installation can take additional actions. Within the United States, utilities are highly regulated and do not have unlimited freedom to negotiate rates. However, they frequently have published alternative rate schedules that provide discounts to customers willing to modify consumption, or can work with installations to develop site-specific tariffs. Other options for active demand management include on-call demand reduction, fixed reduction on preset schedule.

E-3.1 On-Call Demand Reduction.

On-call demand reduction is an agreement in which the utility customer agrees to reduce its load upon request and receives a reduced rate structure in return. The number of times per month for a reduction request is usually limited and the duration and amount of the reduction is limited. The microgrid generator resources (if permitted for non-emergency use) may be used to offset the load, and control systems can be used to shed or manage the load.

E-3.2 Fixed Reduction on Preset Schedule.

This is an agreement in which the utility customer agrees to reduce its load by a fixed amount for a set time every day. The microgrid generator resources (if permitted for non-emergency use) may be used to offset the load, and control systems can be used to shed or manage the load.

Early in the microgrid design process, designers should coordinate with the local commercial power utility. Discussions and contract negotiations may extend for more than a year. The following issues and significant opportunities could arise, depending on discussions with the commercial utility provider(s).

APPENDIX F SUPPLEMENTARY ELECTRICAL FAULT PROTECTION AND GROUNDING

Early consideration should be given to the condition index of the existing electrical system. The Facility Condition Index and Condition Index/Condition Rating should be reviewed as part of the initial assessment. Validate compliance with UFC 3-550-01, NFPA 70, and IEEE C2 for requirements related to general system grounding. Specific engineering analysis is often necessary for short to ensure adequate provision of circuit protection and grounding of islanded networks predominantly energized by facility-scale distributed generation systems.

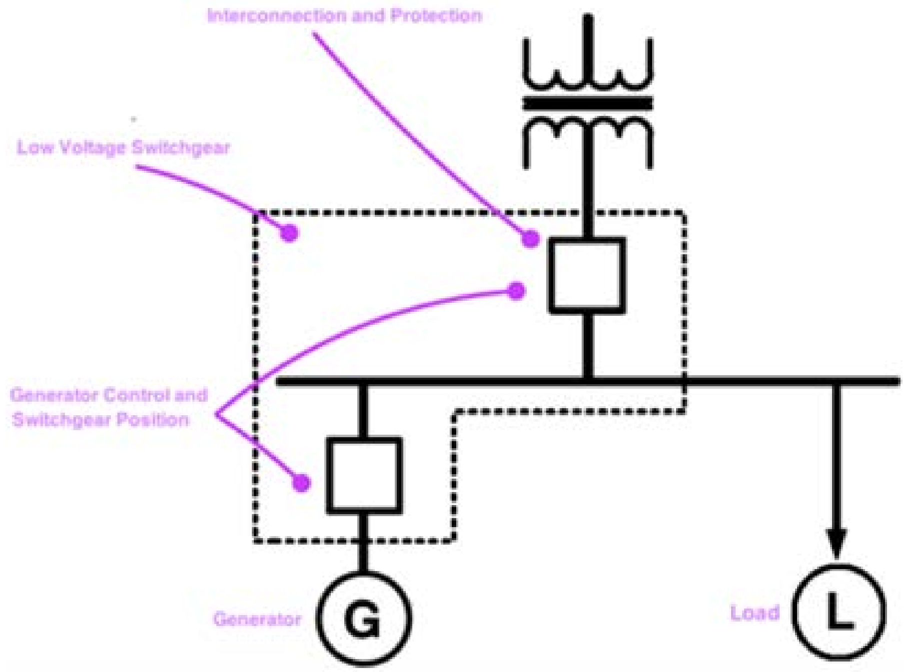
F-1 ELECTRICAL SYSTEM PROTECTION.

A challenge related to the microgrid design is electrical system protection. A pre-microgrid design includes protective devices that can identify faults and nearly instantaneously isolate the faulty circuit feeder to prevent damage to the remainder of the circuit and to the system as a whole. These devices often function by detecting high current levels associated with a fault. When connected to the grid, the utility system is capable of delivering the energy necessary to produce the high current. In microgrid mode, the distributed generators may not have capacity to provide enough energy to produce a sufficiently large current spike that could be detected by the protective equipment; the fault could go undetected and cause system damage. The onsite grid designs and protection equipment that were adequate before a microgrid was implemented may not offer adequate fault protection and may need to be revised. Analysis of the system protection design will include system simulation modeling prior to final design and construction. Protective device coordination studies will be performed as part of design and updated during construction.

F-2 SYNCHRONIZATION.

An additional challenge is synchronization. As soon as the primary grid fails, DERs begin to come online. Many of an installation’s DERs will be standard emergency generators that are associated with specific loads. The DERs will operate autonomously, as they normally do, and will tend to be out of phase with each other. When the PCC is opened and the installation’s connection to the grid is open, the DERs must synchronize before forming a microgrid. DERs must be “in phase” as they are connected (this is also true of the renewable resources that are added to the microgrid). A reference frequency is selected from among the DERs and all other DERs synchronize to the reference. The synchronization process repeats when the grid comes back online and the microgrid prepares to reconnect at the PCC. In this case, however, the microgrid DERs (in unison) use the utility frequency as their reference and synchronize to the utility.

Figure F-1 Interconnection and Protection on Transformer[1]



[1] US Army Corps of Engineers, Energy Research and Development Center, Energy Branch, 2022

APPENDIX G GLOSSARY

G-1 ACRONYMS.

AFCEC	Air Force Civil Engineer Center
AFCEC/CO	AFCEC/Operations Directorate
AFCEC/CN	AFCEC/Energy Directorate
AMI	Advanced meter infrastructure
AO	Approving Official
ATO	Cybersecurity Authorization to Operate
ATS	Automatic transfer switch
BESS	Battery energy storage system
BIA	Bilateral Infrastructure Agreement
CCR	Criterial Change Request
CIO	Command Information Office
CONOPS	Continuity of operations
COTS	Commercial-off-the-shelf
DA	Department of the Army
DER	Distributed energy resource
DoD	Department of Defense
DOE	Department of Energy
DSG	Distributed System Generation
EPSS	Emergency power supply systems
ERCIP	Energy Resilience and Conservation Investment Program
ESPC	Energy Savings Performance Contract
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation

FESS	Flywheel Energy Storage System
High-VAR	High-Voltage Volt Ampere Reactive
HMI	Human machine interface
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, US Army Corps of Engineers
ICS	Industrial control system
IGSA	Intergovernmental Service Agreement
IP	Internet protocol address
IT	Information Technology
MILCON	Military construction
MTR	Military Training Route
NAVFAC	Naval Facilities Engineering Systems Command
NEPA	National Environmental Policy Act
NIPR	Non-classified Internet Protocol Router Network
NIST	National Institute of Standard and Technology
NPS	Naval Post Graduate School
NRECA	National Rural Electric Cooperative Association
OSD	Office of the Secretary of Defense
PCC	Point of common coupling
PPA	Power Purchase Agreement
PV	Photo Voltaic
PW/PWO	Public Works/Public Works Officer
RE	Renewable Energy
RMF	Risk Management Framework
SCR	Short Circuit Ratio

SOC	State of Charge
SOFA	Status of Forces Agreement
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SIPR	Secret Internet Protocol Router Network
UCS	Utility control systems
UPS	Uninterruptible power supply
UESC	Utility Energy Service Contract
UFC	Unified Facilities Criteria
UMCS	Utility Monitoring Control System
UP	Utility privatization
VA	Volt / Amp
VPP	Voluntary Protection Program

G-2 DEFINITION OF TERMS.

Defense-in-depth: Information security strategy integrating people, technology, and operations capabilities to establish variable barriers across multiple layers and missions of the organization. (https://csrc.nist.gov/glossary/term/defense_in_depth).

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APPENDIX H REFERENCES

H-1 GOVERNMENT STANDARDS

FEDERAL

10 U.S.C. 2911, *Energy Performance Goals and Master Plan for the Department of Defense*

EO 14057, *Catalyzing Clean Energy Industries and Jobs through Federal Sustainability*

DEPARTMENT OF DEFENSE

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 1-200-01, *DoD Building Code*

UFC 3-410-02, *Direct Digital Control for HVAC and Other Building Control Systems*

UFC 3-440-01, *Facility-Scale Renewable Energy Systems*

UFC 3-470-01, *Utility Monitoring and Control System (UMCS) Front End and Integration*

UFC 3-501-01, *Electrical Engineering*

UFC 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Applications*

UFC 3-540-08, *Utility-Scale Renewable Energy Systems*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 3-701-01, *DoD Facility Pricing Guide*

UFC 3-730-01, *Programming Cost Estimates for Military Construction*

UFC 3-740-05, *Construction Cost Estimating*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

DoDD 3020.26, *Department of Defense Continuity Program*

DoDD 4270.5, *Military Construction* (http://www.dtic.mil/whs/directives/corres/html/42705.htm)

DoDD 4715.21, *Climate Change Adaptation and Resilience*

DoDI 4170.11, *Installation Energy Instruction*

ERRE Program, *DoD Energy Resilience Readiness Exercise*

Federal Energy Regulatory Commission, FERC Order No. 827, *Reactive Power Requirements for Non-Synchronous Generation*

Mission Resilience and Off-Grid Endurance

DEPARTMENT OF THE AIR FORCE

AFMAN 32-1065, *Grounding Systems,* www.e-publishing.af.mil

STATE

Office of Under Secretary of Defense, *Metrics and Standards for Energy Resilience at Military Installations*, May 20, 2021

California Public Utilities Commission, *Rule 21 Interconnection* https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/rule-21-interconnection

Southern California Edison (SCE) *Microgrids for Developers* (sce.com)

H-2 NON-GOVERNMENT STANDARDS

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2, *National Electrical Safety Code*

IEEE 1366, *Guide for Electric Power Distribution Reliability Indices*

IEEE 1547, *Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*

IEEE 1826, *Power Electronics Open System Interfaces in Zonal Electrical Distribution Systems Rated Above 100 kW*

IEEE 2030.8, *Standard for Testing Microgrid Controllers*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70E, *Electrical Workplace Safety*

NFPA 110, *Standard for Emergency and Standby Power Systems*

UNDERWRITERS LABORATORIES (UL)

UL 1741, *Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources*

UL, *Energy Storage System (ESS) Requirements*

H-3 OTHER RESOURCES

A review of microgrid development in the United States – A decade of progress on policies, demonstrations, controls, and software tools, Wei Feng, Ming Jin, Xu Liu, Yi Bao, Chris Marnay, Cheng Yao, Jiancheng Yu, Applied Energy, Volume 228, 2018, Pages 1656-1668

Assessment of Existing Capabilities and Future Needs for Designing Networked Microgrids, Shamina Hossain-McKenzie, Matthew J. Reno, John Eddy, Kevin P. Schneider, SAND2019- 2436, February 2019

Microgrid Analysis Tools Summary, National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy18osti/70578.pdf

UFC 3-550-07
19 January 2017

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE (O&M): EXTERIOR POWER DISTRIBUTION SYSTEMS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE (O&M): EXTERIOR POWER DISTRIBUTION SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
SUMMARY SHEET

Document: UFC 3-550-07, *Operation and Maintenance (O&M) Exterior Power Distribution Systems*

Superseding:

- AFJMAN 32-1082 (TM 5-684 and MO-200), *Facilities Engineering Electrical Exterior Facilities*.
- Air Force Handbook 32-1282 Volume 1, *Field Guide for Inspection, Evaluation, and Maintenance Criteria for Electrical Substations and Switchgear*.
- Air Force Handbook 32-1282 Volume 2, *Field Guide for Inspection, Evaluation, and Maintenance Criteria for Electrical Transformers*.

Description: UFC 3-550-07 provides guidance for the operation and maintenance of exterior power distribution systems.

Reasons for Document:

- Consolidate guidance;
- Provide technical requirements; and
- Incorporate new and revised industry standards.

Impact: There are negligible cost impacts associated with this UFC. However, standardized guidance will assist operators and maintainers in obtaining higher availability and design life from their installed systems.

Unification Issues: No unification issues noted.

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FIGURES

TABLES

CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This UFC updates the requirements of and replaces AFJMAN 32-1082 /TM 5-684 /MO-200, and AFH 32-1282 V1 & V2.

1-2 PURPOSE AND SCOPE.

This UFC provides guidance for operations and maintenance of electrical power and distribution systems. Electrical systems need regular maintenance to ensure continued compliance with the codes and publications referred to in this document. Such maintenance will prevent system and equipment failures and ensure maximum safety and efficiency in the utilization of the facilities. At each installation, establish a program for proper maintenance and effectively follow it. Include in this program the scope of work, intervals of performance, and methods of application including safety requirements, practices and procedures, and operations and maintenance (O&M) of electrical power and distribution systems.

The information provided applies to the plans and procedures to operate and maintain installation electrical distribution systems. Specific installation conditions may dictate the need for procedures that exceed these minimum requirements.

These systems include substations, overhead and underground electrical distribution systems, exterior lighting systems, and electrical apparatus and components. Guidance for generators is covered in the following publications:

- UFC 3-540-01;
- UFC 3-540-07 (future UFC); and
- UFC 3-520-01.

1-3 APPLICABILITY.

The guidance and standards contained within are the minimum requirements acceptable for military installations for efficiency, economy, durability, maintainability, and reliability of electrical power supply and distribution systems. The provided guidance does not automatically supersede equipment manufacturers’ instructions and requirements. When conflicts exist, follow the most rigorous requirement. The guidance and standards herein are not intended to be retroactively mandatory. Provide, as a minimum, the level of maintenance required to meet the critical mission reliability goals.

- Comply with the requirements of Occupational Safety and Health (OSHA), General Industry Standards, and 29 CFR 1910;

- Comply with UFC 3-550-01 for minimum system and component design standards;
- Comply with UFC 3-560-01 for electrical safety requirements applicable to the installation and operation of electrical systems;
- Comply with UFC 4-010-01 and UFC 4-020-01 for security requirements related to exterior electrical distribution systems; and
- Comply with UFC 3-540-07 for operations and maintenance (O&M) of generators (future UFC).

Note: for privatized utilities, this UFC is for guidance only and compliance is not mandatory.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicability of model building codes and government unique guidance for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety.

1-5 SAFETY.

Safety must always be top priority when working on or near any piece of electrical equipment. The electrical safety requirements for all electrical work activities on DoD utilities are provided in UFC 3-560-01, which provides implementation criteria for the various regulations, codes, and standards that apply to electrical safety activities.

Note: For Army installations, also comply with Army Pamphlet DA PAM 385-26.

1-5.1 Minimizing Hazards.

Material specifications, construction guidance, installation standards, material procedures, and safe working procedures have been developed to minimize hazards. Ensure all work and materials conform to the latest accepted procedures and standards, as defined in publications listed or referred to in this manual.

1-5.2 Qualifications of Electrical Workers.

Due to the inherent hazards encountered in the maintenance of electrical distribution systems and equipment, it is essential that all electrical workers be thoroughly trained and be familiar with the equipment and procedures to be followed.

1-5.3 Certification of Electrical Workers.

Properly trained electric workers will be certified in accordance with applicable publications.

1-5.4 Public Safety.

All necessary precautions will be taken to warn the public of electrical hazards or other conditions which may constitute a danger. This is especially true of temporary hazards due to work in progress.

1-5.5 Personnel Safety.

Any work on or close to electrical equipment of any kind is considered dangerous and proper safety precautions will be taken. All personnel who perform work of any kind on or near electrical equipment must be familiar with and observe all safety precautions. If an agency has a detailed labeling program or reliability program, comply with its requirements.

1-5.5.1 Safety First.

Two safety rules are mandatory as follows:

- Consider all electrical equipment is energized until it is known positively under LOCKOUT/TAGOUT (as by the presence of grounding clamps) that it is not energized. Comply with UFC 3-560-01, the applicable departmental publications, and special publications issued by the local command; and

- Work may be done only by personnel qualified by their job descriptions for that voltage level. Job descriptions to require actual hands-on work service periods to meet local utility approval. All tools and equipment must be maintained in proper operating order, be suitable for the maximum voltage level involved, and be periodically tested for compliance with all safety requirements. Consult departmental publications for specific requirements in each voltage level.

1-5.5.2 Service Safety Requirements.

This UFC addresses some safety requirements, but users must also be familiar with the service specific safety requirements.

1-5.5.3 Personal Protective Equipment.

Personal protective equipment (PPE) is equipment worn to minimize exposure to serious workplace injuries. These injuries may result from contact with electrical, chemical, physical, mechanical, or other workplace hazards. PPE may include items such as gloves, safety glasses and shoes, earplugs or muffs, hard hats, respirators, or coveralls, vests and full body suits. If PPE use is required, implement a PPE program. Address in the PPE program the hazards present; the selection, maintenance, and use of PPE; the training of employees; and monitoring of the program to ensure its ongoing effectiveness. Refer to OSHA standards and UFC 3-560-01 to become familiar with PPE requirements.

1-5.5.4 Personal Protective Temporary Grounding.

This is temporary grounding installed to protect workers engaged in de-energized line maintenance. The grounds are provided to limit the voltage difference between any two accessible points at the work site to a safe value. An expanded discussion of protective grounding principles and practices is contained in IEEE 1048; NFPA 70B; "The Lineman's and Cableman's Handbook;" and UFC 3-560-01.

1-6 CYBER SECURITY.

All control systems (including systems separate from an energy management control system or a utility control system) must be planned, designed, acquired, executed and maintained in accordance with UFC 4-010-06, DoD Instruction 8500.01 and DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

1-7 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-8 GLOSSARY.

Appendix J contains acronyms, abbreviations, and terms.

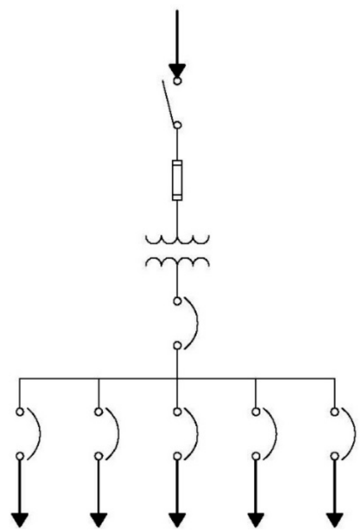
CHAPTER 2 SYSTEM CONFIGURATIONS

2-1 DISTRIBUTION SYSTEM CONFIGURATIONS.

2-1.1 Radial Feed.

Radial feed systems (Figure 2-1) are defined as having a single source and single load with no interconnections to other sources.

Figure 2-1 Radial Feed



2-1.1.1 Benefits and Limitations.

Benefits: Radial feed systems are the least expensive to build and limit losses when there is a problem as only the loads on that feed are affected.

Limitations: Radial feed systems have the highest outage impact due to being unable to feed load from other sources of power. Overhead systems typically employ fuse saving methods using reclosers and sectionalizers to minimize the impacts of the majority of faults that are self-clearing see Section 4-2.

2-1.1.2 Reliability.

System redundancy requires having identical components available and in a usable configuration so that the replacement of a failed component will not result in a long-term outage. Outages / repairs may be able to extend longer based upon the loads being served. In general, redundancy is required to meet a requirement for long-term outage sustainment. The reliability is established by the backup generator.

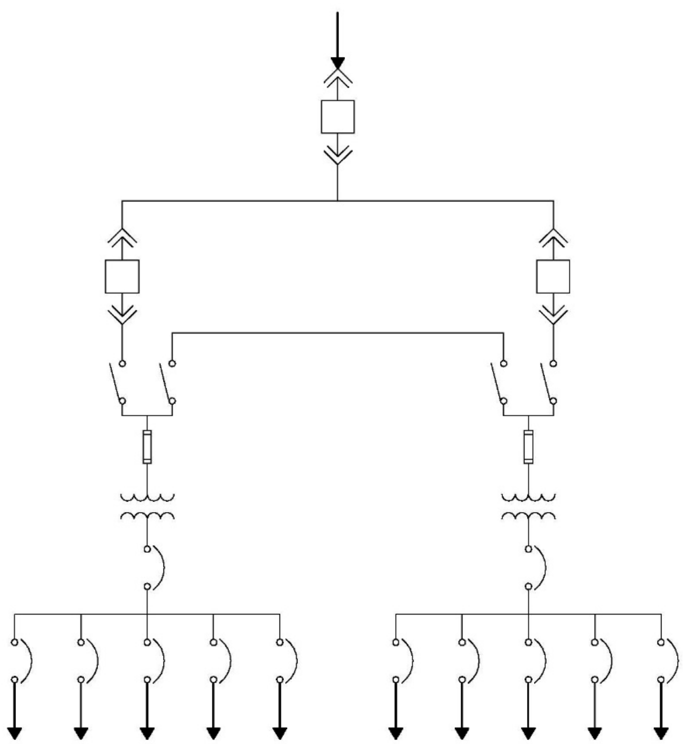
2-1.1.3 Maintenance Implications.

Maintenance tasks require components de-energizing prior to testing. Therefore, any testing must have an outage unless there are redundant feeds or redundant circuit breakers, then one component may be taken out of service and another will feed the load. Outages will be short and quick, as components can be switched out as required.

2-1.2 Loop Feed.

Loop systems (Figure 2-2) loop through the service area and then return to the source. Alternate sources or paths for the service feeder may be installed.

Figure 2-2 Primary Loop System



2-1.2.1 Benefits and Limitations.

Benefits: This is the next lowest cost system. The loop system gives another backup for the primary power feed. If a failure of the system is noted, power can be redirected through a re-configuration of the loop automatically, or manually as the system is set up. Typically, DoD installations are operated in an open loop configuration that only provides a “hot stand-by” for the system. If you operate a loop-feed closed, it can reduce the events that the entire system sees when the downstream protective devices are properly coordinated. However, more fault current is available due to the paralleling effect, which is not desirable. Limitations: By operating it open-looped, you are removing some of the benefits of building the loop. However, in the event of a typical outage caused by a blown splice on a feeder cable, the outage will take down the entire loop. Furthermore, troubleshooting may be more difficult, depending upon how the loop is installed.

2-1.2.2 Reliability.

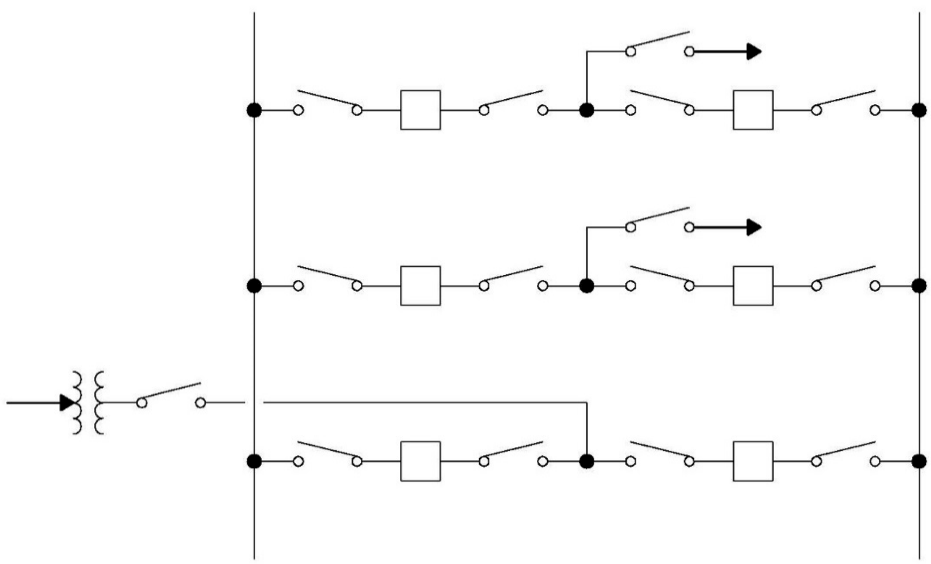
Depending on how it is operated this system is more reliable than the radial system as current has two paths to reach the loads.

2-2 SUBSTATION CONFIGURATIONS.

2-2.1 Double Feed, Double Bus.

In a double bus system (Figure 2-3), two identical busses are used in such a way that any outgoing or incoming feeder can be taken from any of the bus. Every feeder is connected to both of the buses in parallel through individual feeds. With double feeds, only the loads are individual. The system is able to have a failure of any individual feed and have a spare component substituted into its place.

Figure 2-3 Double Feed, Double Bus System



2-2.1.1 Benefit and Limitations.

Benefit: Double bus configuration increases flexibility for maintaining service through outages and performing maintenance in substations.

Limitations: Any large fault on the system will affect both buses. This is also the most expensive system, and has a lower reliability than a ring bus due to the fact that the radial feeds are not able to be maintained or replaced without taking the end load down.

2-2.1.2 Fault Tolerance.

Fault tolerance is the philosophy that states a system should survive faults with minimal downtime and if possible, automatically reconfigure itself to isolate the fault and mark it for repair. A double feed, double bus will have high fault tolerance due to the ability of the system to have alternate paths from the power source to the loads served, except to local loads. Relative fault tolerance – 3.

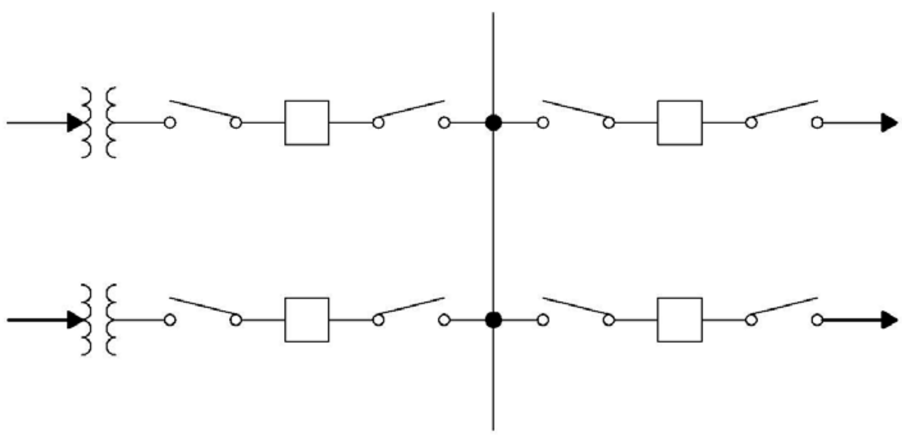
2-2.1.3 Maintenance Implications.

System maintenance is contained within the overcurrent device portion, relays, and in the cable testing.

2-2.2 Straight Bus.

A straight bus (Figure 2-4) is one where there is one source, and individual feeds to the loads. This is the same as the radial feed described above for connectivity purposes.

Figure 2-4 Straight Bus System



2-2.2.1 Benefit and Limitation.

Benefit: Straight bus/radial feed systems are the least expensive to build and radial feeds limit losses when there is a problem as only the loads on that system are affected.

Limitation: Straight bus/radial feed systems have the highest outages and highest mean time to repair due to the entire load being unable to be fed from other sources of power.

2-2.2.2 Fault Tolerance.

Straight bus systems have a very low tolerance of faults, as any one fault on the bus will take down the entire system. Relative fault tolerance – 1.

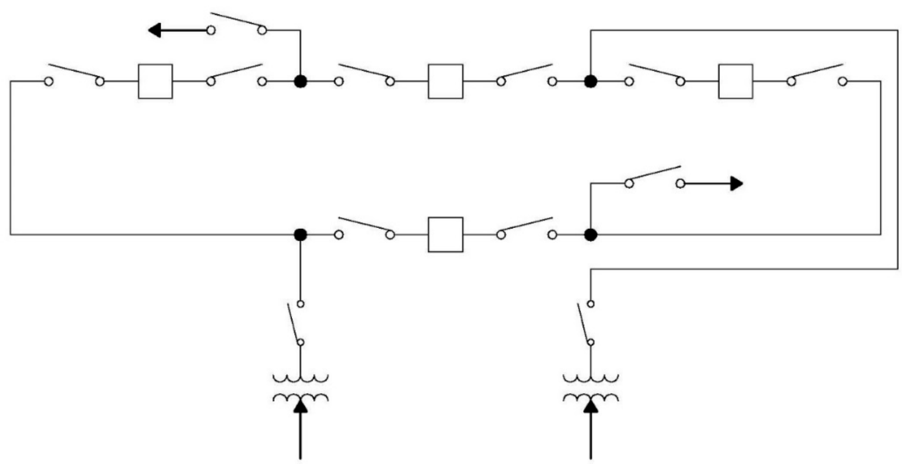
2-2.2.3 Maintenance Implications.

Maintenance tasks require the entire bus de-energized to work on without safety concerns. Outages will occur for all maintenance functions, such as insulation testing, breaker testing, etc.

2-2.3 Ring Bus.

A ring bus (Figure 2-5) is identical to a loop feed on the distribution side. This allows switching components to feed any load based upon faults anywhere on the bus structure. Loop systems must be carefully applied, as tying the two systems together, or completing the loop, will result in a future fault taking down both sides of the loop, rather than just one side. A loop system is fault tolerant to the extent that the faulted portion of the loop can usually be isolated and the entire ring placed back into service while the damaged portion is repaired.

Figure 2-5 Ring Bus System



2-2.3.1 Benefits.

A loop system loops through the service area and then returns to the source. Sometimes there are alternate sources for the power, sometimes just alternate paths.

2-2.3.2 Fault Tolerance.

This system is more expensive that a single bus, however reliability is increased based upon the ability to move feeds to loads from any direction on the bus. Relative fault tolerance – 2.

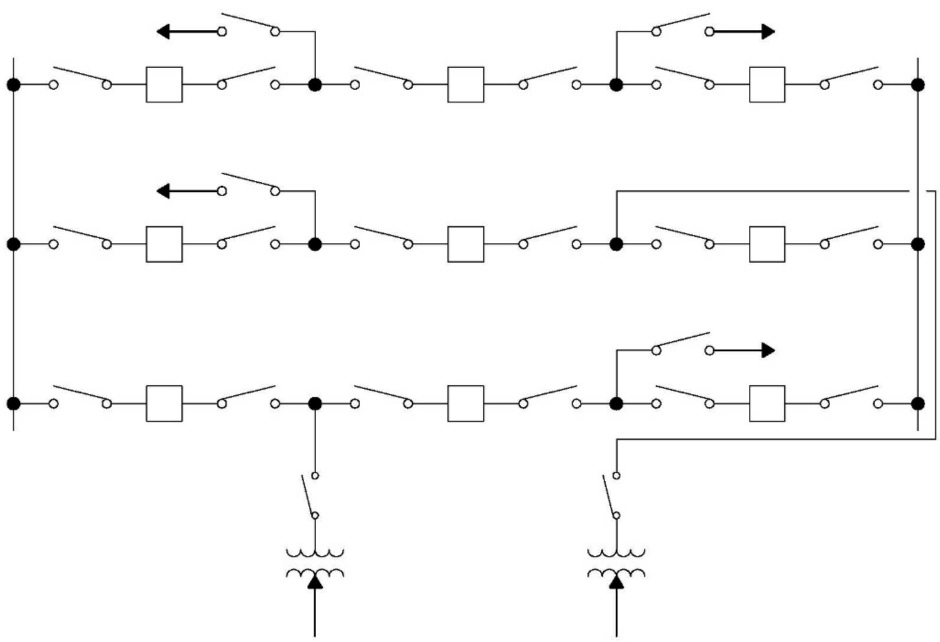
2-2.3.3 Maintenance Implications.

Maintenance tasks are easier as portions of the bus can be taken down systematically and outages required to perform them don't affect the entire system.

2-2.4 Breaker-and-a-Half.

The breaker and a half system (Figure 2-6) is an improvement on the double breaker scheme as costs are lowered by reducing the number of required circuit breakers. For every two circuits, only one spare breaker is provided. The protection is however complicated since it must associate the central breaker with the feeder whose own breaker is taken out for maintenance. Because of the high costs of equipment, even this scheme is not very popular. As shown in the figure that it is a simple design, two feeders are fed from two different buses through their associated breakers and these two feeders are coupled by a third breaker which is called tie breaker. Normally all the three breakers are closed and power is fed to both the circuits from two buses which are operated in parallel. The tie breaker acts as coupler for the two feeder circuits.

Figure 2-6 Breaker and a Half System



2-2.4.1 Benefits and Limitation.

Benefits: During any fault on any one of the buses, that faulty bus will be cleared instantly without interrupting any feeders in the system since all feeders will continue to feed from other healthy bus; however, it is cheaper than the double breaker configuration.

Limitation: This scheme is very expensive due to investment for third breaker.

2-2.4.2 Fault Tolerance.

This scheme is fairly highly tolerant for faults, as the third breaker allows a short time for switching. Relative fault tolerance – 5. Highest tolerance.

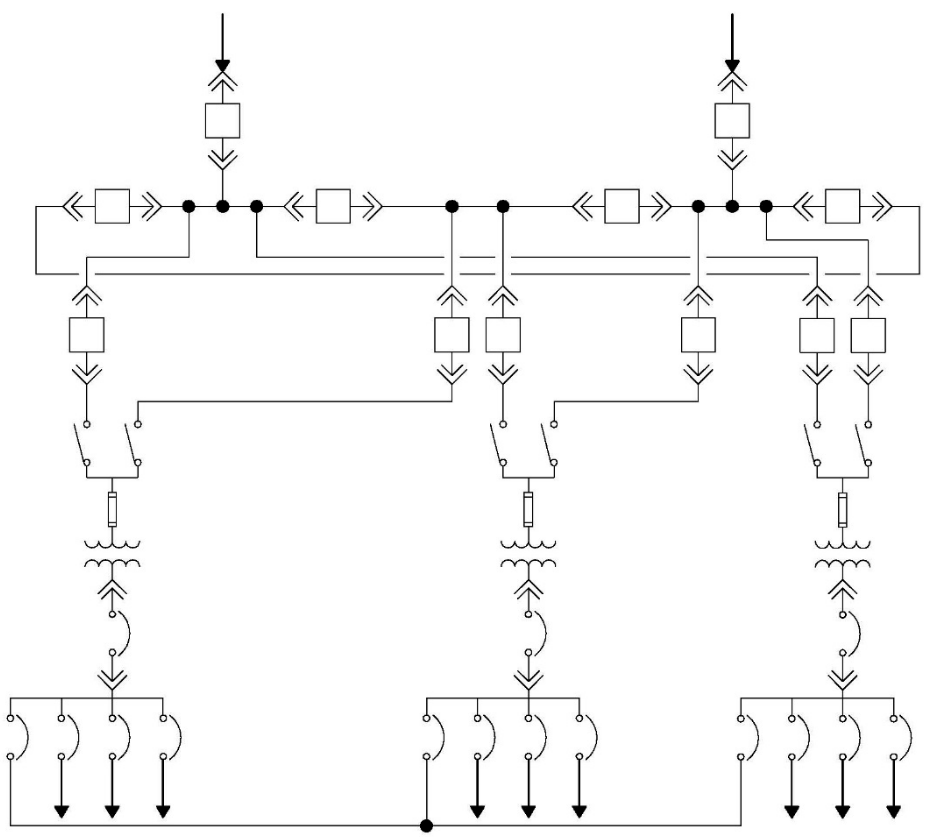
2-2.4.3 Maintenance Implications.

System maintenance is of a comparable level to the double breaker scheme.

2-2.5 Network Model.

A Network model (example provided in Figure 2-7) is a configuration using several of the above mentioned configurations. This allows many options and many configurations. However, this flexibility, because of complexity, requires a cybersecurity certified SCADA (Supervisory Control And Data Acquisition) system and highly trained operators to control feeders, monitor status, control breakers, and report maintenance issues.

Figure 2-7 Network Model



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CHAPTER 3 DEVELOPING AN O&M PROGRAM

3-1 TRAINING.

3-1.1 Qualifications of Test Operators.

Test operators must be thoroughly familiar with the test equipment used in the type of test being performed, and sufficiently experienced to detect any equipment abnormalities or questionable data during the performance of the tests.

All qualified inspecting and repairing personnel must be thoroughly trained to perform such activities required. The following requirements are minimum:

- Familiarity with operating procedures, protective and interlocking schemes, and the equipment capabilities at the specific substation;
- Knowledge of the proper use of power distribution and utility systems control systems to ensure efficient O&M;
- Knowledge of general cybersecurity concerns and protection protocols for net-centric operations;
- Knowledge of the proper use of safety equipment, first aid procedures and equipment, and equipment grounding techniques;
- Access to safeguards such as danger signs, temporary barriers, protective clothing, tools and protective equipment, and all safety manuals and rules. Procedures to clearly indicate insulating requirements and working clearances for any category of energized-line maintenance employed; and
- Keeping proper inspection records and checklists so that observed defects or improper conditions will be promptly corrected.

3-1.2 Electric Workers, Instruments, and Reports.

Perform electrical equipment tests under the supervision of qualified electric workers. If in-house personnel are not available for these tests, the services of a qualified electrical testing agency may be used.

3-1.3 Testing Agency Qualifications.

Require the testing agency to submit proof that it is a corporately independent testing organization which can function independent of the manufacturers, suppliers, and installers of equipment or systems evaluated by the testing firm. The testing agency must meet OSHA criteria for accreditation of testing laboratories, Title 29, Part 1910-7; or be a full member company of the International Electrical Testing Association (NETA) and be regularly engaged in the testing of electrical equipment devices, installations, and systems. The lead technical agency member on-site to have a current certification by NETA or the National Institute for Certification in Engineering Technologies (NICET) in electrical power distribution system testing.

3-2 TOOLS AND EQUIPMENT.

3-2.1 Electrical Tools and Equipment Standards.

Industry standards describe the requirements for electrical protective equipment and for tools. These standards were developed so that the tools, equipment, materials, and test methods used by electrical workers will provide protection from electrical hazards. Electrical protective equipment is included in the ASTM F18 series specifications. Tool and equipment terminology and in-service maintenance and electrical testing are included in ANSI/IEEE 935 and 516 and IEEE 978 respectively. UFC 3-560-01 also contain tool and equipment requirements. In case of conflict, always use the most stringent safety requirement.

3-2.2 Standard Tools and Equipment.

For simplicity and convenience, the tools and equipment required for electrical inspection and maintenance are classified as follows:

- Tools: Tools include hand tools, digging tools, hot line tools, miscellaneous and special tools, and tackle;
- Protective equipment: Protective equipment includes rubber gloves, helmets, lie hose, matting, blankets, insulator hoods, sleeves, barricades and warning devices;
- Climbing equipment: Climbing equipment includes body belts, safety and climber straps, climbers, and ladders;
- Electrical inspecting and testing equipment: Electrical inspecting and testing equipment includes electrical and mechanical devices used to test the operation of electrical equipment, such as voltmeters, ammeters, ohmmeters, tachometers, and similar devices;
- Large portable and mobile equipment: Large portable and mobile equipment includes relatively large and easily transportable equipment for use in maintenance work, such as line trucks, aerial lift trucks, motor-generator sets, posthole diggers, and similar apparatus;
- All hand and mechanically operated tools must be used in a manner to comply with all applicable safety rules. Each worker is responsible for observing safety rules and preventing accidents;

- Energized lines: The methods used when working on energized lines, such as gloving, use of hot line tools, and provision of electrically insulated buckets, will be in accordance with the applicable services' safety manuals. Safety rules governing the use of such tools and equipment are given in these manuals and in applicable OSHA regulations, 29 CFR 1910 and 29 CFR 1926; and

- Material use: An insulating type hydraulic fluid is required in all hydraulic hand tools used on or near energized lines and in insulated sections of aerial lift trucks. Hazardous material procedures must be followed when dealing with such substances.

Apply ANSI/IEEE Std 935 for the identification of tools and equipment used in live line work. Use tools in accordance with Chapter 6 in ANSI/IEEE Std 935. Maintain live line tools and rubber goods in accordance with UFC 3-560-01. Manufactured tools must meet ASTM F18 series specifications, as appropriate to the device and material. Refer to Chapter 6 for tools and equipment associated with overhead distribution.

3-2.3 Specialty Tools and Equipment.

Consider acquiring and using the following specialty tools and equipment:

- Remote racking mechanisms for switchgear circuit breakers – several manufacturers provide remote racking mechanisms that allow the electrical worker to stay well outside the arc flash boundary during circuit breaker racking operation;

- Remote switching actuators for circuit breakers – enables remote circuit breaker operation (open or close);

- Thermal imaging cameras;

- Power quality data loggers – for evaluation of normal system parameters, such as voltage, current, power factor and harmonic distortion, as well as for evaluation of abnormal events, such as voltage swells, sags, or outages;

- Wet/dry hot stick tester;

- Pad-mounted switchgear portable motor operator – for use on pad-mounted switchgear that is not operated with a hot stick; and

- Fault locating equipment.

3-2.4 Care and Storage of Tools and Equipment.

Tools and equipment will be kept in proper operating condition and used only for the purpose for which they were designed. If proper and safe tools are unavailable, report tool needs to a Supervisor.

Inspect all tools at regular intervals and any tool that develops defects when in use will be taken from service, tagged, and not used again until restored to proper working condition.

3-2.5 Electrical Inspecting and Testing Equipment.

The number and types of testing/inspection devices needed will depend on local needs. When available, follow the manufacturer's instructions for the care and maintenance of test equipment. The schedules for the calibration and tests of instruments and meters are dependent upon the particular installation. When precision is not essential, the period between tests is not critical and may be assigned as convenient. For units provided with built-in diagnostic capabilities, check diagnostics when their associated power apparatus is checked.

3-2.5.1 Maintenance of Instruments, Meters, and Test Equipment.

Only personnel trained and qualified to maintain instruments, meters, and test equipment, or personnel under the immediate supervision of such qualified personnel, are allowed to perform accuracy tests, repairs, calibrations, and adjustments of instruments and meters. When selecting meters, match meter accuracy to the requirements of which the reading and records are being used. Procuring equipment with higher accuracy than requirements dictate must be economically justified.

3-2.5.2 Frequency of Inspections.

Use the manufacturer's maintenance recommendations intervals as the initial inspection frequencies for normal conditions. Shorten intervals where adverse conditions exist and may be lengthened only where experience under better-than-normal conditions show this can be done safely. The inspection frequency may vary for similar equipment operating under different conditions.

If calibration standards and equipment are not available, instruments and meters of nearly the same rating can be checked against each one another. When wide discrepancies are noted or the instrument or meter that is obviously incorrect, recalibrate and make any needed repairs.

3-2.5.3 Test instrument Calibrations.

Calibrate instruments every 12 months. Calibrate analog instruments every 6 months. Calibration to provide the full-scale accuracy based on the manufacturer's data, usually

1% for switchboard instruments and 0.25 % for portable instruments. Ensure dated calibration labels are visible, and maintain up-to-date calibration records, instructions, and procedures for each instrument which have had a calibration standard of higher accuracy than that of the test instrument.

3-3 HAZARDOUS MATERIAL PROCEDURES.

Implement a hazard communication program in accordance with 29 CFR 1910.1200 or 29 CFR 1926.59, and DoDI 6050.05, DoD Hazard Communication (HAZCOM) Program, as amended by Agency guidance. The major hazardous items to which electrical workers may be exposed are asbestos, polychlorinated biphenyls (PCB's), sulfur hexafluoride (SF6) and some of the chemicals used to control undesirable brush or pests or to preserve wood. For PCBs, comply with 40 CFR 761 and Overseas Environmental Baseline Guidance Document (OEBGD) DOD 4715.05-G.

3-4 SYSTEM DATA, EQUIPMENT DATA, AND DOCUMENTATION.

Prior to performing any fieldwork, review historical Electrical Preventative Maintenance (EPM) data and applicable safety requirements.

- Assemble all documentation applying to the apparatus being checked:
  - Documentation Maintenance. Installation engineering function must ensure all documentation is maintained for each specific item of electrical apparatus which makes up the facility electrical power systems.
  - Available From Design/Construction Files. The available data may include all of the inspection and testing procedures for the facility, copies of previous reports, single-line diagrams, schematic diagrams, electrical equipment plans, records of complete nameplate data, submittals, and manufacturer's service manuals and instructions.
  - Locally Prepared. Prepare local EPM forms as necessary for installed equipment. Show each item of apparatus on an equipment location plan. Provide unique apparatus designations along with a locally prepared safety electrical one-line diagram and equipment location plan.
- Specific Assembling of Data. Assemble the following data, if available, for each specific item of apparatus:
  - Locally prepared forms and as-built drawings for electric equipment layouts and elevations.

- Trend analysis data to include:
  - Installation acceptance data test results; and
  - Previous EPM reports including any previous systematic evaluations.
- Manufacturer's service manuals including practices and procedures for:
  - Installation;
  - Disassembly/assembly (interconnection);
  - Wiring diagrams, schematics, bills of materials;
  - Operation (set-up and adjustment);
  - Maintenance (including parts list and recommended spares);
  - Software programs; and
  - Troubleshooting guidance.

Systematic Evaluation of Apparatus Condition. Perform a systematic evaluation the electric apparatus condition after an EPM which indicates repairs were necessary beyond normal expected maintenance. The systematic evaluation to include:

- Reasons for the required repairs;
- Work required to complete the repairs;
- Assessment of the remaining service life; and
- Determination of the need for a more frequent EPM.

3-5 TESTING INTERVALS.

Appendix I provides recommended testing intervals.

Comply with DISA Circular 350-195-2 for testing intervals for DoD Information Network facilities' electric power systems.

3-6 RISK MANAGEMENT ANALYSIS.

Risk management is covered under IEEE 399 Chapter 12 and IEEE 493 (Gold Book) which address system reliability. IEEE 493 covers the IEEE recommended practice for the design of reliable industrial and commercial power systems. Risk management is based upon the probability of certain types of devices failing at a given period of time, and addressing maintenance according to schedules to avoid unknown or indeterminate outages. By following the recommendations in these guides, many risks can be mitigated without substantial extraneous failures.

3-7 RELIABILITY AND AVAILABILITY.

Power operational availability is the probability a system is not failed or is undergoing a repair action when it needs to be used. Availability is typically expressed as "nines." A 'three nine' availably equates to 0.999 availability or a 0.001 unavailability. A 0.001 unavailability means the system has the probability of being down 8.76 hours a year (Table 3-1). Power reliability refers to the failure probability and is typically expressed as a percentage. A very reliable system is one that can be repaired or the power brought back rapidly. Resiliency is the capacity of the system to bounce back from a failure or a fault. TM 5-698-3 provides additional reliability background information.

System redundancies, either through loop feeds and/or generators/distributed generation, combined with ability to replace quickly failed components, contribute to high overall system availability. Evaluate mission availability needs when establishing O&M program requirements, specifically address personnel training, critical tools and supplies, and contracted functions response requirements.

Table 3-1 Availability and Downtime

Availability		Unavailability (1-availability)	Hours Per Year Downtime (8760 hours/year x unavailability)	Minutes Per Year Downtime
0.99	(2-9s)	0.01	87.6	-
0.999	(3-9s)	0.001	8.76	-
0.9999	(4-9s)	0.0001	-	52.56
0.99999	(5-9s)	0.00001	-	5.256

3-8 LIFE CYCLE COST ANALYSIS.

Life cycle cost analysis (LCCA) is a good tool for establishing an O&M program or contract scope. LCCA uses the effect of equipment age on the likelihood of failure and maintenance costs to determine when replacement with new equipment becomes the most cost effective O&M solution. Use LCCA to help direct available resources to requirements with highest life cycle and mission payback.

- IEEE 493 provides guidance on recommended design practices for reliable power systems; and

- See Appendices F, G, and H for sample maintenance program checklists, LCCA maintenance work sheet, and a Man-hour Ceiling/Priority Analysis Method (MAPCO) recurring maintenance document.

3-9 RECORD DOCUMENTS - MANUALS, DIAGRAMS AND DRAWINGS.

A comprehensive file of equipment and service records provide the necessary information for aiding inspections, maintenance, or tests. In addition to indicating basic information required for proper inspection of the equipment, these records would indicate where trouble has been experienced and where special procedures may be warranted.

3-9.1 Operation and Maintenance (O&M) Manuals.

Ensure that O&M manuals are provided for any new equipment or system. O&M manual submittal requirements are included with the Unified Facilities Guide Specifications that are developed for a project. For medium voltage or high voltage circuit breakers used at substations or switching stations, refer to IEEE Std C37.12.1 for additional information.

Retain any design analysis for new projects that includes power systems analyses, including power flow, short circuit, electrical coordination, or arc flash. Refer to Section 8 for analysis requirements.

3-9.2 Electrical Drawings.

Develop and maintain the following types of drawings:

- Primary distribution system – layout drawings showing primary distribution overlaid onto the base map;
- Primary distribution system – one-line drawings; and,
- Substations and switching stations – one-line, three-line, and equipment schematic and wiring drawings.

Provide the drawings in a computer-aided drafting (CAD) format. Develop the drawings in a form that is usable for operations and maintenance. These system drawings are not construction drawings. Refer to IEEE Std 3007.1 for additional guidance regarding system drawings.

3-9.2.1 Posting.

Post the primary distribution drawings at the exterior electrical shop and at each substation or switching station.

3-9.2.2 Periodic Update.

Update the primary distribution system drawings at least annually. Coordinate with engineering and drafting personnel to ensure that all known system changes are properly shown on the drawings.

3-9.3 Operating Instructions, Records, and Logs.

Service records constitute a history of all work performed on each item of equipment and are helpful in determining the overall condition and reliability of the electrical facilities. Service records to show type of work (visual inspection, routine maintenance, tests, repair), test results (load, voltage, amperes, temperature), and any other remarks deemed suitable. It is highly recommended that service records include a log of incidents and emergency operating procedures. Logs of incidents, such as power failures, surges, low voltage, or other system disturbances are very useful in planning and justifying corrective action.

Emergency work on electrical facilities is safer and quicker when instructions are prepared and posted in advance. Prepare instructions for each general type of anticipated emergency. Each instruction to state what actions each employee will do, provide alternatives for key personnel, and establish follow-up procedures. Post instructions in the electrical shop, security guard office, substations, operating areas, and such other locations, as the responsible supervisor deems advisable. List employees by name, title, and official telephone number. These instructions must also emphasize safety under conditions of stress, power interruptions, and similar emergencies.

3-9.4 Geospatial Information Systems.

Use of a geospatial information system (GIS) for utility infrastructure is recommended. If the Activity uses GIS, provide nameplate and configuration data for replacement equipment to the organization that updates the GIS information. Coordinate equipment naming conventions and data requirements with the utility GIS analyst so naming and collected data is consistent with the information provided on the installation's CAD and GIS system drawings.

3-10 ENERGIZED WORK PROCEDURES.

3-10.1 Work on Energized Circuits.

Refer to UFC 3-560-01 for energized work requirements. OSHA 29 CFR 1910.333 limits work on live energized electrical equipment as follows: "*Live parts to which an employee may be exposed shall be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*."

Some energized work activities are unavoidable. In these instances, UFC 3-560-01 requires an energized work permit prepared in advance of work execution.

3-10.2 Unique Procedures for an Energized Work Permit.

Unique operating procedures are recommended for each unavoidable routine tasks that involve working on energized electrical equipment. Provide energized work permit requests in NFPA 70E energized electrical work permit format. Use unique operating procedures to obtain energized work permit approvals as described in UFC 3-560-01. Examples of typical operating procedures for energized work on the primary distribution system include:

- Replacing fuses in medium voltage pad-mounted equipment;
- Replacing fuses on overhead circuits;
- Voltage and phase rotation checks;
- Applying and removing temporary grounds;
- Connecting or disconnecting loadbreak elbows;
- Electrical manhole inspections; and
- Pad-mounted electrical equipment inspections.

Refer to Appendix E for examples of an operating procedure.

3-11 LOCKOUT/TAGOUT PROCEDURES.

Comply with UFC 3-560-01 for lockout/tagout requirements.

3-12 CONFIRMATION OF ADEQUATE MAINTENANCE AND TESTING.

Document all maintenance and testing that is completed on electrical equipment. One form of confirmation of documented maintenance and testing is the use of calibration or maintenance stickers applied to the equipment and a documented report of the maintenance and testing that was completed.

3-12.1 Calibration Sticker Classification Codes.

Not all electrical equipment will perform properly when checked. NFPA 70B expands on the concept of a calibration sticker by also specifying a color code system that indicates the functionality of the equipment that was checked:

- White: Serviceable. If a device passes all tests satisfactorily and has met the requirements of the testing specifications, then apply a white decal to the device. This indicates that the device is electrically and mechanically sound and acceptable for return to service. There could be some minor deficiencies with the equipment but none that affect the equipment electrically or mechanically to any large degree. Examples of deficiencies include evidence of slight corrosion, incorrect circuit ID, and nameplate missing.

- Yellow: Limited Service. If the device under test has a minor problem that is not detrimental to the protective operation or major design characteristics of that particular device, then apply a yellow "Limited Service" decal to the device. Examples of limited service classifications include indicating trip targets that don't function properly, slightly lower than acceptable insulation resistance readings, and chipped arc chute.

- Red: Non-serviceable. If the device under test has a problem that is detrimental to the proper electrical or mechanical operation of that device, then apply a red "Non-serviceable" decal to the device. The non-serviceable decal would be attached to the device after attempts at field repair were made. Examples of non-serviceable classifications include no trip on one or more phases, low insulation resistance readings, mechanical trip problems, and high contact resistance readings. In addition, advise management or the owner of this condition.

If Activity uses equipment labeling as part of their testing/calibration program, use of color-coded labels is required.

3-12.2 Test Reports.

A dated test report must include, as a minimum, the following data:

- Description of equipment tested;
- Description of test;
- Test results with ALL fields completed;
- Summary of project findings and recommendations, if required for additional work;
- Documentation of the conditions at which the tests were performed; and
- Name and address of the testing firm along with contact information of the individual doing the testing.

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CHAPTER 4 OPERATION

4-1 DEMAND LOAD.

4-1.1 Characteristics – Residential, Commercial, Industrial.

Most military Activities have power demand characteristics similar to commercial facilities. Most motor load tends to support infrastructure (sewer and water) or heating, ventilation, and air conditioning (HVAC) systems, with motors commonly less than 150 Hp. Industrial-type installations, such as systems with many large motors, including synchronous motors, are much less common.

4-1.2 Seasonal Behavior – Power Demand.

Although there are exceptions, most primary distribution systems exhibit a seasonal variation in the power demand. Figure 4-1 shows an example of a northern military base that shows a peak power demand in the summer. Figure 4-2 shows another example of a southern base with a summer peak demand that extends for several months.

Note: The scales are different for the examples shown below and reflect the actual power demand for different military bases. For example, the military base represented by Figure 4-2 has almost 4 times the peak power demand of the military base represented by Figure 4-1.

Figure 4-1 Power Demand Variation – Northern Base

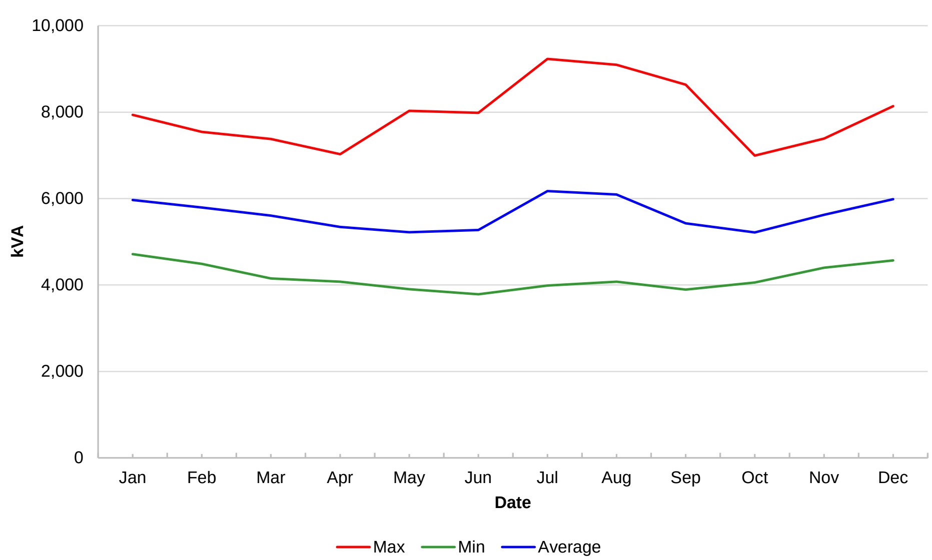
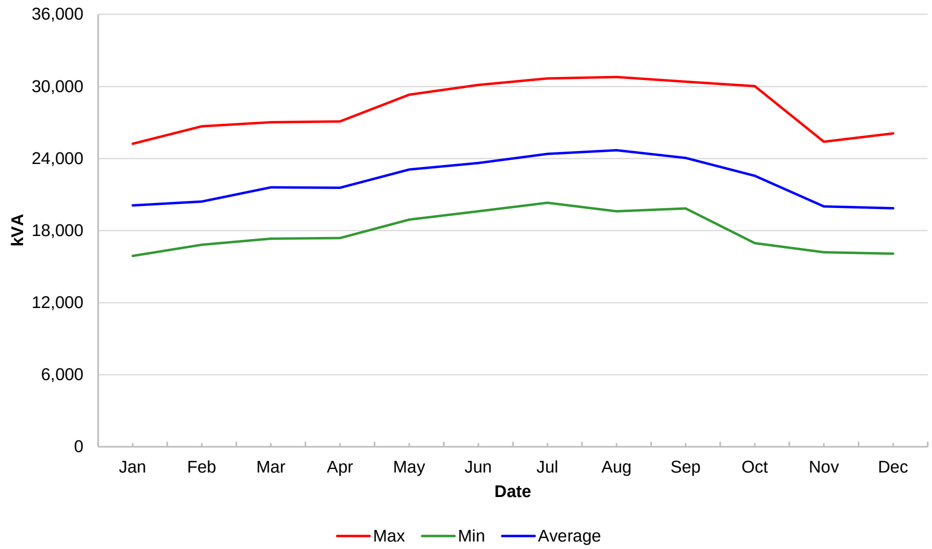
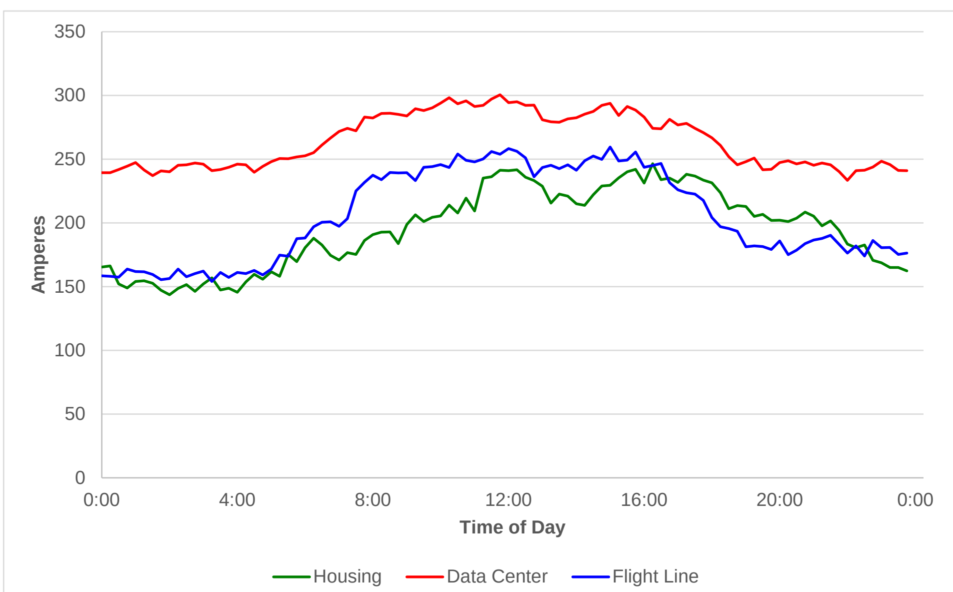


Figure 4-2 Power Demand Variation – Southern Base Demand



Even during the period of summer peak demand, there can be a substantial variation in the daily power demand as shown in Figure 4-3. The actual peak demand for each day might only occur for one hour in the early-to-mid afternoon time frame for a base in the northern part of the USA and it might last for several hours for a base in the southern part of the USA. Figure 4-3 shows the typical southern variation for a mainly housing circuit, a flight line industrial circuit, and a circuit with data center type loads.

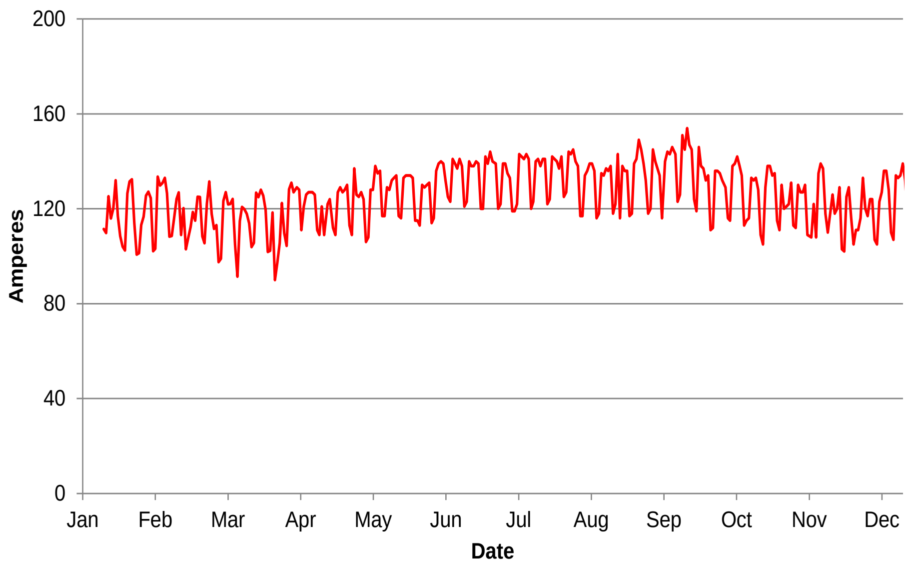
Figure 4-3 Daily Power Demand Variation



4-1.3 Circuits with Minimal Seasonal Behavior.

Not all primary distribution circuits exhibit seasonal variations. Distribution circuits that are dedicated to large facilities, such as data centers, might require year-round air conditioning, with little variation in power demand as shown in Figure 4-4.

Figure 4-4 Data Center Power Demand Variation



4-1.4 Metering Data as an Input to System Operation.

Evaluate the available metering data for the entire primary distribution system as well as for individual circuits to determine optimal operation. Use metering data for the following:

- Determine the optimal open point at cross-connect locations between distribution circuits;
- Identify peak demand loading that approaches ampacity limits on distribution circuits;
- Evaluate the extent of load growth on a distribution circuit and the potential need for upgraded circuits or additional circuits; and
- Confirm the need for additional power factor correction.

Update the metering data at least quarterly to identify any trends in power demand.

4-1.5 Load Shifting.

Load shifting, also known as Load Leveling, is the process of moving or "shifting" load from on-peak to off-peak periods. Popular methods used, but are not limited to: storage water heating, storage space heating, cool storage, and customer load shifts to take advantage of time-of-use or other special rates. Typically, there is an economic incentive built into the utility rate structure in an effort to reduce the demand placed on the system. By incentivizing the shift of load from on-peak to off-peak, the system performance can be enhanced and capital expenditure can be delayed that ordinarily would be required if the peak demand, or "peak shaving," couldn't be achieved. The result of this load shift can have a significant impact on system studies that utilize power flow analysis. If load can be shifted to other sources, any required system capitalization and expansion may be deferred. An economic example is providing an incentive for Activity to reduce their consumption at peak times to later in the day when the cost of energy is generally lower. This could include using the delayed setting on dishwashers which will postpone the operation of the dishwasher for a number of hours when the cost of energy is lower, thus distributing their consumption away from the system peak.

Load shifting can also imply the transfer of load from one source to another, either temporarily or permanently; for example, a temporary shift of load from one substation to another. In these circumstances, and if properly designed, a utility's distribution circuit can be back fed by transferring the load through the use of system 3-phase switches that will allow for maintenance or system inspection be safely performed on the original circuit while allowing most, if not all the consumers, to remain energized. This also is a consideration when a permanent system configuration is necessary and the transfer of load from a heavily loaded or overloaded substation, or circuit, to a new circuit with sufficient equipment capacity to handle the additional transferred load is required. In either case, a good understanding of the system characteristics and dynamics is needed to assure the transfer of load does not negatively affect the delivery of energy to end users. Coordinate load shifting with the utility company when shifting load between substations that are billed separately to prevent the possibility of double demand billing.

Note: Load shifting involving storage cooling or heating can increase the total KWH usage compared to no-storage cooling or heating systems.

4-1.6 Peak Shaving/Load Shedding.

Peak Shaving, or Load Shedding, is the concerted effort to remove unnecessary load from the system peak load. At its simplest, this is the turning off of load at peak load times. However, there are other philosophies, similar to Load Shifting, which provide the utility the ability to transfer large system loads onto a local standby generator(s) by remotely starting the generator(s) and completing the transfer automatically or with coordinated switching procedures with the generator's owner.

Mission operators may also have loads that can be postponed to later in the day or evening. In the case of a more complex system where it is possible to transfer some loads from one revenue meter to another, the operator may reduce the potential impact of contractual Demand Charges (kW) by moving some of the electrical loads. Because of this movement, their electrical reductions reduce the peak demands of their system. Typically, a demand rate is a contractual obligation between the utility and a larger electrical user. These charges are employed for various reasons by the utility, but are principally used to reduce demands on the system at critical times, to recover stranded equipment costs and encourage end users to distribute their electrical requirements throughout the day in order to defer future capital expansion costs. Another method of load shedding is to use distributed generation to address load shedding / peak shaving. Load peak shaving / load shedding or paralleling with the utility grid requires final approval from Agency utility leads, with an approved utility agreement, before utilizing this approach.

4-1.7 Coincidence.

Coincidence or Coincidence Factor is the ratio of the maximum demand of a system, or part under consideration, to the sum of the individual maximum demands of the base areas. In other words, it's the fraction of the peak demand of an area (or individual building), or revenue class of end user, that is in operation at the time of a system peak. Thus, it is the ratio of the installation's demand at the time of the system peak to its non-coincident peak demand. For example, a distribution system may have different classes of end users such as residential and military / commercial. The system peak may occur during the day at a time when the military / commercial Activity is high, but residential load increases late afternoon due to residents arriving home. At this time, both classes of users are placing a demand on the system and, as a whole, create a system peak, but when neither is at their individual class peak.

4-1.8 Trend Analysis.

4-1.8.1 Data.

Trend analysis data to include:

- Installation acceptance data test results;
- Previous EPM reports including any previous systematic evaluations; and
- Industrial Control System (ICS) Archive Server Feeder Trending.

In general, Trend Analysis is the review of historical information and data to determine future expectations and/or requirements. It is also used in predicting failure/risk exposure of installed electrical apparatus in guiding maintenance and replacement philosophies.

4-1.8.2 Analysis.

When applying a trend analysis to electrical distribution systems it is necessary to quantify the scope and duration of the trend. Typically, for short-range plans, a 5-year history suffices. However, as one looks further into the future as a longer-range plan develops, a more extensive historical data set is required and is typically a minimum of 10 years or more of history. These data sets would include a review of peak energy (kWh) and peak demands (kW & kVA) and where those loads are located within the system. This data provides the basis on which system load flow analysis can be used and analyzed. Load flow analysis shows how much load and where our system burdens exist. As these trends of consumption increase, various strategies can be developed based on future expectations that are shown in the analysis. Strategies such as load shedding, system capitalization / expansion, and system voltages can be explored depending upon economic justification. In addition to KW and KWH, trend analysis of cable or equipment failures (outages) is also a useful tool. Upstream outage trend analysis is a valuable part of periodic utility contract reviews. Include all this information in an annual hazard, vulnerability, and capabilities assessment in accordance with DoDI 4170.11, DoDI 4180.11, and service instructions, such as AFI 10-2501 and AFMAN 10-2504 for the Air Force.

Relative to maintenance, trend analysis can identify potential critical weak points within the system that may fail or whose ratings will be exceeded by either load flow analysis or any existing negative electrical characteristics, such as harmonics or system outages that resulted in numerous splices installed. Numerous overhead splices in a given area may indicate a more aggressive tree-trimming program is necessary. Decisions like this result from trend analysis.

4-1.9 Forecasting and Planning.

Load forecasting involves six (6) separate considerations. These are:

- Impact of nominal load growth over time. Typically, some slight growth in demand will be experienced over time. This may be upwards of ½ to 1% per year;
- Impact of equipment changes due to new equipment installations or modifications that are not part of the product (mission) plan, including environmental equipment, new technology applications, or new requirements, such as facility air conditioning or air tempering;
- New and modified production plans to meet requirements of the future product (mission) plan;
- Additional site development due to new on-site buildings(s) and added floor space. Typically, a site may be initially developed to a 15-20%

building to land ratio, with an allowance for future development of up to 30%. Some sites may be constrained for additional development;

- Impact of gas/oil conversion to electric use for some types of product (mission) heating where electric heating may actually be more economical (or reliable) due to inherent process efficiencies; and

- Other types of changes that cannot easily be categorized, such as higher density plant loading, etc.

Planning, or System Planning generally has four (4) aspects. These typically are 1-Objectives, 2-Planning, 3-Execution and 4-Control. The use of forecasting, trend analysis and standards are necessary to identify the Objectives. The long-range goals of the system are required for Planning. The necessary capital expenditures, land use, right-of-way and utility easements, overhead and underground construction costs are necessary for the Execution. Control is a periodic plan review to verify whether any of the first three (3) aspects have changed or still apply.

4-1.10 Demand Management.

4-1.10.1 Definition.

Demand Management is the collection of system load data and characteristics, and facilitates the basis of decision making when implementing any system plan. This data collection, and resulting decision making, can occur on either side of the utility electric meter, be it the producer or consumer.

4-1.10.2 Producer/Provider Demand Management.

With respect to the producer or provider, Demand Management is a means to collect relevant system data, which is then used in system studies to assist in the operation and administrative decision making of their system with the ultimate goal of providing quality, reliable energy at the lowest cost or greatest revenue depending upon mission philosophy, to end users. It allows the provider to coordinate system planning and construction in order that appropriate decisions and expenditures are used in the most efficient means with consideration to future growth, forecasting, and user’s needs.

4-1.10.3 Consumer Demand Management.

Demand management relative to the consumer is more commonly known as Demand Side Management (DSM) and is generally a contractual or economic incentive program that is brought forth by the producer that allows the end user to reduce system losses attributable to their use and consumption. It is an effort to reduce demand. Furthermore, it includes a utility action that reduces or curtails end-use equipment or processes. DSM is often used in order to reduce customer load during peak demand and/or in times of supply constraint. DSM includes programs that are focused, deep, and immediate, such as the brief curtailment of energy-intensive processes used by a utility's most demanding industrial customers, and programs that are broad, shallow, and less immediate, such as the promotion of energy-efficient equipment in residential and commercial sectors. An example of this load shedding is mentioned earlier.

4-2 RECLOSING PRACTICES AND FUSE SAVING.

Apply reclosing only on circuits where there is a reasonable expectation that faults will be temporary in nature. Do not apply reclosing unless there is a reasonable expectation that temporary faults can occur. Temporary faults are likely to occur on overhead distribution, but not on underground distribution. If reclosing capability is installed, disable reclosing if it supplies an underground distribution.

Note: The purpose of reclosing is to automatically restore power whenever a short circuit is only temporary. Industry experience with overhead lines is that 80% to 90% of faults are temporary, typically caused by lightning, wind-blown tree branches, wind-blown wires, birds, and animals. If the fault is temporary, the reclose feature allows power restoration without requiring power system line crews to respond.

Note: IEEE Std C37.104 states that reclosing should be applied only when there is a reasonable likelihood of a temporary fault. IEEE Std C37-230 states that reclosing is generally not applied on feeders with no overhead exposure, because faults on underground feeders are generally permanent.

Reclosing is authorized on distribution circuits as follows:

- Reclosing is allowed on overhead distribution circuits if there is a reasonable expectation that faults will be temporary in nature.
- Do not allow reclosing on underground distribution circuits. UFC 3-550-01 prohibits automatic circuit reclosing on underground distribution circuits.

  Note: Underground distribution faults tend to be permanent, caused by cable faults, termination failures, or improper excavation (another type of cable fault). If the reclosing feature is active when these types of faults occur, the faulted location is repeatedly reenergized until the reclosing device eventually locks out, thereby causing further damage to the fault location and unnecessarily stressing system equipment, including the substation transformer. In instances of cable damage caused by excavation, the reclose feature is an electrical safety hazard in that exposed damaged cable is reenergized with workers nearby.

  Note: Fault indicators are recommended for underground distribution circuits to assist with locating the faulted section of the line.

- For distribution circuits that contain a mix of overhead and underground distribution, treat the circuit as an underground circuit once the percentage of underground distribution exceeds 50%.

  Note: For overhead distribution circuits with main or lateral sections that convert to underground distribution, reclosing is allowed on the overhead line if a 3-gang fused cutout is included at the pole which has the aerial to underground transition point and the fuse rating is coordinated with the upstream recloser.

- For underground distribution circuits with main or lateral sections that convert to overhead distribution, reclosing is allowed at the point where the system changes to overhead distribution.

4-2.1 Reclosing Initiated at Substation or Switching Station Circuit Breakers.

When reclosing is initiated by circuit breakers at a substation or switching station, include the following:

- Provide phase and neutral instantaneous trips on the associated relays. Set the instantaneous trip low enough to be active throughout the distribution circuit; and

  Note: Downstream in-line reclosers might be required for longer distribution circuits that have a relatively low short circuit current in the remote sections of the circuit.

  Note: A sensitive instantaneous trip is desirable to allow temporary faults to clear before downstream fusing can respond.

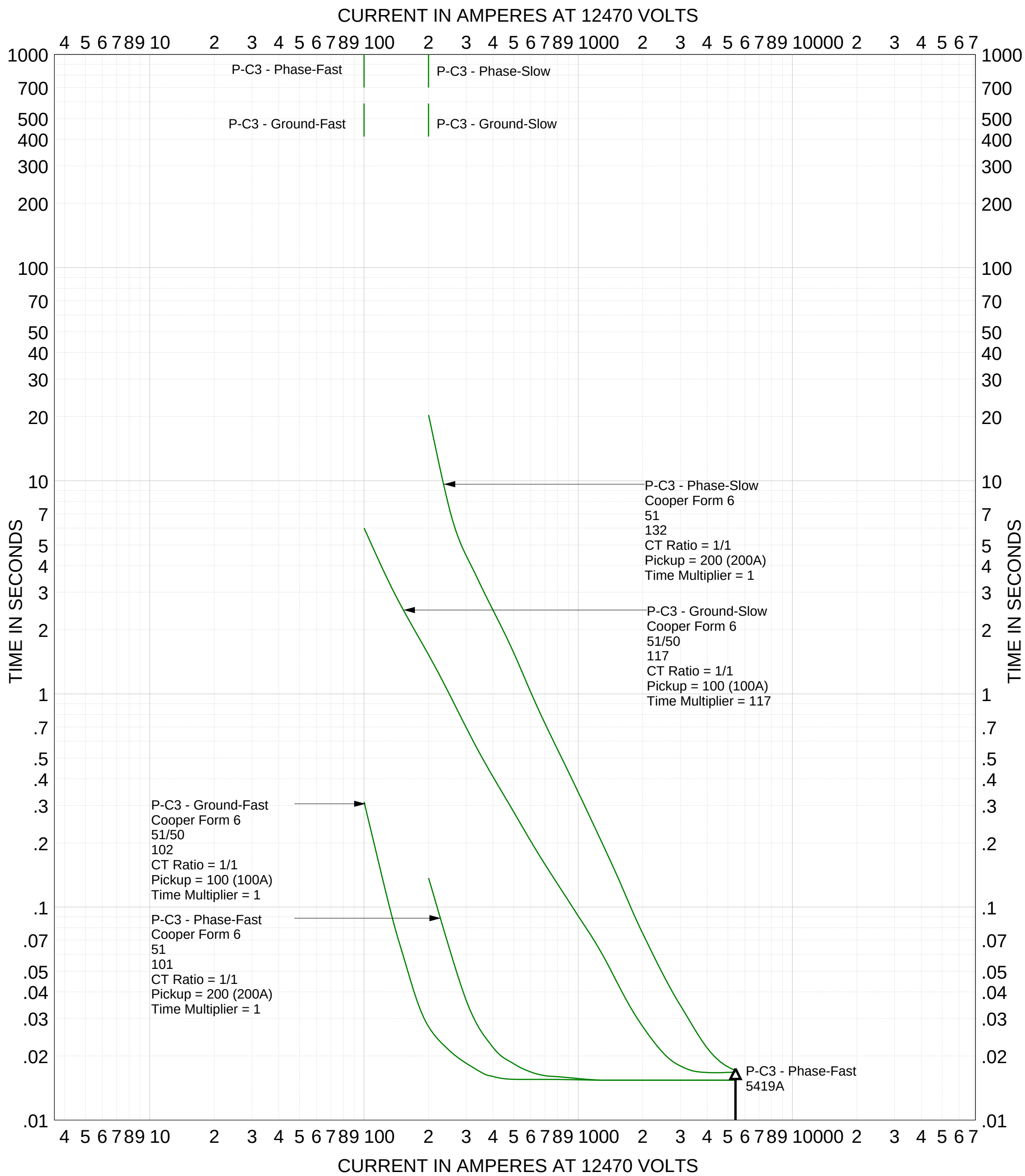
- Set up reclosing to actuate only on the instantaneous trips.

4-2.2 Reclosing Initiated at Downstream Pole- or Pad-Mounted Reclosers.

Reclosers and the associated control units are typically installed at substations, switching stations, and power poles. Reclosers might be installed in a pad-mounted configuration if they are supplying a riser to a downstream overhead distribution. Provide phase and neutral fast trip and slow trip curve settings.

> *Note: Fast trip settings are selected for sensitive rapid trips to avoid clearing of downstream fusing. Slow trip settings are selected with a longer time delay to allow downstream fusing affected by the system fault an opportunity to clear. Figure 4-5 provides an example of these settings.*

Figure 4-5 Typical Recloser Control Unit Settings



4-2.3 Maintenance Practices to Minimize Reclosing Events.

Circuit reclosing on overhead distribution systems is an efficient method for recovering from temporary faults when they occur. However, it is important to maintain the electrical distribution system in a manner that minimizes the occurrence of temporary faults. As part of the periodic review of power poles, address the need for any of the following methods to reduce the frequency of temporary faults:

- Tree trimming – ensure that nearby trees are trimmed as needed to avoid overhead lines;

- If outages are caused by bird strikes, apply IEEE Std 1651 as a guide for maintaining the overhead distribution system;

- Power pole rerouting – in some locations, it might be easier to move the power poles rather than attempt to keep a forested area trimmed;

- In outage-prone areas, consider the use of covered overhead primary (often referred to as *tree wire*) as an alternative to the standard use of bare conductors;

  Note: Tree wire is a type of polyethylene insulated wire that can prevent some direct shorts and flashovers when contact is made with tree branches. Tree wire is similar to aerial cable in that the wires are insulated and provide some level of protection from animals or limbs faulting a line. Although the polyethylene does not apply a code-rated level of insulation, it is usually adequate for preventing phase-to-phase or phase-to-ground faults.

  Note: A downed tree wire line might not allow sufficient line-to-ground current flow to ensure an upstream protective device trip, thereby leaving the line energized while lying on the ground.

- Selective insulation – in some outage-prone locations, the addition of insulating material around the bare conductors might be helpful; and

- Underground installation – in extreme cases, the frequency of temporary faults might warrant converting the overhead distribution to an underground distribution.

4-3 POWER FACTOR CORRECTION.

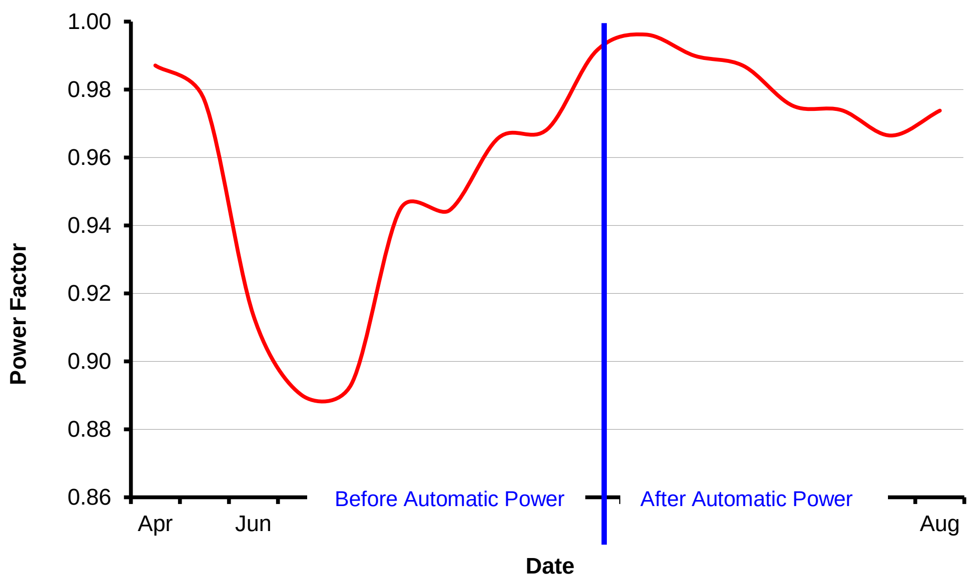
4-3.1 Power Factor Variation.

Figure 4-6 shows a typical power factor variation at a military base. In this instance, Figure 4-6 shows the effect of adding automatic power factor correction capacitors at the utility supply connection point. Before the addition of capacitors, the power factor during the summer tended to fall below 0.90. After the addition of capacitors, the power factor during the summer remains above 0.97. Evaluate available metering data to determine:

- If capacitors are needed for power factor correction; and
- If existing capacitors can be removed from service without degrading the system power factor.

Primary distribution systems that are predominantly overhead often install capacitors on each circuit. Primary distribution systems that are predominantly underground often do not require additional power factor correction.

Figure 4-6 Typical Power Factor Variation



4-3.2 Power Factor Evaluation.

Complete an evaluation of the need for power factor correction before installing or removing capacitors in the system. Figure 4-6 shows an example of the typical variation that might be seen on a primary distribution system, with and without power factor correction. The following locations are typical candidates for power factor correction.

- Substations and switching stations. Larger (typically rated for more than 1,000 kVAR) shunt capacitor installations might be installed to improve system power factor. This is also a consideration if the local utility imposes a power factor penalty;
- Overhead distribution. Smaller (typically rated for less than 600 kVAR) shunt capacitor installations intended to improve line loading and system power factor; and

- Underground distribution. Pad-mounted capacitor installations might be installed, but underground distribution circuits typically have higher natural capacitance, which reduces the need for power factor correction.

Refer to IEEE Std 18 for rating and application criteria for capacitor installations. Apply IEEE Std C37.99 for overcurrent protection. Refer to TSEWG TP-2 at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248, for examples of capacitor sizing calculations.

Note: The addition of capacitors that are routinely switched, such as with automatic power factor correction, can result in voltage transients (momentary voltage spikes) that can be damaging to sensitive electronic and electrical equipment.

4-3.3 Operation.

Capacitor installations are often left in service for extended periods and would typically only be de-energized if necessary for seasonal variations of power factor or for repairs.

Follow electrical safety requirements in UFC 3-560-01 when energizing and de-energizing capacitor installations.

4-3.4 Automatic Operation.

Automatic capacitor operation might be installed in select locations and often have two or more capacitor banks that are switched in steps as necessary to maintain power factor within a specified range. Size the capacitors for each step operation based on the system kVAR demand and ensure a lagging power factor is maintained for each step.

4-4 DISTRIBUTED GENERATION.

Distributed generation can consist of three (3) broad categories: fossil fuel facility level generators (diesel, natural gas and propane generators, natural gas micro-turbines, combined heat and power, fuel cells), fossil fueled utility scaled generation (natural gas turbines) and renewable energy (photovoltaic, wind, geothermal, landfill gas, and solid waste). Distributed generation may also include energy from existing battery systems (electric vehicles). Each of these systems has special considerations. Studies are required prior to connecting Distributed Generation (DG) to the grid. There are studies ranging from dynamic simulations to power flow and effects. Problems like transient overvoltage (TOV), power quality, etc. can occur. Time is required to determine the Minimum Daytime Load (MDL) of a circuit. DG can impact the system operation when islanding is considered. The coordination with the utility is required for safety, billing considerations, and synchronization. Refer to UFC 3-540-08 and UFC 3-440-01.

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CHAPTER 5 MAINTENANCE, INSPECTION, TESTING AND REPAIR

5-1 SYSTEM COMPONENTS AND MINIMUM REQUIREMENTS.

5-1.1 Substations.

Recommended intervals of maintenance of various pieces of equipment are also available in Annex L of NFPA 70B and NETA MTS Appendix B Frequency of Maintenance Tests. There are four different types of maintenance: Preventative, Predictive, Breakdown or Failure, and Corrective.

5-1.1.1 Preventative Maintenance.

Preventative maintenance involves collecting data, maintaining equipment in suggested intervals and maintaining up-to-date equipment files.

5-1.1.2 Predictive Maintenance.

Predictive substation maintenance is the concept of using reliability-centered maintenance. Reliability is defined as the probability that a system will perform a given function satisfactorily for a specified time under specified operating conditions. The four (4) fundamental principles of pure reliability centered maintenance theory are:

- The primary objective of reliability-centered maintenance is to preserve the system function;
- A good reliability-centered maintenance program identifies specific failure modes to define loss of function or functional failure;
- A reliability-centered maintenance program prioritizes the importance of the failure modes; and
- A reliability-centered maintenance program identifies effective and applicable preventive maintenance tasks.

The fundamental goals of reliability-centered maintenance are to preserve the function or operations of a system and to schedule all preventive maintenance tasks to preserve the defined function. The substations system function to preserve is the delivery of safe, reliable electric power to customers (missions).

5-1.1.3 Breakdown or Failure.

Breakdown or failure is simply repairing those item(s) that break. This is not optimal because it does not tend to analyze the origin of the failure.

5-1.1.4 Corrective.

Corrective maintenance is repair and analysis of a failure and determining the root cause of the failure and attempting to mitigate the cause of failure.

5-1.1.5 Maintenance Checklists and Reports.

Generally, for (mission-owned) substations, a third party is contracted to perform substation maintenance work since most (missions) lack the resources and experience to properly maintain high-voltage equipment. An inspection checklist, tailored to a specific substation and containing all items to check, is recommended. See Substation Inspection Checklist (IEEE 141) and Technology Matrix (USDA RUS Bulletin 1724E-300). Include visual and infrared inspections of substations as part of the regular items to complete on the checklist. Tabulate, analyze, and compare in detail the periodic system data and reports, such as substation maintenance reports and min-max voltmeter readings, for trending conditions.

5-1.2 Power Transformers Recommended Intervals and Requirements.

Perform visual and mechanical inspections on an annual basis. However, general inspections can be performed anytime the power transformer is visited. Track results and trend analysis performed. Typical NETA MTS items inspected are:

- Inspect physical and mechanical condition;
- Inspect anchorage, alignment and grounding;
- Verify presence of PCB labeling, if present;
- Prior to cleaning the unit perform as-found tests, if required;
- Clean bushings and control cabinet;
- Verify operation of alarms, control and trip circuits;
- Verify that cooling fans and pumps operate correctly;
- Inspect bolted electrical connections for high resistance;
- Verify correct liquid level;
- Verify that positive pressure is maintained on gas blanketed transformers;
- Perform inspections and mechanical test on recommended by manufacturer;

- Test load tap-changer, if applicable;
- Verify the presence of transformer surge arresters;
- Perform as-left tests;
- Verify de-energized tap changer position is left as specified; and
- Check integrity of oil containment dike and drain any storm water collected.

Perform electrical inspections, such as insulation testing and gas analysis annually or every five (5) years depending upon the apparatus of the transformer, unless a fault event has occurred. These tests depend upon the critical nature of the transformer regarding dissolved gas. This could apply to 500 kVA units or higher. Smaller, oil filled units such as those that serve residential units probably require no testing. Electrical testing should be performed after any event. Track results and trend analysis performed. Typical NETA MTS items inspected are:

- Resistance measurements through bolted connections with a low resistance ohm meter, if applicable;
- Perform insulation-resistance tests;
- Perform turns ratio tests at designated tap position;
- Perform insulation power-factor or dissipation-factor test on all windings;
- Perform power-factor or dissipation-factor tests on each bushing;
- Perform excitation-current test;
- Measure the resistance of each winding at the designated tap position;
- If the core ground strap is accessible, remove and measure the core insulation resistance at 500 volt (V) direct current (DC);
- Measure the percentage of oxygen in the gas blanket, if applicable;
- Remove a sample of the insulating liquid and test for;
    - Dielectric breakdown voltage
    - Acid neutralization number
    - Specific Gravity

  - Interfacial tension
  - Color
  - Visual condition
  - Water in insulating liquids
  - Measure power factor or dissipation factor

- Remove a sample of the insulating liquid and perform a dissolved gas analysis (DGA);
  - Include Furan DGA for cellulose paper insulation degradation determination.
  - The baseline Furan Gas percentage can be used for predictive testing of remaining life of substation transformers by performing periodic Furan Dissolved Gas tests.
- Test the instrument transformers;
- Test the surge arresters;
- Test the transformer neutral ground impedance devices, if applicable; and
- When replacing transformers, 'right-size' the transformers to reduce or eliminate unnecessary arc flash incident energy levels.

5-1.3 Switching Equipment.

Switching equipment can contain numerous types of apparatus utilizing air, oil or SF_6 as an insulating medium. For this document, switching can be broken into two categories; Low Voltage (<1000V) and Medium Voltage Switching (>= 1000V). Generally, substations may contain both voltage classes. No work is allowed on switches until both sides of each phase are de-energized and properly grounded. In addition, follow the specific maintenance directions of the switch manufacturer.

5-1.3.1 Inspection Frequency.

Inspect switches visually at a frequency determined by local conditions, such as atmospheric contamination, use of contamination control coatings, operations, or fault current exposure.

5-1.3.2 Need.

If a switch cannot be maintained on a periodic basis, its service life may be affected. When operated, it is recommended that the switch be opened and closed several times in order to clean the contacts and free the moving parts.

5-1.3.3 Visual Aids.

Binoculars can facilitate spotting switches that are obviously in need of repair or maintenance because of broken insulators or other parts. Visual inspection of a wet switch, or the use of a temperature-scanning detector, may indicate hot spots which are possible sources of trouble. Directional microphones or ultrasonic detectors can be used to locate local corona sources needing removal.

5-1.3.4 Scheduling.

A relatively small amount of maintenance is required on modern switches. It is recommended that the schedule for such maintenance be coordinated with that of associated equipment. Schedule special inspection and maintenance whenever the switch has carried heavy short-circuit current.

5-1.3.5 Checking.

Examination of de-energized and grounded switches to include the following items:

- Operating Mechanism. Check the adjustment of the operating mechanism, operating rod, and interphase tie rods (if used) to ensure simultaneous and smooth operation of the switch blades. Clean and lubricate mechanisms only when so recommended, and then only in accordance with the manufacturer’s instructions as many modern switches are built with self-lubricating bearings. Examine all metallic parts of an operating mechanism including operating handle connection for signs of rust, corrosion, and loose or broken connectors. Switches located outside of a fenced and locked area, and having operating handles at ground level, require locking provisions on handles for both the open and closed positions. Switches located within a fenced and locked area, are subject to local regulations for locking.

  – Inspect all live parts for scarring, gouging, or sharp points, which could contribute to excessive radio noise and corona. Check corona balls and rings for damage which could impair their effectiveness.

  – Power-operating mechanisms for switches are usually of the motor-driven, spring, hydraulic, or pneumatic type. Follow the manufacturer’s instructions with regard to the limit switch adjustment. Check associated relay equipment for poor contacts, burned out coils, and adequacy of supply voltage. Check the complete electrical circuit of a motor-operated mechanism to ensure proper operation and wiring which is secure and free of insulation defects.

- Inspect, check, and test all safety interlocks for proper operation.

- Insulators. Examine insulators for cracks, chips, breaks, and evidence of flashover. Replace bad insulators. Clean insulators to remove any contaminating materials that may be present. Report the presence of an excessive amount of contamination to the supervisor, as it may require corrective measures;

- Mounting. Check mountings for evidence of rust and corrosion and to ensure proper alignment and securement. Ground connections must be tight;

- Blades. Inspect the blade or movable contact of the switch for evidence of overheating, which may be indicated by discolorations. If overheating is caused by poor contact, adjust and clean contacts to improve contact. Report to the supervisor any switches that appear to have overheated due to load currents in excess of rating;

- Blade Latch. A blade latch is used on a hook stick operated switch to hold the blade in closed position. Check the switch in the closed position to determine whether the catch is functioning properly;

- Contacts. Clean contacts and adjust in accordance with manufacturer's instructions. Modern switches are normally designed so that the contacts are self-cleaning by the opening and closing action of the switch. After a switch remains in either position for a long time, operate several times during a maintenance inspection. This operation will clean the contact surfaces. Operate only after getting clearance and after the circuit has been de-energized;

  - Do not use a coarse abrasive to clean contacts. If contact pitting is minor, smooth the surface with clean crocus cloth or as the manufacturer recommends.

  - Where arcing horns are used, ensure they make contact as intended during opening and closing operations.

  - Use a non-oxidizing lubricant to protect the contacts against oxidation and to lubricate the blade hinge. Silicone greases are excellent for this purpose, as they are relatively unaffected by changes in temperature and are highly water resistant.

- Terminals and connections. Check terminals to ensure that they are secure. Correct connections showing evidence of heat as a high-resistance contact is indicated; and

- Interrupting elements. Load interrupter switches are equipped with an interrupter element, designed to quench the arc that results when the switch is opened under loaded conditions. These elements are shunt devices, installed as part of the switch, through which current passes only as the switch is opened. In some higher voltage designs, the arc quenching medium is air.

5-1.3.6 Medium Voltage Switches.

For medium voltage switches and switching equipment, include all the inspection and mechanical testing identified in the low voltage section along with the following:

- Verify that expulsion-limiting devices are in place on all fuses that have expulsion-type elements;

- Verify that phase-barrier mounting is intact;

- Verify correct operation of all indicating and control devices;

- Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces; and

- Perform as-left tests.

Electrical tests for medium voltage switches and switching equipment within a substation are comparable to those for low voltage switches with the inclusion of the following:

- Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole to ground with all other poles grounded.

5-1.4 Tap Changers/Voltage Regulators.

These apparatus may be devices that are active or change internal mechanical positions several times a day depending upon the device. For example, a power transformer may have mechanically held Tap Changers which require powering off the transformer to enable the repositioning of the taps within the transformer. Other tap changers, such as Automatic Load Tap Changers can step up or down voltages through the day, similar to Voltage Regulators, as the loading of the substation changes through the day. Inspect the mechanical apparatus along with the contacts internal to the tested changer/regulator.

5-1.4.1 Visual Inspections:

Perform visual inspection and cleaning on an annual basis. Perform voltage regulator model validation along with performance testing every five (5) years. For tap changers and voltage regulators:

- Inspect physical and mechanical condition;
- Inspect anchorage, alignment and grounding;
- Record position indicator as found, maximum and minimum values, and record reading on tap changer operations counter;
- Prior to cleaning the unit, perform as-found tests;
- Clean the unit;
- Inspect bolted electrical connections for high resistance;
- Verify correct auxiliary device operation;
- Verify motor and drive train for correct operation and automatic motor cutoff at maximum lower and maximum raise;
- Verify correct liquid level in all tanks;
- Perform specific inspections and mechanical tests as recommended by the manufacturer;
- Visually inspect wear/erosion indicators on vacuum bottles, if applicable;
- Perform an internal inspection;
    1. Remove oil.
    2. Clean carbon residue and debris from compartment.
    3. Inspect contacts for wear and alignment.
    4. Inspect all electrical and mechanical connections for tightness using calibrated torque wrench.

5. Inspect tap changer compartment terminal board, contact support boards and insulated operation components for evidence of moisture, cracks, excessive wear, breakage, and/or signs of electrical tracking.

6. Electrically operate tap-changer through full range of taps.

7. Replace gaskets and seal compartment.

8. Fill with filtered oil.

- Use appropriate lubrication on moving current carrying parts and on moving and sliding surfaces;
- Perform as-left tests; and
- Record as-found and as-left operation counter readings.

5-1.4.2 Electrical Tests.

Electrical tests to:

- Perform resistance measurements through bolted connections with low-resistance ohmmeter;
- Perform insulation-resistance test in any off neutral position;
- Perform insulation power-factor or dissipation-factor tests in the off neutral position;
- Perform winding resistance test;
- Perform special tests and adjustments as recommended by the manufacturer;
- Perform turns-ratio test at all tap positions;
- Remove sample of insulating liquid and test for;
  - Dielectric breakdown voltage.
  - Color.
  - Visual condition.
- Remove sample of insulation liquid and perform DGA;

- Perform vacuum bottle integrity tests across each vacuum bottle with contacts in the open position; and

- Verify operation of heaters.

5-1.5 Relays, Instruments and Controls.

5-1.5.1 Discussion and Requirements on Controls.

Protective devices must operate during abnormal plant operating conditions and, in most instances, are the last line of defense to protect equipment from a catastrophic failure. It is critical these protective devices function properly to adequately protect the associated piece of equipment and that adjustments and calibrations are routinely conducted to eliminate the possibility of the protective device mis-operation. Therefore, it is imperative to conduct periodic maintenance testing to validate that the operational parameters of the functional protective device are properly set and coordinated, and to analyze findings to reveal trends which might lead to future failures.

5-1.5.2 Test Considerations.

Tests should simulate normal operating conditions. Avoid over testing because such tests can often cause more problems than they correct. The variables that may cause problems are relay complexity, environment, history, and facility relay-type experience. Other considerations are relay age and relay stress (relays operated at greater currents and/or control voltages because of station expansions).

5-1.5.3 Frequency.

Inspections made every 2 to 3 years are usually sufficient. Testing may be necessary after a relay operation. Additional visual inspections can be made at any time other area visual inspections are required. Check relay settings at least once a year and after any incorrect operation or redesign of the system. These inspections, supplemented by suitable tests, should be thorough enough to detect any faulty relays, settings, or wiring errors before trouble is encountered. During annual testing, provide a dated copy of the native microprocessor relay settings electronic file to the installation electrical engineer for archival purposes. For example, provide the ".rdb" file for SEL relays to the installation electrical engineer.

Completely disconnect relays from any live circuit when they are inspected or tested. Only permit specially trained electricians to repair and adjust relays, and check manufacturer's instructions for the proper procedures. Major repairs and testing should be conducted in a facility's testing laboratory or by contract personnel with access to any special testing equipment needed. NETA MTS suggestions include:

- Inspect relays and case for physical damage;

- Prior to cleaning the unit, perform as-found tests, if required;
- Clean the unit;
- Relay case;
  - Tighten case connections.
  - Inspect cover for correct gasket seal.
  - Clean cover glass.
  - Inspect shorting hardware connection paddles, and/or knife switches.
  - Remove any foreign material from the case.
  - Verify target rest.
- Relay;
  - Inspect relay for foreign material, particularly in disk slots of the damping and electromagnets.
  - Verify disk and contact clearance and spring bias.
  - Inspect spiral spring convolutions.
  - Inspect disk and contact for freedom of movement and correct travel.
  - Verify tightness of mounting hardware and connections.
  - Burnish contacts.
  - Inspect bearings and/or pivots.
- Verify that all settings are in accordance with coordination study or setting sheet supplied by owner;
- Perform as-left tests. Primary injection testing is required for end-to-end testing. Secondary injection testing of only the relay is not adequate to determine proper system operation;
- Intervals for electromechanical relays;

Table 5-1 Electromechanical Relay Test Intervals

Required Tests	Recommended Interval
Calibration maintenance	2 years
Relay functional test	2 years
Check for relay power supply indicating light	Weekly
Calibration maintenance	2 years
Relay functional test	2 years

- Contacts;
- Moving parts;
- Connections;
- Case and cover;
- Intervals for electronic relays;

Table 5-2 Electronic Relay Test Intervals

Maintenance or Test	Recommended Interval
Check for relay trouble light	Weekly
Relay functional test Monitored	6 years
Relay function test Unmonitored	4 years

- Relay functional testing of microprocessor relays will include the testing of the digital and analog inputs and outputs; and
- Monitored – A microprocessor relay is considered unmonitored unless facility monitoring meets all the following requirements:
  - Real time monitoring and alarm of the relay internal self-monitoring alarm.
  - Real time monitoring and alarm for DC supply or power supply failure.

- – Monitoring of trip coil continuity (either real time or via red light check interval).
- – If applicable, monitoring of protection telecommunication system (real time or periodically per test interval).
- – Monitoring DC battery voltage (real time or per test interval).
- – Verification of relay inputs and outputs (real time or per test interval).
- – End-to-end testing – confirmation the overcurrent test signal energized the trip coil and tripped the breaker.

5-1.6 Stationary Batteries and Battery Chargers.

Maintain substation and switching station stationary batteries in accordance with the following industry standards as modified by the requirements specified in the applicable section below.

- Vented lead acid batteries – IEEE Std 450
- Valve regulated lead acid batteries – IEEE Std 1188
- Nickel cadmium batteries – IEEE Std 1106

Use the protective equipment and follow the safety precautions specified by the applicable IEEE standard. For further battery requirements, refer to UFC 3-550-01.

5-1.6.1 Stationary Battery Approach Boundaries.

Substation and switching station stationary batteries typically operate at either 48 or 125 VDC. Observe the minimum approach distances specified in Table 5-3 and apply the arc flash PPE Category specified in Table 5-4 for the available short circuit current. Refer to UFC 3-560-01 for further information.

Table 5-3 Qualified Worker Minimum Approach Distances – DC Systems

Nominal System Voltage Range Phase to Phase	Limited Approach Boundary		Restricted Approach Boundary
	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Reduced Inadvertent Movement Adder
<100 V	Not specified	Not specified	Not specified
100 V to 300 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>300 V to 1 kV	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)

Table 5-4 Arc Flash PPE Categories for DC Systems

Equipment	PPE Category	Arc Flash Boundary
Storage batteries, DC switchboards, and other DC supply sources 100 V> Voltage < 250 V Maximum arc duration and working distance: 2 sec @ 18 in.		
Short-circuit current <4 kA	1	3 ft
4 kA ≤ short-circuit current < 7 kA	2	4 ft
7 kA ≤ short-circuit current < 15 kA	3	6 ft
Storage batteries, DC switchboards, and other DC supply sources 250 V ≤ Voltage ≤ 600 V Maximum arc duration and working distance: 2 sec @ 18 in.		
Short-circuit current 1.5 kA	1	3 ft
1.5 kA ≤ short-circuit current < 3 kA	2	4 ft
3 kA ≤ short-circuit current < 7 kA	3	6 ft
7 kA ≤ short-circuit current < 10 kA	4	8 ft

5-1.6.2 Vented Lead Acid Batteries.

Perform battery inspections, tests, and maintenance in accordance with IEEE Std 450 as modified below. Correct deficient items as they are discovered.

5-1.6.2.1 Weekly. Verify the battery charger(s) is operating at the battery float voltage within battery manufacturer's specified range.

5-1.6.2.2 Monthly. Check and record the following:

- Float voltage measured at the battery terminals;
- Charger output current as expected and voltage within battery manufacturer's specified range;
- General appearance and cleanliness of the battery, battery rack or battery cabinet, and the battery area;
- Electrolyte levels adequate;
- No cracks in cells or evidence of electrolyte leakage;
- Any evidence of corrosion at terminals, connectors, racks, or cabinets; and
- Ambient temperature adequate and ventilation system operable.

5-1.6.2.3 Quarterly. Augment the monthly inspection with the following:

- Voltage measured of each cell; and
- Battery cell temperature at representative cells.

5-1.6.2.4 Annually. Augment the quarterly inspection with the following:

- Visual inspection of each cell;
- Evaluation of structural integrity of the battery rack or cabinet; and
- Measurement of cell-to-cell and terminal connection resistance or torque check in accordance with manufacturer's instructions.

5-1.6.2.5 As Required. Complete the following as specified:

- Record a complete set of specific-gravity readings upon initial installation and after two years of service;
- If the battery has experienced an abnormal condition, perform an annual inspection to verify that the battery has not been damaged. Refer to IEEE 450 for additional guidance for abnormal conditions; and

- Schedule for a battery replacement every 12 years. In lieu of a battery replacement, it is acceptable to perform the IEEE 450 battery capacity test every two years after the battery has been in service for 10 years. If capacity tests are performed, replace the battery when capacity falls below 80% of rated capacity.

5-1.6.3 Valve Regulated Lead Acid (VRLA) Batteries.

Perform battery inspections, tests, and maintenance in accordance with IEEE Std 1188 as modified below. Correct deficient items as they are discovered.

5-1.6.3.1 **Weekly.** Verify the battery charger(s) is operating at the battery float voltage within battery manufacturer's specified range.

5-1.6.3.2 **Monthly.** Check and record the following:

- Float voltage measured at the battery terminals;
- Charger output current as expected and voltage within battery manufacturer's specified range;
- General appearance and cleanliness of the battery, battery rack or battery cabinet, and the battery area;
- No cracks in cells or evidence of electrolyte leakage;
- Any evidence of corrosion at terminals, connectors, racks, or cabinets;
- Any evidence of cell/unit jar or cover distortion; and
- Ambient temperature adequate and ventilation system operable. *Note: a high ambient temperature can lead to battery thermal runaway. Correct the high temperature condition immediately.*

5-1.6.3.3 **Quarterly.** Augment the monthly inspection quarterly with the following:

- Measurement of cell/unit internal ohmic measurement. Typically, a change of 30% to 50% from a baseline is considered significant. Evaluate any measurements indicating a high internal resistance and replace the cell/unit, if needed;
- Temperature of the negative terminal of each cell/unit of battery; and
- Voltage of each cell/unit.

5-1.6.3.4 **Annually.** Augment the quarterly inspection annually with the following:

- Measurement of cell-to-cell and terminal connection resistance or torque check in accordance with manufacturer's instructions.

5-1.6.3.5 **As Required.** Complete the following as required:

- If the battery has experienced an abnormal condition, perform an annual inspection to verify that the battery has not been damaged. Refer to IEEE 1188 for additional guidance for abnormal conditions; and

- Perform a performance test of the battery capacity in accordance with IEEE 1188 after the battery has been in service for three years and every two years thereafter. Alternately, replace the battery after three years of service. If capacity tests are performed, replace the battery when capacity falls below 80% of rated capacity.

5-1.6.4 Nickel Cadmium Batteries.

Perform battery inspections, tests, and maintenance in accordance with IEEE Std 1106 as modified below. Correct deficient items as they are discovered.

5-1.6.4.1 **Weekly.** Verify the battery charger(s) is operating at the battery float voltage within battery manufacturer's specified range.

5-1.6.4.2 **Quarterly.** Check and record the following:

- Float voltage measured at the battery terminals;

- Charger output current as expected and voltage within battery manufacturer's specified range;

- General appearance and cleanliness of the battery, battery rack or battery cabinet, and the battery area;

- Electrolyte levels adequate;

- No cracks in cells or evidence of electrolyte leakage;

- Any evidence of corrosion at terminals, connectors, racks, or cabinets; and

- Ambient temperature adequate and ventilation system operable.

5-1.6.4.3 **Semi-Annually.** Augment the quarterly inspection semi-annually with the following:

- Voltage measured of each cell.

5-1.6.4.4 **Annually.** Augment the semi-annual inspection annually with the following:

- Evaluation of structural integrity of the battery rack or cabinet; and
- Measurement of cell-to-cell and terminal connection resistance or torque check in accordance with manufacturer's instructions.

5-1.6.4.5 **As Required.** Complete the following as required:

- If the battery has experienced an abnormal condition, perform an annual inspection to verify that the battery has not been damaged. Refer to IEEE 1106 for additional guidance for abnormal conditions; and
- Schedule for a battery replacement every 15 years. In lieu of a battery replacement, it is acceptable to perform the IEEE 1106 battery capacity test every two years after the battery has been in service for 12 years. If capacity tests are performed, replace the battery when capacity falls below 80% of rated capacity.

5-1.7 Instrument Transformers.

The basic difference between current and potential transformers must be observed. A voltage transformer should never be short circuited. A current transformer requires the secondary circuit always be closed. Under no circumstances open the secondary of a current transformer while the primary circuit of the transformer is energized unless the terminals of the current transformer are of the short circuiting type. Schedule instrument transformers for a maintenance inspection every 2 years. In addition, inspect visually any time the apparatus with which they are associated is inspected, but not less than every 6 months.

Maintain the bushings and terminals of an instrument transformer as described in the NETA maintenance guide. Inspect the case or tank for evidence of corrosion and leaks. Tighten all loose joints in conduit around fittings, terminal boxes and supporting clamps. Clean and paint corroded areas. Verify tightness of all bolted connections. Verify that wiring, grounding and shorting connections provide good contact. Test the proper operation of the voltage transformer withdrawal mechanisms (tip out) and grounding operation. Accomplish instrument transformers electrical testing per NETA standards.

5-1.8 Capacitors and Inductors.

Capacitors:

- Observe the condition of fuses;
- Inspect for damaged tanks and bushings and for leakage of the dielectric; and
- Recommended intervals and requirements.

Inductors:

- Very few inductors exist in military primary distribution systems.

5-1.9 Insulators.

Examine insulators for cracks, chips, breaks, and evidence of tracking or flashover. Replace bad insulators. Clean insulators to remove any contaminating materials that may be present. Report the presence of an excessive amount of contamination to the supervisor as it may require corrective measures.

Check mountings for evidence of rust and corrosion and to ensure proper alignment and securement. Ground connections must be tight.

5-1.10 Bushings.

Information in this section pertains to bushings on such substation apparatus as power transformer, sulfur hexafluoride (SF6) and oil circuit breakers, and high-voltage instrument transformers. Bushings are always an integral part of a specific apparatus and should be inspected along with that apparatus.

- Examine bushings for cracks, chips, breaks, and evidence of tracking or flashover. Replace bad bushings. Clean bushings to remove any contaminating materials that may be present. Report the presence of an excessive amount of contamination to the supervisor as it may require corrective measures, and
- Check mountings for evidence of rust and corrosion and to ensure proper alignment and securement. Ground connections must be tight.

Power factor testing of a bushing is an indication of the effectiveness of the insulation to function properly. Power-factor test bushings at the time of installation and at regular intervals. Follow IEEE Std 62.

5-1.11 Bus Structures.

A bus structure is an assembly of bus conductors with associated connection joints and insulating supports. It can have bare or insulated conductors. A busway is a grounded metal enclosure, containing factory-mounted, bare or insulated conductors, which are usually copper or aluminum bars, rods, or tubes. Each serves as a common connection between two or more circuits.

- Schedule bus structures visual inspections at regular intervals. Joints on bus structures need regular visual and infrared inspections;

- Bus cleaning is limited primarily to that of eliminating excessive contamination from the supporting insulators. It is not necessary to remove corrosion from the conductors except where it either affects contact resistance of connections or can lead to deterioration of conductors; and

Generally, no testing is required in connection with a bus structure other than infrared.

5-1.12 Terminations.

Inspect and test terminations and connections on a regular basis. Infrared thermography can provide a non-contact means of online evaluation of “hot spots” in an energized system. When a loose or corrosive connection is present under loaded conditions, the infrared viewer can detect the temperature difference between the connection and the surrounding conductors:

- When doing infrared scanning, take into account the following considerations. Infrared scanning surveys should be done during periods of maximum possible loadings, but not less than 40% of rated load of the electrical equipment being inspected. However, since many systems are not loaded to this level, the most important understanding is to measure when there is an adequate temperature difference for the scanner to detect. Try to measure at maximum possible loading, referring back to the seasonal loading chart regarding when to schedule; and

- Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1 ^{0}C at 30 ^{0}C.

Ultrasound is another method of testing and evaluating terminations on a system that is energized. Ultrasound detectors are used to detect inaudible noises on equipment that could indicate potential problems:

- Test on an annual basis.

5-1.13 Grounding.

Grounding is an essential part of protecting staff and equipment from high potential caused by electrical faults. Grounding conductors of switchyard equipment and gate structures are subject to failure due to corrosion, loose connections, and mechanical damage. Grounding also may be compromised during equipment addition and removal or other construction type activities. Verifying grounding system integrity through periodic testing is an important maintenance activity:

- Check all accessible ground connections for secureness, and measure the overall ground grid resistance if it has not been done for a number of years. Since it is desirable to disconnect shield wire grounds and system neutral connections to make this measurement, de-energize the total substation for these tests. Perform visual and mechanical inspections annually. Test grounding electrode and substation/switchyard grid every 6 years (Table 5-5); and

Table 5-5 Battery Monitor System Maintenance

Maintenance or Test	Recommended Interval
Visual/physical inspection	Annually
Grounding electrode and substation/switchyard grid tests	6 years
Ground loop impedance test	6 years

- Comply with IEEE 80, IEEE 1246, and IEEE 837.

5-1.14 Fences.

Metal fences must be properly grounded and bonded. Fences, physical protection, enclosures or other protective means, where required to guard against unauthorized access or accidental contact with exposed energized conductors and circuit parts, will be maintained. Bond across all gate opening and gaps of fences from fence post to post.

5-1.14.1 Grounding.

The grounding connections will be made either to the enclosed equipment grounding system or to a separate ground:

- Fences will be grounded at each side of a gate or other opening;

- Gates will be bonded to the grounding conductor, jumper or fence;

- A buried bonding jumper will be used to bond across a gate or the opening in the fence, unless a non-conducting fence section is used;
- If barbed wire strands are used above the fence fabric, the barbed wire strands will be bonded to the grounding conductor, jumper or fence;
- When fence posts are of conducting material, the grounding conductor will be connected to the fence post or posts, as required, with suitable connecting means; and
- When fence posts are of non-conducting material, suitable bonding connection will be made to the fence mesh strands and the barbed wire strands at each grounding conductor point.

5-1.14.2 Fence Structure.

The following are minimum inspection requirements:

- Check for minimal gap under the fence or under the gate. A reasonable rule of thumb would be less than 2 inches under the fence and 4 inches under the gate;
- Ensure the fence fabric is intact and there is no rust;
- Check that the barbed wire is taut;
- Ensure the gate latches are operable;
- Ensure flexible braid-type connections are intact;
- Verify that no wire fences are tied directly to the substation fence; and
- Recommend revised corrosion control intervals and requirements based upon observed local conditions.

5-1.14.3 Structural Grounding Maintenance.

Fence maintenance consists of material preservation, maintenance of structural integrity, and maintenance of a good ground. The following procedures are recommended:

- Material preservation. In noncorrosive locations, double-dipped (ASTM A 90, Class II) hot dipped galvanizing on chain-link fences will normally furnish adequate protection for many years. In corrosive locations, use of an aluminized fabric is the preferred installation. Wood fences are not usually considered to provide adequate security for substations. Consider replacement with chain-link fencing. Screening, if required, can be provided with privacy slats of polyester-fiberglass or aluminum;

- Structural integrity. Security requires that structure integrity be maintained by replacing damaged posts or other materials as required. Keep chain-link fencing taut. Replace spalling or broken components of masonry fencing;

- Grounding. Grounding must be maintained as a safety feature. Make visual inspections as a part of the monthly inspections, especially at the gate bonding straps. Periodically test and correct defects immediately; and

- Comply with UFC 3-550-01 for policy and guidance for design criteria and standards for electrical power and distribution systems.

5-1.15 Lightning Protection.

5-1.15.1 Surge Arrestors.

Modern surge arresters require little operational maintenance and the degree to which such maintenance can be done is normally limited by lack of adequate test equipment. This limits surge arrester maintenance to visual inspection and simple electrical tests. It is recommended that defective units be replaced rather than repaired. Where an arrester is composed of two or more individually complete units, test each unit separately to allow bad unit replacement and retaining good units. Surge arresters are almost always applied with one terminal connected to an electrically energized source and one terminal to ground. No work is allowed on, or contact made with, surge arresters connected to the energized source.

5-1.15.1.1 Visual Inspections.

Periodically visual inspect to ensure that:

- The line lead is securely fastened to the line conductor and the arrester;

- The ground lead is securely fastened to the arrester terminal and ground;

- The arrester housing is clean and free from cracks, chips, or evidence of external flashover;

- The arrester is located in such a manner as not to be subject to:

  - Damaging fumes or vapors

  - Excessive dirt or other current-conducting deposits

   - Excessive humidity, moisture, dripping water, steam, or salt spray

   - Abnormal vibrations or shocks

   - Ambient temperatures in excess of 40° C

- Any external gaps are free from foreign objects and set at proper spacing.

5-1.15.1.2 Electrical Tests.

Visual inspection will not always detect a damaged arrester. Interior damage may result from a broken element, presence of moisture, a severe direct lightning stroke, or the use of an arrester with an incorrect rating. Sometimes these conditions will cause radio interference. Electrical tests, to detect inferior arrester units, may be made either in the field or shop. Tests must be made strictly in accordance with manufacturer's recommendations and the results interpreted in line with manufacturer's criteria:

- Power factor tests. Each type and class of lightning arrester has a specific power factor when new. Periodic testing of a unit will show little deviation from the original (when new) power factor so long as it remains in good operating condition. A major deviation from the original value indicates that the arrester has been mechanically damaged or contains moisture;

- Insulation resistance testing tests. An insulation resistance test can be made to provide additional information on the condition of an arrester. Such a test may indicate shorted valve elements in valve-type arresters; and

- Operation tests. Electrical tests to determine 60 Hz breakdown and leakage current may be made in the field or shop, but must be made cautiously to avoid damage to the arrester. It is questionable whether these tests can be justified for military installations, where the number of arresters potentially subject to such tests is relatively small.

5-1.15.2 Grounding Electrodes.

All grounding electrodes used for grounding of the power system, grounding of communication systems, and grounding of lightning protection systems will be effectively and permanently bonded to each other as required by the National Electric Code (NEC) and NFPA 780.

5-1.15.3 Lightning Protection – Downcomers and Air Terminals.

Lightning protection is intended primarily to dissipate the energy from a lightning strike in a manner that is safe for personnel and that causes the least amount of equipment damage. The lightning protection system may have multiple interconnections with building steel and the power system ground. Since lightning is a cloud to earth phenomenon, the resistance between the lightning protection/power system ground point the outside earth is an important factor. NFPA 780 recommended guidelines for the maintenance of the lightning protection system be provided to the owner (mission) at the completion of installation.

5-1.15.3.1 Inspection.

It is understood that all new lightning protection systems must be inspected following completion of their installation. Recommended guidelines for the maintenance of the lightning protection system are provided to the owner at the completion of installation. In addition to regular periodic inspections, inspect the lightning protection system whenever any alterations or repairs are made to a protected structure, as well as following any known lightning discharge to the system.

It is recommended that lightning protection systems be visually inspected at least annually. In some areas where severe climatic changes occur, it is advisable to visually inspect systems semiannually or following extreme changes in ambient temperatures:

- Complete, in-depth inspections of all systems every 3 to 5 years. It is recommended that critical systems be inspected every 1 to 3 years, depending on occupancy or the environment where the protected structure is located; and

- Complete testing and inspection includes the visual inspections.

5-1.15.3.2 Maintenance.

Maintenance of a lightning protection system is extremely important even though the lightning protection design engineer has taken special precautions to provide corrosion protection and has sized the components according to their particular exposure to lightning damage. Many system components tend to lose their effectiveness over the years because of corrosion factors, weather-related damage, and stroke damage. The physical as well as the electrical characteristics of the lightning protection system must be maintained in order to remain in compliance with design requirements:

- Establish lightning protection system maintenance procedures for each system and include as part of the overall maintenance program for the structure that it protects; and

- Keep complete records all maintenance procedures and routines and of corrective actions that have been or will be taken. Such records provide a means of evaluating system components and their installation. They also serve as a basis for reviewing maintenance procedures as well as updating preventive maintenance programs.

5-1.16 Structure Maintenance / Corrosion Control.

Inspect all structures in close proximity to buses, energized portions of equipment, etc., and make necessary repairs to galvanizing and painted surfaces. Test paint for hazardous material, i.e. lead, before disturbing. If lead based paint is confirmed, follow applicable handling/abatement procedures.

5-1.16.1 Material Preservation – Galvanizing.

In noncorrosive locations, the protective coating produced by the galvanizing process is normally a long-lived coating; however, the coating will eventually fail and rust will appear. It has been observed that ASTM A 90, Class II hot-dipped galvanizing in rural locations will normally furnish adequate protection for many years. The life of the coating on structural steel used in substations should generally be longer than 12 years, except possibly for upper flat surfaces of horizontal members. Any failure of the coating will usually occur in spots rather than over an entire surface. The following procedure is recommended:

- Clean the surface with a wire brush or by other mechanical means to remove rust and dirt. If the surface is contaminated with grease or oil, use a solvent to remove those contaminants. Mineral spirits or a weak solution of trisodium phosphate can be used as the solvent. A solution of 1 ounce of trisodium phosphate to 1 gallon of warm water is suggested for cleaning the metal. In the event that it is uneconomical or impractical to remove all rust, a reasonably satisfactory job can be obtained by deactivating the rust through chemical treatment. A weak solution of phosphoric acid is suggested for deactivating rust. Use proper skin and eye protection;

- Apply a priming coat to the clear dry surface using a zinc dust–zinc oxide paint. Allow ample time for the paint to dry before applying the finish coats; and

- Apply two finish coats using the same type of paint as was used for priming. Allow ample drying time between finish coats. One finish coat is needed for areas on which the galvanized coating remains intact. The color of the paint is gray, but colors in oil may be added to the finish coats to obtain other shades. Other paints normally used as final coats for metal (such as aluminum paint) may be used as the final coat in place of the zinc dust–zinc oxide paint.

In corrosive locations, use of an aluminized fabric is a preferred installation.

5-1.16.2 Material Preservation – Painting.

Most steel for indoor substations, and some steel for outdoor substations, is not galvanized and paint is used for preservation. If required spot painted covers more than 5 percent of the visible surfaces, paint the entire structure. It is recommended that painting of outdoor metalwork be done only when the temperature is above 7.2 ^{0}C (45 ^{0}F) and when the relative humidity is below 80 percent. The durability of paint coating depends on thickness, cohesion, and continuity. Generally, 5 mils (0.005 inch) is an adequate thickness. The thickness should be uniform, and paint should not be easily scraped off the metal. Pay particular attention to welds, edges, and other hard-to-coat areas. Structures of aluminum alloy normally need no surface protection. Painting of aluminum alloy members is not recommended except where esthetics is of prime importance.

- Test paint for hazardous material, i.e. lead, before disturbing. If lead based paint is confirmed, follow applicable handling/abatement procedures.

- Thoroughly remove all loose paint, blisters, and scale. Where the condition of the finish is poor remove the paint entirely. Wire brushing, sand papering, or scraping is desirable where only partial surface cleaning is necessary. Paint removers will soften and aid in removal. However, neutralize the paint remover before attempting to paint. For removal of oil and dirt, use weak solvents such as mineral spirits, other petroleum thinners, or turpentine substitutes.

- Paint as soon as possible after cleaning. Cover all bare metal with a primer. Where only chalking has occurred, one finish coat is sufficient. Primer and finish paints may be obtained from most equipment manufacturers and sometimes from local sources. A zinc chromate alkyd resin primer followed by an alkyd base paint is a suitable air-dry combination for exterior surfaces. Allow the primer coat to air-dry thoroughly and follow it with two finish coats with sufficient time allowed between coats for drying.

5-1.16.3 Material Preservation – Wood Structures.

Inspect and treat permanent wood structures.

5-1.16.4 Material Preservation – Concrete for Structure Foundation.

Visually check concrete during the course of other maintenance and repair. Repair cracks wider than about 1/16th of an inch (0.16 mm) with a sand-cement grout. Replace badly deteriorated concrete.

5-1.16.5 Structure Connections and Joints.

Regardless of material, check all connections and joints periodically for tightness of fastening hardware. Tighten or replace loose, broken, or missing parts as required to maintain a rigid structure.

5-1.17 Substation Yards.

In some cases, there may be no outdoor yard in connection with a substation. These are exceptional situations, and most substations will have an adjoining yard. Removal of vegetation, elimination of low spots in the yard, and control of grassed areas is necessary. If grass is permitted, careful maintenance is necessary both for esthetics and safety reasons. Where chemical application for removal of vegetation is required, comply with environmental requirements.

Do not permit miscellaneous storage except for those specific areas reserved for this purpose. Ensure allowed storage does not to interfere with operations and items are stored in a protected, tidy, and accessible manner.

5-1.17.1 Fences.

Fence maintenance consists of material preservation, maintenance of structural integrity, and maintenance of a good ground.

5-1.17.2 Warning Signs.

Place warning signs conforming to OSHA standards and state the voltage on each fence gate, on each substation building door accessible from outside the yard, and at intervals along the fence. At least one sign must be visible from any position along the fence. Check location and legibility of all signs as part of the monthly inspections.

5-1.18 Wildlife Deterrents.

Apply IEEE Std 1264 for the control of wildlife and birds around substations.

5-1.19 Frequency Converters (Motor-Generator (MG) Sets) and Synchronous Condenser.

For MG sets and synchronous condensers, ensure the lubrication oil or grease is installed and maintained according to manufacturer’s instructions for type. Many oils and greases are not compatible with each other and if mixed may form sludge or acids, wrecking the lubricant and pitting the bearings.

Electrical tests for these devices are comparable to those for motors of the same voltage. Perform a dielectric withstand voltage test on each pole. High potential testing is not recommended for MG sets or for synchronous condensers. Determine test frequency by operating conditions. Dusty, high-humidity conditions require more frequent testing than clean, dry conditions. A machine in a dry atmosphere may be down for several months without absorbing moisture, while a device on an island might absorb sufficient moisture while being down for one week to fail during start-up. Items to check include: bearings, noise (clues to bearing life), lubrication, and every three years – insulation tests.

5-2 MEDIUM VOLTAGE (MV) DISTRIBUTION.

5-2.1 Overhead Distribution.

Refer to Chapter 6 for requirements associated with working on overhead distribution. Chapter 6 addresses the following topics related to operation of the overhead distribution system:

- Qualified worker qualification requirements;
- Pole handling, installation, replacement, and removal;
- Pole climbing;
- Line installation;
- Aerial rope and tools; and
- Tree trimming near energized aerial lines and overgrown vegetation surrounding equipment.

Refer to IEEE Std C135.90 as a guide for all types of hardware used for overhead distribution systems.

5-2.1.1 Power Poles.

Identification.

Develop a naming convention for power poles and label each pole with its identification number. Use this number for identification on electrical distribution system drawings and for the GeoBase data system.

5-2.1.1.1 Record Keeping. Maintain records that contain the following information:

- Identification number;
- Location (can be a GPS location included in the GeoBase documentation);
- Date of installation; and

- Manufacturer and brand.

Wood Pole Inspection Frequency.

The average life span of a full-length pressure-treated wood pole can be maintained and even extended another 10 to 20 years with a proper inspection, treatment, and reinforcement program.

Perform pole inspections at the following frequency:

- Visual inspection of pole line – annually. Drive along each pole line to observe problems such as pole degradation, leaning poles, sagging lines, damaged cross-arms, blown surge arresters, open fused cutouts, or leaking pole-mounted equipment;

- Spot check of 10% of power poles – approximately every 5 years. Perform a detailed inspection of selected power poles. Apply the inspection data to determine if a 100% inspection is required and to identify any poles requiring replacement; and

- Full inspection – Perform a detailed inspection of all power poles every 12 years or as required by results of a spot inspection.

Wood Pole Visual Inspection.

Perform the following visual inspection as part of a general inspection, spot check, or full inspection. Examine each pole for the following defects:

- Excessive checking, cracking, or splitting;

- Evidence of woodpecker holes or insect colonies;

- Excessive above-ground decay;

- Lightning damage;

- Corroded or damaged guying;

- Damaged bracing;

- Leaning pole requiring resetting; and

- Any other obvious defects.

Evaluate each pole for the following additional problems:

- Sagging lines that require re-tensioning;

- Damaged cross-arms;
- Blown surge arresters;
- Open fused cutouts; and
- Leaking pole-mounted equipment.

5-2.1.1.2 Wood Pole Detailed Inspection.

Perform the following as part of a spot check or full inspection. Examine each pole for the following defects:

- External decay. Where surface decay is found at the ground line, excavate around the deteriorated section of the pole. Measure and record the pole circumference at the ground line, remove the surface decay down to sound wood, and record the new circumference of the pole;
- Internal decay. Inspection methods include sounding and boring when necessary. The sounding test is fast and completely nondestructive, but it will not reveal the extent and type of defect. It will not indicate whether the pole has a harmless void or a large and dangerous decay pocket. Boring will reveal details on the type and severity of decay but it is rather slow, somewhat destructive, and may conceivably introduce decay-causing organisms into a sound pole; and
- Pole top and cross-arm defects. Either use bucket truck or climb pole if a visual inspection from grade is indeterminate.

5-2.1.1.3 Wood Pole Maintenance Crew Instructions.

Provide crews used for pole inspections with instruction and training regarding inspection precautions, duties, safety requirements, and use of equipment. Review available pole history before starting. The duties of the crew include observing the pole tops, cross arms, and attachments; inspecting the pole to a height that can be conveniently reached from the ground; excavating and inspecting the pole below the ground line; applying ground line treatment; keeping accurate records; and associated work.

Replace or reinforce any pole that has lost strength from decay or other cause to the point of being hazardous.

5-2.1.1.4 Wood Pole Cross Arms and Structures.

Properly installed cross arms require little maintenance. Cross arms can decay; aging can cause separations such as checks or shakes; lightning can splinter cross arms; or they may twist or bend by overload. These conditions may require replacement.

Evaluate cross arms as part of each pole inspection. Check cross arms for any damage caused by lightning, woodpeckers, or other causes. Inspect for checks, splits, or decay pockets, particularly at holes bored through the arm. Replace cross arms when defects are discovered.

5-2.1.1.5 Concrete Poles.

Reinforced or pre-stressed concrete poles have a projected life of 60 to 80 years and require no attention except for replacement when damaged. Concrete poles are preferred under conditions where the life of wood poles would be unduly shortened by decay or pests.

5-2.1.2 Insulators.

If insulators require cleaning to remove contaminants, apply IEEE Std 957 for cleaning of insulators for energized and de-energized circuits.

5-2.1.3 Reclosers.

Reclosers require maintenance when they have operated the equivalent of a rated duty cycle, where a rated duty cycle is defined as the maximum number of fault interruptions a recloser is capable of performing before servicing is required. Manufacturers provide the rated duty cycle in their product literature and the duty cycle vary for each recloser type or model. In general, vacuum interrupters have a higher duty cycle compared to oil interrupters. At the completion of a duty cycle, the following can be expected:

- Oil-interrupting recloser: The interrupter assemblies, stationary contacts, and movable contacts will be badly eroded and burned. The condition of the insulating oil will be of poor quality; it will be black and dirty, with a significant amount of sludge (carbon buildup) covering the recloser's internal components. Unwanted by-products, including water, will be present in the oil; and

- Vacuum-interrupting recloser: The contacts will be eroded and worn and the vacuum interrupters will require replacement. Insulating oil will not be degraded because the arc is contained with the vacuum interrupters. But, the oil will require replacement or filtering as it might have reduced dielectric strength. Also, there might be water present in the oil.

Maintain a record of the recloser operations. If the information is available at the substation or switching station, maintain a record of fault current date, time, and magnitude for comparison to the rated duty cycle capability. Newer recloser control units also offer event recording capability. If available, review recloser control event data for comparison to the duty cycle rating.

5-2.1.3.1 Oil-Interrupting Reclosers.

Maintain oil-interrupting reclosers in accordance with the manufacturer's instructions at the following intervals:

- Before the end of a rated duty cycle;
- At least every three years;
- More frequently than every three years if operating experience indicates poor internal contact and oil condition when checked; and
- More frequently than every three years if the recloser operates frequently and no records have been maintained that indicate the fault current associated with each recloser operation.

Reclosers require periodic maintenance. Manufacturers provide detailed inspection and test requirements for their reclosers. For older reclosers, consider replacement rather than maintenance. Also, manufacturers provide modernization instructions for some older reclosers.

5-2.1.3.2 Oil- or Air-Insulated Vacuum Interrupting Reclosers.

Maintain vacuum-interrupting reclosers in accordance with the manufacturer's instructions at the following intervals:

- Before the end of a rated duty cycle;
- At least every six years;
- More frequently than every six years if operating experience indicates poor internal contact and oil condition when checked; and
- More frequently than every six years if the recloser operates frequently and no records have been maintained that indicate the fault current associated with each recloser operation.

Reclosers require periodic maintenance. Manufacturers provide detailed inspection and test requirements for their reclosers. For older reclosers, consider replacement rather than maintenance. Also, manufacturers provide modernization instructions for some older reclosers.

5-2.1.3.3 Recloser Control Units.

If the recloser has a separate recloser control unit, which is typical for larger three-phase reclosers, perform a maintenance check on the recloser control unit at the same time that recloser maintenance is performed. Include the following:

- Perform maintenance and testing in accordance with the manufacturer's instructions. If the recloser control unit is obsolete, consider replacement with a new recloser control unit;
- Test the battery in accordance with the manufacturer's instructions. Replace the battery if it is older than 6 years or if battery testing indicates that the battery capacity is inadequate; and
- Confirm that the recloser control settings are as required by the most recent electrical coordination study. Change settings as required.

5-2.1.4 Fused Cutouts and Switches.

Select and replace fuses for overhead distribution systems in accordance with IEEE Std C37.48. Perform periodic maintenance on pole-mounted air switches in accordance with IEEE Std C37.35.

5-2.1.5 Transformers.

Pole-mounted distribution transformers require no periodic maintenance or testing. As part of the annual visual inspection of poles, visually inspect pole-mounted distribution transformers for the following:

- Evidence of oil leakage;
- Damaged surge arresters; and
- Excessive corrosion.

Correct problems as they are discovered.

5-2.1.6 Conductors and Splicing.

Apply IEEE Std 1283 for the evaluation of overhead conductors and accessories in high-temperature locations.

5-2.1.7 Lightning and Surge Arresters.

Select and install surge arresters for overhead distribution systems in accordance with Section 6 of IEEE Std C62.22. Apply IEEE Std 1410 as a guide for maintaining the lightning resistance of the overhead distribution system.

5-2.1.8 Tree Trimming.

Evaluate all overhead distribution system lines annually for the need for tree trimming. Refer to Section 6-14 for tree trimming procedures.

5-2.1.9 Wildlife.

Apply IEEE Std 1651 as a guide for maintaining the overhead distribution system.

5-2.2 Underground.

5-2.2.1 Cables and Splicing.

MV power cables are exposed to a variety of environmental and operational stressors, including elevated temperatures, high UV radiation, high humidity, water submersion, and exposure to dust, dirt and corrosive contaminants. Electromechanical forces resulting from the passage of high levels of short circuit current through a power cable can cause mechanical damage to cable jacket and insulation material and cable conductors. High-voltage stress from lightning strikes or power system transients can degrade the dielectric strength of cable insulation. For an acceptable range for different types of tests and specific trend analysis flags such as rate of change in resistance levels, refer to IEEE 400, IEEE 510 and ANSI/NEMA WC 74/ICEA S-93-639.

For cables that do fail early, the failure modes are typically attributed to:

- Partial discharge – localized electrical discharge that partially bridges the insulation and causes excessive heating and degradation of the cable insulating materials and ionization of the air in the vicinity of the leakage current;

- Treeing – tree-like erosion propagated by electrical discharges in a cable insulation or covering;

- Power workmanship – direct mechanical damage, such as bending, abrasion, cutting, contact, deformation and perforation resulting from installation or maintenance activities; and

- Vermin - rodents eating insulation.

The following maintenance tests and frequencies for MV power cables are recommended:

- Time-based preventive - equipment is off-line, de-energized and disconnected from service (planned major shutdown) (Table 5-6);

Table 5-6 Time-Based Preventive Tests

Test	Comments
DC hi-potential withstand test.	Relies on a source of high DC voltage.
	Simple, portable, inexpensive, low skills required to perform the test.
	Can be destructive when performed on service-aged MV cable insulation, misses certain types of insulation defects.
Alternating Current (AC) hi-potential withstand test.	Uses AC high voltage greater than the rated voltage of tested equipment.
	Good test for conductive and high-impedance defects in cables.
	Requires much larger power source and multiple personnel which makes it expensive.
Very Low-Frequency (VLF) withstand test.	Similar to AC hi-potential but at lower frequency.
	Simple, portable, inexpensive test equipment.
	Can aggravate existing insulation defects in aged extruded cables; considered a destructive test.
Power factor/dissipation factor condition assessment test – insulation power factor.	Most common test performed to determine condition of solid insulation.
	Moderately expensive, may require additional equipment.
VLF dissipation factor condition assessment test – “tan delta” test.	Simple, extremely portable, inexpensive to purchase and operate – true diagnostic test.
	At 60 Hz, can present inaccurate cable insulation assessments results.
Off-line partial discharge condition assessment test.	“Off-line PD testing” assesses power cables insulation, identifies electrical trees, contamination, delamination.
	Newer test; capable of testing up to 3 miles of power cable.
	Limited to power cables with continuous metallic shields, requires extensive outages, most costly to perform.
Thermography of underground terminations, elbows and splices.	Non-contact.

- Time-based predictive tests – equipment is online; electrical outage is cost prohibitive (Table 5.7);

Table 5-7 Time-Based Predictive Tests

Test	Comments
Online partial discharge condition assessment test	“Online PD test” performed while the equipment is energized at normal operating voltages; provides snapshot-in-time samples.
	Not calibrated, test results are not objective and have no comparable data to factory tests or IEEE standards.

- Recommended frequency of testing after installation acceptance test for “normal” class of service; and
  - First maintenance test – 3 years
  - Second maintenance test – 8-9 years
  - Period between succeeding maintenance test – 5-6 years
- Recommended frequency of testing after installation acceptance test for “critical” class of service:
  - First maintenance test – 12-18 months
  - Second maintenance test – 2-3 years
  - Period between succeeding maintenance test – 4-5 years

5-2.2.2 Lightning and Surge Arresters.

Surge arresters may be constructed as a gapped silicon-carbide or either a gapped or a gapless metal oxide. Metal-oxide surge arresters (MOSAs) should be considered for replacement when silicon-carbide types fail. Surge arresters are usually applied with one terminal connected to an electrically energized source and one terminal to ground. Review availability and use positive failure indication arrestors to replace failed arrestors. No work is allowed on, or contact made with, surge arresters connected to the energized source.

The following time-based preventive maintenance is recommended:

- Visual inspection – semi-annually;
- Clean insulator using cleaning agents and waxes in accordance with manufacturer’s directions and check integrity of connections – 6 years; and

- Insulation resistance tests – 6 years:
  - Power frequency dielectric loss
  - DC insulation resistance
  - Power factor

5-2.2.3 Switches.

No work will be done on switches until both sides of each phase have been de-energized and properly grounded. Switches must be tested in the test position. If there is no test position (stationary interrupter switches) test after the interrupter switches have been de-energized and grounded.

The following time-based preventive maintenance is recommended:

- Visual inspection – semi-annually; and
  - Component inspection
  - Fuses and holders
  - Interrupter
  - Anchorage and grounding
- Major maintenance / overhaul function – 6 years:
  - Contact-resistance tests across each switch blade and fuse holder.
  - Insulation resistance tests on each pole phase-to-phase and phase-to-ground for one minute.

5-2.2.4 Transformers.

Oil-immersed, MV, pad-mounted transformers will be switched, de-energized and energized by trained personnel only. Completely isolate from sources of power transformers before being tested and inspected.

5-2.2.4.1 Time-Base Preventative Maintenance.

The following maintenance of transformer and accessories is recommended:

- Visually inspect transformer enclosure for rust and oil leaks every 2 years. Check and record gauges.

5-2.2.4.2 Time-Based Predictive Maintenance.

The following time-based predictive maintenance of transformer and accessories is highly recommended for mission critical transformers or primary installation substations (utility point of service). For non-mission critical transformer and accessories systems, perform visual inspections:

- Perform DGA oil test every 2 years; and
  - Take samples from the bottom for mineral oil-insulated units and from the top for less flammable liquid-insulated units.
  - Samples must be laboratory tested.
  - Acceptable test limit values for new and service-aged oil are given in IEEE 57.106.
- Check for hot spots using thermography every 2 years. Use IR equipment capable of detecting at least 1 ^{0}C temperature difference between the object and the 30 ^{0}C reference area by detecting emitted radiation and converting it to a visual signal. Scan all current-carrying equipment and conductor connections during periods of maximum possible loading. Always measure the IR temperature from several different positions to minimize errors from reflected IR energy or from solar gain for outdoor installations.

5-2.2.4.3 Corrective Maintenance.

The following corrective maintenance of transformer and accessories is recommended:

- Oil treatment:
  - Particle filtration
  - Drying
  - Outgassing
  - Cleanup and depollution
  - Oil replacement, recycling and PCB decontamination
- On-site repairs:
  - Leakages
  - Gasket replacements

– Improvement of contact resistances

5-2.2.5 Manholes and Handholes.

Underground junction boxes and vaults inspections every 5 years is suggested to determine deterioration and degradation of the junction boxes and associated wiring and supports. Check for termite infestations and include treatment for termites within manholes if found. Some base safety requirements allow entry into energized manholes for purposes of inspection only and some locations will not allow this. This must be handled safely on a case by case basis in accordance with procedures already in place.

5-2.3 Ground Systems.

Grounding is an essential part of protecting staff and equipment from high potential caused by electrical faults. Grounding conductors of switchyard equipment and gate structures are subject to failure due to corrosion, loose connections, and mechanical damage. Grounding also may be compromised during equipment addition and removal or other construction type activities. Verifying grounding system integrity through periodic testing is an important maintenance activity.

Check all accessible ground connections for secureness, and measure the overall ground grid resistance if it has not been done for a number of years. Since it is desirable to disconnect shield wire grounds and system neutral connections to make this measurement, de-energized the total substation for these tests.

- Perform visual and mechanical inspections annually. Perform grounding electrode and substation/switchyard grid tests every 6 years.

5-2.4 Metering.

Electrical meters are devices used to measure and register the cumulative value of electrical quantities with respect to time.

Routine maintenance tests are required annually and to cover the following:

- Cleanliness, connections, calibration;
- Multipliers;
- Alignment, damage, freedom of movement; and,
- Contacts.

5-2.5 Animal Control.

Apply IEEE 1264 for wildlife deterrents.

5-3 ROADWAY/STREET/PARKING AREA LIGHTING.

5-3.1 Voltage Level.

Street lighting circuits might be either low-voltage multiple circuits or high-voltage series circuits. It is important that the type of circuit be identified and placed in an electrically safe work condition before starting work because of the different voltage levels involved. Workers must wear PPE in accordance with UFC 3-560-01 when working on street lighting circuits.

5-3.2 Clearance Requirements.

Street lighting lines, fixtures, and wires must be considered energized, which requires wearing personnel protective equipment, unless a Safe Clearance permit is obtained and the line grounded. The voltage of street lighting circuit must be treated as that of the highest voltage occupying any of the poles on which the street lighting circuit is run.

5-3.3 Multiple Street Lighting Circuits.

Multiple street lighting circuits must be treated with the same precautions as the circuits to which they are connected, unless the circuit is located on a structure with a higher voltage wire, in which case it must be considered as the higher voltage level.

5-3.4 Series Street Lighting Circuits.

Before a series street lighting circuit is opened and work is performed, the following procedures must be followed:

- Disconnect the circuit from the source of supply by opening disconnecting switches or other cutouts in accordance with a Safe Clearance permit and lockout-tag out equipment. Do not depend on time switches or other automatic devices;

- Jumper the circuit to avoid an open-circuit condition; and

- In replacing street light bulbs and lamp globes in street lighting brackets, there is danger of an arc developing and causing serious damage and injury if the spring clips in the receptacle do not make contact. These springs might have been heated to the extent that they have lost their temper, or for some other reason, do not close the circuit when the lamp socket is pulled out. Use approved changers with at least 6 ft (1.8 m) handles for replacing lamps on series street lighting circuits. Workers must wear appropriate PPE when removing or installing lamps where lamp changers cannot be used.

5-3.5 Climbing Space.

Maintain safe access by hanging street lighting fixtures clear of the climbing space. All bolts, lag screws, and other hardware used in securing the fixtures must be cut, filed, or coated to eliminate sharp or protruding edges or points.

5-3.6 Time Switches.

When winding time switches and working on automatic time switches, workers must not trip the switch "on" without first pulling the transformer disconnects or first making sure that street lighting circuits cannot be energized. On time clocks with high-voltage connections, workers must always wear rubber gloves and appropriate personal protective equipment when winding, resetting, or otherwise maintaining the clock.

5-4 DISTRIBUTED GENERATION.

The same O&M concepts and requirements that apply to utility generated electrical distribution systems are directly applicable to Distributed Generation Systems (DGS), with a few notable exceptions. DGS synchronization relaying and permitting must be approved by the local utility. Therefore, operations must notify the local utility whenever modifications are made to the system, or parts are taken out for maintenance, as this will affect the stability of their network if the distributed generation is not islanded, or operated as a stand-alone system. The primary interconnect requirements are stated in NEC article 705; however, each utility will have requirements far above or beyond these minimum requirements for DGS. For safety, when a distributed generation system is modified, or a planned disconnection or re-connection, notify the local utility in advance of action.

CHAPTER 6 WORKING ON OVERHEAD DISTRIBUTION

6-1 OVERHEAD DISTRIBUTION WORK.

This chapter includes specific requirements for poles and structures, pole-mounted equipment, and aerial lines. Requirements addressed include pole handling and erection, climbing and working on poles, stringing of lines, working around pole-mounted lighting and other equipment, tool handling, and tree and brush trimming adjacent to an aerial line right-of-way.

Note: Installations in California are governed by the California Public Utilities Commission General Order 95, Rules for Overhead Electric Line Construction.

6-1.1 Working in Elevated Positions.

Additional safety requirements are needed for overhead distribution work since climbing poles is often necessary. Not all work can be accomplished from aerial lifts. Electrical workers must both recognize electrical hazards, and be trained how to prevent falls. This includes training in safe climbing procedures when the structure design cannot accommodate optimum fall protection load requirements.

Comply with OSHA Standards (29 CFR 1910 and 1926) for fall protection when working in elevated conditions. Refer to IEEE Std 1307 and UFC 3-560-01 for additional guidance.

Note: For the Navy, follow the requirements outlined in the Department of the Navy Fall Protection Guide for Ashore Facilities, which can be obtained at http://www.dcfpnavymil.org/Personnel%20Protection/Subs/Fall%20Protection/Fall%20Protection%20Guide%2015%20February%202012%20(2).pdf.

Note: For the Army, Department of the Army Pamphlet DA PAM 385-10 provides additional requirements regarding fall protection.

Note: For the Air Force, Air Force Instruction 91-203 provides additional requirements regarding fall protection.

6-1.2 Qualified Climber.

Only workers who meet “Qualified Climber” requirements are permitted to do work requiring climbing poles or trees. Each Activity must establish these requirements for both Activity personnel and contract personnel. The requirements apply to all persons whose work involves climbing.

6-1.3 Criteria for Qualified Climbers.

Comply with the requirements of OSHA 29 CFR 1910.269 (q) “Overhead Lines.” The majority of the work will be done in an elevated position above ground level. Climbing aerial line structures such as poles may be required. Situations with limited structure access can prevent use of an aerial lift bucket truck. The structure design may not accommodate positive fall protection load requirements. Only workers who meet "Qualified Climber" requirements are permitted to do work which requires climbing poles or trees. Establish “Qualified Climber” requirements both for Activity personnel and for contract personnel, including the following:

- Physical fitness required for climbing – documented not only by an annual physical, but also be validated by supervisory observation;
- Climbing duties – included as a part of routine job activities, not an occasional occurrence;
- A minimum of 2 years of documented climbing training. Include hazard recognition and hands-on-training incorporating appropriate safe climbing practices and rescue training;
- Demonstrated proficiency is required on structure types similar to those that are to be climbed, showing that these structures have been climbed on a routine basis within the last 5 years; and
- A worker in training may function as qualified only when working under the direct supervision and observation of a “Qualified Climber.”

6-2 POLE HANDLING OPERATIONS.

Precautions are necessary in handling poles safely. Poles are long, heavy, and treated with potentially hazardous pesticides and preservatives. They pose hazards to the workers involved in installation and dismantling operations. Additionally, mistreatment of poles during installation may degrade their ability to meet service requirements, and could endanger those workers who climb them.

6-2.1 General.

The authorized individual-in-charge must either do it themselves or assign a crew member to direct the handling of poles and give all signals when poles are being lifted or handled. Poles must, whenever possible, be handled starting from the top and the end of the stack. Workers must roll poles away from them using cant hooks or bars. Poles must not be caught with cant hooks while in motion. Whenever possible, carrying hooks must be used when carrying poles.

6-2.2 Pole Contact Precautions.

Creosote is applied to poles as a preservative and can cause skin burns on contact. Take the following precautions to avoid burns:

- Keep arms covered with long sleeved shirts when handling poles;
- Always wear gloves;
- Keep neck well covered with a collar or a handkerchief;
- Keep trousers as long as practical to protect ankles;
- Never rub eyes or wipe perspiration from face using hands or shirtsleeves after they have been exposed to creosote; and
- Protect hands, arms, and face with a preparation made up of one part gum acacia or gum tragacanth, and three parts lanolin where direct contact with creosote is likely to occur. If this preparation cannot be obtained, acceptable protection can be provided by petroleum jelly (such as Vaseline™). First aid treatment must be obtained immediately when bare skin or eyes come in contact with creosote.

6-2.3 Receiving Pole Shipment.

Poles are usually shipped to an Activity's pole storage yard using flatbed railway cars on which they are secured with skids, stakes, slings, and binding. Removal is safe if done properly. The principal objectives are to unload poles so that none are broken, and so that the poles do not roll onto any worker. Perform the following:

- Skids, rope lines, and slings must preferably be 1/2 in or 5/8 in (12.5 to 16 mm) wire rope. Inspect before use to ensure they are in satisfactory condition for the operation;
- Inspect all binding wire, stakes, and other fastenings for weak or broken areas before unloading;
- Always preposition lines as necessary to restrain loads when stakes and binding wires are cut;
- The authorized individual-in-charge must determine that all workers are safely in the clear before permitting binders or stakes are cut;
- Cut binding wires with long-handled wire cutters. Never cut binders from the top of the load; and
- Only one person is permitted on top of a loaded car at a time. No one is allowed on top of a carload of poles to cut wires, or if any wires or braces have been cut or removed.

6-2.4 Ground Handling.

Once on the ground the poles can be positioned by the use of cant hooks. Special precautions must be taken while using these hooks:

- Keep hooks sharp and protected when not in use;
- Inspect the hook bolt periodically for wear. If a worn hook bolt breaks in use, sudden and possibly severe injuries could result;
- Injuries most often occur when a pole handle breaks or the hook comes out. Be sure the hook is firmly set in the pole;
- The cant hook is a one-worker tool. It is likely to break if two workers double up. If a job requires two workers, two cant hooks must be used;
- Before moving the pole, make sure that there are no tripping hazards near the workers;
- Stand so the pole is rolled away. Pulling the pole allows the pole to roll on a foot or crush a leg;
- Be particularly careful if the pole is rolled over a hump, since the pole could roll back when the grip and position of the hook is changed; and
- When moving a pole by hand, with a pole cart, or with the truck derrick, warn anyone nearby who could possibly be struck. If necessary, station a worker with a red flag to warn or stop traffic.

6-2.5 Long Term Pole Storage.

- Poles that are stored for considerable periods must be stacked above the ground on racks. The racks must provide ventilation, and properly block the poles to keep them from shifting or rolling;
- Never store poles with cross-arms, braces, steps, or hardware attached;
- Store poles according to size and make them accessible; and
- Maintain an area around stored poles of at least 10 ft (3.0 m) free of grass and weeds. Provide sufficient space under poles to permit removal of leaves and debris.

6-2.6 Temporary Pole Storage.

- Poles stored temporarily on or near roadways, before erection or removal, must be placed as close as possible to the curb or edge of roadway as is safe; however, never store poles at points along the road where there are sharp turns. Do not place the poles where they interfere with traffic, driveways, or walkways;
- Place each pole so that its top points in the direction of traffic. Poles temporarily stored alongside highways must not have cross arms attached;
- When laid on an incline, poles must not be placed where they can interfere with drainage; and
- The authorized individual-in-charge must decide whether danger signs (by day) or red lights (at night) are required.

6-2.7 Hauling Poles.

- Pole hauling must be done in a manner to not endanger workers or the public;
- After being loaded on a vehicle, secure poles in at least two places and in such a manner to ensure poles will not be released when traveling over rough terrain. Never use a chain smaller than 3/8 in (9.5 mm) diameter;
- Assign a minimum of two workers (a driver and a helper) to haul a load of poles. The helper must assist the driver by watching traffic both from the sides and the rear. The helper must also check that there is ample clearance when turning corners, entering highways, or crossing intersections. When necessary, the helper acts as a flagman to warn and direct traffic; and
- Attach a warning device on poles extending more than 4 ft (1.2 m) beyond the back of a truck or trailer. Attach a red flag by day and a red light by night to the rear end of the poles being hauled. The red flag or light must be visible from the sides and rear. Observe all local and state highway regulations when poles are transported over off-base highways.

6-3 POLE INSTALLATION, REPLACEMENT, AND REMOVAL.

Poles for new aerial lines are often installed by contract workers; however, Activity workers might need to install poles to replace storm-damaged, insect-damaged, or decayed poles. Remember that poles and guys must be properly located relative to the local Activity property line or utility right-of-way.

This section provides guidance that applies mainly to wooden poles. Refer to IEEE Std 1025 for installation of concrete power poles.

6-3.1 Pole Holes.

Dig new holes if new poles are being set adjacent to existing poles being dismantled. Power tools are available for digging, such as power borers or augers, and only qualified personnel must use these tools. Rock cutting drills are generally a safer alternative than the use of explosives, where rock is encountered. Many pole holes can be dug by hand if power diggers are unavailable or cannot be used. The area where poles are being set must be scoped and all utilities identified and marked. Take special care when digging close to underground energized cables/circuits.

6-3.2 Digging Holes.

Digging a pole hole involves significant hazards that can cause major injuries. These hazards range from electrocution, shock, vehicular hazards, crushing injuries, eye injuries from flying dirt and rocks, blisters on the hands from the use of hand tools, and foot and leg injuries resulting from falling over tools, particularly shovels that have been left turned up.

6-3.3 Covering a Hole.

Cover all open pole holes as soon as they are dug when other related work must continue near the hole, except when the pole is being immediately set into the hole after digging. Install covers that are at least 30 in (760 mm) in diameter and strong enough to support two men. Place four or five shovels of soil on the cover after it is placed over the hole. If necessary, also set up cones to secure the area.

6-3.4 Hole Casings.

Casings may be required in sandy or swampy soil to prevent the sides of a hole from caving in. Casing covers are required if the pole setting is not done immediately.

6-3.5 Setting Poles.

Pole setting is a hazardous job even with experienced personnel using the best equipment. The methods authorized for manually setting poles are:

- The pike pole method;
- The winch line method; and
- The gin pole method.

The use of a line truck is the preferred method whenever possible.

6-3.5.2 Pike Pole Method.

Figure 6-1 illustrates the pike pole method. This is the earliest method of raising poles and might be used when a truck cannot be brought in. A jenny initially supports the pole, and a cant hook keeps the pole from rolling. The bump board protects the wall of the hole from being caved in by the pole butt. Pikers lift the line pole by punching into the pole, the steel spikes of the pike poles. The number of pikers required increases with the pole length as shown in Table 6-1.

Table 6-1 Average Crew Size Required to Raise Poles by Piking

Pole Length		Size of Crew	Number of Pikers	Number of Jennymen	Number of Personnel at Butt
Feet	Meters				
25	7.5	5	3	1	1
30	9.0	6	4	1	1
35	10.5	7	5	1	1
40	12.0	8	6	1	1
45	13.5	9	7	1	1
50	15.0	10	8	1	1

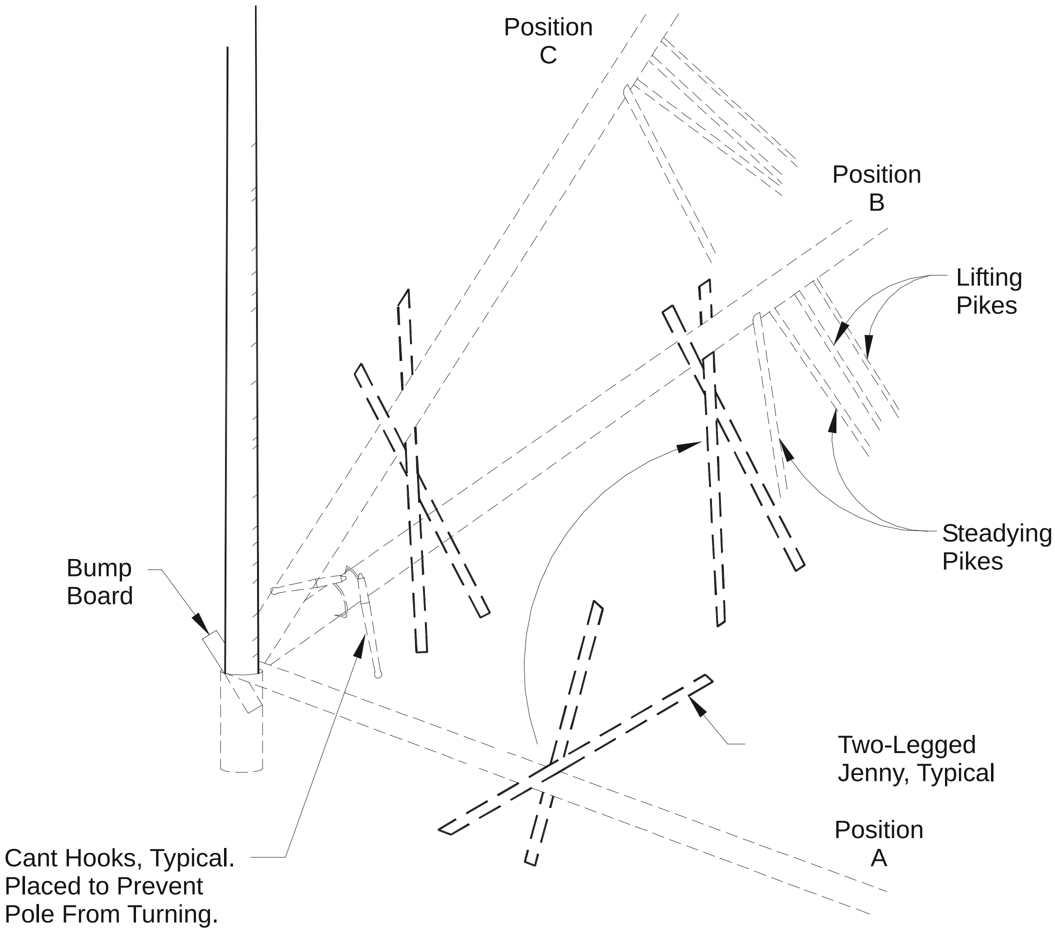
6-3.5.2.1 Preparation.

Before setting a pole, the authorized individual-in-charge must ensure there is a clear working space and that all movable obstacles are removed from the area. Personnel must not wear safety harnesses, climbing belts, or climbers when setting poles. Tools or other items must not be substituted for bump boards. Always use a jenny to support the pole until it is high enough to use pikes. Only experienced workers must use the jenny. The angle of contact between the pole and jenny must be maintained as close to 90° as possible.

6-3.5.2.2 Number of Personnel.

At least three experienced workers must be used in addition to the authorized individual-in-charge. One person must handle the butt of the pole, and a minimum of two side pikers are needed. Inexperienced workers used in this work must be thoroughly instructed on the hazards involved. A two-legged jenny must be used. It is the responsibility of the authorized individual-in-charge to verify that all pole-lifting tools are in acceptable condition prior to the lift.

Figure 6-1 Pike Pole Method



Position A:

Place jenny near top of pole at approximately right angles to pole. Footing of jenny should be at a point where it will not slip when the pole is lifted and supported by the jenny. Lift pole and jenny to Position B.

Position B:

Place two cant hooks, one to pull against, the other to prevent pole from turning. Place hooks about two feet above the probable ground line. Station a crew member to hold the hooks as the pole is being raised.

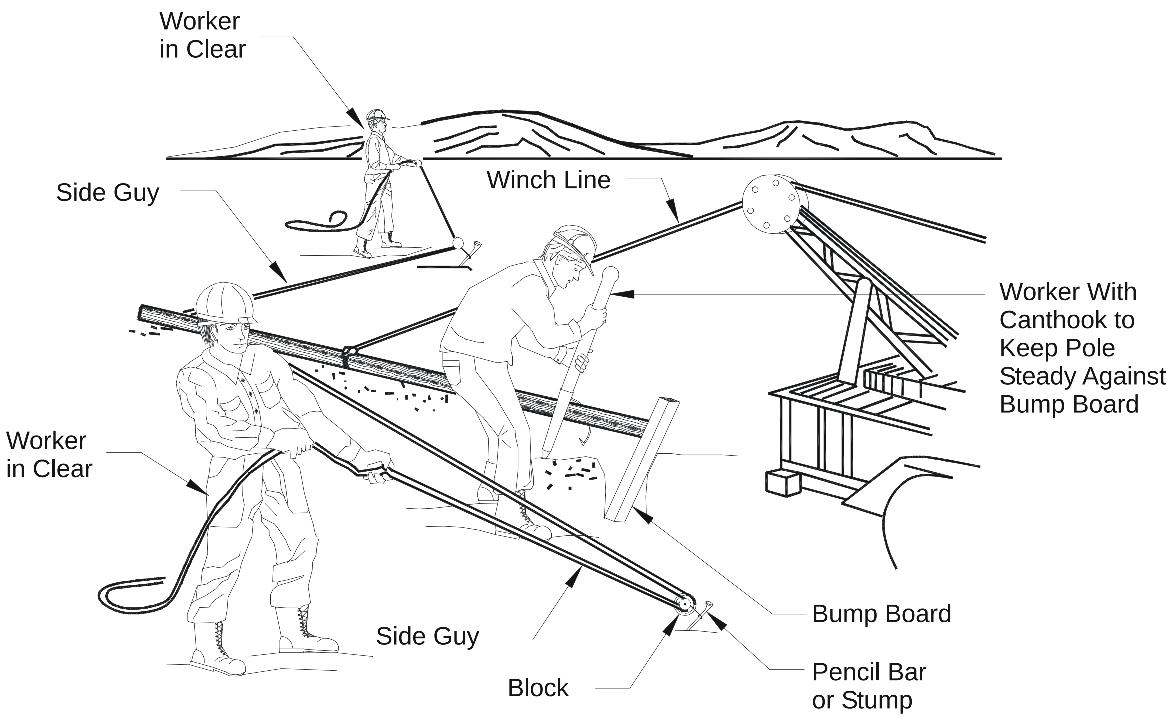
Position C:

As pole is being raised by pikers, jenny is moved down the pole until pole weight is supported by jenny (always keep fork of jenny in contact with pole). Repeat operation until pole slides into hole.

6-3.5.3 Winch Line Method.

Figure 6-2 illustrates the winch line method. When erecting poles by truck winch and winch line, ensure all workers are in the clear. Depending on the pole size and class, up to three experienced workers may be needed in addition to the authorized individual-in-charge. For a safe lift, the gins (or maneuverable rigging assembly) must have enough teeth to handle the pole. Do not use pikes in combination with a winch.

Figure 6-2 Winch Line Method



Attach side guys used in setting poles or structures to pencil bars driven into the ground. Never wrap tie lines or other guy lines around any worker's body.

6-3.5.4 Gin Pole Method.

In setting extra-heavy poles or those of 45 ft (13.5 m) or longer, it is best to use a tackle block attached to another pole rather than the pike pole method. The other pole is called the gin pole (or maneuverable rigging point), and is either existing or is especially installed for raising the new pole. The gin pole must be guyed sufficiently with not less than 5/8 in (16 mm) diameter rope to hold it erect under the strain of the load. When the new pole is raised using power from a vehicle, the temporary guy must be run from a snatch block at the bottom of the gin pole to a substantial anchor. This prevents the gin pole from slipping at the ground line. Otherwise, the gin pole must be set in a hole of depth 1 to 2 ft (305 to 610 mm).

6-3.6 Pole Setting Trucks.

Park pole setting trucks, where feasible, so that the boom will never be closer than 10 ft (3.0 m) to energized overhead conductors. When the work is being done near energized conductors and it is impossible to lower the boom sufficiently to be in the clear, place the conductors in an electrically safe work condition before starting work. When it is not possible to de-energize the conductors, and work must be done with the boom close to energized conductors, all personnel must keep away from the frame of the truck and must not touch the pole. Use pole guards or insulated blankets. Never touch with bare hands a pole that is being set in an energized line. Instead, an insulated cant hook or dry rope around the butt of the pole may be used to guide it into the hole.

6-3.7 Setting Poles in Energized Lines.

Only an electrical worker qualified as a Journeyman or Craftsman is permitted to guide poles through energized conductors. This operation is classified as “energized work” and appropriate permits and/or authorizations must be obtained. Employees must wear appropriately rated arc flash personal protective equipment as specified in UFC 3-560-01. UFC 3-560-01 does not allow Navy personnel to set poles in energized lines.

When a pole of any type is being set or removed between or near conductors energized at more than 600 V, the pole, winch cable, and truck frame must be effectively grounded with protective grounds. Lines must be covered with rubber protective equipment to prevent poles from touching energized parts, and workers must use rubber gloves. Attach a protective ground to the frame of all winches. If the pole is being erected by hand (pikes), the protective ground must be attached to the pole (using an approved grounding band) approximately 15 ft (4.5 m) from the butt end. Installing and use pole guards. In all cases, exercise extreme care to keep the pole from contacting conductors.

Note: Wood poles do not provide adequate insulation from energized lines.

6-3.8 Backfilling the Hole.

Backfill the hole after the pole placed. Use pikes to align the pole while backfilling. Do not remove pikes until sufficient tamping has been done to prevent the pole from falling.

6-3.9 Dismantling Poles.

Pole dismantling from a live line is a particularly hazardous operation. Exercise extraordinary care. Restrain each pole in at least three different directions by ropes before any work proceeds on the pole. This may be done by the following procedure:

- Make two turns around the pole with a sling and tie securely;

- Tie three lines around the sling at the proper angles;
- Insert pike poles under two sides of the sling well up the pole; and
- Snub off securely by pencil bars driven into solid ground or by any other substantial snub.

Always check the pole to see if additional support may be necessary because of pole conditions or strains. Include the following:

- Determine the condition of the pole butt before removing guys or wires, and support the pole with additional pike poles or temporary guys if necessary;
- When an old or reinforced pole is being dismantled, guy it sufficiently to withstand any altered strain on it. Include the weight of personnel who are to work on the pole while dismantling;
- When changing the strain on a pole, the authorized individual-in-charge must ensure it is sufficiently guyed to stand the altered strain and prevent the pole from falling. Do not climb a pole that is under an abnormal strain;
- A truck equipped with an “A” frame and backed up to the pole can be used to restrain the pole. The top of the “A” frame can be tied by the winch line to the pole. The pole at the ground line level can be securely tied off to the truck;
- In locations where poles cannot be lowered with a rope or derrick, attach a guideline so that the pole moves in the desired direction;
- All members of a crew who are not actively engaged in pole removal must stand well clear in case the pole must fall. Where appropriate, stop all pedestrians and traffic during pole removal; and
- When a pole is being removed, dismantle the pole before beginning the excavation around the butt.

6-4 CLIMBING AND WORKING ON POLES.

Workers must be familiar with the general rules for climbing poles and approaching the overhead work area, the differences of climbing wood poles as opposed to steel towers, and the dangers inherent in crossing overhead structures from one side to another.

6-4.1 General Rules.

- Do not work at the base of a structure or a pole while others are working above;
- Before climbing a pole the worker must first determine;
  - What circuits are energized and their voltage, and any unusual conditions which might pose a hazard.
  - The types and locations of circuits, and the direction of feeds.
  - The best climbing space to avoid all live wires, grounded wires, and signal circuits.
- Ensure there is an ample supply of rubber protective equipment on hand to completely protect the worker on the pole from all live wires, grounded wires, and signal circuits;
- Only one worker is permitted to ascend or descend a pole at any one time. Other workers must be in place on the pole or on the ground before the worker ascends or descends the pole;
- Extraordinary care is required of the workers when it becomes necessary for one worker to work above the other; and
- Before climbing poles, ladders, scaffolds, or other elevated structures; riding span wires, messengers or cables; or entering cable cars, boatswain chairs or similar equipment; each worker must first ensure the structure or device is strong enough to sustain the worker's weight.

6-4.2 Pole Inspection Before Climbing.

The type of pole being climbed affects the precautions that the worker must take in regards to climbing equipment and procedures. All types of poles must be safe to climb in terms of being strong enough to bear the weight of the climbers and their tools, and having adequate climbing space. Before allowing anyone to climb on a pole, the authorized individual-in-charge must ensure the pole is inspected, i.e. hammer tested and pike pole rocking test, and that it can be safely climbed based on the following:

6-4.2.1 Pole Condition.

Determine age, physical condition, and treatment of the pole. Do not climb a pole unless you are sure it can safely hold your weight. Before climbing, inspect the pole for the following:

- General condition – buckling at the ground line or an unusual angle may indicate pole has rotted or is broken;

- Cracks – horizontal cracks perpendicular to the grain of the pole may weaken pole. Vertical cracks can pose a hazard to the climber; keep gaffs away from them while climbing;

- Holes – hollow spots or woodpecker holes can reduce the strength of a wood pole;

- Rotting and decay – are cutout hazards and are possible indication of the age and internal condition of the pole;

- Knots – one large knot or several smaller ones at the same height may be evidence of a weak point on the pole;

- Depth of setting – evidence of the existence of a former ground line substantially above the existing ground line may be an indication the pole is no longer buried to a sufficient extent;

- Soil conditions – soft, wet or loose soil may not support any changes of stress on the pole; and

- Burn marks – burning from transformer failures or conductor faults could damage the pole.

6-4.2.2 Test Methods.

Inspect and test wood poles by the qualified employee prior to any climbing activities using one of the following methods:

- Hammer Test – rap the pole sharply with a hammer weighing about 3 lb (1.4 kg) hammer, starting near the ground line and continuing upwards circumferentially around the pole to a height of approximately 6 ft (2 m). The hammer will produce a clear sound and rebound sharply when striking sound wood. Decay pockets will be indicated by a dull sound or a less pronounced hammer rebound. Also, prod the pole as near the ground line as possible using a pole prod or a screwdriver with a blade at least 5 in (127 mm) long. If substantial decay is encountered, the pole is considered unsafe; and

- Rocking Test – apply a horizontal force to the pole and attempt to rock it back and forth in a direction perpendicular to the line. Caution must be exercised to avoid causing power lines to swing together. The force may be applied either by pushing with a pike pole or pulling with a rope. If the pole cracks during the test, it is considered unsafe.

6-4.2.3 Additional Checks.

Determine the following:

- If the configuration of conductors and equipment on the pole will provide adequate climbing space;
- If the removal of supporting conductors or guys may affect the safety of workers; and
- If the poles being climbed can be supported in such a way as to safely support workers on the poles. Pikes are not acceptable as a support method while personnel are working on poles.

6-5 POLE CLIMBING EQUIPMENT.

6-5.1 General Rules.

Observe the following:

- Make sure each worker who is authorized to climb has a full set of climbing equipment. Never loan or borrow a set of climbing equipment;
- Carefully inspect climbing equipment before each day's climbing activities. Examine leather for cuts, cracks, and enlarged buckle tongue holes. Examine metal parts for cracks, wear, or loose attachments. Examine climbers (gaffs) for proper cutting edges, length, and shape;
- The authorized individual-in-charge, or a designated worker, must inspect all tools, safety devices, and other equipment in use on a weekly basis. Any item that is not considered safe must be condemned, regardless of ownership, and must not be used;
- Ensure that employees understand that fabricated or purchased fall protection must meet or exceed the requirements outlined in ANSI Z359 and with ASTM F887. Body harnesses, meeting the requirements of ANSI Z359, with straps or lanyards, must be worn to protect personnel working at elevated locations on bucket trucks, power poles, towers, platforms, and other structures. Inspect body harnesses and straps before use each day to determine they are in safe working condition; and
- Use body harnesses instead of body belts for fall protection.

6-5.2 Wooden Pole Climbing Equipment.

6-5.2.1 Climbing Equipment.

Equipment sets each consist of a body belt (or body harness), a pole strap, and climbers (an assembly of gaffs, leg straps, and pads). Climbing equipment must meet the following requirements:

- Leg iron (shank) to be made of spring steel;
- Gaff (spur) to be forged from tool steel;
- Leg iron length must be in the range from 15 to 18 in (381 to 457 mm) from the instep to end of the shank;
- Leather straps must be at least 1-1/4 in (32 mm) wide and 22 in (559 mm) long; and
- Pads must adequately protect the calves.

Repair before use any climbers, pole straps, and other leather items that have any of the following defects:

- Cracked, dry, or rotten leather;
- Leather that is worn thin;
- Cuts or worn places which are of sufficient depth to weaken the leather;
- Broken stitches or loose rivets at buckles, D-rings, or snaps;
- Snaps which have weak springs behind the tongue or loose rivets which hold the tongue;
- Loose tongues in buckles; and
- Buckles, D-rings, or snaps that show considerable wear or which have been cracked or bent.

6-5.2.2 Leather Care.

Provide care for leather equipment as follows:

- Leather equipment in regular use must be cleaned and dressed at least every three months, and more frequently when the equipment is wet from rain or perspiration, or is soiled with dirt or mud. Leather equipment not in regular use must be cleaned and dressed at least every six months;

- Wipe off all surface dirt and mud with a sponge dampened (not wet) with water. Never use gasoline or other cleaning fluids, as they tend to dry out and harden the leather;

- Wash leather with a clean sponge in clear lukewarm water and a neutral soap (free from alkali), preferably Saddle soap. Thoroughly wash the entire length of the leather and work the lather well into all parts. Place in a cool area to dry;

- Dress leather with oil after each cleaning. Use a small quantity (about 20 milliliters (4 teaspoons)) of pure neatsfoot oil per set of equipment and apply it gradually with the hands, using long light strokes while the leather is still damp from washing. Leave in a cool place to dry for about 24 hours, and then rub the leather vigorously with a soft cloth to remove all excess oil; and

- When safety harnesses/belts and straps are not in use, store them in designated compartments on the service truck or other suitable location to protect them from damage. When stored, wrap climbers in pairs and fasten with their straps.

6-5.2.3 Climbing Equipment Inspections.

Keep climbers, straps, and pads in good conditions at all times. Inspect climbers before each use to detect nicked or dulled cutting edges on the gaff. Check them as soon as possible after striking them against hard objects such as pole hardware or nails. The worker must inspect climbers in regular use at least weekly. If any of the following conditions are found, repair or replace the climbers before using:

- Loose gaff;

- Nicks and depressions in the gaff;

- Ridge of gaff not in alignment;

- Dull gaffs;

- Broken or distorted gaff points;

- Broken, loose leg or foot strap loop;

- Excessively worn, cracked, or torn straps and pads;

- Enlarged buckle holes in the straps;
- Broken or damaged strap buckles;
- Fractured or cracked leg irons and stirrups;
- Excessively worn stirrups;
- Fractured leg iron sleeves;
- Broken or loose rivets or screws on sleeves and straps;
- Defective strap rings;
- Broken or damaged loop clip-on straps;
- Gaff guards not in good condition; or
- Improper length of gaffs.

6-5.2.4 Gaff Requirements.

Gaffs must be at least 1-1/4 in (32 mm) long, measured from the point of the gaff to the point of contact with the stirrup on the underside. Sharpen climbers using a gaff-shaping bit as follows:

- Place the climber between wood in a vise with the leg iron horizontal and the gaff on the topside;
- Use a smooth cut file and finish with a sharpening stone. Never grind with an emery wheel as this takes the temper out of the metal;
- The outer ridge of the gaff must never be filed. To obtain the proper width, a file may be used on the rounded portion. Apply strokes that follow the contour of the gaff;
- To sharpen the gaff to proper thickness, file the metal from the flat inner side of the gaff. Care must be taken to prevent notching the leg irons or stirrup. Use forward motions toward the point and down to edges of the underside of the gaff. Do not allow rocking motions of the file because this can round the edges of the gaff. After the proper thickness has been reached, the underside of the gaff must be straight to within 1/16 in (1.6 mm) of the point, then rounded slightly toward the ridge of the gaff on a radius of 1/4 in (6.4 mm). Additional sharpness may be obtained following filing by dressing the underside and rounded portion of the tip with the

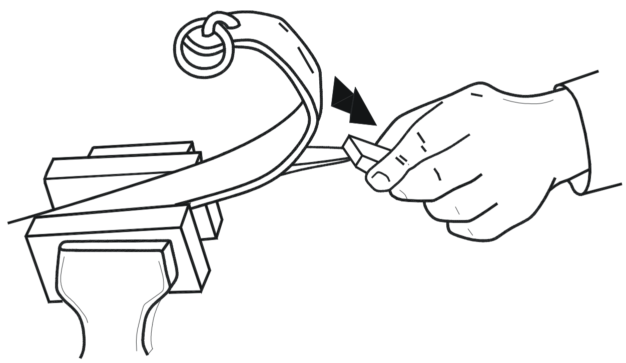
honing stone. Burrs along the edges must also be removed with the stone; and,

- Never use a climber with a gaff shorter than 1-1/4 in (32 mm), as measured on the flat side.

Restore damaged or dull gaffs to original shape by filing and honing (see Figure 6-3). If gaffs cannot be restored, replace them.

Figure 6-3 Honing a Gaff

Hone Lengthwise - Not Crosswise



6-5.2.5 Properly Sharpened Gaffs.

Three methods are normally used to determine if gaffs are properly sharpened.

6-5.2.5.1 Gaging Method.

The gaging method is used to determine the length, width, and thickness of the gaff and profile of the point. Reference lines are scored on the gage with slots provided to determine if the gaff length is satisfactory. Most gages also provide a contour test to determine if the point is properly curved. Openings are provided for determining if the point is too keen. Each manufacturer makes a gaff gage to use with its own climbers. Thus, gaff gages are not usually interchangeable. Use manufacturer's instructions if available. The "thickness" slot in the gage is used to measure the thickness of the gaff at 1/2 in (12.7 mm) from the point. These measurements are made with the outer ridge of the gaff resting flat against the part of the gage containing the scored lines. If the point of the gaff extends beyond the farthest line, the gaff is too thin. If it does not reach the nearest line, then it is too thick. The "width" slot on the gage is used to measure the width 1/2 to 1 in (12.7 to 25.4 mm) from the point. The same methods and reference line are used in measuring for thickness. A minimum length reference line is provided, intersecting the thickness measurements, to determine if the gaff meets minimum lengths.

6-5.2.5.2 Plane Test Method.

The plane test method may be used with the gage, or independently if the gaffs are sharpened by machine process. The test is made by using a soft board to determine if proper sharpness has been reached. Place the climber with the gaff side down and parallel to the board without applying downward pressure above the gaff. Push the climber along the board. If the gaff is properly contoured and sharpened, it can dig into the wood and hold within approximately 1 in (25.4 mm). If the climber continues to glide along the board for more than 1 in (25.4 mm), additional honing is required. After the "plane test" has been made, it can be supplemented by applying a cutout test. Jab the gaff into the board at about a 30-degree angle for approximately 1/4 in (6 mm). Bring the leg iron down against the wood while applying forward pressure--one hand holds the leg iron and the other holds the stirrup. If the gaff cuts out within 3 in (76 mm), it is improperly sharpened.

6-5.2.5.3 Pole Cutout Method.

The pole cutout method is used after climbers have been machine sharpened or gauged (and as often as required thereafter). Perform a pole cutout test in accordance with Table 6-2 before climbing. Check failed gaffs with a gaff gauge to determine the reason for failure and correct the deficiency.

Table 6-2 In-Use Check of Pole Climber Gaffs

Check
Initial placement. Place the climber on the leg, holding the sleeve with the hand, palm facing the pole. With the leg at about a 30 degree angle to the pole and the foot about 12 in (305 mm) off the ground, lightly jab the gaff into the pole to a distance of approximately 1/4 in (6 mm).
Intermediate action. Keeping enough pressure on the stirrup to keep the gaff in the pole but not so much as to cause the gaff to penetrate any deeper, push the climber and the hand toward the pole by moving the knee until the strap loop of the sleeve is against the pole.
Full pressure. Making certain that the strap loop is held against the pole with pressure from the leg, gradually exert full pressure of the foot straight down on the stirrup without raising the other foot off the ground (to maintain balance if the gaff does not hold).

6-5.2.6 Gaff Protection.

To protect the gaffs, use gaff guards when climbers are not being used. Gaff guards must also be used when other tools and materials are stored or transported along with the climbers.

Note: Never store or transport climbers without appropriate gaff guards.

Do not wear climbers when:

- Working on the ground;
- Traveling to and from a job;
- Piking poles;
- Walking through underbrush or rough terrain; or
- Riding in motor vehicles.

6-5.3 Concrete and Steel Pole Climbing.

OSHA standards (29 CFR 1910 and 1926) require fall protection for certain working heights. Acceptable fall protection includes the use of standard railings and toe boards, floor opening covers, or a personal fall arrest system. A body belt is no longer acceptable as part of a personal fall arrest system.

Fall protection is required for operations and maintenance activities when personnel are required to work at a height of 4 ft (1.2 m) or more above ground or to the next lower level. For construction activities, workers must be protected from falls when working at a height of 6 ft (1.8 m) or more. An approved positioning device that limits a fall to less than 2 ft (0.6 m) must be used when a worker needs to be supported on an elevated vertical surface such as a wall or utility pole, and working with both hands free while leaning. Observe the following requirements:

- A proper anchor point must be identified and evaluated by qualified personnel before an appropriate system can be selected. OSHA regulations accept pad eyes, bolt holes, and other sturdy structures capable of supporting 5,000 lb (2,200 kg) per attached worker;
- Positive systems have an anchor point independent of the support method, a harness to hold the worker, and a connecting device between the anchor point and the harness;
- Harnesses must only be used for the personal protective purpose for which they are designed. In addition to fall-arrest harnesses, there are fall-arrest/positioning, fall-arrest/suspension, fall-arrest/retrieval, and retrieval/positioning harnesses;
- Manufacturer’s instructions in regard to height and weight must be followed for sizing of the harnesses and their connecting devices, and for inspection and maintenance of the complete systems. All equipment must be taken out of service and inspected for damage after being subjected to a fall impact; and

- Workers authorized to climb must have a complete set of approved tools. The number of tools carried in tool belts must be kept to a minimum. Tools must not be carried in safety harnesses.

6-6 POLE CLIMBING AND WORK PRECAUTIONS.

Only after a determination of the pole's safety, the collection of necessary climbing equipment and work tools, and obtaining assurance that the line is placed in an electrically safe work condition, and the planned energized work is authorized, can the worker start climbing. Protect hands and arms by wearing gloves and long sleeve shirts. Refer to Section 6-4 for pole inspection requirements before climbing.

6-6.1 General Pole Climbing Precautions.

Observe the following precautions:

- Arrange tools and equipment to allow both hands to be free for climbing;

- Do not stand on mailboxes, signs, fire alarm boxes, or similar equipment that may be attached to the pole or located near it;

- Do not race up and coast down poles;

- Do not use safety straps while climbing, except when climbing over slippery or ice-coated cross arms or timbers. Whenever the hands are apt to slip off, a safety strap must be used. The use of rope safeties is prohibited;

- Remove all signs from a pole before any worker climbs or does any work above them on a pole. It is not desirable to have signs on poles, but some signs, such as street signs, may be necessary. If street signs are removed, they must be replaced as soon as possible after work is completed;

- Climb on the high side of a raked or leaning pole, if possible, but do not climb on the side where the ground wire is attached. Avoid grasping pins, brackets, cross arms, braces, or other attachments that might pull lose and cause a fall;

- Never slide down any type of pole or any guy wire. If it is impossible to use climbers for ascending and descending such places, ladders or other means must be used;

- Do not ride overhead guys or cables. (This is not intended to apply to cables installed for river crossings or otherwise designed to support workers in suitable conveyances);

- If more than one worker needs to work on the pole at the same time, the first worker must reach working position before the next worker leaves the ground. Ordinarily, no worker must work directly under another worker on the same pole. When this is necessary, take extreme care to prevent tools or other objects from being dropped on the worker below;

- Minimize the number of tools carried in tool belts. Keep all other tools on the ground until they are required. Needed tools must be raised and lowered by means of a canvas bucket attached to a hand line;

- When carrying a hand line up a pole, leave the hand line uncoiled with one end attached to the rear of the body belt or harness. When climbing with a hand line, take care to prevent the hand line from fouling on any pole attachments;

- Wear appropriately rated arc flash personal protective equipment as specified in UFC 3-560-01; and

- Discontinue work during adverse weather conditions such as thunderstorms, rain, high winds, and icy conditions. In bad weather, do not climb poles except for emergency restoration work.

6-6.2 Wooden Pole Climbing Precautions.

Observe the following precautions:

- Seat gaffs securely. Be especially vigilant when the pole is ice or sleet covered;

- Use pole steps whenever they are available, but only after checking that they can be used safely;

- Use climbers carefully on the pole to avoid injury to another worker on the pole; and

- Be careful to avoid weather cracks, checks, knots, shakes, rots, and hard places, which might cause gaffs to cut out. Remove any tack or nails which may impede safe climbing.

6-6.3 Concrete and Steel Pole and Tower Climbing Precautions.

Observe the following precautions:

- Always make sure that gloves and shoe soles are in good condition and free from grease or other lubricants. Many falls are caused by slick work gloves or slick shoes. Rough cord sole shoe or boots are recommended. Be particularly careful in wet or icy weather conditions; and

- Carefully wear and regularly inspect the safety harness since steel and concrete surfaces can easily damage or cut the harness.

6-6.4 Working on Poles.

Never change the amount of strain on a pole by adding or removing wires until you are sure that the pole can stand the altered strain. If in doubt, consult the authorized individual in charge.

6-6.5 Safety Straps.

Wear safety straps at all times when handling wires or apparatus while on a pole or structure. Take the following precautions:

- Be careful in attaching snaps to D-rings. Visually ensure that the snap keeper is fully closed in the correct ring before any weight is applied to the safety strap;

- Always be sure that safety straps are connected and not twisted while in use;

- Never depend on a cross arm or cross arm pins and braces for support;

- Never attach safety straps above the cross arm in the top gain or around insulator pins, cross arm braces, transformer hangers, pole steps, or guy wires. If there is no cross arm in the top gain, the strap must not be placed closer than 2 ft (0.6 m) to the top of the pole. In this case take precautions to assure that the strap does not slip off. Ideally the strap must be below the top pole attachment, except where that attachment is above eye level;

- Never fasten both safety harness snaps in the same D-ring in order to reach out farther on the pole. An extension safety strap must be used or the safety harness let out so that work can be performed with the safety harness snaps fastened one in each D-ring; and

- Do not attach metal hooks or other metal devices to body harnesses. Metal chains and keepers must not be used. Instead, use leather straps or rawhide thongs with hard wood or fiber keepers. Care must be taken to prevent the snaps on the safety harnesses/belts from coming in contact with anything that may open a snap. The tongue of the snap on the safety harness/belt must face away from the body.

6-6.6 Hoisting or Lowering Materials.

Take the following precautions when hoisting or lowering materials:

- Drop material that cannot be lowered safely only if there is no danger to workers or the public;
- Position workers engaged in hoisting tools and materials so that they cannot be injured by a falling item; and
- Do not leave materials and tools overhead in an insecure position. Large objects must be securely lashed.

6-7 CROSSING STRUCTURES.

To get from one side of a double-pole supported structure to the other, the worker must descend to the ground and go up the other pole unless there are adequate handholds and adequate clearances from live parts to allow safe crossing along the structure. Observe the following precautions:

- When it is necessary to climb half-way across a cross arm to inspect middle phase insulators, the worker may climb the rest of the way across, provided that a safety harness/belt can be kept strapped around a timber as a safeguard;
- Never cross through an open-air switch unless both sides are placed in an electrically safe work condition;
- Do not use air switch arcing horns for support in walking timbers since these horns break easily and a fall could result; and
- Never walk along an H-frame cross-arm with the line energized.

6-8 STRINGING OR REMOVING DE-ENERGIZED CONDUCTORS AND OVERHEAD GROUND WIRES.

6-8.1 Pre-Work Meeting.

Discuss the plan of operation, type of equipment being used, adjacent energized lines, necessary grounding devices and procedures, crossover methods, and Safe Clearance requirements before stringing or removing de-energized conductors or overhead ground wires.

6-8.2 Work Adjacent to Energized Lines.

Note: For the Navy and Air Force, work adjacent to energized lines is not authorized.

Observe the following precautions during all work activities:

- The worker attending the payout reel must wear rubber gloves when pulling wire over or near energized conductors, and be positioned on an insulated stand of a size equivalent to or larger than a standard rubber blanket;

- Ground the payout reel. The authorized individual-in-charge must approve any deviation in grounding the payout reels;

- A bull line, which must be of dry polypropylene rope ≥1/2 in (12.7 mm) diameter, must be placed in position to pull the wire before attempting to string it. The bull line must be of sufficient length to reach the distance the wire is being pulled. Fasten the wire to the end of the bull line and pull it into position;

- A vehicle used to pull the wire must be positioned so that the driver can see the signals of the reel operator. Both in pulling in and in sagging the wire, the pulling must be slow and steady to prevent swinging the wires into the energized conductors. The wire must be watched carefully to prevent its hanging up on tree limbs, weeds, and other obstructions;

- Do not touch any conductors or wires on the ground without rubber gloves;

- Wear rubber gloves and use other protective devices, as appropriate, when wires are strung and sagged over, under, or across conductors carrying a voltage of 5,000 V or less. Positively and constantly ground conductors carrying more than 5,000 V during the stringing operation. Ground the wire with standard grounding devices as soon as it is ready to dead-end;

- Discontinue operations and seek appropriate shelter when notified that a lightning warning is in effect. Electrical charges can appear on the line from a lightning strike or from induced static charges from a very dry atmosphere. Be in contact with the Base Weather Service and cease outside activities when notified of a lightning warning. Waiting for an indication of lightning can expose a work crew to adverse weather conditions; and

- Keep wires being strung along or across streets or highways higher than any expected car or truck traffic. Block traffic when this line elevation is not possible.

6-8.3 Grounding.

Refer to UFC 3-560-01 and IEEE Std 1048 for requirements for grounding of de-energized lines. Other grounding requirements are as follows:

- Permanent ground wires are installed to protect workers. All permanent grounds must be installed in accordance with the requirements of NFPA 70 or IEEE C2, as applicable. If the permanent grounds are not installed, the metallic case, covering, or mounting support of any energized piece of electrical equipment must be treated as if it is energized at full voltage;

- Install ground wires clear of all metallic line equipment (except that which is normally grounded), hardware, and street lighting fixtures; and

- Install ground wires on distribution wood poles with protective molding for the entire working length of the pole to protect them from damage. The entire working length of the pole is the distance from the point where ground wire terminates near the top of the pole to 5 ft (1.5 m) below the lowest cross arm or bracket, and from the ground line to 8 ft (2.5 m) above the ground line.

Never cut an overhead ground wire or neutral wires without the specific approval of the authorized individual-in-charge. Always avoid opening a joint in such a wire without first bridging the joint with wire of equal or larger size.

6-8.4 Handling and Stringing.

IEEE Std 524 provides general recommendations on the methods, equipment, and tools used for the stringing of overhead line conductors and ground wires. Safety precautions include:

- Use adequate braking to stop all payout reels. Do not touch or attempt to hand stop a revolving reel;

- Securely fasten the inside end of the coil wire to the reel to prevent the wire from getting loose when the wire has been extended out. If the inside end of the coil cannot be secured, a tail rope must be fastened securely to the wire before the end is reached to prevent its getting loose;

- Bond and ground all stringing equipment, such as reel stands, trailers, pullers, or tensioners;

- String the lines to clear the ground by an amount not less than that specified in IEEE C2. These minimums depend upon whether the line is above a street (consider its traffic classification), above a pedestrian way, or over or near other structures. Wire and guys that are being strung must be kept clear of any possible interference with public traffic of any type. Where it is necessary to block traffic temporarily while wires and guys are being installed, one or more members of the crew must be assigned to direct traffic; and

- Stringing by Activity personnel must normally be done by the tension method, since this keeps the conductor clear of energized conductors and clear of obstacles that might cause surface damage to the wire. Slack stringing may be appropriate for new short line extensions. Sag the lines to meet the requirements of IEEE C2:

  - Take care not to put kinks into any part of the line when stringing wires. Kinks reduce the strength of the wire and may result in fallen wires later.

  - Before changing the strains on a pole by adding wires, an engineering evaluation must be completed to ensure that the pole can safely stand the new strain.

6-8.5 Clipping-In or Tying Wires.

This involves the transferring of sagged conductors from their stringing travelers to their permanent insulator positions where they may either be clamped or tied to insulators. Safety precautions include:

- Securely tie wires at each tie-in-type insulator to prevent the wires becoming loose and falling to the ground. Where double arms are provided, line wires must be well tied-in to insulators on each arm. This applies to both pin- and post-type tie-top insulator work. Clamp-type insulators must have the clamps tightened as specified by the manufacturer;

- Test the phase wires with a potential transformer or other means, to make sure that the phase wires of one circuit are being connected to the corresponding phase wires of the other circuit when it is necessary to connect circuits at any point on the line; and

- Be sure that the phase wires are not crossed when turning the vertical angle on three-phase lines; that is, phase wires must take the same position leaving an angle as coming into it.

6-8.6 Secondary Line Installation.

Install secondary lines to meet line clearance requirements of IEEE C2. Lines can be single or triplex wires. Workers must be particularly careful in stringing secondary services to avoid the hazards of working in close proximity to primary lines. Deenergize and ground nearby or adjacent energized lines before stringing secondary wires. Take care not to injure the weatherproof covering when handling and stringing of weatherproof-covered wires.

6-8.7 Removing Lines.

Use the same general precautions as stringing wires when removing or salvaging wires. Where practical, the removed wire must be completely pulled out and laid flat on the ground before any attempt is made to coil the wire by hand or on a non-power-driven reel. Never change the strains on a pole by removing wires until certain that the pole can safely stand the altered strain. Where a pole will be weakened by the removal of the wires, it must be guyed before these wires are removed. All wires must be lowered with a hand line. Use care before cutting a wire aloft to avoid contact with other wires.

Do not allow lines which are being cut or rearranged to sag on, or be blown against other electric power lines, signal lines, signal equipment, metal sheaths of cables, metal pipes, ground wires, metal fixtures on poles, guy wires, or span wires. Do not allow wires which have been cut, or which are being arranged, to fall near or on a roadway where they might endanger traffic. Notify all persons working on lower levels of poles and all personnel on the ground well in advance of the cutting so that they may stand clear.

6-8.8 Guying.

Do not install or remove guys without engineering guidance.

6-8.8.1 Installation.

Install guys to meet the following requirements:

- When insulators are used they must be connected into the guy wire line before the guy wire is set in place. In new work, guys must generally be installed before line wires are strung. In reconstruction work, guys must be installed before any changes are made in the line wires and care must be taken not to place excessive pull on the pole and wires already in position;

- Install guys so that there is minimal interference with the climbing space, and to clear all energized wires;

- Provide guy strain insulators to obtain necessary insulation when required by building or safety codes;

- Install guys to the correct tension. Where necessary, a guy hook may be used to prevent the guy from slipping down the pole. Locate these hooks so they do not interfere with climbing, and place them so they are not convenient for use as a step. Where guys are liable to cut into the surface of a pole, the pole must be protected by a guy plate at the point where the guy is attached. The plate must be well secured to the pole to prevent the possibility of injury to a worker climbing up or down the pole;

- Install guys so that they do not interfere with street or highway traffic. Equip guys located near streets, or highways, with traffic guards. Traffic guards are sometimes called "anchor shields". Guy guards (traffic shields or anchor shields) must be yellow;
- Install guy wires so that they do not rub against messenger or signal cables; and
- Do not use guy wire containing snarls or kinks for line work. Use guy wires of the correct length to avoid splices.

6-8.8.2 Removal of Guys.

Determine the condition of the pole before removing guys. Brace the pole securely if it is weak before any changes in pole strains are made. Brace the pole temporarily if the removal of guys from a pole can change the strain and present a dangerous condition.

Where it is not possible to install side guys, poles may need bracing to be self-supporting. Install pole bracing so that it does not interfere with climbing or with street or highway traffic. Pole braced guys must not be used on poles which must be climbed.

6-8.9 Insulators.

Pick up insulators by their tops to avoid cutting gloves or hands on the insulator petticoats. Do not screw down insulators too tightly because their tops might break off, cutting gloves or hands.

6-9 ENERGIZED WORK.

Energized work requirements are provided in UFC 3-560-01.

6-10 WORKING ON OR NEAR POLE-MOUNTED EQUIPMENT.

This paragraph provides precautions applicable to equipment that is mounted above grade. Be aware that some local and state safety regulations do not permit grounding of enclosure cases on wood poles when there is a possibility that an accidental contact with bare aerial lines could occur. The equipment on the Activity might have been installed in accordance with these regulations. Transformers connected to an energized circuit must be considered as being energized at the full primary voltage unless positive verification is made that they are adequately grounded.

6-10.1 Surge Arresters.

Check that the permanent ground connection is intact before any work is done. Do not climb on or strap off to surge arresters.

6-10.2 Switches and Fuses.

The maintenance of switches and fuses might require temporary line modifications to permit repairs while maintaining service continuity. Engineering guidance must likely be required in preparing a step-by-step modification procedure. Both sides of fuses must be placed in an electrically safe work condition in order for repair work to proceed.

6-10.3 Capacitors.

Individual capacitor banks must be grounded if insulated capacitor mounting racks are not used. Provide grounding in accordance with the manufacturer's instructions.

6-10.4 Power Transformers and Voltage Regulators.

Work on energized pole-mounted transformers is prohibited except for testing, replacement of fuses, and switching. Observe the following precautions during installation:

- Carefully inspect all frames and tackles used in erecting pole-type transformers before each use. Repair defects before the frames and tackles are used;

- Wherever possible, junction poles, subsidiary poles, and street lighting poles must not be used as transformer poles. When it is necessary to install transformers on junction, subsidiary, or street lighting poles, be careful to maintain proper climbing space and to avoid crowding of wires and equipment;

- Install transformers only on poles strong enough to carry their weight. Transformer poles must be straight and, where necessary, guyed to prevent leaning or raking of the pole after the transformer is hung;

- All crew members must stand clear and detour traffic when transformers are raised or lowered. In congested traffic locations, the pole space must be roped off. Personnel on the pole must place themselves on the opposite side from that on which the transformer is being raised or lowered. Pole steps and other obstructions in the path of ascent/descent of large transformers must be removed;

- When transformers are installed, the pole climbing space must be protected so that climbing workers do not come too close to transformer cases;

- Do not install pole-type transformers until they are filled with a sufficient amount of the appropriate oil or fluid;

- Determine phase rotation before the old bank is removed, and before the new three-phase bank of pole-type transformers is installed, check voltage and phase rotation as well as the nomenclature plate;

- Only qualified climbers must be allowed to climb poles to inspect and test pole-type transformers. Never stand on or otherwise contact transformer cases;

- Disconnect all energized connections to transformers and provide a Safe Clearance from all live circuits before changing or replenishing transformer oil; and

- Do not use lighted matches or open flames of any kind when opening transformers.

6-10.5 Fuses.

When installing fuses, workers must be careful to avoid contact with any live lines and with other metal surfaces even if they are supposed to be grounded (i.e., grounded lines, the casings of grounded transformers, street lighting fixtures, signal lines, signal equipment, the metal sheathing of cables, metal conduits, span wires, or guy wires).

Before installing fuses in new cutouts, replacing fuses, or opening disconnects, workers must wear and use the appropriate personal protective equipment in accordance with UFC 3-560-01.

6-10.6 Service Wires.

Use at least two qualified workers when installing services from a transformer pole when primary conductors energized at 4,000 V or more are within contact distance of the secondary wires.

Service wires must not be installed on transformer poles, unless minimum separation requirements can be maintained between the service wires and the energized primary conductors or apparatus. The neutral wire must be connected first when making connections to secondary buses followed by the phase conductors. Reverse the procedure when disconnecting services.

6-10.7 Testing.

Qualified personnel must perform testing of transformers, autotransformers, and similar equipment. All temporary leads used in testing, such as secondary leads of potential transformers, thermometer leads, and recording voltmeter leads, must be securely supported on the pole and must clear all vehicular traffic. The positions of these leads must not interfere with the climbing space or with other maintenance work which may be required while the testing is in progress.

6-11 AERIAL ROPE.

6-11.1 Conductivity.

Properly maintained polypropylene synthetic rope (not natural-fiber rope) which meets IEEE Std 516 requirements must be used for aerial lines, hand lines, and tag lines for energized work. Keep rope stored in a clean, dry location and protected from damage and contamination. Rope lines used must be constructed without wire reinforcement, and be at least 1/2 in (12.7 mm) in diameter.

6-11.2 Terminology of Rope Use.

The following terms are used:

- Hand lines are used to raise and lower light materials and tools. They may be used for holding small transformers away from the pole during raising or lowering;
- Throw lines are used to pull a larger rope into place for performing a task beyond the capacity of a hand line. They are small diameter ropes designed to be thrown over support objects such as cross arms or tree limbs;
- Bull ropes are used when a hand line is not strong enough to raise heavier equipment. They are used also for fastening temporary poles, for holding out heavier transformers, and for lowering trunks or heavy limbs in tree trimming operations;
- Running lines are used for pulling several span lengths of wire at one time;
- A sling is a looped rope assembly useful for many purposes, such as, hoisting heavy equipment, lashing tools or materials in place; attaching a block or a snatch block to a pole; making temporary installations such as lashing an old pole to a new pole; or for tying up line wires;
- A safety line is used only for lowering a worker to the ground; and

- A snatch block is a rope sheave and hook with one side of the sheave open to avoid threading the rope through a hole.

6-11.3 Knots and Splices.

Where it is necessary to connect two aerial rope lines permanently, a splice must be made. No metal, wire, or clamps can be used in making the splices. The strength of a splice can be close to the original strength of the rope, and is always much greater than the strength of a knot.

Knots, friction tape, cord, or marlin must not be used in joining the two parts of an aerial rope line. Properly assembled splices are not normally bulky. Each end of the rope line must be finished (served) to prevent unraveling of the strands. A hand line must be dry and strong enough for use as a safety line for lowering a person safely from a pole.

6-11.4 Hand Line and Rope Line Precautions.

Although the term hand line is used in the following paragraphs, these precautions apply to all rope lines:

- Hand lines must be at least twice as long as the height of the highest cross arm, and equipped with single sheaves. No metal must be used on any hand line, except for the use of a standard hook;

- Hand lines with worn or frayed parts must be scrapped immediately;

- Hand lines must be carried up a pole uncoiled and attached to the back of body harness/belt before any work is done. A worker climbing with a hand line must take care to prevent the hand line from catching on pole attachments;

- Hand lines must not be pulled over sharp bends, sharp edges, or surfaces with splinters;

- Hand lines must be kept free from solder, oil, grease, snarls, and knots;

- Hand lines must not be stored while they are wet;

- When not in use, hand lines must be rolled up and stored in a dry and protected place. Always thoroughly dry hand lines before storing. Hand lines must never be permitted to lie on the street or highway;

- Where hand lines are being let out on the poles, at least one member of the crew must be stationed at a safe distance from the base of the pole to take care of the loading and unloading of the hand line, and to see that the ends are kept free from all street traffic; and

- One hand line must be kept in reserve and maintained in a dry condition to use as a safety line in case there is a need to rescue a worker from a pole. This hand line must be stored in a protected part of the truck where it cannot become wet.

6-11.5 Tackle Blocks.

Tackle blocks used on maintenance work must be equipped with safety snaps to prevent wire grips and live tools from coming loose and falling.

6-12 TOOLS.

Aerial line work involves the use of portable power tools and other miscellaneous tools.

6-12.1 Portable Power Tool Precautions.

Use only approved portable power tools on poles, towers, or structures:

- Keep electric tools and connected power cords a safe distance from any circuit or apparatus energized in excess of 600 V, phase to phase. Power cords must be adequately insulated and properly secured to prevent accidental contact with any conductor;

- Do not use air-driven and hydraulic-driven tools when their conducting parts can come closer than the restricted approach boundary to any energized conductor or apparatus. Cover the energized conductors or apparatus with protective equipment appropriate for the voltage involved when the minimum clearances cannot be obtained. Supply hoses must be made of non-current carrying material throughout, be properly maintained, and secured in use to prevent accidental contact with any energized conductor or apparatus;

- Use power saws in an elevated position on a pole, tower, or structure only when approved by the authorized individual-in-charge; and

- Non-current carrying metal parts of hand-held portable electric power tools must be grounded unless supplied from a ground-fault interrupting (GFI) circuit. Approved double-insulated tools and tools fed from ungrounded isolated power supplies need not be grounded.

6-12.2 Miscellaneous Tool Precautions.

- Pike pole handles must be sound and free from splinters. Spear points (gaffs) must be sharp and securely fastened to a pole. When carried on trucks, pike poles must be placed to prevent injuries;

- Maintain cant hooks and carrying hooks in a safe condition;
- Never use Jennies with cracked or broken legs, dull teeth, or loose bolts. Use only approved Jennies;
- Never use pole jacks with defective releases, or jacks that might slip when loaded;
- Only use approved bumper boards. A bumper board must be either 2 by 6 in (50 by 150 mm) board of length 6 to 8 ft (1.8 to 2.4 m), or 1-1/2 by 6 in (38 by 150 mm) channel iron of length at least 6 ft (1.8 m);
- Never use wire reels with defects evident. All wire reels must have suitable brakes;
- Close folding-type knives before placing them in toolboxes or other storage containers. Open knives must be kept in scabbards when not in use;
- Maintain personal tools in good condition; and
- Keep live-line tools clean, dry and in good condition.

6-13 AERIAL LIFTS AND INSULATED BUCKETS.

Aerial lifts must be constructed, maintained, and tested to meet the following standards:

- ANSI/SIA A92.2
- ANSI/SIA A92.3
- ANSI/SIA A92.5
- ANSI/SIA A92.6

The following provides requirements regarding their use.

6-13.1 Types of Aerial Lifts.

Aerial lifts include the following types of vehicle-mounted aerial devices used to elevate personnel to job-sites aboveground:

- Extendable boom aerial device.

6-13.2 Aerial Ladder.

- Articulating boom aerial device;

- Vertical tower; or
- A combination of any of the above.

The vehicle may be a truck, trailer, or all-terrain vehicle.

6-13.3 Insulating Versus Non-Insulating.

The aerial device manufacturer must state in the manual and on the instruction plate whether the aerial device is insulating or non-insulating. Insulating device categories are provided in Table 6-3.

Note: Insulating aerial devices do not protect personnel from phase to phase or phase to ground contacts at the platform end. When working from an insulated aerial device the primary source of insulation will be the insulating protective equipment (personal protective equipment, rubber sleeves, live-line tools, and rubber gloves).

Note: Only insulating aerial devices tested and rated for the application and use provided in Table 6-4 are allowed to be used when working on overhead lines.

Table 6-3 Insulating Device Categories

Category	Description
A	Aerial devices designed and manufactured for work in which the boom is considered primary insulation (bare-hand work) must have all conducted components at the platform end bonded together to accomplish equipotential of all such components. Mark devices at the platform indicating such bonding. Equip aerial devices with a lower test electrode system. When these devices are qualified for work above 138 kV, equip them with a gradient control device and conductive shield(s) over the lower test electrode system. For those devices with ratings 138 kV and below, conducting shield(s) over the lower test electrode system are required. The necessity of gradient control device is to be determined by the qualification test.
B	Aerial devices designed and manufactured for work in which the boom is not considered primary insulation, but secondary, such as that using insulating (rubber) gloves. Isolation or bonding of the conductive components at the platform end is not a requirement. Equip aerial devices with a lower test electrode system.
C	Aerial devices designed and manufactured for work in which the boom is not considered primary insulation, but secondary, such as that using insulating (rubber) gloves. Isolation or bonding of the conductive components at the platform end is not a requirement. These aerial devices are not equipped with a lower test electrode system and are designed for 46kV and below.

Note: Bare-hand work is prohibited.

Table 6-4 Application and Uses of Aerial Devices

Category	Bare-Hand	Gloving	Hot Stick*	Construction De-energized
A	X	**	X	X
B	**	X	X	X
C		X	X	X
Non-Insulated			X	X

** Aerial device is used as a work platform*

*** An aerial device manufactured as a Category A may be modified and used as a Category B and a Category B may be modified and used as a Category A. In the event this is done, give particular attention to the appropriate qualification test, gradient control devices, conductive shields, conductive liners, and bonding.*

6-13.3.1 Insulated Buckets.

An insulated bucket of an aerial lift is provided with a non-conductive bucket liner. Support the liner by the inside bottom surface of the basket. Do not provide drain holes or access openings in the insulating buckets.

Tools and other equipment carried in the bucket must be stowed carefully to avoid damaging the non-conductive liner.

6-13.3.2 Testing and Certification.

Establish testing intervals by the owner in accordance with the manufacturer's recommendations and ANSI/SIA 92.2. Intervals are dependent upon component function and exposure to wear, deterioration and other agents which adversely affect component life. Testing and inspection frequencies are shown below. In addition, conduct a dielectric test of the bucket liners annually in accordance with the requirements of ANSI/SIA 92.2, below:

- Frequent Inspection and Test performed at daily to monthly intervals; and
- Periodic Inspection and Test performed at one to twelve month intervals.

ANSI/SIA 92.3, ANSI/SIA 92.5, and ANSI/SIA A92.6, whichever is applicable for the construction, type and manufacture of the lifts, require more frequent inspection, testing and certification as shown below:

- Frequent Inspection performed at 3 month intervals or 150 hours of use, whichever comes first; and

- Annual Inspection performed no later than 13 months from the date of the prior annual inspection.

Note: For the Navy, maintenance and testing requirements follow the requirements of NAVFAC P-300 for aerial lifts and boom trucks.

6-13.3.3 Maintenance.

Perform periodic maintenance in accordance with the manufacturer's operations and maintenance manual. Perform electrical tests on insulation no less than annually in accordance with ANSI/SIA A92.2, to the values referenced in the following tables:

Table 6-5 Periodic Electrical Test Values for Insulating Aerial Devices with a Lower Test Electrode System (Category A and Category B)

Unit Rating	60 Hz (rms) Test			Direct Current Test		
	Voltage	Maximum Allowable Current	Time	Voltage	Maximum Allowable Current	Time
46 kV & below	40 kV	40 microamperes	1 minute	56 kV	28 microamperes	3 minutes
69 kV	60 kV	60 microamperes	1 minute	84 kV	42 microamperes	3 minutes
138 kV	120 kV	120 microamperes	1 minute	168 kV	84 microamperes	3 minutes
230 kV	200 kV	200 microamperes	1 minute	280 kV	140 microamperes	3 minutes
345 kV	300 kV	300 microamperes	1 minute	420 kV	210 microamperes	3 minutes
500 kV	430 kV	430 microamperes	1 minute	602 kV	301 microamperes	3 minutes
765 kV	660 kV	660 microamperes	1 minute	924 kV	462 microamperes	3 minutes

Table 6-6 Insulating Aerial Devices without Lower Test Electrode System (Category C)

60 Hz (rms) Test				Direct Current Test		
Unit Rating	**Voltage**	**Maximum Allowable Current**	**Time**	**Voltage**	**Maximum Allowable Current**	**Time**
46 kV & below	40 kV (rms)	400 microamperes	1 minute	56 kV	56 microamperes	3 minutes

Table 6-7 Insulating Aerial Ladders and Insulating Vertical Aerial Towers

	60 Hz (rms) Test			Direct Current Test		
Unit Rating	**Voltage**	**Maximum Allowable Current**		**Voltage**	**Maximum Allowable Current**	**Time**
46 kV & below	40 kV (rms)	400 microamperes	1 minute	56 kV	56 microamperes	3 minutes
20kV and below	20 kV (rms)	200 microamperes	1 minute	28 kV	28 microamperes	3 minutes

Table 6-8 In Field Tests for Insulating Aerial Devices – ANSI/SIA A92.2 Section 5.4.3.2 Item 10(c)

Aerial Device Category	AC Voltage	Maximum Allowable Current	Time of Test
A or B	Line to Ground	1 milliampere / kVAC	3 minutes
A or B	Line to Ground	0.5 microamperes / kVAC	3 minutes
Note: This test may be used as a Periodic Test when the voltage is at least double that of any circuit on which the aerial device is to be used, but not exceeded the Qualifications Voltage of the aerial device.			

Retain all records for the annual and frequent inspections documentation for a period of at least three years for Manually Propelled Elevating Aerial Platforms (ANSI/SIA A92.3), Boom Supported Elevating Work Platforms (ANSI/SIA A92.5), and Self-Propelled Elevating Work Platforms (ANSI/SIA A92.6). Retain written, dated and signed inspection and periodic test reports and records for five years for Vehicle-Mounted Elevating and Rotating Aerial Devices as required by ANSI/SIA A92.2.

6-13.4 General Requirements.

Comply with the following requirements:

- Test lift controls each day prior to use if the lift is being used that day, to determine if the controls are in safe working condition. Test lift controls on a monthly basis when not in use;

- Do not alter the insulated portion of an aerial lift in any manner that might reduce its insulating value;

- Ensure the manufacturer's operation manual is available with any aerial lift;

- Do not allow anyone to touch the truck or equipment when aerial equipment is operating near energized conductors. The vehicle must be grounded, or if not grounded, must be considered as energized and properly barricaded. Ensure that everyone in the vicinity of the truck or equipment is aware of and protected from the hazards of step and touch potential;

- The requirements for use of rubber or other protective equipment while working on poles and structures also apply to work from aerial buckets. Consult UFC 3-560-01 for additional information on rubber protective equipment;

- Use a body harness with a secured safety lanyard for any work from an aerial bucket, basket or platform unless the manufacture of the equipment precludes use of a harness based on the manufacture of the equipment and applicable OSHA standards. Provide arc-rated harnesses in accordance with ASTM F887. Do not belt off to an adjacent pole, structure, or equipment while working from an aerial lift. Use the manufacturer's provided attachment point on the equipment;

- Do not wear climbers while performing work from an aerial lift;

- Wear personnel protective equipment in accordance with UFC 3-560-01;

- Only qualified electrical workers may operate aerial lift equipment within the restricted approach boundary distances specified in UFC 3-560-01;

- Operate any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines so that a clearance is maintained in accordance with the limited approach boundary limits for exposed movable conductors in Table 3-1 of UFC 3-560-01. However, under any of the following conditions, the clearance may be reduced;

- If the vehicle is in transit with its structure lowered, the clearance may be reduced to 4 ft (122 cm). If the voltage is higher than 50 kV, increase the clearance requirement by 4 in (10 cm) for every 10 kV over that voltage.

- If insulating barriers are installed to prevent contact with the lines, and if the barriers are rated for the voltage of the line being guarded and are not a part of or an attachment to the vehicle or its raised structure, the clearance may be reduced to a distance within the designed working dimensions of the insulating barrier.

- If the equipment is an aerial lift insulated for the voltage involved, and if the work is performed by a qualified electrical worker, the clearance (between the uninsulated portion of the aerial lift and the power line) may be reduced to the restricted approach boundary distances specified in UFC 3-560-01.

- Insulated aerial lifting devices used for working on energized electrical systems must be specifically designed for that sole function. Use the aerial lift only for electrical-related work;

- Stay clear of pressurized oil or air escaping from a ruptured line or fitting. The pump, compressor, or engine must be stopped as soon as a leak is detected;

- All hydraulic and pneumatic tools that are used on or near energized equipment must have non-conducting hoses rated for no less than normal operating pressure;

- Do not exceed the manufacturers' boom and bucket load limits; and,

- Provide both platform (upper) and lower controls for articulating boom and extensible boom platforms, primarily designed as personnel carriers. Upper controls must be in or beside the platform within easy reach of the operator. Lower controls must provide for overriding the upper controls. Controls must be plainly marked as to their function. Lower level controls must not be operated unless permission has been obtained from the worker in the lift, except in case of emergency. All controls must be clearly identified as to their function and protected from damage and unintentional actuation. Design the boom position and carrying attachment controls to return to their neutral position when released by the operator.

Note: The aerial lift may become energized when the boom or the aerial basket comes in direct contact with energized conductors or equipment.

6-13.5 Training.

Train operators in accordance with the manufacturer's operation manual and the applicable ANSI standard. Any ground safety personnel acting as the ground person during the operation of the lift must be qualified and have received training in accordance with the manufacturer's operation manual and the applicable ANSI standard. Operators must also be trained for working from aerial lifts according to OSHA 29 CFR 1910.269, 1910.333(c), and NFPA 70E, Article 130.

Note: Follow the licensing requirements of NAVFAC P-300 for Navy personnel.

6-13.6 Driving Precautions.

Comply with the following requirements:

- Drivers of aerial bucket trucks must be constantly alert to the fact that the vehicle has exposed equipment above the elevation of the truck cab and will be sure that roadways provide the necessary overhead clearance. They must avoid the need to move the truck into the opposing traffic stream by prior planning of the order of work;

- Any backing of the truck must be done slowly and under the direction of one person on the ground. This person must have an unobstructed view of the intended path of the vehicle;

- Do not move a truck with the boom elevated in working position. Secure booms in the cradled position prior to any movement; and

- When traveling to and from job sites, pin-on type buckets must be removed and stored on the truck, or secured in a horizontal position to the boom, to avoid obstructing the driver's vision.

6-13.7 Setting Up and Knocking Down at the Job Site.

Upon arriving at the work area, legally park the truck while the vehicle and pedestrian warning signs, lights, and barricades are being placed. Give careful consideration to the location of overhead conductors and the surrounding conditions before the truck is moved into the work position. Make every effort to place the truck so that all work areas at that location may be reached by the boom without movement of the truck. Perform a job site "tail-gate" safety briefing including application of operational risk management principles.

Note: Air Force Only – Job site "tail-gate" safety briefings including application of operational risk management principles and actions must be documented in writing.

Comply with the following requirements:

- Examine available footing for the truck wheels and outriggers carefully and exercise extra caution if there is snow, ice, mud, soft ground, or other unusual conditions. Blind ditches, manholes, culverts, cesspools, wells, and similar construction features are additional possible hazards;

- Before lowering the stabilizers, outriggers, or hydraulic jacks, the operator must be certain that no persons are close enough to be injured. Wheels must be chocked and cribbing may be needed to ensure stability of the truck body;

- When working on an inclined road or street, check each outrigger or jack to make sure a stable setup has been achieved. The truck must be approximately level as viewed from the rear;

- A warm-up period for the truck is usually needed at the beginning of each day's work. This time must vary with different truck makes and models, and with different temperatures. Follow the manufacturer's recommendations;

- When lowering the boom to a cradled position, workers must stand clear of the path of the bucket and boom; and

- When work is completed, secure aerial ladders in the lower traveling positions by the locking device on top of the truck cab and the manually operated device at the base of the ladder before the truck is moved for highway travel.

6-13.8 Operating at the Job Site.

Comply with the following requirements:

- One worker must be responsible for all operations required in placing the bucket in operating position, use of the bucket, and restoring it to the traveling position. This worker must check to ensure the truck handbrake is set, the wheels of the truck chocked, and if the truck is equipped with outriggers or stabilizers, they are in the down position. If this worker has any doubt as to the stability of the truck, particularly because of the terrain, the outriggers or stabilizers must be specially checked for proper positioning before a load is lifted;

- When the boom must be maneuvered over a street or highway, necessary precautions must be taken to avoid mishaps with traffic or pedestrians. Consider use of a flagman;

- Workers must enter the bucket only with the bucket resting in the position for which entry was designed;

- The operator must face in the direction in which the bucket is moving so that all obstructions are noted and avoided when the bucket or boom is raised, lowered, or rotated;

- The operator must follow the proper sequence prescribed by the manufacturer in raising the boom section;

- Before reaching any area containing obstructions, the operator must test all controls of the boom and bucket to ensure that they are in proper working order;

- The operator must suspend operations upon indication the controls are not working properly;

- Raising the bucket directly above energized conductors or equipment must be kept to a minimum;

- When possible, locate buckets to the side of lines, to help workers aloft avoid contacting energized conductors and equipment;

- If the work is within reach of energized conductors or equipment, a worker must be properly protected with rubber sleeves and rubber gloves of an insulation rating appropriate for the voltage level;

- Energized conductors and equipment must be covered with protective devices when necessary to perform the work safely;

- Adequate clearance must be maintained so that protruding tools must not come in contact with conductors, tree limbs, or other obstructions;

- A worker must always stand on the floor of the bucket. Never on top of the bucket or on planks placed across the top of the bucket, or tools/materials within bucket while performing work. Do not alter buckets to facilitate additional reach;

- A worker must not belt onto an adjacent pole, structure, or equipment while performing work from the bucket;

- The operator must ensure that hand lines and tools do not become entangled with the levers that operate the boom; and

- Secure all tools not in use when working aloft.

When the bucket is being used in any manner that might result in contact between an energized conductor and the bucket, boom, or any attachment thereto, the vehicle must be considered energized at line potential, and the following safe practices observed for ground operations:

- Materials or tools must not be passed between a worker on the vehicle and a worker on the ground, unless both workers wear rubber gloves and use other required protective devices;
- Workers operating ground controls must be on the vehicle or insulated from the ground using rubber gloves and other protective equipment;
- Before entering or leaving the vehicle, a worker must make sure that the boom or bucket is not in contact with or near energized equipment;
- Workers on the ground must not work directly below the work area of the bucket; and
- Tools or materials must not be thrown to or from the elevated bucket.

6-13.9 Aerial Lift Equipment Operation near Energized Electrical Equipment.

Only qualified electrical workers may operate aerial lift equipment between the approach distances given provided in UFC 3-560-01. Comply with the following requirements:

- An approved Job Hazard Analysis (JHA) and Standard Operating Procedures (SOP) must be completed;
- The activity is being performed under the direct supervision of a designated person who is trained and competent in this type of work;
- The distances between energized parts and the aerial lift equipment is monitored while the aerial lift equipment is being moved and or repositioned;
- The aerial lift equipment is grounded; and
- No one, other than necessary workers, is allowed within 10 ft (3.0 m) of the equipment during its operation. Workers are to perform their work while on the equipment, not from a position on the ground.

6-14 TREE TRIMMING AND BRUSH REMOVAL.

Tree trimming and brush removal is necessary to maintain the integrity of electric lines and apparatus and provide right-of-way clearance.

6-14.1 Training Qualifications.

Permit only workers certified as “Qualified Climbers” to climb trees. Work accomplished from an aerial lift must only be performed by workers qualified in use of the aerial lift. If using ladders, review the requirements for their safe use. In all cases, only qualified workers must perform work near energized lines.

Trimming must be done in a manner that does not damage the tree, and meets ANSI Z133.1 requirements. The worker must be qualified to do tree trimming.

6-14.2 Public Safety.

Erect suitable signs and barriers to prevent the public from passing under trees being trimmed, and to prevent stumbling over brush on the ground. Brush must not be piled on sidewalks, or left on streets and highways overnight.

6-14.3 Tool Safety.

Raise and lower tools with a hand line. Use only saws and pruning knives or shears for cutting limbs. Do not carry unnecessary tools up the tree. Do not hang or store tools on tree limbs.

6-14.4 Work Near Energized Lines.

Be aware that lines may not always be de-energized for tree trimming operations. Review the rules for live line safety, and for climbing and working on a pole. Especially be aware of the energized lines in the area and the relevant dangers.

When working near energized lines, arrange the safety line so that a slip or fall will carry you away from the energized lines.

6-14.5 Climbing and Working on Trees.

Comply with the following requirements:

- Workers in trees must use harnesses/belts and safety straps;
- Climbing trees must be avoided unless ladders or aerial lifts cannot provide the necessary access;
- Workers in trees must be careful to prevent contact with aerial electric and telephone wires passing through the trees;
- If climbers are used, make sure they are tree climbers approved for the bark thickness of the tree being climbed. Never use pole climbers;

- Use a harness and safety strap or lifeline. Place the strap around a tree limb of sufficient size to hold the worker's weight, but never around the tree limb being cut;

- Do not stand on tree limbs too small to support your weight. Extreme care must be exercised when working in trees that have brittle wood; and

- Check each tree for dead or broken tree limbs when climbing. Remove unsound tree limbs during the climb. Lower cut-off tree limbs with a rope because falling tree limbs can cause injury or property damage.

6-14.6 Felling Trees.

Before felling trees, inspect tools to be used (such as ropes, tackle, ladders, and chain saws) to ensure they are in proper condition. Place signs warning pedestrian and vehicular traffic of the danger from work being performed. Station flagmen if necessary.

Inspect each tree for obstructions (conductors and fences) in the line of fall. If possible, de-energize nearby conductors. Trees taller than 25 ft (7.6 m) in height and larger than an 8 in (203 mm) trunk diameter must have ropes attached before felling. The ropes can be used to guide the tree as it falls. Always have a clear a path of retreat when felling a tree.

6-14.7 Power Trimming Equipment.

Chain-saw operators must be familiar with and follow the manufacturer's operating instructions. Comply with the following requirements:

- Carefully inspect chain saws prior to each use. Chain saws must be clean and sharp, and in sound mechanical condition with all guards, spark arresters, mufflers, handles, and other items properly installed and adjusted;

- Permit only workers trained in chain saw operation to perform the work;

- Clear away brush or other material that might interfere with cutting operations before starting to cut;

- Wear appropriate personal protective equipment when operating the chain saw. Eye, ear, hand, foot, and leg protection are minimum requirements;

- Never operate a chain saw when physically tired or under the influence of alcohol, medication, or other drugs;

- Do not store fuel near flammable materials. Fuel for chain saws must be stored in approved, vented containers clearly marked to show the contents;

- Do not start the chain saw within 10 ft (3.0 m) of a fuel container; and

- Do not fuel the chain saw with it running or hot, or with open flame nearby.

6-14.8 Right-Of-Way Brush Removal.

Brush clearance is part of electrical maintenance work to clear right-of-ways. Comply with the following requirements:

- Wear personal protective equipment; i.e., eye protection, hearing protection, and proper clothing;

- Cutters felling heavy brush or small trees must give sufficient clearance to other personnel. Never work so close that one worker could injure another with a swinging ax or hook;

- Brush chippers must be operated only when authorized. The worker must stand to the side of the chipper chute while feeding the butt end of brush into the chipper first. Use the automatic shut-off/stop control at the operator's station in an emergency;

- Do not hang tools such as saws, axes, bush hooks, pruning shears, scythe blades, and pitch forks in bushes or small trees, or out of the obvious view of other workers; and

- Restrict personnel assigned to remove or pile brush to maintain a safe distance behind workers using the cutting tools.

6-15 WORKING NEAR COMMUNICATIONS ANTENNAS.

If personnel work near communications antennas that are attached to electric power line structures, apply IEEE Std 1654 as a guide for the safety requirements.

CHAPTER 7 OUTAGES

7-1 TROUBLESHOOTING AND FAULT DETECTION METHODS.

Troubleshooting procedure:

- Install fault detectors
- Determine fault type
  - Open Conductor Fault – cable completely broken or interrupted at the location of the cable fault.
  - Shorted Fault – low resistance continuity path to ground.
  - High Impedance Fault – resistive path to ground (shunted fault) that is large in comparison to the cable's surge impedance.
- Test the cable
  - Fault Resistance and Loop Test – Insulation Resistance Insulation tester
  - TDR (Test Domain Reflectometer) Test
  - DC High Potential Test – surge generator connected to cable under test
  - Bridge Method
- Analyze the data
- Localize – Pre-locate the fault
- Locate – Pinpoint the fault

For cable failures, test to determine which cables to replace first:

- Insulation breakdown (water / trees). RF Test-point Injection Probing:

  Step 1: Couple an RF signal through elbow test-points;

  Step 2: Experimentally confirmed coupling greater than 1MHz signal; and

  Step 3: Measure attenuation, velocity of propagation as a function of instantaneous cable voltage. The mechanisms: at cable voltage V=0 the voids filled with water in the water tree are not connected and at higher voltage, micro-channels open due to Maxwell Mechanical Stresses and water will penetrate the channels making electrical contact.

- Loss of protective grounding shield - concentric neutrals (CN). Detected imbalances or lack of CN current as a sign of degradation:
  - Magnetic CN probing - measure current in concentric neutrals by sensing emanating magnetic field.
  - Anisotropic Magnetic Resistance (AMR) - measure return or phase imbalance currents (10%-20%).

7-2 FAULT ANALYSIS.

Fault in a circuit is any failure that interferes with the normal system operation:

- Lightning strikes cause most faults on high-voltage transmission lines producing a very high transient that greatly exceeds the rated voltage of the line:
  - This voltage usually causes flashover between the phases and/or the ground creating an arc.
  - Since the impedance of this new path is usually low, an excessive current may flow.
- Transient faults are faults involving ionized current paths. They usually clear if power is removed from the line for a short time and then restored:
  - Approximately 75% of all faults in power systems are transient in nature.
- Permanent faults where one, two or all three phases break or insulators break due to fatigue or inclement weather are faults that remain after a short removal and restoration of power.

Knowing the magnitude of the fault current in a power system is important when selecting protection equipment (type, size, etc.). Type of faults:

- Symmetrical three phase (3P) – symmetrical fault when, before the fault only AC voltages and currents are present, but immediately after the fault a transient DC component is added on top of the symmetrical AC component;

- When the fault occurs, the AC component of current jumps to a very large value, but the total current cannot change instantly because of the series inductance of the machine.
- The transient DC component is just large enough such that the sum of AC and DC components just after the fault equals the AC current just before the fault.
- The DC components decay quickly, but they initially average about 50-60% of the AC current flow the instant after fault occurs.
- There are three periods of time:
  - Sub-transient period – first cycle or so after fault – AC current is very large and falls rapidly; current can be as much as 10 times the steady-state fault current.
  - Transient period: current falls at a slower rate; current is often 5 times the steady-state fault current.
  - Steady state period – current reaches its steady value.

- Single line-to-ground (SLG) unsymmetrical fault;
- Line-to-line (LL) unsymmetrical fault; and
- Double line-to ground (DLG) unsymmetrical fault.

7-3 DOCUMENTING/REPORTING.

Documentation and reporting must be performed according to National Testing Standards (NTS). This means recording problems or failures, reasons for these problems, time to repair, costs both in materiel and labor, and suggestions to avoid future problems of the same type. Check with Activity lead office for specific outage reporting requirements. Suggested report data items include:

- Installation name;
- Incident date and time;
- Area(s) affected by outage;
- Reset date and time;
- Outage duration;
- Name of operator in charge;

- Name of person who re-set the switchgear, relay, or PLC;
- Name of person making report;
- List of contractors or personnel doing permitted work on electrical system at time of outage. Attach copies of permit(s) to the report;
- Switchgear relay readings;
- Amperage and voltages at time of outage, if possible;
- Primary alarms and outage as determined by PLC, SCADA, or switchgear;
- List outage cause(s), failed equipment, and specific failure locations;
- Implemented remedy to return to power;
  - Was damage found prior to reset, or determination of cause? (y/n);
  - Was damage fixed or isolated prior to re-energizing? (y/n);
- Estimated outage cost (labor and equipment); and,
- Suggested system or procedural modifications to make future outages less likely.

7-4 SCHEDULING AND PLANNING.

Outages consist of unplanned and planned (scheduled) events. An unplanned outage is where equipment is unexpectedly taken out of service for a variety of reasons, from weather events to grid overload. Return to service depends upon severity of outage and the resources available to evaluate and correct the failure.

A planned outage is where the equipment is taken out of service on a pre-established schedule, such as for maintenance actions or construction. Control outage costs by properly planning, sequencing, and executing the system switching and cutovers. Consider the following when planning an outage:

- Create a checklist of everything to consider before shutdown and when to consider it. Include in checklist the field verification of as-built system(s), including CT and PT ratios, conductor size and length, conductor insulation types, 100% or 133% insulation levels, and insulation temperature level MV-90 or MV-105, relay make/model/settings, breaker make/model/short circuit rating, and switchgear make/model/bus rating/short circuit rating.

- Ensure the proper tools, supplies, and technologies are available and on hand to execute the outage and accomplish the scheduled work.
- Establish good contractor relations and communication avenues for normal and emergency discussions.
- Clearly define expected contractor and in-house actions, and timing of actions, to establish an effective workflow. Review high-risk areas and update actions if planned conditions change.
- After outage is completed, evaluate shutdown effectiveness, and update procedures and checklists for future outages.

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CHAPTER 8 POWER SYSTEM STUDIES AND COMPUTER MODELS

8-1 TOOLS, DATA AND DEVELOPMENT.

8-1.1 General Process.

Maintain a power system study for the primary distribution system. The power system study includes the following:

- Field verification of as-built system configuration including CT ratios, PT ratios, conductor size, conductor insulation type, 100% or 133% insulation level, and insulation temperature level MV-90 or MV-105, conductor length, relay make/model/settings, breaker make/model/short circuit rating, and switchgear make/model/bus rating/short circuit rating;
- Development of electrical layout and one-line drawings for the primary distribution system;
- Electrical analysis of the system; and
- Identification of recommended system changes and upgrades.

The various electrical analyses, referred to as a power system study, provide design confirmation of the inherent ability of the electrical power distribution system to perform reliably under normal and abnormal conditions. A power system study includes:

- Power flow;
- Short circuit;
- Arc flash;
- Electrical protection and coordination; and
- Specialty analyses, such as power quality or Aurora evaluation.

8-1.2 UFC 3-501-01 Requirements.

UFC 3-501-01 provides detailed requirements for electrical analyses and compliance is mandatory for the design of electrical systems at all facilities and installations. Upgrades or modifications to electrical systems to consider the design criteria in UFC 3-501-01, but it is not intended that an entire facility or system require modernization solely because of a minor modification.

Although UFC 3-501-01 does not specifically apply to an existing primary distribution system, apply its power system analysis criteria for exterior power distribution systems as supplemented by this UFC.

8-1.3 Software Requirements.

Specify the analysis software required for the power system study. If the power system study is provided by a contractor, require the contractor to provide the electronic software files with each submittal.

For the Air Force, only EasyPower is certified in accordance with AFI 33-210 for use on standard desktop systems connected to the Air Force Global Information Grid and placed on the Air Force Evaluated/Approved Products List. Other software products can be used on standard desktop systems connected to the Air Force Global Information Grid after they have been certified in accordance with AFI 33-210 and placed on the Air Force Evaluated/Approved Products List.

If the Activity has electrical analysis software, maintain the software at the latest available version. The latest software version is required for the following reasons:

- Electrical analysis software is not backwards compatible. Any models or revisions to models developed by contractors cannot be opened by an older version of the software; and
- The arc flash analysis requirements continue to evolve. The latest version of the software is required to ensure that any arc flash calculations comply with the current state of the art with respect to analysis methodology.

8-1.4 Periodic Updates.

Upon completion of an initial power system study, update the study as follows:

- Complete a new power system study every six years;
- Update the power system study when significant changes occur to the system. Examples of changes that require an update include;
  - Substation or switching station replacement.
  - Modification of utility transmission system supply.
  - Primary distribution system upgrade, such as conversion of one or more feeders from overhead distribution to underground distribution.
  - Major change to facilities within a base, such as construction of multiple facilities in support of a new mission;
- Update the power system study when significant changes occur to the industry standards that form the analytical basis for analysis. For example, an arc flash calculation will require an update if the equations

used for the analysis are changed by the applicable industry standards; and

- Complete an annual review of the electrical model when the annual electrical drawing review described in Section 3-9 is performed and update the model as necessary to reflect the existing electrical distribution system.

Note: Changes to the electrical distribution system require evaluation in accordance with UFC 3-501-01.

8-2 MODELING.

8-2.1 Equipment Naming Conventions.

Equipment naming is considered an important part of the base-wide electrical safety program. Civilian personnel, military personnel, and contractors should have no doubt regarding their work location and which equipment to work on. Coordinate with base personnel to develop a standardized naming convention for the following equipment:

- Substation equipment, including feeder designations;
- Transformers – pole mount and pad mount;
- Pad-mounted switchgear;
- Sectionalizing cubicles;
- Power poles; and
- Manholes.

8-2.2 Equipment Modeling.

Develop an electrical model of the primary distribution system that includes the following system elements as applicable for the system design:

- All utility connection points for the supply to the primary distribution system. Obtain the following from the utility for each connection access;
  - Three-phase short circuit current and associated X/R ratio.
  - Single line to ground short circuit current and associated X/R ratio.
  - Request minimum and maximum values for each short circuit type. If the variation between minimum and maximum short circuit values

has a significant effect at the primary distribution level, then provide calculations at both extremes.

- Substation equipment, including transformers, switches, circuit breakers, capacitors, and associated protective devices;
- Electrical system conductor type, size, and length – overhead and underground;
- Overhead distribution – all power poles that contain electrical equipment, lateral taps, or conductor size changes;
- Pad-mounted switchgear, including VFI settings or fuse sizes;
- Sectionalizing cubicles;
- Distribution transformers, including primary conductors from the upstream source and secondary side conductors to the service entrance equipment; and
- If the Activity is supplied by a prime power plant, include the prime power plant generators in the model and address the minimum and maximum numbers of generators that are expected to be in operation.

Identify missing data as part of the power system study and document assumptions made to complete the analysis. Examples of missing data include:

- Distribution system transformers with missing nameplates;
- Pole-mounted transformer nameplates – inaccessible without the use of lift equipment and likely corroded by outdoor exposure;
- Fuse size for internal fuses in distribution system transformers or some pad-mounted switchgear that cannot be confirmed without requiring extensive system outages;
- Size and type of aerial lines – might depend on available drawings and knowledge of exterior shop personnel; and
- Size and type of some underground lines – might depend on available drawings and knowledge of exterior shop personnel.

8-3 POWER FLOW.

8-3.1 Overview.

A power flow analysis is commonly called a load flow analysis; the terms are used synonymously. A power flow analysis determines voltages and power flow throughout the electrical system and provides insight into many aspects of system performance, including:

- Adequacy of voltage levels throughout the system;
- Current flow through all branches of the system;
- The ability of generators to supply required load without exceeding their rating;
- The ability of system equipment (such as switchgear, panels, transformers, or cables) to carry the required load without exceeding any ratings;
- Inappropriate or low reliability system lineups, including an evaluation of cross-connect and alternate feed capability;
- System expandability and choke points for load addition; and
- Equipment sizing and rating specifications for new/replacement equipment.

A power flow analysis includes an evaluation of system performance under various conditions and operating modes. Different conditions of interest might include:

- Cross connect capability between the feeders (partial or full);
- Proposed load additions;
- System changes involving re-powering loads from a different feeder (load re-balancing); and
- Variations in transformer tap settings.

8-3.2 Metering Data.

8-3.2.1 Utility Metering Data.

Obtain metering data from the utility, if applicable, for each metered location. The preferred format includes real and reactive power obtained at 15-minute intervals for a period of several years. The purpose of this data is to establish peak power demand and when peak power occurs for each metered location.

8-3.2.2 Primary Distribution System Metering Data.

If the electrical system design includes metering or recording of the current on each distribution circuit, obtain this data to help establish the power demand on each circuit.

Note: If metering data is available from an installed Advanced Meter Infrastructure (AMI) system, obtain the trended load data as an input to the power system study.

Note: If primary distribution system power demand data is available from an Industrial Control System (ICS) with feeder metering, obtain the historical trended load data as an input to the power system study.

8-3.3 System Electrical Measurements.

Obtain electrical measurements, including voltage, current, power factor, voltage harmonic distortion, and current harmonic distortion, at accessible locations in the primary distribution system. Use collected data to accurately match replacement equipment to actual facility loads.

Note: The intent of this requirement is to establish, wherever possible, the typical system load. Power system studies performed at over 50 Air Force Bases have validated that the average transformer loading is about 20% to 25% of rated value during periods of peak demand. For example, if an Air Force Base has a summer peak demand of 20,000 kVA, the total connected transformer kVA might be as much as 100,000 kVA. When replacing transformers, size for actual system loading to reduce potential arc flash incident energy levels.

Note: Low-voltage measurements can often be taken on the secondary side of distribution transformers. Medium-voltage measurements can often be taken at some pad-mounted switchgear or sectionalizing cubicles.

8-3.4 Power Flow Analysis.

Perform a power flow analysis that accomplishes the following:

- Provides an assessment of peak demand on each distribution feeder;
- Identifies any ampacity limitations throughout the electrical system;
- Calculates voltage drop throughout the electrical system;
- Identifies any unusual system voltage associated with off-nominal transformer tap ratios;

- Include emergency power load flow analysis scenarios in the power flow model;

- Include alternate feeder load flow analysis where switching paths allow alternate load flow scenarios; and

- Include any prime power generation capability, including renewable energy sources.

8-3.5 Cross-Connect Analysis.

A cross-connect analysis is an extension of a power flow analysis and evaluates the capability of each system cross-tie location. Identify any ampacity or voltage drop limitations associated with each cross-tie location.

8-4 SHORT CIRCUIT ANALYSIS.

8-4.1 Overview.

A short circuit analysis provides a means to evaluate the following aspects of a power system:

- The ability of system distribution equipment (such as switchgear, cables, disconnect switches, panels, motor control centers, or bus ducts) to withstand the available fault current without damage;

- The ability of system protective devices (e.g.;, circuit breakers, fuses) to successfully interrupt a fault without failing;

- The adequacy of electrical protective device settings and sizes;

- System lineups that result in unacceptable levels of fault current; and

- Baseline fault current levels (maximum and minimum) for calculating arc flash energy levels.

Short circuit current levels for several types of faults are generally evaluated during a short circuit analysis, including:

- Three phase bolted fault – all three phases of a three-phase system short together with no appreciable fault impedance (generally produces the highest available fault currents and always produces the most fault energy);

- Phase-to-ground fault – one phase of a three-phase system shorts to ground (also called a line-to-ground fault or ground fault);

- Phase-to-phase fault – two phases of a three-phase system short together (also called a line-to-line fault); and

- Phase-to-phase-to-ground fault – two phases of a three-phase system short together and to ground simultaneously (also called a double line-to-ground fault).

8-4.2 Short Circuit Results.

Provide short circuit results for each bus in the system, including X/R ratio at each location. Provide short circuit results throughout the primary distribution system and extending to the service entrance bus of each facility. As a minimum, include three-phase and single line to ground faults in the power system study.

8-4.3 Equipment Duty Evaluation.

All equipment exposed to the short circuit current must be capable of withstanding the mechanical and thermal stresses caused by the current until the short circuit is isolated. Identify any equipment that is potentially exposed to a short circuit current that exceeds its interrupting rating.

8-5 ARC FLASH ANALYSIS.

8-5.1 Analysis Criteria.

Perform an arc flash analysis in accordance with UFC 3-501-01. Use the following criteria:

- Apply IEEE Std 1584 and IEEE Std 1584.1 for voltages below 15 kV;

- Apply IEEE C2 for overhead distribution above 15 kV; and

- Apply the equations referred to in NFPA 70E, Informative Annex D for pad-mounted equipment for voltages above 15 kV.

  Note: Electrical analysis software automatically defaults to these equations above 15 kV.

Test all the protective devices involved in the analysis to ensure that they are functioning properly and have not deviated from the design settings. If deviations are found, the protective devices must be retested and serviced as described in the manufacturer’s instructions.

8-5.2 Arc Flash Labels.

Provide arc flash labels in accordance with UFC 3-560-01.

8-5.3 Maintenance and Testing Requirements.

An arc flash calculation result is based on the correct time-current response of an upstream protective device. If the following types of equipment are credited for clearing an arcing fault as part of an arc flash study, the equipment must have commissioning performed in accordance with NETA ATS, if new; and, periodic maintenance and testing performed in accordance with NETA MTS or NFPA 70B, if existing:

- Medium voltage power circuit breakers;
- Medium voltage pad-mounted switchgear;
- Low voltage power circuit breakers;
- Overcurrent protective relays;
- Switchboards and panel boards – main circuit breaker at each location and all circuit breakers rated for 225 amperes, or higher (molded case circuit breakers and insulated case circuit breakers); and
- Electronic trip units associated with the above equipment.

Refer to NETA MTS and NFPA 70B for the maintenance and test frequency.

8-6 ELECTRICAL COORDINATION.

8-6.1 Overview.

A properly protected and coordinated system will:

- Rapidly isolate a faulted circuit at the closest possible point upstream of the fault, while minimizing disruptions to unaffected portions of the system;
- Minimize damage to the faulted circuit or equipment by rapidly removing it from service;
- Minimize the possibility of damage to equipment upstream of the fault that “sees” the fault current, but is otherwise unaffected; and
- Minimize the possibility of catastrophic equipment failure, fire, and personnel hazards.

8-6.2 Coordination System Study Documentation and Criteria.

Ensuring proper electrical protective device settings is important to maintaining a reliable and safe electrical power distribution system. Document coordination studies in accordance with UFC 3-501-01. Include protective device settings and fuse sizes in the documentation.

Apply the coordination criteria listed in Table 8-1. The criteria apply to the following:

- Overcurrent relays;
- Recloser control units;
- Pad-mounted switchgear containing vacuum fault interrupter (VFI) trip units;
- Pad-mounted switchgear containing fuses;
- Overhead distribution fused cutouts;
- Low voltage circuit breaker electronic trip units;
- Low voltage circuit breaker thermal-magnetic trip units; and
- Low voltage fuses.

Table 8-1 Electrical Protection and Coordination Criteria

Upstream Device	Downstream Device	Criteria
Relay or Recloser	Relay	A minimum margin of 0.4 seconds between time-current (TC) curves in the time delay region. No overlap between the TC curves for instantaneous elements with 10% margin.
Relay or Recloser	Switchgear Breaker and Fuse	A minimum margin of 0.3 seconds between the TC curve and the switchgear breaker/fuse curve in the time delay region. No overlap between the TC curves for instantaneous elements with 10% margin.
Switchgear Breaker	Switchgear Breaker	No overlap between TC curves. All tolerances are accounted for in the curves.
Fuse	Fuse	Total clearing time of downstream fuse must be below the minimum melt time of upstream fuse. Alternatively, the average clearing times of the fuses must not overlap with a 10% margin applied to each fuse. Alternatively, the I^2t of the downstream fuse must be lower than the I^2t of the upstream fuse. The I^2t requirement is considered satisfied if fuse manufacturer's selectivity ratio is maintained.
Fuse	MCCB	No overlap between MCCB TC curve and minimum melt time curve for fuse. Alternatively, no overlap between MCCB TC curve and average clearing time curve for fuse with 10% margin. No coordination above intersection of fuse TC curve and MCCB instantaneous curve.
MCCB	Fuse (Non-Current Limiting)	Total clearing time of fuse must be below the minimum trip time of breaker in the time delay region. Alternatively, the fuse average clearing time must be below the minimum trip time of breaker with 10% margin. Maximum fault current sensed by MCCB must be limited to below the MCCB instantaneous pickup.
MCCB	Fuse (Current Limiting)	Total clearing time of fuse must be below the minimum trip time of breaker in the time delay region. Alternatively, the fuse average clearing time must be below the minimum trip time of the breaker with 10% margin. Peak let-through current of fuse must be below the MCCB instantaneous pickup.
Transformers		Protective device must clear the fault before the transformer damage curve is exceeded. Conservatively use frequent fault damage curves. Upstream protective device setting must allow for transformer inrush without nuisance trip.
Cables		Protective device must clear the fault before cable I^2t damage curve is exceed.

Refer to the following appendices for additional guidance:

- Appendix C – recommended fuse sizes for overhead distribution and pad-mounted switchgear fusing; and
- Appendix D – recommended pad-mounted switchgear vacuum fault interrupter (VFI) trip settings.

8-6.3 Coordination System Study – Substations and Switching Stations.

Model all protective devices. Determine the required protection settings and confirm acceptable coordination and protection for the primary distribution extending from the utility supply to the substation, and from there to downstream distribution system equipment. This includes:

- Utility supply coordination with substation primary side relaying;
- Differential protection for transformers and buses;
- Reverse power protection, if installed;
- Main circuit breaker secondary side transformer overload protection;
- Main and feeder circuit breaker coordination;
- Main and cross-tie circuit breaker coordination; and
- Feeder circuit breaker coordination with downstream primary distribution system equipment.

8-6.4 Circuit Breaker Instantaneous Trips.

8-6.4.1 Main Circuit Breaker.

Do not specify instantaneous trips on main circuit breakers unless justified in the coordination study analysis. Main circuit breakers function as backup protective devices for the feeder circuit breakers and should not trip for a feeder fault unless the feeder breaker fails to trip.

8-6.4.2 Feeder Circuit Breaker.

The decision of whether or not to include an instantaneous trip on a particular feeder circuit breaker relay depends on 1) the downstream devices with which it has to coordinate, 2) the line length, 3) the presence of automatic circuit breaker reclosing and 4) the need for coordination with downstream overcurrent protective devices. Depending on the circuit design, it might be very difficult to coordinate with downstream fusing or vacuum fault interrupter trip units unless an instantaneous trip is set very high or is disabled. Apply the following criteria:

- Provide instantaneous trips for circuit breakers supplying predominantly overhead distribution when automatic circuit reclosing is applied;

- Disable instantaneous trips for underground distribution circuits that include downstream pad-mounted switchgear fusing or vacuum fault interrupter trip units. Select circuit breaker trip time delays to coordinate with downstream protective devices; and

- Instantaneous trips can be provided for distribution circuits that supply a single facility.

8-6.5 Feeder Circuit Breaker Relay Settings for Underground Distribution.

Apply IEEE C37-230 to distribution lines as a guide for system protection. Evaluate the specified settings with downstream pad-mounted switchgear fuse sizes or vacuum fault interrupter (VFI) trip settings. Adjust settings for all protective devices as needed to optimize coordination for each distribution feeder.

8-7 AURORA ANALYSIS.

Aurora is a term applied to a particular type of power system vulnerability in which rotating electrical equipment (motors and generators) is deliberately subjected to opening breakers and closing them out of synchronism with utility frequency. The induced mechanical and electrical stresses results in equipment exceeding maximum torque limits and equipment damage/failure.

Assess each Activity regarding its Aurora vulnerability. Figure 8-1 summarizes the Aurora evaluation process. Ensure mission critical motors and prime power-capable generators are specifically evaluated during the assessment. Update assessment and protective measures whenever new critical equipment is installed.

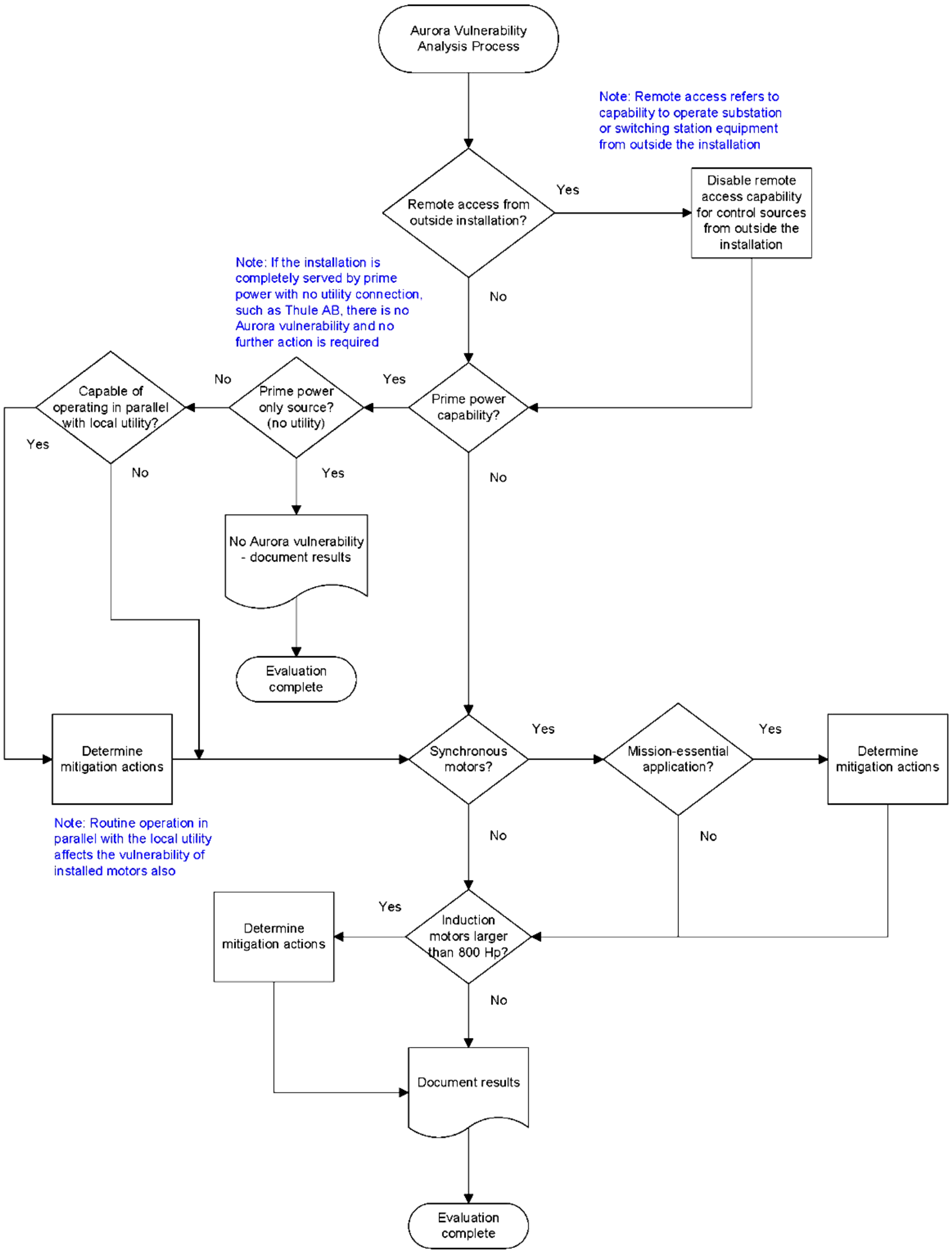
If an evaluation determines that a vulnerability exists, provide recommendations regarding protection methods. Protection options include a combination of:

- Adding protective devices designed to detect an Aurora event and isolate vulnerable systems and equipment before damage can occur. Known protective devices include the Schweitzer SEL-700G Generator Protection Relay, SEL-751A Feeder Protection Relay, and the Cooper Rotating Equipment Isolation Device (REID);

- Ensuring Activity utility control system is isolated from exterior communication networks; and

- Maintaining a strong password/access control protocol to Activity utility control network/software.

Figure 8-1 Aurora Vulnerability Assessment Flowchart



CHAPTER 9 POWER AVAILABILITY/RELIABILITY/RESILIENCY

9-1 METRICS.

The metrics for a power system include outages, time of outages, lengths of outages, time between outages and power quality (which in itself requires voltage, frequency, harmonics, and power factor).

9-2 POWER QUALITY.

Power Quality is the concept of powering and grounding electronics equipment in a manner that is suitable to the operation of the equipment and compatible with the premise wiring system and other connected equipment. A high level of power quality is generally understood as a low level of power disturbances; however, a high level of equipment tolerance may also be an effective solution. Power quality can be a broad concern depending upon the end user or mission perspective, ranging from voltage interruption, sags, transients and harmonics and/or current transients and harmonics that negatively affect utilization equipment. Understanding the implied definition by the end user will assist in determining what the root cause of the disturbance is and what/where monitoring should take place.

Evaluate power quality in accordance with IEEE 1159. Apply IEEE 519 for the evaluation of harmonic distortion limits.

9-2.1 Monitoring.

Power Quality Monitoring (PQM) generally involves line voltage sags, interruptions, voltage swells, and transients (generally short duration, high frequency voltage fluctuations). PQM can also include analysis of harmonic waveforms and grounding systems. During PQM, special attention is paid to time, duration, location, and magnitude of both voltage and current waveforms with respect to each and other system disturbances or characteristics such as capacitor switching.

9-2.2 Harmonics.

Harmonics are rarely an issue. Harmonics, by definition, is a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.

Harmonics are generally a negative consequence to having non-linear loads. Typical harmonic “generators” are:

- Converters;
- Arc Furnaces;
- Static VAR Compensator;

- Inverters for Dispersed Generation;
- Electronic Phase Control;
- Switched Mode Power Supply (i.e. Computer Power Supplies);
- Pulse Width Modulation; and
- Electronic Ballasted Lighting.

These harmonic effects can cause:

- Current harmonics cause an increase in copper (conductor) losses and stray flux losses. As a result, neutral conductors and transformers can experience excessive heating, beyond what they are rated for. De-rating of electrical equipment or the use of K rated transformers, designed to handle the harmonic contribution, are differing approaches;
- Current harmonics can also cause issues with circuit breakers tripping because of reaching thermal limits. In addition, Total Harmonic Distortion (THD) levels greater than 10% may affect relay / breaker operation;
- Voltage harmonics cause an increase in iron losses within the transformer; and
- Voltage harmonics may cause the premature failure of switchgear insulation.

9-2.3 Voltage Unbalance.

Voltage unbalance is rarely an issue. Low or high voltage might be an issue, but usually not voltage unbalance unless a single-phase voltage regulator has failed.

- Voltage unbalance in a three-phase system takes place when the magnitudes of phase or line voltages are different and the phase angles differ from the balanced conditions, or both.
    - Voltage unbalance is defined as the ratio of the negative sequence voltage component to the positive sequence voltage component.
- Variations in single-phase loading cause the currents in the 3-phase conductors to be different, producing different voltage drops and causing the phase voltage to become unbalanced.
- When unbalanced phase voltages are applied to 3-phase motors, the phase voltage unbalance causes additional negative-sequence currents to circulate in the motor, increasing the heat losses primarily in the rotor.

9-2.4 Phase Current Imbalance.

Phase current imbalance describes a common condition that can cause a distribution line fuse to blow if a phase is unbalanced in relation to current on the other two phases. Connect distribution system single phase loads such that a balanced condition exists between the three individual phase currents.

9-3 PERFORMANCE AND EVALUATION.

Performance and evaluation of an electrical distribution system generally focuses on the service quality. The two aspects of service quality are power quality and system reliability. Power quality is discussed in Chapter 9. System reliability is evaluated at a number of levels:

- Utility Supply: Reliability of incoming power is of paramount importance to the end user or mission. There are numerous acceptable Reliability Indices. The three major time indices are:
  - System Average Interruption Frequency Index (SAIFI),

    $\boldsymbol{SAIFI} = \sum(N_i) \; / \; N_T$

    Where,

    Σ = Summation function.

    N_i = Total number of customers interrupted.

    N_T = Total number of customers served.

  - Customer Average Interruption Duration Index (CAIDI), in minutes;

    $\boldsymbol{CAIDI} = \sum(r_i * N_i) \; / \sum(N_i)$

    Where,

    Σ = Summation function.

    r_i = Restoration time, in minutes.

    N_i = Total number of customers interrupted.

  - System Average Interruption Duration Index (SAIDI), in minutes,

    $\boldsymbol{SAIDI} = \sum(r_i * N_i) \; / \; N_T$

    Where,

Σ = Summation function.

r_i = Restoration time, in minutes.

N_i = Total number of customers interrupted.

N_T = Total number of customers served.

- Configuration: Typically represented by one-line diagram or system map.

- Control and Protection: The one-line diagram to contain all the protective devices of the system. Utilize this to perform a protective device coordination analysis as directed by IEEE 242.

- Physical Installation: A thorough inspection of the physical condition of a (mission's) distribution system can be utilized, hopefully on a continual basis, to improve reliability. All systems serving critical loads or process should be part of a comprehensive preventive and predictive maintenance (PPM) program, which combines periodic visual inspections of equipment with mechanical and electrical testing to identify and correct deteriorating conditions before they result in unscheduled outages. Guidelines for inspection and testing of electrical equipment can be found in the relevant IEEE and ANSI standards documents, in published data, in NFPA 70B, and in the standards of the International Electrical Testing Association.

- Operations and Maintenance: Mentioned earlier that an effective PPM program is important in achieving the designed-in reliability of critical power systems, this is only one of many aspects of Operations and Maintenance that can impact reliability. Other considerations include commissioning, training, documentation, and spare parts stocking.

9-4 PREDICTIVE ANALYSIS.

Predictive analysis is based upon metrics and past documentation as a worst-case, and extrapolated using reliability factors in IEEE Std 493 (Gold Book) for a prediction of future problems. By following recommended maintenance procedures, a substantial amount of failures can be avoided.

CHAPTER 10 PHYSICAL SECURITY

10-1 PHYSICAL SECURITY.

UFC 4-010-01 and UFC 4-010-02 provide facility physical security requirements. Typically, power systems are located in locked or sealed vaults, underground junction boxes, and/or secured locations and are minimally impacted by these UFCs.

10-2 LESSONS LEARNED.

A record must be made on all switching and component failures which must list with specificity the problem, the attempted solution, and the permanent solution. This must be free of naming faults attributable to individuals in order to become a training source for the elimination of future repetitions of the same problems.

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APPENDIX A REFERENCES

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.ansi.org/

ANSI/SIA A92.2, *Vehicle-Mounted Elevating and Rotating Aerial Devices*

ANSI/SIA A92.3, *Manually Propelled Elevating Aerial Platforms*

ANSI/SIA A92.5, *Boom Supported Elevating Work Platforms*

ANSI/SIA A92.6, *Self-Propelled Elevating Work Platforms*

ANSI Z133.1, *Arboricultural Operations -- Pruning, Repairing, Maintaining, and Removing Trees, and Cutting Brush, Safety Requirements*

ANSI Z359, *Fall Protection Code*

ANSI/NEMA WC 74/ICEA S-93-639, *5-46kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*

AMERICAN SOCIETY FOR TESTING AND MATERIALS INTERNATIONAL (ASTM)

http://www.astm.org/Standard/standards-and-publications.html

ASTM F18, *Electrical Protective Equipment for Workers*

ASTM A90, *Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings*

ASTM F887, *Specifications for Personal Climbing Equipment*

DEPARTMENT OF THE AIR FORCE

http://www.e-publishing.af.mil/

AFH 32-1282 V1 & V2 *Field Guide for Inspection, Evaluation, and Maintenance Criteria for Electrical Substations and Switchgear*

AFI 10-2501, *Air Force Emergency Management Program Planning and Operations*

AFI 33-210, *Air Force Certification and Accreditation (C&A) Program (AFCAP)*

AFMAN 10-2504, *Air Force Incident Management System (AFIMS) Standards and Procedures*

AFJMAN 32-1082 /TM 5-684 /MO-200 *Facilities Engineering Electrical Exterior Facilities*

DEPARTMENT OF THE ARMY

http://www.apd.army.mil/

DA PAM 385-10, *Army Safety Program*

DA PAM 385-26, *Army Electrical Safety Program*

EM 385-1-1, US Corps of Engineers, *Safety and Health Requirements Manual*

TM 5-698-3, *Reliability Primer for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*

DEPARTMENT OF DEFENSE

http://www.dtic.mil/whs/directives/

DISA Circular 350-195-2, *Electric Power Systems for Department of Defense Information Network (DODIN) Facilities*

DoD 4715.05-G, *Overseas Environmental Baseline Guidance Document*

DoD Instruction 4170.11, *Installation Energy Management*

DoD Instruction 4180.11, *DoD Energy Policy*

DoD Instruction 8500.01, *Cybersecurity*

DoD Instruction 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*

DEPARTMENT OF THE NAVY

http://doni.documentservices.dla.mil/default.aspx

Fall Protection Guide for Ashore Facilities

NAVFAC P-300, *Management of Civil Engineering Support Equipment*

IEEE

www.ieee.org

IEEE/ANSI C2, *National Electrical Safety Code*

IEEE Std 18, *IEEE Standard for Shunt Power Capacitors*

IEEE Std C37.12.1, *IEEE Guide for High-Voltage (>1000 V) Circuit Breaker Instruction Manual Content*

IEEE Std C37.35, *IEEE Guide for the Application, Installation, Operation, and Maintenance of High-Voltage Air Disconnecting and Interrupter Switches*

IEEE Std C37.48, *IEEE Guide for the Application, Operation, and Maintenance of High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories*

IEEE Std C37.48.1, *IEEE Guide for the Operation, Classification, Application, and Coordination of Current-Limiting Fuses with Rated Voltages 1–38 kV*

IEEE Std C37.99, *IEEE Guide for the Protection of Shunt Capacitor Banks*

IEEE Std C37.104, *IEEE Guide for Automatic Reclosing of Line Circuit Breakers for AC Distribution and Transmission Lines*

IEEE Std C37-230, *IEEE Guide for Protective Relay Applications to Distribution Lines*

IEEE Std 57.106, *IEEE Guide for Acceptance and Maintenance of Insulation Oil in Equipment*

IEEE Std C62.22, *IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems*

IEEE Std 80, *IEEE Guide for Safety in AC Substation Grounding*

IEEE Std C135.90, *IEEE Standard for Pole Line Hardware for Overhead Line Construction*

IEEE Std 141, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants*

IEEE Std 242, *IEEE Guide for Synchronization, Calibration, Testing, and Installation of Phasor Measurement Units (PMUs) for Power System Protection and Control.*

IEEE Std 399, *IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis*

IEEE Std 400, *IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage*

IEEE Std 446, *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)*

IEEE Std 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*

IEEE Std 493, *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book)*

IEEE Std 510, *IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing*

IEEE Std 516, *IEEE Guide for Maintenance Methods on Energized Power Lines*

IEEE Std 519, *IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*

IEEE Std 524, *IEEE Guide to the Installation of Overhead Transmission Line Conductors*

IEEE Std 837, *IEEE Standard for Qualifying Permanent Connections Used in Substation Grounding*

IEEE Std 902, *IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems (Yellow Book)*

ANSI/IEEE Std 935, *IEEE Guide on Terminology for Tools and Equipment to be Used in Live Line Working*

IEEE Std 957, *IEEE Guide for Cleaning Insulators*

IEEE Std 978, *IEEE Guide for In-Service Maintenance and Electrical Testing of Live-Line Tools*

IEEE Std 1025, *IEEE Guide to the Assembly and Erection of Concrete Pole Structures*

IEEE Std 1048, *IEEE Guide for Protective Grounding of Power Lines*

IEEE Std 1100, *IEEE Recommended Practice for Powering and Grounding Electronic Equipment (Emerald Book)*

IEEE Std 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*

IEEE Std 1159, *IEEE Recommended Practice for Monitoring Electric Power Quality*

IEEE Std 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid Storage Batteries for Stationary Applications*

IEEE Std 1246, *IEEE Guide for Temporary Protective Grounding Systems Used in Substations*

IEEE Std 1264, *IEEE Guide for Animal Deterrents for Electric Power Supply Substations*

IEEE Std 1283, *IEEE Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories*

IEEE Std 1307, *IEEE Standard for Fall Protection for Utility Work*

IEEE Std 1410, *IEEE Guide for Improving the Lightning Performance of Electric Power Overhead Distribution Lines*

IEEE Std 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations,* including Amendments 1 and 2

IEEE Std 1584.1, *IEEE Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with Std 1584*

IEEE Std 1651, *IEEE Guide for Reducing Bird-Related Outages*

IEEE Std 1654, *IEEE Guide for RF Protection of Personnel Working in the Vicinity of Wireless Communications Antennas Attached to Electric Power Line Structures*

IEEE Std 3007.1, *IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems*

IEEE Std 3007.2, *IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems*

IEEE Std 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems*

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION

www.netaworld.org

NETA ATS, *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*

NETA MTS, *Standard for Maintenance Test Specifications for Electrical Power Equipment and Systems*

NATIONAL FIRE PROTECTION ASSOCIATION

www.nfpa.org

NFPA 70, *National Electrical Code*

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 780, *Standard for the Installation of Lighting Protection Systems*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

https://www.osha.gov/law-regs.html

29 CFR 1910, *General Industry Standards*

29 CFR 1926, *Construction Standards*

40 CFR 761, *Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions*

UNDERWRITER'S LABORATORY

UL 681, *Installation and Classification of Burglar and Holdup Alarm Systems for alarm system installation*

UL 2050, *National Industrial Security Systems*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *General Building Requirements*

UFC 3-440-01, *Facility-Scale Renewable Energy Systems*

UFC 3-501-01, *Electrical Engineering*

UFC 3-540-01, *Engine-Driven Generator Systems for Backup Power Applications*

UFC 3-540-07, *Operations and Maintenance (O&M) for Generators*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-560-01, *Electrical Safety, O&M*

UFC 3-575-01, *Lighting and Static Electricity Protection Systems*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-010-06, *Cybersecurity of Facility Related Control Systems*

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*

UFC 4-020-02, *DoD Security Engineering Facilities Design Manual*, currently in Draft and unavailable

UFC 4-021-02NF, *Security Engineering Electronic Security Systems*

UFC 4-020-04A, *Electronic Security Systems: Security Engineering*

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA)

http://www.rd.usda.gov/publications/regulations-guidelines/bulletins/electric

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UNITED STATES DEPARTMENT OF INTERIOR BUREAU OF RECLAMATION

http://www.usbr.gov/library/reclamationpubs.html

Facilities Instructions, Standards, and Techniques Volume 4-1B, *Maintenance Scheduling for Electrical Equipment*

TRI-SERVICE ELECTRICAL WORKING GROUP (TSEWG)

http://www.wbdg.org/ccb/browse_cat.php?c=248

TSEWG TP-2, *Capacitors for Power Factor Correction*

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APPENDIX B IEEE COLOR BOOKS

The IEEE Color Books have been a key electrical engineering reference source for decades. But, the IEEE Color Books will eventually be phased out and replaced by the IEEE 3000 Standards Collection. As of July 2015, all IEEE Color Books are still listed as active standards and the IEEE 3000 Standards Collection is still under development, with 9 standards issued, 20 standards under active development, and additional standards planned, but not started.

For UFCs and UFGSs, the IEEE Color Books are still suitable as a reference. In some instances, the IEEE 3000 Standards Collection standards should also be referenced. Some care should be taken to confirm if either or both types of standards should be referenced. For example, IEEE 902-1998, *IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems* (Yellow Book), is still listed as an active standard, even though it has been replaced by IEEE 3007.1, IEEE 3007.2, and IEEE 3007.3.

The following tables list the status of the IEEE Color Books and the IEEE 3000 Standards Collection. This information was obtained from the IEEE website.

Table B-1 IEEE Color Books

IEEE Standard	Color	Title	Status
141-1993	Red	IEEE Recommended Practice for Electric Power Distribution for Industrial Plants	Active Standard
142-2007	Green	Recommended Practice for Grounding of Industrial and Commercial Power Systems	Active Standard
241-1990	Gray	IEEE Recommended Practice for Electric Power Systems in Commercial Buildings	Active Standard
242-2001	Buff	IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems	Active Standard
399-1997	Brown	IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis	Active Standard
446-1995	Orange	IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications	Active Standard

IEEE Standard	Color	Title	Status
493-2007	Gold	IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems	Active Standard
551-2006	Violet	Recommended Practice for Calculating AC Short-Circuit Currents in Industrial and Commercial Power Systems	Active Standard
602-2007	White	IEEE Recommended Practice for Electric Systems in Health Care Facilities	Active Standard
739-1995	Bronze	IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities	Active Standard
902-1998	Yellow	IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems	Active Standard
1015-2006	Blue	Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems	Active Standard
1100-2005	Emerald	IEEE Recommended Practice for Powering and Grounding Electronic Equipment	Active Standard

Table B-2 IEEE 3000 Standards Collection

Standard	Title	Status
IEEE 3000 Standard: Fundamentals		
P3000	Recommended Practice for the Engineering of Industrial and Commercial Power Systems	Active Project
IEEE 3001 Standards: Power Systems Design		
P3001.2	Recommended Practice for Evaluating the Electrical Service Requirements of Industrial and Commercial Power Systems	Active Project
P3001.9	Recommended Practice for the Lighting of Industrial and Commercial Facilities	Active Project

Standard	Title	Status
P3001.11	Recommended Practice for Application of Controllers and Automation to Industrial and Commercial Power Systems	Active Project
IEEE 3002 Standards: Power Systems Analysis		
P3002.2	Recommended Practice for Conducting Load-Flow Studies of Industrial and Commercial Power Systems	Active Project
P3002.3	Recommended Practice for Conducting Short-Circuit Studies of Industrial and Commercial Power Systems	Active Project
P3002.7	Recommended Practice for Conducting Motor-Starting Studies in Industrial and Commercial Power Systems	Active Project
P3002.8	IEEE Draft Recommended Practice for Conducting Harmonic-Analysis Studies of Industrial and Commercial Power Systems	Active Project
IEEE 3003 Standards: Power Systems Grounding		
P3003.1	Recommended Practice for the System Grounding of Industrial and Commercial Power Systems	Active Project
3003.2-2014	IEEE Recommended Practice for Equipment Grounding and Bonding in Industrial and Commercial Power Systems	Active Standard
IEEE 3004 Standards: Protection and Coordination		
3004.1-2013	IEEE Recommended Practice for the Application of Instrument Transformers in Industrial and Commercial Power Systems	Active Standard
P3004.3	Recommended Practice for the Application of Low-Voltage Fuses in Industrial and Commercial Power Systems	Active Project
P3004.4	Recommended Practice for the Application of Medium- and High-Voltage Fuses in Industrial and Commercial Power Systems	Active Project

Standard	Title	Status
3004.5-2014	IEEE Recommended Practice for the Application of Low-Voltage Circuit Breakers in Industrial and Commercial Power Systems	Active Standard
P3004.7	Recommended Practice for the Protection of Power Cables and Busway Used in Industrial and Commercial Power Systems	Active Project
P3004.8	Recommended Practice for Motor Protection in Industrial and Commercial Power Systems	Active Project
P3004.9	Recommended Practice for the Protection of Power Transformers Used in Industrial and Commercial Power Systems	Active Project
P3004.10	Recommended Practice for Generator Protection in Industrial and Commercial Power Systems	Active Project
P3004.11	Recommended Practice for Bus and Switchgear Protection in Industrial and Commercial Power Systems	Active Project
P3004.13	Recommended Practice for Overcurrent Coordination in Industrial and Commercial Power Systems	Active Project
IEEE 3005 Standards: Energy & Standby Power Systems		
No document status provided on IEEE website.		
IEEE 3006 Standards: Power Systems Reliability		
P3006.2	Recommended Practice for Evaluating the Reliability of Existing Industrial and Commercial Power Systems	Active Project
P3006.3	Recommended Practice for Determining the Impact of Preventative Maintenance on the Reliability of Industrial and Commercial Power Systems	Active Project
3006.5-2014	IEEE Recommended Practice for the Use of Probability Methods for Conducting a Reliability Analysis of Industrial and Commercial Power Systems	Active Standard
3006.7-2013	IEEE Recommended Practice for Determining the Reliability of 7x24 Continuous Power Systems in Industrial and Commercial Facilities	Active Standard

Standard	Title	Status
P3006.8	Recommended Practice for Analyzing Reliability Data for Equipment Used in Industrial and Commercial Power Systems	Active Project
3006.9-2013	IEEE Recommended Practice for Collecting Data for Use in Reliability, Availability, and Maintainability Assessments of Industrial and Commercial Power Systems	Active Standard
IEEE 3007 Standards: Maintenance, Operations, & Safety		
3007.1-2010	IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems	Active Standard
3007.2-2010	IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems	Active Standard
3007.3-2012	IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems	Active Standard

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APPENDIX C PRIMARY DISTRIBUTION SYSTEM FUSING

C-1 OVERHEAD DISTRIBUTION FUSING.

Apply the following criteria for sizing expulsion fuses for distribution cutouts:

- Determine the optimal fuse size for each location. Future system outages can include a fuse link check, with replacements as necessary;
- Select a fuse link size based on standard industry guidance. Refer to the following tables for examples of fuse sizing for various system voltages. Scale the results as needed for other system voltages. Type K and T fuses are rated for 50% overload capability. Type H and Type QA fusing is not rated for overload capability as shown in Figure C-1. Table C-10 provides one example of fuse sizing for Type H or QA fuses;
- If the fused cutouts supply more than one pad-mounted transformer in a looped configuration, base the selected fuse link size on the combined kVA rating of the transformers, and possibly downsized by one fuse size to account for typical less than full load conditions. Note that fused cutouts might not provide adequate protection for any transformer in this configuration. Each transformer must have its own internal set of fuses for adequate protection; and
- In-line fuses must be capable of carrying the entire expected load of the downstream circuit. If the circuit must be capable of carrying another circuit via a downstream cross-connect switch, the in-line fuse size must take this additional loading into account or else this cross-connect path might not be suitable for use.

Note: UFC 3-550-01 requires IEEE C37.41 rated backup current limiting fuses in series with Type K expulsion fuses on systems that are rated 1) above 15 kV or 2) 15 kV and lower that have available fault currents equal to or greater than 7,000 asymmetrical amperes. When backup current limiting fuses are installed in series with an expulsion fuse, review and follow the manufacturer's installation requirements regarding maximum expulsion fuse size that can be installed in series with a backup current limiting fuse.

Note: All fusing for single-phase transformers is based on a phase-to-neutral connection.

Table C-1 Type K or T Fuse Link Sizing for Individual Transformers – 2.4 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	10.83	15
25	75	18.04	20
37.5	112.5	27.06	30
50	150	36.08	40
75	225	54.13	60
100	300	72.17	75
167	500	120.28	125
250	750	180.42	200

Table C-2 Type K or T Fuse Link Sizing for Individual Transformers – 4.16 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	6.25	8
25	75	10.41	12
37.5	112.5	15.61	20
50	150	20.82	25
75	225	31.23	40
100	300	41.64	50
167	500	69.39	80
250	750	104.09	140
—	1000	138.79	200

Table C-3 Type K or T Fuse Link Sizing for Individual Transformers – 11 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.36	3
25	75	3.94	6
37.5	112.5	5.90	8
50	150	7.87	10
75	225	11.81	15
100	300	15.75	18
167	500	26.24	30
250	750	39.36	50
—	1000	52.49	65
—	1500	78.73	100
—	2000	104.97	125

Table C-4 Type K or T Fuse Link Sizing for Individual Transformers – 11.5 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.26	3
25	75	3.77	6
37.5	112.5	5.65	8
50	150	7.53	10
75	225	11.30	15
100	300	15.06	18
167	500	25.10	30
250	750	37.65	50
—	1000	50.20	65
—	1500	75.31	100
—	2000	100.41	125

Table C-5 Type K or T Fuse Link Sizing for Individual Transformers – 12.47 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.08	3
25	75	3.47	6
37.5	112.5	5.21	6
50	150	6.94	8
75	225	10.42	12
100	300	13.89	15
167	500	23.15	30
250	750	34.72	40
—	1000	46.30	50
—	1500	69.45	80
—	2000	92.60	100

Table C-6 Type K or T Fuse Link Sizing for Individual Transformers – 13.2 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	1.97	3
25	75	3.28	6
37.5	112.5	4.92	6
50	150	6.56	8
75	225	9.84	12
100	300	13.12	15
167	500	21.87	30
250	750	32.80	40
—	1000	43.74	50
—	1500	65.61	80
—	2000	87.48	100

Table C-7 Type K or T Fuse Link Sizing for Individual Transformers – 13.8 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	1.88	3
25	75	3.14	6
37.5	112.5	4.71	6
50	150	6.28	8
75	225	9.41	12
100	300	12.55	15
167	500	20.92	25
250	750	31.38	40
—	1000	41.84	50
—	1500	62.76	80
—	2000	83.67	100

Table C-8 Type K or T Fuse Link Sizing for Individual Transformers – 22 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	1.18	3
25	75	1.97	3
37.5	112.5	2.95	6
50	150	3.94	6
75	225	5.90	8
100	300	7.87	12
167	500	13.12	20
250	750	19.68	30
—	1000	26.24	40
—	1500	39.36	65
—	2000	52.49	80

Table C-9 Fuse Link Sizing for Individual Transformers – 34.5 kV

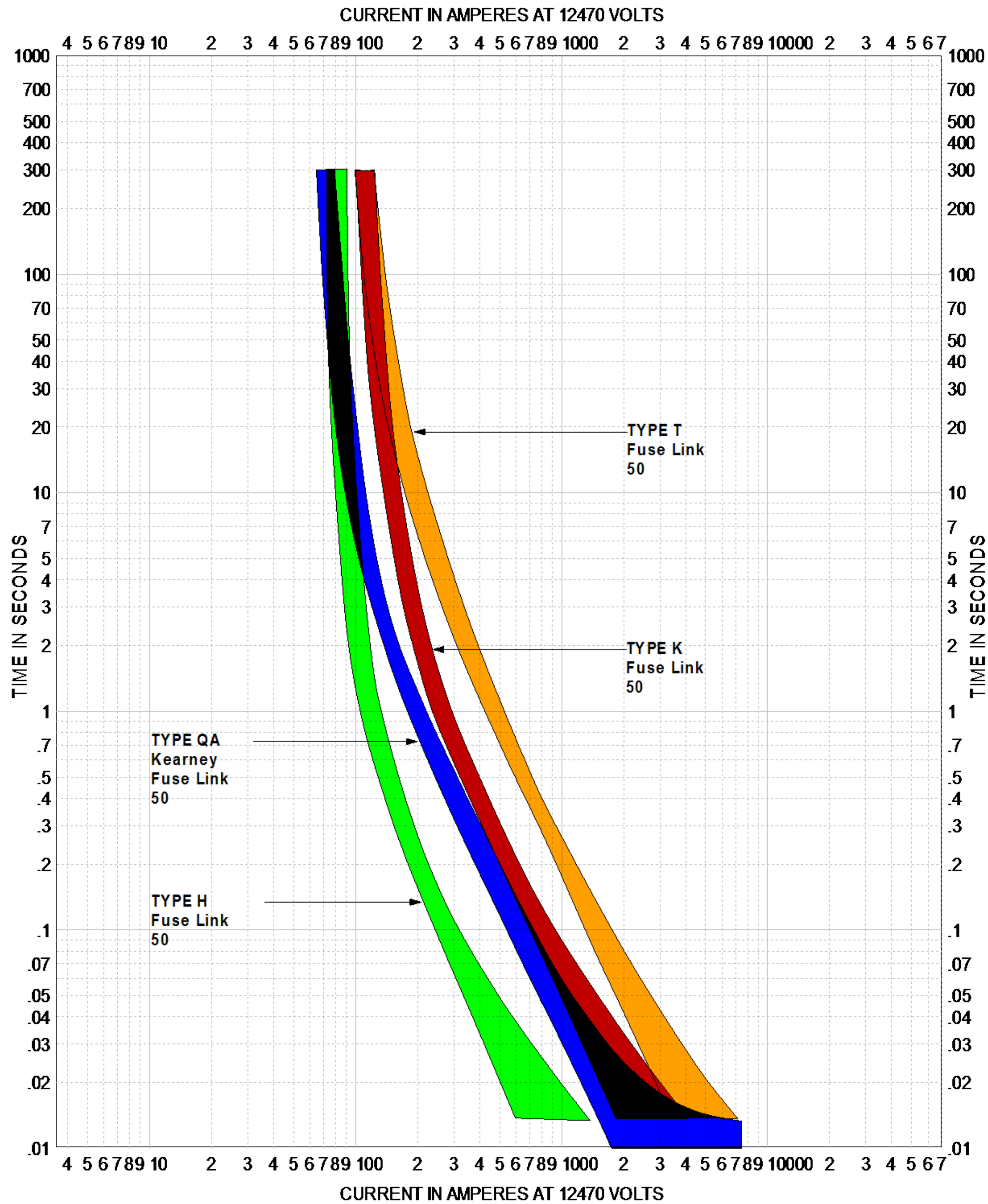
Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	0.75	3
25	75	1.26	3
37.5	112.5	1.88	3
50	150	2.51	6
75	225	3.77	8
100	300	5.02	8
167	500	8.37	12
250	750	12.55	20
—	1000	16.73	25
—	1500	25.10	40
—	2000	33.47	50

Note: Ensure selected fuse is rated for the applied voltage. Some fuse types can only be used on solidly grounded 34.5 kV distribution systems. Fuse sizes vary among manufacturers; select the closest available larger fuse size if the specified fuse size is not available. Refer to UFC 3-550-01 for additional requirements for fusing.

Table C-10 Type H or QA Fuse Link Sizing for Individual Transformers – 12.47 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.08	5
25	75	3.47	10
37.5	112.5	5.21	15
50	150	6.94	20
75	225	10.42	25
100	300	13.89	30
167	500	23.15	50
250	750	34.72	75
—	1000	46.30	100
—	1500	69.45	150
—	2000	92.60	200

Figure C-1 Various Fuse Link Type Time-Current Response



C-2 PAD-MOUNTED SWITCHGEAR FUSING.

Apply the following general criteria for fuse sizing for air-insulated pad-mounted switchgear:

- Provide adequate protection throughout the system, taking into account the unique system design features downstream of each switchgear compartment; and
- Select fuses that are as small as possible, while considering the constraints of downstream circuit full-load and inrush capability. The goal is to encourage the fuses to clear for a downstream fault, if possible, rather than just have the main feeder relaying respond to the fault.

Based on the above, apply the following specific criteria to fusing evaluations:

- If only one transformer is supplied and it does not have internal fuses:
    - Select a fuse size that provides primary transformer protection. The following tables provide examples of fuse sizing for this application and scale as needed for different system voltages. These tables are based on S&C Type SMU-20 or Type SM standard “E” speed fusing, which is the most common fusing used in pad-mounted switchgear. The Eaton Type DBU or Cooper CMU fusing is equivalent to the SMU-20 in terms of time-current response.
- If only one transformer is supplied and it does have internal fuses:
    - Select a fuse size that is at least one size larger than the internal fuses that provide transformer protection.
- If multiple transformers are supplied from a single fused compartment:
    - Ensure selected fuse size can carry the full-load current of downstream transformers;
    - Ensure selected fuse size can withstand the inrush current of simultaneously energizing the downstream transformers;
    - Provide conductor protection; and
    - Coordinate as well as possible with upstream phase and neutral relay settings.

Note: All fusing for single-phase transformers is based on a phase-to-neutral connection.

Table C-11 Fuse Sizing for Individual Transformer Primary Protection – 2.4 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	10.83	15E
25	75	18.04	20E
37.5	112.5	27.06	30E
50	150	36.08	40E
75	225	54.13	60E
100	300	72.17	75E
167	500	120.28	125E
250	750	180.42	200E
—	1000	240.56	250E
—	1500	360.84	400E
—	2000	481.13	---

Table C-12 Fuse Sizing for Individual Transformer Primary Protection – 4.16 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	6.25	10E
25	75	10.41	15E
37.5	112.5	15.61	20E
50	150	20.82	25E
75	225	31.23	40E
100	300	41.64	50E
167	500	69.39	80E
250	750	104.09	125E
—	1000	138.79	200E
—	1500	208.18	250E
—	2000	277.57	---

Table C-13 Fuse Sizing for Individual Transformer Primary Protection – 11 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.36	3E
25	75	3.94	7E
37.5	112.5	5.90	10E
50	150	7.87	10E
75	225	11.81	15E
100	300	15.75	20E
167	500	26.24	30E
250	750	39.36	50E
—	1000	52.49	65E
—	1500	78.73	100E
—	2000	104.97	125E

Table C-14 Fuse Sizing for Individual Transformer Primary Protection – 11.5 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.26	3E
25	75	3.77	5E
37.5	112.5	5.65	7E
50	150	7.53	10E
75	225	11.30	15E
100	300	15.06	20E
167	500	25.10	30E
250	750	37.65	50E
—	1000	50.20	65E
—	1500	75.31	100E
—	2000	100.41	125E

Table C-15 Fuse Sizing for Individual Transformer Primary Protection – 12.47 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	2.08	3E
25	75	3.47	5E
37.5	112.5	5.21	7E
50	150	6.94	10E
75	225	10.42	15E
100	300	13.89	20E
167	500	23.15	30E
250	750	34.72	50E
—	1000	46.30	65E
—	1500	69.45	100E
—	2000	92.60	125E

Table C-16 Fuse Sizing for Individual Transformer Primary Protection – 13.2 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	1.97	3E
25	75	3.28	5E
37.5	112.5	4.92	7E
50	150	6.56	10E
75	225	9.84	13E
100	300	13.12	15E
167	500	21.87	25E
250	750	32.80	40E
—	1000	43.74	50E
—	1500	65.61	80E
—	2000	87.48	100E

Table C-17 Fuse Sizing for Individual Transformer Primary Protection – 13.8 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	1.88	3E
25	75	3.14	5E
37.5	112.5	4.71	7E
50	150	6.28	10E
75	225	9.41	15E
100	300	12.55	20E
167	500	20.92	25E
250	750	31.38	40E
—	1000	41.84	50E
—	1500	62.76	80E
—	2000	83.67	100E

Table C-18 Fuse Sizing for Individual Transformer Primary Protection – 22 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	1.18	3E
25	75	1.97	3E
37.5	112.5	2.95	7E
50	150	3.94	7E
75	225	5.90	10E
100	300	7.87	12E
167	500	13.12	20E
250	750	19.68	30E
—	1000	26.24	40E
—	1500	39.36	65E
—	2000	52.49	80E

Table C-19 Fuse Sizing for Individual Transformer Primary Protection – 34.5 kV

Transformer Single-Phase (kVA)	Transformer 3-Phase Rating (kVA)	Full Load Line Current	Fuse Size
15	45	0.75	3E
25	75	1.26	3E
37.5	112.5	1.88	3E
50	150	2.51	7E
75	225	3.77	7E
100	300	5.02	10E
167	500	8.37	12E
250	750	12.55	20E
—	1000	16.73	25E
—	1500	25.10	40E
—	2000	33.47	50E

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APPENDIX D VACUUM FAULT INTERRUPTER (VFI) TRIP SETTINGS

D-1 GENERAL CRITERIA.

Apply the following general criteria for VFI trip settings in pad-mounted switchgear:

- Provide adequate protection throughout the system, taking into account the unique system design features downstream of each switchgear compartment.
- Do not leave VFI settings at the factory default values. Select VFI settings that are as small as possible, while considering the constraints of downstream circuit full-load and inrush capability. The goal is to encourage the VFIs to clear for a downstream fault, if possible, rather than have the main feeder relaying respond to the fault.

Based on the above, apply the following specific criteria for determining VFI settings:

- If only one transformer is supplied and it does not have internal fuses:
  - Select a trip setting that provides transformer protection. Refer to tables in the following sections for VFI settings and scale as needed for different system voltages. Note that each manufacturer's overcurrent trip unit is equipped with minimum settings that have to be considered. For higher operating voltages, smaller rated transformers cannot be properly protected by the minimum available VFI trip settings.
  - Note that very few transformers fall into this category. Most distribution transformers will have internal fusing.
- If only one transformer is supplied and it does have internal fuses:
  - Select a trip setting that is approximately one size larger than the internal fuses that typically provide transformer protection.
  - The purpose of this selection is to possibly allow the transformer fusing to respond to an internal fault. But, more importantly, this lateral will be removed from service as soon as possible to minimize any effect on the main feeder.
- If multiple transformers are supplied from a single compartment:
  - Ensure selected trip settings can carry the full-load current of the downstream transformers.

- Ensure selected trip settings can withstand the inrush current of simultaneously energizing the downstream transformers.

- Provide conductor protection.

- Coordinate as well as possible with upstream phase and neutral relaying.

- Allow for cross-ties if the downstream loads allow cross-connect to another feeder.

- A table is not provided for this case. Each configuration requires a specific review. For relatively small laterals with limited load, the settings will tend to be set low so that the lateral will be removed from service as soon as possible to minimize any effect on the main feeder.

- If the VFI serves as a higher ampacity cross-tie point between feeders:

  - Do not use the tables in the following sections. Perform a specific evaluation.

  - If the manufacturer's overcurrent trip unit has the capability, select a 51 relay curve, including ground trip, and coordinate the cross-tie location with the upstream feeder.

D-2 S&C VISTA PAD-MOUNTED SWITCHGEAR.

The following tables provide recommended settings for S&C Vista switchgear based on providing primary protection to an individual transformer. Refer to Section D-1 for guidance when a VFI supplies more than one downstream transformer.

Figure D-1 S&C Vista Switchgear

Notes for S&C Vista Tables:

1. *The S&C Vista switchgear typically have CT ratios of 660:1, which should be confirmed. Minimum trip setting is 25 amperes.*

2. *Available E-speed settings are 25E, 30E, 40E, 50E, 65E, 80E, 100E, 125E, 150E, 175E, 200E, 250E, 300E, and 400E.*

3. *The factory-shipped default settings are 200E.*

Table D-1 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 2.4 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	10.83	25
25	75	18.04	25
37.5	112.5	27.06	30
50	150	36.08	40
75	225	54.13	65
100	300	72.17	80
167	500	120.28	125
---	750	180.42	200
---	1000	240.56	250
---	1500	360.84	400
---	2000	481.13	400

Table D-2 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 4.16 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	6.25	25
25	75	10.41	25
37.5	112.5	15.61	25
50	150	20.82	25
75	225	31.23	40
100	300	41.64	50
167	500	69.39	80
---	750	104.09	125
---	1000	138.79	175
---	1500	208.18	250
---	2000	277.57	300

Table D-3 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 11 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	2.36	25
25	75	3.94	25
37.5	112.5	5.90	25
50	150	7.87	25
75	225	11.81	25
100	300	15.75	25
167	500	26.24	40
---	750	39.36	50
---	1000	52.49	65
---	1500	78.73	100
---	2000	104.97	125

Table D-4 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 11.5 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	2.26	25
25	75	3.77	25
37.5	112.5	5.65	25
50	150	7.53	25
75	225	11.30	25
100	300	15.06	25
167	500	25.10	40
---	750	37.65	50
---	1000	50.20	65
---	1500	75.31	100
---	2000	100.41	125

Table D-5 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 12.47 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	2.08	25
25	75	3.47	25
37.5	112.5	5.21	25
50	150	6.94	25
75	225	10.42	25
100	300	13.89	25
167	500	23.15	30
---	750	34.72	50
---	1000	46.30	65
---	1500	69.45	100
---	2000	92.60	125

Table D-6 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 13.2 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	1.97	25
25	75	3.28	25
37.5	112.5	4.92	25
50	150	6.56	25
75	225	9.84	25
100	300	13.12	25
167	500	21.87	30
---	750	32.80	50
---	1000	43.74	65
---	1500	65.61	100
---	2000	87.48	125

Table D-7 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 13.8 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	1.88	25
25	75	3.14	25
37.5	112.5	4.71	25
50	150	6.28	25
75	225	9.41	25
100	300	12.55	25
167	500	20.92	30
---	750	31.38	50
---	1000	41.84	65
---	1500	62.76	100
---	2000	83.67	125

Table D-8 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 22 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	1.18	25
25	75	1.97	25
37.5	112.5	2.95	25
50	150	3.94	25
75	225	5.90	25
100	300	7.87	25
167	500	13.12	25
---	750	19.68	30
---	1000	26.24	40
---	1500	39.36	65
---	2000	52.49	80

Table D-9 S&C VFI Settings to Provide Primary Protection for Individual Transformers – 34.5 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	0.75	25
25	75	1.26	25
37.5	112.5	1.88	25
50	150	2.51	25
75	225	3.77	25
100	300	5.02	25
167	500	8.37	25
---	750	12.55	25
---	1000	16.73	25
---	1500	25.10	30
---	2000	33.47	40

Note: All settings for single-phase transformers are based on a phase-to-neutral connection.

D-3 G&W VFI PAD-MOUNTED SWITCHGEAR.

The following tables provide recommended settings for G&W switchgear based on providing primary protection to an individual transformer. Refer to Section D-1 for guidance when a VFI supplies more than one downstream transformer.

Figure D-2 G&W VFI Switchgear

The available settings vary with the trip unit and typically have the following available settings:

- Pickup Range 15-300E: 15, 20, 25, 35, 45, 60, 75, 100, 125, 175, 225, and 300.
- Pickup Range 30-600E: 30, 40, 50, 70, 90, 120, 150, 200, 250, 350, 450, and 600.

Note: Minimum setting is either 15 or 30 amperes, and varies with the style. Select nearest available setting is trip unit configuration does not include the above settings.

Newer G&W switchgear might be equipped with electronic trip units with a variety of setting options.

Table D-10 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 2.4 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	10.83	20
25	75	18.04	35
37.5	112.5	27.06	45
50	150	36.08	60
75	225	54.13	100
100	300	72.17	125
167	500	120.28	225
---	750	180.42	300
---	1000	240.56	450
---	1500	360.84	450
---	2000	481.13	600

Table D-11 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 4.16 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	6.25	15
25	75	10.41	20
37.5	112.5	15.61	25
50	150	20.82	35
75	225	31.23	60
100	300	41.64	75
167	500	69.39	125
---	750	104.09	175
---	1000	138.79	225
---	1500	208.18	350
---	2000	277.57	450

Table D-12 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 11 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	2.36	15
25	75	3.94	15
37.5	112.5	5.90	15
50	150	7.87	20
75	225	11.81	25
100	300	15.75	35
167	500	26.24	60
---	750	39.36	75
---	1000	52.49	100
---	1500	78.73	175
---	2000	104.97	225

Table D-13 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 11.5 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	2.26	15
25	75	3.77	15
37.5	112.5	5.65	15
50	150	7.53	20
75	225	11.30	25
100	300	15.06	35
167	500	25.10	60
---	750	37.65	75
---	1000	50.20	100
---	1500	75.31	175
---	2000	100.41	225

Table D-14 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 12.47 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	2.08	15
25	75	3.47	15
37.5	112.5	5.21	15
50	150	6.94	20
75	225	10.42	25
100	300	13.89	35
167	500	23.15	60
---	750	34.72	100
---	1000	46.30	125
---	1500	69.45	175
---	2000	92.60	225

Table D-15 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 13.2 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	1.97	15
25	75	3.28	15
37.5	112.5	4.92	15
50	150	6.56	20
75	225	9.84	25
100	300	13.12	35
167	500	21.87	60
---	750	32.80	100
---	1000	43.74	125
---	1500	65.61	175
---	2000	87.48	225

Table D-16 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 13.8 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	1.88	15
25	75	3.14	15
37.5	112.5	4.71	15
50	150	6.28	20
75	225	9.41	25
100	300	12.55	35
167	500	20.92	60
---	750	31.38	100
---	1000	41.84	125
---	1500	62.76	175
---	2000	83.67	225

Table D-17 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 22 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	1.18	15
25	75	1.97	15
37.5	112.5	2.95	15
50	150	3.94	15
75	225	5.90	15
100	300	7.87	15
167	500	13.12	25
---	750	19.68	45
---	1000	26.24	60
---	1500	39.36	75
---	2000	52.49	100

Table D-18 G&W VFI Settings to Provide Primary Protection for Individual Transformers – 34.5 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	E-Speed Setting (amperes)
15	45	0.75	15
25	75	1.26	15
37.5	112.5	1.88	15
50	150	2.51	15
75	225	3.77	15
100	300	5.02	15
167	500	8.37	15
---	750	12.55	20
---	1000	16.73	35
---	1500	25.10	45
---	2000	33.47	60

Note: All settings for single-phase transformers are based on a phase-to-neutral connection.

D-4 COOPER VFI PAD-MOUNTED SWITCHGEAR.

D-4.1 Overview.

Figure D-3 shows a typical Cooper VFI switchgear.

Figure D-3 Cooper VFI Switchgear

The VFI trip units are referred to as Tri-Phase trip units. Different types of Tri-Phase trip units can be used, including:

- Tri-Phase – provides time overcurrent and instantaneous trip capability. Tripping can be selected for either a three-phase trip or a single-phase trip.
- Tri-Phase with Ground Trip (TPG) – provides Tri-Phase capability as well as ground fault tripping. This includes ground fault time overcurrent and instantaneous trip capability.
- Tri-Phase with minimum response accessory – improves coordination capability by allowing a minimum time delay before a time overcurrent response is activated. An instantaneous trip, if specified, can still occur without any deliberate time delay.
- SCADA Accessory Board for Tri-Phase Units – allows for inrush restraint and emergency overcurrent trip settings.

D-4.2 Trip Unit Characteristics.

The following provides additional information regarding the overcurrent trip response of these trip units:

- The EF time-current curve is an extremely inverse response curve. From the time of initial overcurrent detection (response), the total clearing time is typically less than 3 cycles. Both the initial response and the final clearing time is important.

- The minimum trip (pickup) settings are set by a series of dip switches. The default minimum phase trip is 20 amperes and the default minimum ground trip is 10 amperes. The actual pickup point will be the sum of the dip switches set to ON plus this default minimum value. The settings recommended in this document often use the minimum available values of 20 amperes for phase trips and 10 amperes for the ground trip. These minimum values are achieved by setting all phase or ground dip switches to the OFF direction. Refer to the Cooper instruction manual for additional information.

- The instantaneous trip settings are adjustable from 1X to 15X, where ‘X’ refers to the specified pickup point described above. Setting the OFF-ON switch to ON accomplishes an instantaneous trip setting of 1X and additional dip switches are set to achieve the desired setting. The instantaneous trip includes a fixed time delay of 25 milliseconds. For high fault current levels, this 25 millisecond time delay will be ignored because the EF time-current curve response shown on Figure 8 will still process an instantaneous trip.

- The EFR style of trip unit includes a minimum response time, which effectively forces a pre-set time delay beyond which time the VFI can trip. This minimum response time is adjustable from 0.050 to 0.580 seconds. If the minimum response time dip switch is set to STD, there is no minimum response time and the time-current response will follow the EF curve. This style of trip unit was installed on the first five switches of the Suwannee Feeder.

- If the ground trip block switch is turned to ON, ground tripping will be disabled if it has been provided. The phase trip settings will still be active.

- A selector switch enables either single-phase or three-phase tripping. If set on single-phase tripping, only the affected phase will trip. This selection might be used in areas using predominantly single-phase loads, such as housing areas.

- The factory-shipped default settings are:

  - Phase pickup – 80 amperes.

  - Ground pickup – 40 amperes.

  - Ground trip block – off.

  - Trip type – 3-phase.

– Emergency minimum trip multiplier – off.

– Inrush restraint minimum trip multiples – off.

– Minimum trip multiplier switch – off.

D-4.3 Example Trip Settings.

Notes:

1. *Minimum phase trip setting is 20 amperes. Minimum neutral trip setting is 10 amperes. These minimum settings provide minimal protection for the smallest distribution transformers.*

2. *Pickup settings can only be increased in increments of 10.*

3. *Instantaneous trip settings are only available in odd numbers, ranging from 1X to 15X, where X is the specified pickup setting. For example, if the pickup is specified at 20 amperes, an instantaneous trip value of 5X is 100 amperes (5 x 20 = 100).*

4. *For solely single phase installations, increase ground trip pickup as needed to ensure adequate margin for normal neutral current flow.*

Figure D-4 shows the factory default phase and ground trips:

- The phase trips have dip switches on for 20A and 40A. The phase trip factory default setting is 20 (min) + 20 + 40 = 80 amperes.

- The ground trip has its dip switches on for 10A and 20A. The ground trip factory default setting is 10 (min) + 10 + 20 = 40 amperes.

- All dip switches are off for the instantaneous trips. The instantaneous trips are OFF.

Figure D-4 Factory Default Settings

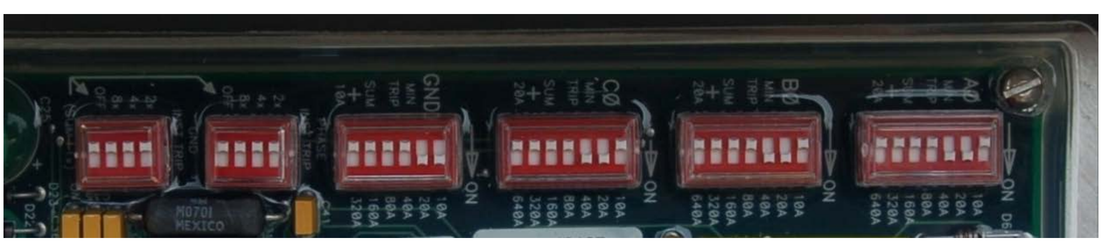
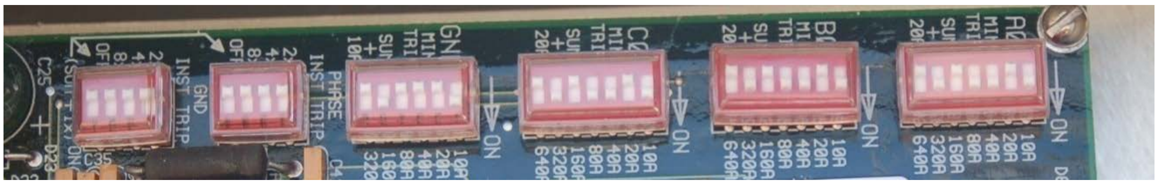


Figure D-4 shows another example trip unit:

- The phase trips have dip switches on for 320A, 80A, 40A, and 10A. The phase trip setting is 20 (min) + 320 + 80 +40 + 10 = 470 amperes.

- The ground trip has its dip switches on for 160A and 10A. The ground trip setting is 10 (min) + 10 + 160 = 180 amperes.
- All dip switches are off for the instantaneous trips. The instantaneous trips are OFF.

Figure D-5 Example Tri-Phase Trip Settings – Higher Trip Values



D-4.4 Recommended Settings.

The following tables provide recommended settings for Cooper VFI switchgear based on providing primary protection to an individual transformer. Refer to Section D-1 for guidance when a VFI supplies more than one downstream transformer.

Table D-19 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 2.4 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	10.83	20	10	3X	3X
25	75	18.04	30	10	5X	5X
37.5	112.5	27.06	50	20	5X	5X
50	150	36.08	60	30	7X	7X
75	225	54.13	100	40	9X	7X
100	300	72.17	130	50	9X	11X
167	500	120.28	220	60	9X	11X
---	750	180.42	300	80	9X	11X
---	1000	240.56	440	100	9X	11X
---	1500	360.84	600	120	9X	9X
---	2000	481.13	600	150	9X	9X

Table D-20 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 4.16 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	6.25	20	10	3X	3X
25	75	10.41	20	10	5X	5X
37.5	112.5	15.61	30	20	5X	5X
50	150	20.82	40	20	7X	7X
75	225	31.23	60	30	9X	7X
100	300	41.64	80	40	9X	11X
167	500	69.39	130	60	9X	11X
---	750	104.09	180	80	9X	11X
---	1000	138.79	230	100	9X	11X
---	1500	208.18	350	100	9X	9X
---	2000	277.57	450	100	9X	9X

Table D-21 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 11 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	2.36	20	10	3X	3X
25	75	3.94	20	10	5X	5X
37.5	112.5	5.90	20	10	5X	5X
50	150	7.87	20	10	7X	7X
75	225	11.81	30	20	9X	7X
100	300	15.75	30	20	9X	11X
167	500	26.24	50	30	9X	11X
---	750	39.36	80	40	9X	11X
---	1000	52.49	100	60	9X	11X
---	1500	78.73	150	80	9X	9X
---	2000	104.97	200	100	9X	9X

Table D-22 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 11.5 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	2.26	20	10	3X	3X
25	75	3.77	20	10	5X	5X
37.5	112.5	5.65	20	10	5X	5X
50	150	7.53	20	10	7X	7X
75	225	11.30	30	20	9X	7X
100	300	15.06	30	20	9X	11X
167	500	25.10	50	30	9X	11X
---	750	37.65	80	40	9X	11X
---	1000	50.20	100	60	9X	11X
---	1500	75.31	150	80	9X	9X
---	2000	100.41	200	100	9X	9X

Table D-23 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 12.47 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	2.08	20	10	3X	3X
25	75	3.47	20	10	5X	5X
37.5	112.5	5.21	20	10	5X	5X
50	150	6.94	20	10	7X	7X
75	225	10.42	20	20	9X	7X
100	300	13.89	30	20	9X	11X
167	500	23.15	50	30	9X	11X
---	750	34.72	80	40	9X	11X
---	1000	46.30	100	60	9X	11X
---	1500	69.45	150	80	9X	9X
---	2000	92.60	200	100	9X	9X

Table D-24 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 13.2 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	1.97	20	10	3X	3X
25	75	3.28	20	10	5X	5X
37.5	112.5	4.92	20	10	5X	5X
50	150	6.56	20	10	7X	7X
75	225	9.84	20	20	9X	7X
100	300	13.12	30	20	9X	11X
167	500	21.87	50	30	9X	11X
---	750	32.80	80	40	9X	11X
---	1000	43.74	100	60	9X	11X
---	1500	65.61	150	80	9X	9X
---	2000	87.48	200	100	9X	9X

Table D-25 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 13.8 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	1.88	20	10	3X	3X
25	75	3.14	20	10	5X	5X
37.5	112.5	4.71	20	10	5X	5X
50	150	6.28	20	10	7X	7X
75	225	9.41	20	20	9X	7X
100	300	12.55	30	20	9X	11X
167	500	20.92	50	30	9X	11X
---	750	31.38	80	40	9X	11X
---	1000	41.84	100	60	9X	11X
---	1500	62.76	150	80	9X	9X
---	2000	83.67	200	100	9X	9X

Table D-26 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 22 kV

Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	1.18	20	10	3X	3X
25	75	1.97	20	10	3X	3X
37.5	112.5	2.95	20	10	5X	5X
50	150	3.94	20	10	5X	5X
75	225	5.90	20	20	9X	7X
100	300	7.87	20	20	9X	7X
167	500	13.12	30	20	9X	7X
---	750	19.68	40	20	9X	9X
---	1000	26.24	50	30	9X	9X
---	1500	39.36	80	40	9X	9X
---	2000	52.49	110	50	9X	9X

Table D-27 Cooper VFI Settings to Provide Primary Protection for Individual Transformers – 34.5 kV

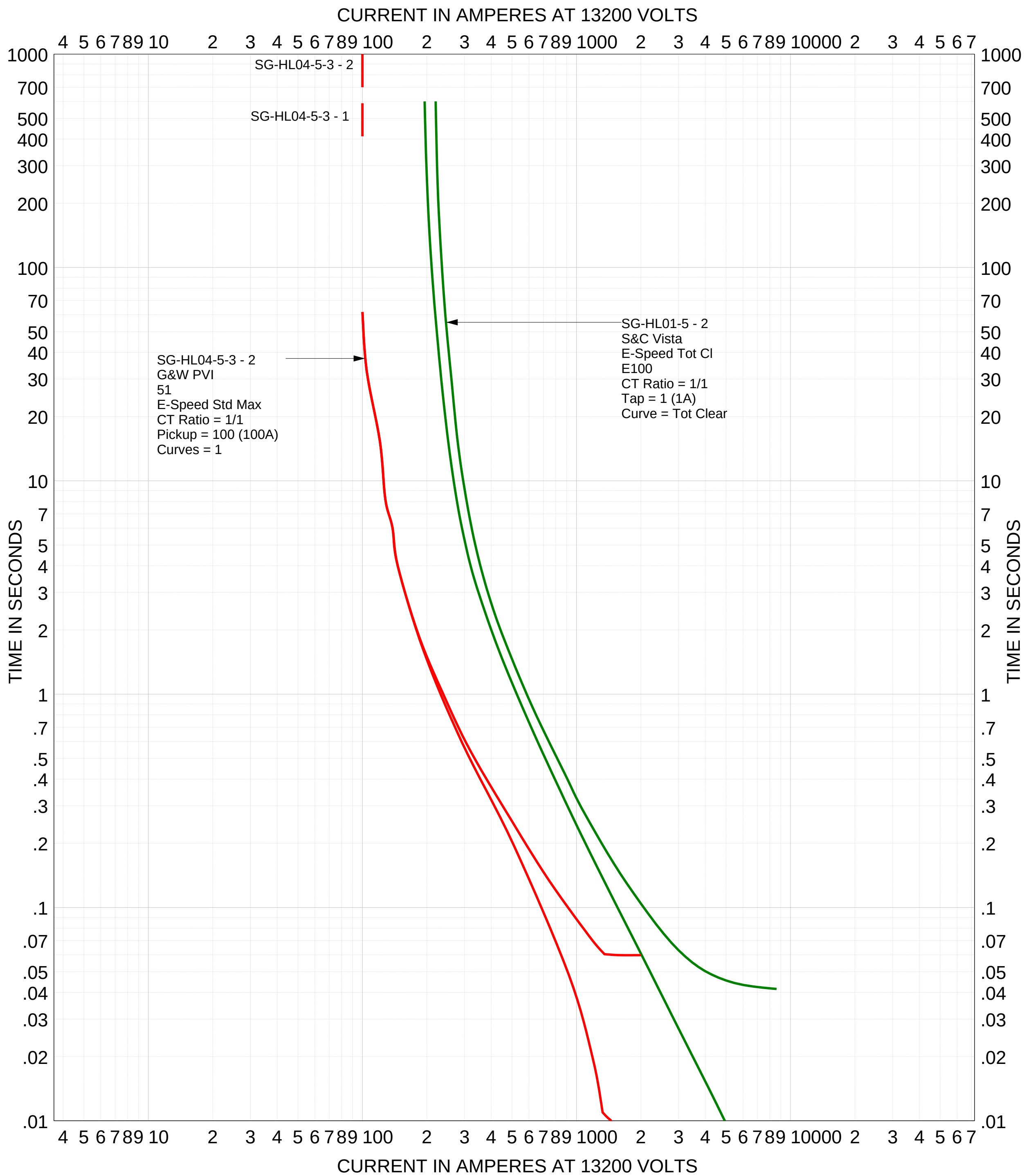
Transformer 1-Phase Rating (kVA)	Transformer 3-Phase Rating (kVA)	3-Phase Full Load Line Current	Phase Pickup Setting (amperes)	Ground Pickup Setting (amperes)	Phase Inst Trip Setting (value)	Ground Inst Trip Setting (value)
15	45	0.75	20	10	3X	3X
25	75	1.26	20	10	5X	5X
37.5	112.5	1.88	20	10	5X	5X
50	150	2.51	20	10	7X	7X
75	225	3.77	20	10	9X	7X
100	300	5.02	20	10	9X	11X
167	500	8.37	20	10	9X	11X
---	750	12.55	30	20	9X	11X
---	1000	16.73	40	20	9X	11X
---	1500	25.10	50	30	9X	9X
---	2000	33.47	70	40	9X	9X

Note: All settings for single-phase transformers are based on a phase-to-neutral connection.

D-5 COMPARISON OF S&C, COOPER, AND G&W TRIP SETTINGS.

The VFI trip settings for S&C, Cooper, and G&W switchgear are not equivalent. Although all types of VFIs can follow an E-speed curve, the S&C settings emulate S&C fuses, whereas the Cooper and G&W settings do not. Figure D-6 provides an example for a trip setting of 100 amperes. Notice that the G&W VFI will trip at 100 amperes, but the S&C Vista VFI will not trip until about 200 amperes. This difference in trip characteristic should be considered when establishing trip settings.

Figure D-6 Comparison of S&C Vista and G&W Switchgear VFI Settings



APPENDIX E STANDARD OPERATING PROCEDURES FOR ENERGIZED WORK PERMITS

E-1 OVERVIEW.

This appendix addresses the use of Standard Operating Procedures (SOPs) as a means of satisfying the energized work permit requirements of UFC 3-560-01. The preferred work approach is to establish an electrically safe work condition by deenergizing the equipment before allowing work. However, there are routine activities on the primary distribution system that involve energized work.

Done properly, an energized work permit is a time-consuming, detailed evaluation of the planned work and the safety precautions required to ensure the work is performed safely. For specified tasks, an SOP is a pre-approved energized work permit that can simplify the preparation for an energized work activity while still complying with mandated regulations and industry standards.

E-1.1 OSHA Criteria.

OSHA 29 CFR 1910.333 limits work on live energized electrical equipment as follows: "*Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*."

E-1.2 SOP Limitations.

SOPs are recommended for electrical-related work activities that might be performed routinely. Unusual or non-routine work activities that involve working on or near energized electrical equipment require an energized work permit in accordance with UFC 3-560-01.

An SOP is a pre-approved energized work permit rather than a detailed technical procedure. The SOP assumes that the qualified electrical worker is proficient in the technical aspects of the designated work activity and the SOP focuses on the safety aspects that would be typically included in an energized work permit.

E-1.3 Items to Address in an SOP.

Develop SOPs by a risk assessment based upon job hazard analyses (JHA) using Operational Risk Management (ORM) principles. Include the following in an SOP:

- The purpose of the SOP;
- References and definitions appropriate for the work activity;
- The hazards that will be avoided by using the SOP;

- Specific procedures that will be used to reduce/minimize/eliminate the hazards;
- Potential energy sources, including limits of approach;
- Specific required training/certifications;
- Number of required employees;
- Rescue procedures and equipment;
- Potential incident energy level exposure;
- Appropriate personal protective equipment (PPE) such as arc rated clothing, face shields, and electrical gloves for exposure level; and
- Management approvals.

The following sections provide examples of SOPs that might be appropriate for working on the primary distribution system:

- Appendix E-2 provides a sample SOP for operating fused cutouts from a bucket truck; and
- Appendix E-3 provides a sample SOP for operating loadbreak elbows from grade.

E-2 SAMPLE SOP – FUSED CUTOUTS: OPENING, CLOSING, OR REPLACING FUSES.

The following is a sample SOP for operating overhead distribution fused cutouts or replacing fuse links inside cutouts.

1.0 Purpose.

This procedure defines the requirements for opening fused cutouts, closing fused cutouts, or replacing fuse links in fused cutouts on the overhead distribution system.

2.0 Applicability.

This procedure applies to exterior electrical shop personnel that are designated as a qualified person with respect to working on or near primary overhead distribution systems.

3.0 References.

- 29 CFR 1910
- UFC 3-560-01
- NFPA 70E

4.0 Definitions.

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

Balaclava (Sock Hood). An arc-rated hood that protects the neck and head except for the facial area of the eyes and nose.

Boundary, Arc Flash. When an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second degree burn if an electrical arc flash were to occur.

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Electrical Hazard. A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Fused Cutout. A pole mounted interrupting device, equipped with fuses, that provides a method for de-energizing and protecting downstream electrical equipment.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Low-Voltage. Any voltage below 600 V.

Medium Voltage. Voltages above 600 and ranging to 34,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on": 1) diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; and, 2) repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method. For this SOP, this includes working inside an elevated bucket, handling of live-line tools, and pole-top rescue.

Document all training.

6.0 Required Approach Distances.

Table E-2-1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of PPE appropriate for the potential electrical hazards, or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table E-2-1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	Arc Flash Boundary	Limited Approach Boundary		Restricted Approach Boundary (3) (4)
	From Phase to Phase Voltage (5), (6)	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 7 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 3 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 4 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table E-2-1:

1. *For single phase systems select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted within the arc flash boundary.*

7.0 Personal Protective Equipment.

Comply with NFPA 70E.

De-energizing equipment before opening equipment is the preferred work procedure. If mission prohibits de-energizing equipment:

1. Review arc flash label or arc flash calculation for potential incident energy level;

2. If no label or current arc flash calculation, perform arc flash calculation to determine potential incident energy level;

3. Select PPE equipment to exceed calculated potential incident energy level; and,

4. If calculated incident energy level exceeds available PPE rating (in-house or contracted workforce), equipment de-energizing is mandatory.

8.0 Opening a Fused Cutout.

Perform the following steps:

Note: If the overhead distribution circuit overcurrent protection includes reclosing ability, disable upstream reclosing before starting work. Enable reclosing when work is complete.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.

2. If possible, remove load from the fused cutouts by opening the secondary main breakers in all facilities supplied through the fused cutouts.

3. Select voltage-rated gloves with leather protectors. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work inside the bucket.

4. Select and inspect the live-line insulated tool (hot stick) being used for the work. Confirm that hot sticks have been dry tested within the last 6 months and wet tested with the last 2 years. Ensure that all tools are rated for the voltage being worked on.

5. Position the insulated bucket truck in a position as far as possible from active traffic lanes. Place cones, barricades, and traffic markers as appropriate. Turn on all warning flashers and yellow beacons (day and night).

6. Enter and maneuver the bucket close enough to reach the fused cutouts with the insulated tool without having to reach or lean outside of the bucket.

7. Grasp the hot stick with both hands and insert the working end into the pull handle on the individual fused cutout. Pull it open in one smooth motion.

8. Open the remaining fused cutouts by the same process described above.

9. If changing the fuse(s), use the hot stick to lift and remove the fuse cartridge from the fused cutouts. To install the replacement fuse cartridge, pick up the fuse

cartridge with the working end of the hot stick, position the fuse, and drop into place in the fused cutout.

10. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

9.0 Closing a Fused Cutout.

Perform the following steps:

Note: If the overhead distribution circuit overcurrent protection includes reclosing ability, disable upstream reclosing before starting work. Enable reclosing when work is complete.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.

2. If possible, remove load from the fused cutouts by opening the secondary main breakers in all facilities supplied through the fused cutouts.

3. Select voltage-rated gloves with leather protectors. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work inside the bucket.

4. Select and inspect the live-line insulated tool (hot stick) being used for the work. Confirm that hot sticks have been dry tested within the last 6 months and wet tested with the last 2 years. Ensure that all tools are rated for the voltage being worked on.

5. Position the insulated bucket truck in a position as far as possible from active traffic lanes. Place cones, barricades, and traffic markers as appropriate. Turn on all warning flashers and yellow beacons (day and night).

6. Enter and maneuver the bucket close enough to reach the fused cutouts with the insulated tool without having to reach or lean outside of the bucket.

7. Grasp the hot stick with both hands and insert the working end into the pull handle on the individual fused cutout. Lift and push closed in one smooth motion.

8. Close the remaining fused cutouts by the same process described above.

9. If changing the fuse(s), use the hot stick to lift and remove the fuse cartridge from the fused cutouts. To install the replacement fuse cartridge, pick up the fuse cartridge with the working end of the hot stick, position the fuse, and drop into place in the fused cutout.

10. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

11. If load was removed from the fused cutouts by opening the secondary main breakers in facilities supplied through the fused cutouts, restore power to the facilities by closing the secondary main breakers.

E-3 SAMPLE SOP – CONNECTING/DISCONNECTING LOADBREAK ELBOWS.

The following is a sample SOP for connecting or disconnecting load break elbows.

1.0 Purpose.

This procedure defines the requirements for or connecting or disconnecting load break elbows on an energized circuit.

2.0 Applicability.

This procedure applies to exterior electrical shop personnel that are designated as a qualified person with respect to working on or near primary underground distribution systems.

3.0 References.

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Electrical Safety, O&M*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 Definitions.

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

Balaclava (Sock Hood). An arc-rated hood that protects the neck and head except for the facial area of the eyes and nose.

Boundary, Arc Flash. When an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second degree burn if an electrical arc flash were to occur.

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Elbow. A connector component for connecting a power conductor to a bushing, designed so that when assembled with the bushing, the axes of the conductor and bushing are perpendicular.

Electrical Hazard. A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Insulated Cap. An accessory device designed to electrically insulate, electrically shield, and mechanically seal a bushing insert or integral bushing.

Insulated Parking Bushing. An accessory device designed to electrically insulate, electrically shield, and mechanically seal a power cable terminated with an elbow and installed into a parking stand.

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Loadbreak Connector. A connector designed to close and interrupt rated load current or less on energized circuits under rated conditions.

Low-Voltage. Any voltage below 600 V.

Medium Voltage. Voltages above 600 and ranging to 34,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Separable Insulated Connector. A fully insulated and shielded system for terminating an insulated power conductor to electrical apparatus, other power conductors, or both, and designed such that the electrical connection can be readily made or broken by engaging the connector at the operating interface.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of “working on”: 1) diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; and, 2) repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Document all training.

6.0 Required Approach Distances.

Table E-3-1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of PPE appropriate for the potential electrical hazards, or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table E-3-1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	Arc Flash Boundary	Limited Approach Boundary		Restricted Approach Boundary (3) (4)
	From Phase to Phase Voltage (5), (6)	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 7 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 3 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 4 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table E-3-1:

1. *For single phase systems select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted within the arc flash boundary.*

7.0 <u>Personal Protective Equipment.</u>

Confirm equipment is de-energized/locked out/tagged out. If equipment is to remain energized,

1. View arc flash label for incident energy level.
2. If label not present, calculate equipment incident energy level.
3. Select the minimum PPE level as required by NFPA 70E for the calculated incident energy level.

Voltage-rated gloves with leather protectors (Table E-3-2) for work inside the restricted approach boundary. Select as follows:

Table E-3-2 Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	1 (25)
0	Red	1,000	1 (25)
1	White	7,500	1 (25)
2	Yellow	17,000	2 (50)
3	Green	26,500	3 (75)
4	Orange	36,000	4 (100)

Notes for Table: Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.

8.0 <u>Precautions.</u>

Maneuver loadbreak connectors with an eight foot fully insulated "shot gun" line-line type tool. Ensure the working area is clear of obstructions or contaminants that might interfere with the operation of the connector or cause it to fall into the exposed bushing well. The operating position should allow establishing a firm footing and enable grasping the live-line tool securely, while maintaining positive control over the movement of the loadbreak connector before, during, and directly after the operating sequence. Because of the control, speed, and force required to engage or disengage an elbow, certain operating positions are more advantageous than others. If there are any concerns regarding an adequate position for handling a loadbreak connector, the operation must be performed on a de-energized circuit.

The following lists additional precautions and limitations for handling loadbreak connectors on an <u>energized</u> circuit:

- Limit work to dry weather conditions. Do not operate loadbreak connectors during wet conditions;

- Loadbreak connectors can be operated inside manholes only if the work can be accomplished with the qualified electrical worker standing outside the manhole at grade;
- Operation (connecting or disconnecting) loadbreak connectors inside a manhole with the qualified electrical worker standing inside the manhole is prohibited;
- Making a connection into a suspected fault is prohibited. De-energize the circuit prior to connection;
- If a fault occurs during connection or disconnection, replace the elbow connector and the bushing;
- Never connect an energized load break elbow into a transformer that has not been tested for proper operation;
- Never connect loadbreak elbow type surge arresters into an energized transformer or circuit;
- Never use a loadbreak connector to switch energized capacitors; and
- Check the appropriate manufacturer's operating instructions to confirm the device(s) is rated for energized operation, either connecting or disconnecting.

9.0 Loadbreak Operation (Connecting) at Grade.

Perform the following steps:

Note: This operation might be performed as part of a switching order. If so, then coordinate the Activity with the rest of the switching order.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.
2. Select voltage-rated gloves with leather protectors using Table E-3-2. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work.
3. Select and inspect the live-line insulated tool (hot stick) being used for the work. Confirm that hot sticks have been dry tested within the last 6 months and wet tested with the last 2 years. Ensure that all tools are rated for the voltage being worked on.
4. Ensure the area is clear of obstructions or contaminants that might interfere with the operation of the connector.

5. Open the equipment where the loadbreak connector operation will be performed.

6. Prepare the bushing for the elbow connector by removing the insulated cap. Attach the live-line tool to the insulated cap pulling eye and remove from the bushing.

7. Securely fasten a shot gun live-line tool to the load break connector pulling eye.

Note: This procedure assumes that the loadbreak connector is on an insulated parking bushing on the apparatus parking stand before work starts.

8. Without exerting any pulling force, slightly rotate the connector to break any surface friction prior to disconnection from the insulated parking bushing on the apparatus parking stand.

9. After establishing a firm footing and positive control of the elbow connector, withdraw the elbow from the insulated parking bushing on the apparatus parking stand with a fast, firm, and straight motion, while being careful to avoid the ground plane.

10. Place the elbow connector receptacle area over the bushing plug and insert the elbow male contact (arc flower portion) into the bushing until a slight resistance is felt. Immediately push the elbow into the locked position with a fast, firm, and straight motion. Apply sufficient force to engage the internal lock on the elbow connector and bushing interface.

11. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

10.0 **Loadbreak Operation (Disconnecting) at Grade.**

Perform the following steps:

Note: This operation might be performed as part of a switching order. If so, then coordinate the Activity with the rest of the switching order.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crewmembers.

2. Select voltage-rated gloves with leather protectors using Table E-3-2. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work.

3. Select and inspect the live-line insulated tool (hot stick) being used for the work. Confirm that hot sticks have been dry tested within the last 6 months and wet

tested with the last 2 years. Ensure that all tools are rated for the voltage being worked on.

4. Ensure the area is clear of obstructions or contaminants that might interfere with the operation of the connector.

5. Open the equipment where the loadbreak connector operation will be performed.

6. Place the insulated parking bushing on the apparatus parking stand.

7. Firmly tighten a shot gun live-line tool to the loadbreak connector pulling eye.

8. Without exerting any pulling force, slightly rotate the connector to break any surface friction prior to disconnection.

9. After establishing a firm footing and positive control of the elbow connector, withdraw the elbow from the bushing with a fast, firm, and straight motion, while being careful to avoid the ground plane.

10. Place the connector on the insulated parking bushing and secure.

11. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

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APPENDIX F SAMPLE MAINTENANCE PROGRAM CHECKLISTS

Front Page

SHOP RWP BOOK REVIEW					
INSPECTOR:		DATE:			
SECTION A	RWP LISTING FOR ALL FREQUENCIES	YES	NO	N/A	FINDINGS/REMARKS
	1. Are all the craft codes correct?				
	2. Are all the maintenance frequencies correct?				
	3. Have estimated hours been cross checked with actual hours?				
	4. Is each MAS number correct for the task listed?				
SECTION B	MAINTENANCE ACTION SHEETS				
	1. Is the cost center correct for all MAS sheets?				
	2. Is each MAS description accurate?				
	3. Are all task frequencies correct?				
SECTION C	DETAILED EQUIPMENT LIST				
	1. Are the items in priority order?				
	2. Are Bldg numbers correct?				
	3. Are all equipment install dates listed?				
	4. Are recommended replacement dates listed for each item/system?				
	5. Have replacement costs been identified?				
	6. Are there open jobs for old items?				
	7. Has the condition code been indicated for each item?				
	8. Has the Equipment List been cross checked with the RWP Facility List?				
	9. Has the Equipment List -Recommended Replacement Dates- been cross checked with the 5 yr Projects List?				
SECTION D	FIVE YEAR PROJECTS				
	1. Have 5 yr projects been identified and submitted to ME?				
SECTION E	BOOK REVIEW CHECKLISTS and COST ANALYSIS REPORTS				
	1. Has a Shop RWP Book Review Checklist been completed?				
SECTION F	BASE MAP				
	1. Does the shop have all current applicable base maps?				
SECTION G	HISTORY				
	1. Is there a Prior Year Shop RWP Book Review?				

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REMARKS 1

FOLLOW UP

APPENDIX G SAMPLE LIFE CYCLE COST MAINTENANCE WORKSHEET

RECURRING WORK PROGRAM WORKSHEET

RWP Item:

Review Date	Initials	Comments	Review Date	Initials	Comments

Review Method: ☐ Requirement Elimination ☐ MAPCO ☐Life-Cycle Cost

Approximate Cost of Item Being Maintained:

Requirement Elimination:

Can the RWP item be removed due to the very low replacement cost of the item and non-mission criticality? YES NO

Can the item be replaced with any zero-maintenance components? YES NO

Can the RWP item be contracted out to a service contractor? YES NO

Comments:

Man-Hour Ceiling/Priority Analysis (MAPCO)

Note: The MAPCO method is designed to help show whether a shop has enough manning to accomplish particular RWP items and help determine alternate ways of accomplishing required RWP tasks.

Is this a mandatory RWP item? YES NO

Note: If this is not a mandatory RWP item even though it is costs effective, this particular item should be prioritized for accomplishment after all other mandatory items are completed and additional manhours are available.

Is shop manning sufficient to accomplish this RWP item as required? YES NO

Can this item be included in the 1219 program? YES NO

Can this item be done through a service contract? YES NO

Comments:

Life-Cycle Cost Analysis

Note: The Life-Cycle Cost Analysis method is used to determine the economic value of doing a particular RWP item as compared to the cost of doing no maintenance and simply replacing the piece of equipment when it breaks. This method is typically used for larg items of critical value to a facility.

1. Item replacement price (installed): $ 25,000.00
2. Item re-build cost: $8,000.00
3. Cost of RWP item per Month: __$50__(Material) + __$50__(Labor) = $ 100.00

   Cost of RWP item per Quarter:__$100__(Material) + _$100_ (Labor) = $ 200.00

   Cost of RWP item per Year:___$150___(Material) + _$150__(Labor) = $ 300.00

(A) Freq of Mx	(B) Freq of Failure	(C) Annual RWP Cost	(D) PC of Repair/Replace	(E) PC of RWP	(F) Total PC of Option
Monthly	15	$2,300.00	$8,000.00	$34,500.00	$42,500.00
Quarterly	10	$1,500.00	$12,000.00	$22,500.00	$34,500.00
Annually	5	$600.00	$24,000.00	$9,000.00	$33,000.00
Never	2	$0.00	$60,000.00	$0.00	$60,000.00

(B): Determine Frequency of Failure from manufacturer data (years until failure)

(C): Number of RWP occurences within the year x cost per occurrence from 3 above

(D): Replacement cost (item 1 above) x # of replacements needed to reach highest number in (B)

(E): Column (C) x highest number of years from Column (B)

(F): Column (D) + Column (E)

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APPENDIX H SAMPLE MAPCO MAINTENANCE DOCUMENT

RWP: Recurring Work Program

Method 3: Man-hour Ceiling/Priority Analysis Method (MAPCO)

It can be very difficult for many work centers to provide the manpower needed to properly implement the recurring work program. Every center has a limited number of man-hours that can be committed to a project. The Operations Flight understands this, and realizes that an alternative to the life-cycle cost analysis method and RWP requirement elimination method is sometimes needed. The third and final RWP method is called, "man-hour ceiling/priority analysis method," or MAPCO. MAPCO enlists the help of program engineers, innovative problem solving in a team setting, and effective scheduling by the work center manager. There are many benefits that can be realized by this method of RWP.

To use MAPCO, the following conditions should be present:

- limitations on manpower in the work center
- the scope of RWP is known
- the locations of RWP is known
- the materials for RWP are known

There are several options for making RWP successful under the above conditions. A manager should consider using a combination of options in order to have an effective program in the work center.

The following are options for successfully implementing RWP in a work-center with limited manpower available:

- Manager can budget man-hours to RWP on a prioritized schedule so that most important issues are budgeted first. The inspection schedule should be completed every year.
- Execute RWP in conjunction with a facility visit (such as 1219-type work). When the work is scheduled, WIMS can generate a listing of RWP for that facility throughout the period between the visit and the next programmed visit. This listing will include the mandatory requirements followed by the nonmandatory requirements. As the crafts pursue the 1219 Direct Scheduled Work and Maintenance Action Sheet requirements, they complete all mandatory RWP items. At the end of the visit, if additional man-hours are available in the schedule, they can begin to complete the nonmandatory items in priority order.
- Contract redundant, manpower intensive, or critical RWP requirements. This decision is typically a team decision, made by the program engineers, work center chiefs, and senior craftsmen.
- MAPCO benefits RWP because it optimizes the program in a thorough stepped process. It also improves engineer and work center coordination, and increases engineer exposure to the infrastructure environment.

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APPENDIX I RECOMMENDED TESTING INTERVALS

	Frequency						
Device	As needed	Weekly	Monthly	Semi-annually	Annually	Every 2 years	Every 5 years
Aerial lift devices	x						
Anchor assemblies	x						
Anchors, submarine cable	x						
Arresters, surge, visual inspection	x				x		
Arresters, surge, electrical tests	x					x	
Batteries, booster charge	x		x				
Batteries, check	x		x		x		
Batteries, equalizing charge	x		x				
Batteries in storage	x			x			
Battery maintenance test equipment	x		x				
Battery chargers	x		x				
Buses, substation	x		x				
Bushings, inspection	x				x		
Bushings, power factor tests	x						
Bushings, insulation resistance test	x						
Cable maintenance tests					x		
Cable, overhead	x						
Cable, paper-insulated	x				x		
Cable, pressure	x				x		
Cable records	x						
Cable, submarine					x		
Cable, underground, routine inspection						x	
Cable, underground, insulation resistance					x		
Cable, varnished-cambric	x						
Capacitors	x			x			
Capacitor bushings	x						
Capacitor busbar supports	x						
Circuit breaker maintenance						x	
Circuit breaker, high-voltage					x		
Circuit breaker, medium-voltage	x					x	

	Frequency						
Device	As needed	Weekly	Monthly	Semi-annually	Annually	Every 2 years	Every 5 years
Circuit breaker, low-voltage	x					x	
Circuit switchers						x	
Conductor re-sagging						x	
Connections					x		
Connectors, tap	x						
Contacts			x				
Control magnet-operated devices			x		x		
Control thermally-operated devices			x				
Control motor-operated devices			x				
Control mechanically-operated devices				x			
Control static accessories				x			
Control, non-electromagnetic				x			
Crossarms							x
Cutouts							x
Disconnecting switches						x	
Fuse	x						
Grounds	x					x	
Guys and anchors	x						
Hardware							x
Instruments and meters-inspection	x			x			
Instruments and meters-tests							
Insulating liquids	x						
Insulators, distribution	x						x
Insulators, substation	x					x	
Interference	x						
Interference, harmonic	x						
Lamps		x					
Leathergoods				x			
Lightning protection shielding devices	x			x			
Luminaires					x		
Manholes					x		
Meters and instruments-inspection	x						
Meters and instruments-tests					x		
Poles, metal	x						
Poles, concrete	x						

	Frequency						
Device	As needed	Weekly	Monthly	Semi-annually	Annually	Every 2 years	Every 5 years
Portable or mobile substations	x						
Potheads	x				x		
Reclosers, automatic circuit	x				x		
Regulator, voltage					x		
Relays	x						
Relay settings					x		
Resistors, bypass	x						
Rubber goods				x			
Service drop						x	
Street lighting fixtures					x		
Street lighting lamps	x						
Street lighting photocells					x		
Street lighting protective relays						x	
Street lighting primary oil switch						x	
Substation fence and gate			x				
Substation signs			x				
Substation yard	x						
Substation overall, infrared					x		
Substation overall, visual			x				
Switch, load interrupter	x					x	
Switch, photoelectric				x			
Switch, time (accuracy)			x				
Switch, time (contacts)					x		
Tap changer, load					x		
Telephone interference	x						
Terminations	x				x		
Test instrument calibrations, analog				x			
Test instrument calibrations, other					x		
Tools, live-line inspection	x						
Tools, live-line test records	x				x		
Transformer, constant current					x		
Transformer, distribution					x		
Transformer, instrument	x						
Transformer, power	x						x
Tree trimming	x					x	

Note: If system(s) have reliability requirement established by other requirements, no not exceed presented recommended frequencies.

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APPENDIX J GLOSSARY

J-1 ACRONYMS

A	Ampere
AC	Alternating Current
AFI	Air Force Instruction
AMR	Anisotropic Magnetic Resistance
ATPV	Arc Thermal Performance Value
BIA	Bilateral Infrastructure Agreement
CAD	Computer-Aided Drafting
CAIDI	Customer Average Interruption Duration Index
CFR	Code of Federal Regulations
cm	Centimeters
CN	Concentric Neutrals
CT	Current Transformer
DC	Direct Current
DG	Distributed Generation
DGA	Dissolved Gas Analysis
DGS	Distributed Generation System
DSM	Demand Side Management
EBT	Energy of Breakopen Threshold
EPM	Electrical Preventative Maintenance
ETL	Engineering Technical Letter
FPOC	Facility Point Of Connection
GIS	Geographical Information Systems
HVAC	Heating, Ventilation, and Air Conditioning
ICS	Industrial Control System
IP	Internet Protocol
ft	Feet (or Foot)
Hp	Horsepower
Hz	Hertz
I^2t	Current Squared Time
in	Inch
JHA	Job Hazard Analysis
kA	Kiloampere
kV	Kilovolt
kVA	Kilo-Volt-Ampere
kVAR	Kilo-Volt-Ampere-Reactive
kW	Kilowatt
kWh	Kilowatt-hour
LCCA	Life Cycle Cost Analysis
m	Meter
MAPCO	Man-hour Ceiling/Priority Analysis Method
MCCB	Molded Case Circuit Breaker

MDL	Minimum Daytime Load
MG	Motor-Generator
MOSA	Metal-Oxide Surge Arresters
mm	Millimeter
MTS	Maintenance Test Specifications
MV	Medium Voltage
NEC	National Electric Code
NESC	National Electrical Safety Code (IEEE C2)
NICET	National Institute for Certification in Engineering Technologies
NTS	National Testing Standards
O&M	Operation and Maintenance
ORM	Operational Risk Management
PCB	Polychlorinated Biphenyls
PI	Polarization Index
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
PPM	Parts Per Million
PQM	Power Quality Monitoring
PT	Potential Transformer
rms	Root-Mean-Square
RUS	Rural Utility Service
RWP	Recurring Work Program
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SDS	Safety Data Sheet
SF6	Sulfur Hexafluoride
SOP	Standard Operating Procedure
TC	Time-Current
TDR	Test Domain Reflectometer
TOV	Transient Overvoltage
TSEWG	Tri-Service Electrical Working Group
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
V	Volts
VAR	Volt Amperes Reactance
VFI	Vacuum Fault Interrupter
VLF	Very Low Frequency
VRLA	Valve-Regulated Lead Acid
X/R	Ratio of Reactance to Resistance

J-2 DEFINITION OF TERMS

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

Balaclava (Sock Hood). An arc-rated hood that protects the neck and head except for the facial area of the eyes and nose.

Boundary, Arc Flash. When an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second degree burn if an electrical arc flash were to occur.

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

Chicken Switch: Remote actuating device to operate an interrupting device from a safe distance. Typically electrically operated, magnetic device that can remotely activate a switch.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Elbow. A connector component for connecting a power conductor to a bushing, designed so that when assembled with the bushing, the axes of the conductor and bushing are perpendicular.

Electrical Hazard. A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Fused Cutout. A pole mounted interrupting device, equipped with fuses, that provides a method for de-energizing and protecting downstream electrical equipment.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Insulated Cap. An accessory device designed to electrically insulate, electrically shield, and mechanically seal a bushing insert or integral bushing.

Insulated Parking Bushing. An accessory device designed to electrically insulate, electrically shield, and mechanically seal a power cable terminated with an elbow and to be installed into a parking stand.

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Loadbreak Connector. A connector designed to close and interrupt rated load current or less on energized circuits under rated conditions.

Low-Voltage. Any voltage below 600 V.

Low Voltage System: An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage. Voltages above 600 and ranging to 34,500 V.

Medium Voltage System: An electrical system having a maximum RMS AC voltage of 1,000 volts to 34.5 kV. Some documents such as ANSI C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Separable Insulated Connector. A fully insulated and shielded system for terminating an insulated power conductor to electrical apparatus, other power conductors, or both, and designed such that the electrical connection can be readily made or broken by engaging the connector at the operating interface.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of “working on”: Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

UFC 3-555-01
01 March 2024

UNIFIED FACILITIES CRITERIA (UFC)

AIRCRAFT POINT-OF-USE POWER SYSTEMS

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UNIFIED FACILITIES CRITERIA (UFC)

AIRCRAFT POINT-OF-USE POWER SYSTEMS

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 3-555-01N dated 16 January 2004, the electrical sections of UFC 4-121-10N, dated 16 January 2004, and the special power system requirements in UFC 4-211-01 dated 13 April 2017, Change 3 dated April 20 2021.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD-3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

The purpose of this UFC is to provide technical requirements for the electrical design of specialized Point-of-Use (POU) power distribution systems for aircraft, and electrical power systems associated with aircraft hangars and aviation support facilities. This includes 400 Hertz, 270 VDC, and 28 VDC systems. Apply the criteria provided in this UFC for the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP). It serves as the minimum electrical design requirements for design-build and design-bid-build projects. Project conditions may dictate the need for a design that exceeds these minimum requirements.

The aircraft power feeder distribution systems for new designs are required to be low voltage (less than 600 VAC) POU utility systems. Each of the 400 Hz, 270 VDC, and 28 VDC converters are prohibited from serving more than one aircraft receptacle, unless specifically noted otherwise within this document.

1-1.1 Upgrades and Modifications to Existing Systems

Modernization of electrical systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required. Minor upgrades or modifications of existing facilities should consider the design criteria in this UFC, but it is not intended that an entire facility require modernization solely because of a minor modification to a part of the facility.

- Medium voltage 400 Hz distribution systems and low voltage (less than 600 volts) 400 Hz distributed systems are also not permitted for new designs. These systems require extensive specialized technical knowledge and experience to design and maintain, and should only be utilized on limited repair type projects for existing systems.

1-2 REISSUES AND CANCELS.

This UFC replaces and cancels UFC 3-555-01N dated 16 January 2004 and incorporates canceled electrical sections of UFC 4-121-10N dated 16 January 2004.

1-3 APPLICABILITY.

The information in this UFC applies to the design of all new construction projects, including additions, alterations, and renovation projects within the United States and outside of the United States and its territories and possessions.

Note: This UFC takes precedence over the aircraft hangar UFC 4-211-01 for the specialty electrical system power. The hangar UFC will be modified to reference this UFC during its next review cycle.

1-4 CONFLICTS.

If a conflict exists between this UFC and any other referenced code, standard, or publication, this UFC takes precedence. When there is a known deviation to a normally complied with standard (such as an “exception to” or “more stringent requirement” than one in MIL-STD-704), the specific deviation is identified in either the UFC or the associated UFGS.

1-5 REGULATORY AUTHORITIES.

The military authorities having jurisdiction for Specialty Power Systems are included below.

1-5.1 Navy and Marine Corps.

Due to the new, more stringent technical requirements in the UFGS, including the 400 Hz requirement to be fully rated in kW at unity power factor vs being rated in kVA, and the 270 VDC requirements that have been developed without referring to proprietary documents, all manufacturers will have to develop and prove their new designs. These designs, including the factory routine, factory special, and field test plans, reports and backup data, must be reviewed and approved by NAVAIR and NAVFAC LANT. This is an extensive process requiring specific technical expertise in working with and verifying compliance with MIL-STD-704, and witnessing the tests at the manufacturer’s facilities.

NOTE: The manufacturer’s previous versions of military converters, and their commercial equipment, will not comply with this new criteria.

Coordination is therefore mandatory during the DD Form 1391, concept development and the design-build request for proposal (RFP) or design phases with NAVAIR (Naval Air Systems Command) and NAVFAC to determine the extent of the equipment review and approval process that is to be implemented and to identify funding requirements. The UFGSs for the converter systems identify numerous optional requirements which must also be edited appropriately based on the command requirements. It is anticipated, that until multiple manufacturers have achieved “approved designs, test plans and reports” from NAVAIR, both NAVAIR and NAVFAC LANT will need to be in the shop drawing review and approval loop.

- Contact NAVAIR POC: Henry Dent at (240) 434-6861.
  Email: henry.c.dent.civ@us.navy.mil.
  Command: Naval Air Warfare Center Aircraft Division (NAWCAD Test Methods and Facilities AB44).
- Contact NAVFAC POC: Rob Boller at (757) 322-4327.
  Email: robert.r.boller.civ@us.navy.mil.
  Command: NAVFAC Atlantic (LANT), Code PDC 44, Electrical Criteria Manager.

1-5.2 NAVAIR and NAVSEA Additional POC Information.

This criteria is not to be used for procurement of power converters installed on board aircraft or ships without specific authorization from both the Naval Air Warfare Center Aircraft Division (NAWCAD Power and Energy Division (AB43) at (301) 342-4161), and from the Naval Sea Warfare Command (contact the Technical Warrant Officer for the appropriate ship classification).

1-6 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-6.1 Facility Requirements Document (FRD).

The airframe manufacturer's FRD, or equivalent document, is an integral requirement of aircraft specialty power systems design that contains additional airframe specific facilities requirements. FRDs are typically authored by the airframe manufacturer, contain many specific details, and are voluminous. Coordinate with the project manager to obtain the pertinent sections of the FRDs that are applicable to the project.

This UFC is not a substitute for the FRD of the design airframe(s) associated with the project. However:

- The UFC and associated UFGSs may have additional technical requirements that override the FRD requirements. An example is the new requirement for 400 Hz converters to be sized in kW vs the industry standard of kVA. The Navy and Marine Corps, and the Army FRDs are being addressed to incorporate this NAVAIR and Army mandated change. See paragraph Aircraft 400 Hertz (Hz) Service for additional information.
- The FRD may have new airframes, or existing platforms may have new requirements that this UFC has not addressed. These additional technical facility requirements, data or other items may impact the aircraft power system design. When that occurs, the facility Basis of Design must identify the exceptions to criteria and how the requirement is being addressed and satisfied in addition to the requirements of this UFC.

1-7 SAFETY.

Comply with UFC 3-560-01*, Operation and Maintenance, Electrical Safety*, and NFPA 70E, *Standard for Electrical Safety in the Workplace*, for equipment-related electrical safety requirements.

Coordinate with requirements identified in paragraph Aircraft Interlock Circuit.

1-8 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, *Cybersecurity of Facility Related Control Systems* and as required by individual Service Implementation Policy.

The Electrical Designer of record must determine if the equipment being provided will include a control system (i.e. remote access panels or any other form of remote controls). If it does, edit the UFGS 25 05 11, "*Cybersecurity for Facility-Related Control Systems*" in the project documents to identify the extent of cybersecurity required.

1-9 SUPPLEMENTAL TECHNICAL INFORMATION.

APPENDIX A contains additional technical information.

1-10 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-11 REFERENCES.

APPENDIX C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 EXTERIOR DISTRIBUTION REQUIREMENTS

2-1 POINT OF USE (POU) UTILITY SYSTEMS.

Provide a fixed Point of Use (POU) utility system based upon the number and type of aircraft to be served, ground support requirements of the particular aircraft, expected diversity and demand of the aircraft loads, and site configuration of facilities. This will include identifying the central facilities utility demands, equipment capacities, line size and routing of the distribution system, and aircraft service point requirements.

2-1.1 Planning.

The POU concept is based upon the economy of supply of aircraft utilities from a centralized plant / location using 60 Hertz (Hz) energy-efficient components. Include the following considerations in planning for each aircraft facility:

a. Orderly expansion of the system components to accommodate probable future hangar bays and parking apron service points.

b. Economic feasibility of supplying adjacent or nearby facilities (existing or future) from the centralized supply.

c. Relocatability of ground support equipment versus installed equipment.

d. Probability of function relocation or base closure.

2-1.2 Aircraft Services.

Provide electrical POU systems for ground-power operations using solid state conversion equipment to change 60-Hz input to 400-Hz, 270 VDC, and 28 VDC outputs as required for the applicable aircraft.

2-1.3 Central Equipment Facilities.

In multiple facility development, provide a central facilities area for the equipment building, and a yard area for pad mounted / substation type transformers and switchgear for the main electrical service. Include the electrical service and distribution apparatus in the building.

2-1.4 Utilities Distribution.

Provide an underground 60 Hz distribution system including equipment, manholes and ductbanks to the maintenance hangar service points and parking apron service points in accordance with UFC 3-550-01. Coordinate with the mechanical designer and the mechanical sections of UFC 4-211-01, *Aircraft Maintenance Hangars*, and route the mechanical systems (such as compressed air and pre-conditioned air) in the same trench with the electrical conduits. Locate the access manholes outside the paved areas.

2-1.5 Site Configuration.

Coordinate the layout of the POU systems with the siting of the maintenance hangars, parking apron space and taxiways in accordance with UFC 3-260-02, *Pavement Design for Airfields,* and the following requirements:

- Include load calculations and voltage drop calculations in the Basis of Design for all service and distribution feeders in accordance with UFC 3-501-01. See Table 2-1 Notes for additional discussion on the possible increased load on the input of the converter due to the full kW at Unity design requirement.
- Utilize 60 Hz service and distribution equipment rated for exterior use in accordance with NEMA 250, IEC 60529, and UFC 3-550-01. Utilize 400 Hz, 270 VDC, and 28 VDC equipment rated for exterior use in accordance with NEMA 250 and the options designated in the UFGSs.
    a. **For Navy and Marine Corps**: provide enclosures rated NEMA Type 3SX (or IEC IP55) or better, with corrosion resistant paint, provide sealed non-ventilated electronics enclosures, and conformal coating on electronic components such as PC boards.
    b. **For Army and Air Force**: provide enclosures rated NEMA Type 3S (or IEC IP55) or better. In corrosive locations, provide enclosures rated NEMA Type 3SX (or IEC IP55) or better, with corrosion resistant paint, and provide sealed non-ventilated electronics enclosures and conformal coating on electronic components such as PC boards.
- Consider the following for multiple facility and equipment location development:
    a. Locate the central equipment facility as near the hangar as practical at a location offering the most direct access to the parking apron. Minimize the length of the underground mains to the parking apron.
    b. Locate the section of underground mains between the central facilities and the first transition point outside the apron and taxiway pavements.
    c. Locate the feeder distribution center, consisting of pad-mounted equipment, off the apron as close as practical to the service points to minimize aircraft service voltage drop.
    d. When voltage drop calculations permit, the feeder distribution centers for apron service points may be located in the hangar or located outside nearer to the hangar. This may limit the amount of primary distribution that is required to be run throughout the site. It may also increase the number of distribution components that are located in dry environments instead of harsh environments which may be less expensive and require less maintenance.

e. When structures are installed on the apron for the aircraft parking spots, coordinate the location of the service points to be adjacent to, but not under the structures. Note – A new UFC is under development by the Airfield Criteria Team to clarify that these structures are designated to be "sun shades" and not "shelters". That UFC will establish requirements, including that utilities are not permitted to be under "sun shades".

f. See Figure 2-1 for one example of a typical POU system layout for serving a hangar and parking apron complex.

g. See Figure 2-2 and Figure 2-3 for examples of different layouts and types of structures installed at some bases.

For the Navy and Marine Corps, see UFC 2-000-05N; *Facility Panning for Navy/Marine Corps Shore Installations* for additional information on the parking apron layout for Navy and Marine Corps Shore Installations.

Figure 2-1 POU System "Aircraft Parking Apron" – Site Plan Layout Typical

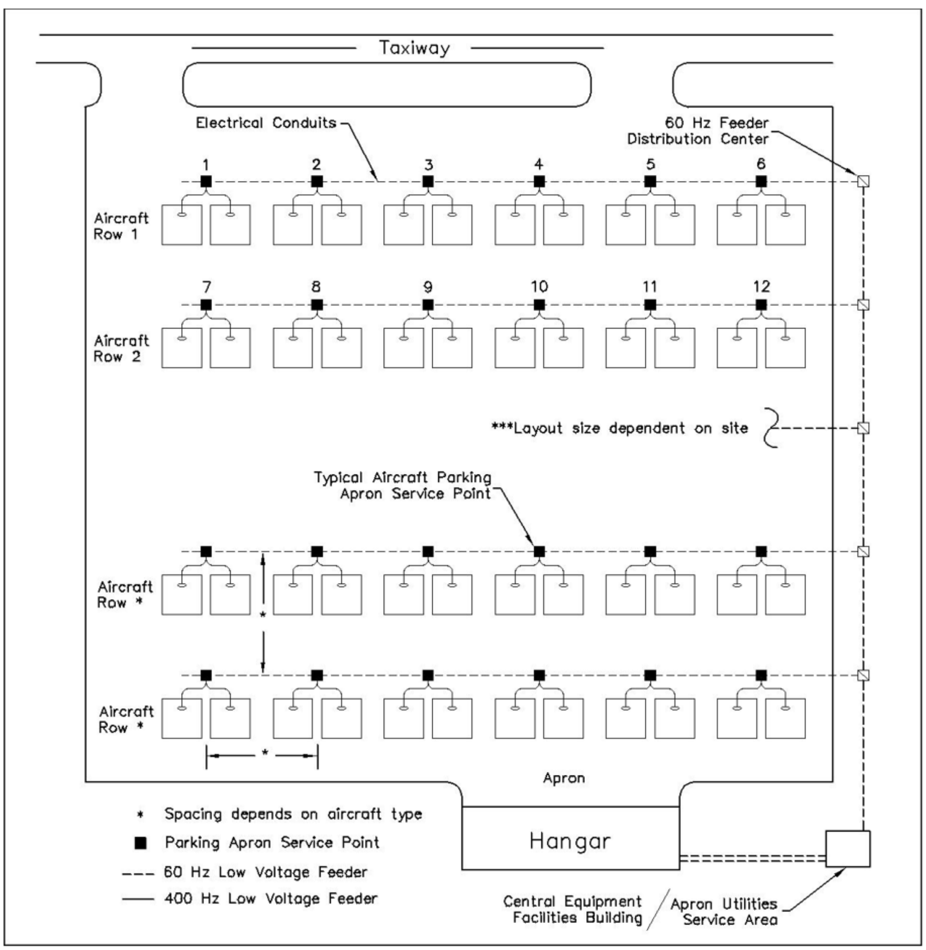


Figure 2-2 Example of Apron Layout with “Sun Shades”

Figure 2-3 Example of Apron Layout with POU Equipment

2-2 UTILITY SYSTEM LOAD DETERMINATIONS.

Use the total number and type of aircraft, plus the demands of other ground support activities to be supplied by the fixed point facilities, and determine load requirements for the utility system.

2-2.1 Aircraft Unit Demands.

For the Navy and Marine Corps: Utilize Table 2-1 Navy and Marine Corps Aircraft Electrical Requirements when completing load calculations.

Table 2-1 Navy and Marine Corps Aircraft Electrical Requirements

Aircraft Load Type	Aircraft Voltage: 400 Hz or 270 VDC	Designated Converter Size (See Notes 1 & 2)	Designated Cable Ampacity	Designated Cable Length
Fixed Wing	**400 Hz**	90 kW – see Note 3	260 Amp	105 ft (32 m)
Rotary Wing	**400 Hz**	45 kW - see Note 3	180 Amp	105 ft (32 m) (see Note 4)
Fixed Wing	**270 VDC**	72 kW - see Note 5	333 Amp	83 ft (25 m)
UAVs and limited other aircraft that are dedicated to 28 VDC	**28 VDC**	TBD – see Note 6		

Note 1: Provide designated Converter size unless there are specific project design requirements that have been approved by NAVFAC and NAVAIR. See paragraph *Regulatory Authorities* herein for POC information. Provide one cable per converter.

Note 2: Design to provide full capacity for each converter, measured at the aircraft end of the servicing cable, and utilize demand loading for utility distribution and transformer sizing. Coordinate with UFC 3-550-01 and UFC 3-501-01. Use Table 2-1, applicable to the number of aircraft being serviced in the facility under design, and apply the resulting number for the design demand factor for the Aircraft Load.

Note 3: The required load ranges for the 400 Hz converters are defined in the UFGS. The UFGS requires full load current (90 kW = 261 Amperes per phase and 45 kW = 130 Amperes per phase) compliance from the worst case lowest lagging power factor (currently 0.5 lagging), through full load at unity, up to the highest leading power factor (currently .7 leading).

a. These are very stringent requirements that are not met by a commercial off the shelf unit, or by previous converter designs. The two sizes, 90 kW and 45 kW have been standardized on, in order to facilitate approval of the equipment.

b. Because of the new requirements for the load range, converter input load will increase, possibly causing an increase in the feeder breaker conduit and wire sizes serving each unit. For new projects, and for apron unit replacement and building renovation projects where existing kVA sized units are being replaced by kW sized units, the Designer of Record (DOR) must obtain nameplate data from at least two manufacturers and document this information in their Basis of Design calculations.

c. Based on recent experiences with two manufacturers, it is imperative that NAVAIR and NAVFAC LANT POCs be involved on all projects in order to establish a database of manufacturers who have developed new designs.

d. As identified in the UFGS, these designs must be proven by the manufacturers by also developing Special and Routine Test Plans and Reports that are geared specifically to all the new requirements in the UFGS.

e. After NAVAIR approval of these test plans and the report format, the government intent is to witness the actual tests being performed at the factory.

f. Those documented reports from the witness testing would then be submitted in for NAVAIR and NAVFAC LANT final approval.

Note 4: Provide the designated Cable Length unless the project design requirements that have been approved by NAVFAC and NAVAIR identify a 90 ft (27 m) length as being required.

Note 5: The 270 VDC converters are used to supply 270 VDC (267 Amps) and limited amounts of 28 VDC electrical Interlock voltage (15 Amps), measured at the aircraft end of the servicing cable. See UFGS 26 35 44 for details.

a. The new UFGS requirements will require an identical approval process by NAVAIR and NAVFAC LANT POCs as described for the 400 Hz converters in Note 3 above.

b. For 270 VDC output systems, there is no difference in KW and KVA ratings. A 72 kW / 72 kVA DC converter must deliver 267 Amps under specified conditions.

Note 6: Per NAVAIR, when there is a requirement for a 28 VDC platform, request the specific FRD for the UAV or other limited aircraft, and coordinate with the NAVAIR POC designated in this UFC for any known special requirements that should be incorporated into the design and into a project specification. The NAVFAC LANT and NAVAIR POCs may have some sample specification paragraphs or testing requirements that could be used with a draft project specification, until an official UFGS has been developed.

2-2.2 System Load Demand.

In addition to establishing the system demand for individual apron and hangar loads, apply a system demand factor to the overall base system.

- Use Table 2-2 to establish the number of aircraft expected to exert a simultaneous demand for the portion of the system under consideration. The demand factors apply to aircraft using 270 VDC or 400 Hz.
- Base the electrical demand for the 60 Hz, 400 Hz, and 270 VDC systems, per the table; i.e. in a 36 aircraft squadron, the power demand should account for powering 12 aircraft (31 percent x 36 aircraft = 11.7, rounded up to 12). Proportion the resulting demand between parking apron service points and hangar service points with a ratio of 2 to 1 respectively.

Implement these results when establishing the service transformer and distribution equipment requirements in accordance with UFC 3-550-01 and basis of design calculations in accordance with UFC 3-501-01.

Table 2-2 System Demand Factors

Number of Aircraft	Demand Factor Percent
1	100
2	90
3	83
4	77
5	71
6	66
7 to 9	61
10 to 12	50
13 to 15	45
16 to 21	40
22 to 40	31
41 to 60	28
Over 60	25

2-2.3 Additional Load Considerations.

In addition to aircraft, there are other loads that may require 400 Hz, 270 VDC and 28 VDC power. Prior to supplying these facilities, verify that equipment installed will not be damaged by the hangar POU power tolerances. Separate local converters should normally be used for these systems. These loads include the following:

- Avionics. Repair shops for electronic equipment require specialty power for maintenance and testing. Coordinate with the using agency to obtain the actual load requirements in such cases.
- Other Facilities. Research, development, training, and other types of facilities may require 400-Hz, 270 VDC, and 28 VDC distribution systems. If the using agency cannot provide the actual load requirements, compute such loads on a watts per square foot (square meter) basis when firm loads are not available in accordance with UFC 3-501-01.

2-3 ELECTRICAL REQUIREMENTS ON APRONS.

Provide electrical service on aircraft parking aprons to accommodate the aircraft types and operational function of the squadron or group. The electrical distribution system may consist of pad mounted switches, transformers, switchboards, panelboards, service point equipment enclosures, and underground distribution feeders located near each row of planned aircraft parking. Provide a one line diagram, with legend and details clearly indicating the planned arrangement. Provide this equipment in accordance with UFC 3-550-01. An example of a one line for a typical system is shown in Figure 2-4.

2-3.1 Parking Apron Service Points.

Provide service from the Switchboards to each service point.

a. In the example distribution system indicated in Figure 2-1, each service point would serve two converters and each of these converters would serve an aircraft.

b. On some sites, a dedicated service point may be used for each aircraft parking spot if it is validated with the Activity. However, this may add more enclosures and equipment on the airfield.

c. The electrical requirements at each location, (often called an island) normally include 60 Hz receptacles and miscellaneous loads in addition to whichever special power system converters (400 Hz, 270 VDC or 28 VDC) are required. An example one line for a typical 400 Hz system is shown in Figure 2-5, and the associated legend is in Figure 2-6.

d. The UFGS now requires “individual converters”; i.e. one converter serving each parking spot. However, if space is a consideration on the apron, a single, low-profile, factory built and tested, dual converter unit is permitted. It must consist of two, independent, fully rated, simultaneous converters in a single enclosure, housing all the necessary components. The unit’s construction part of the UFGS may have to be modified to explain this exception. Coordinate with the Activity to verify that having a dual unit is acceptable, since it may entail outages for two aircraft instead of one during maintenance issue.

e. Coordinate the island locations and layout with the mechanical utilities designer to determine if a compressed air dispensing system needs to be incorporated into the main service point enclosure. If it does, incorporate the mechanical components in the rear half of the enclosure and the electrical components in the front half of the enclosure. (See UFC 4-211-01 for the mechanical requirements).

Figure 2-4 POU Aircraft Parking Apron – One Line Diagram

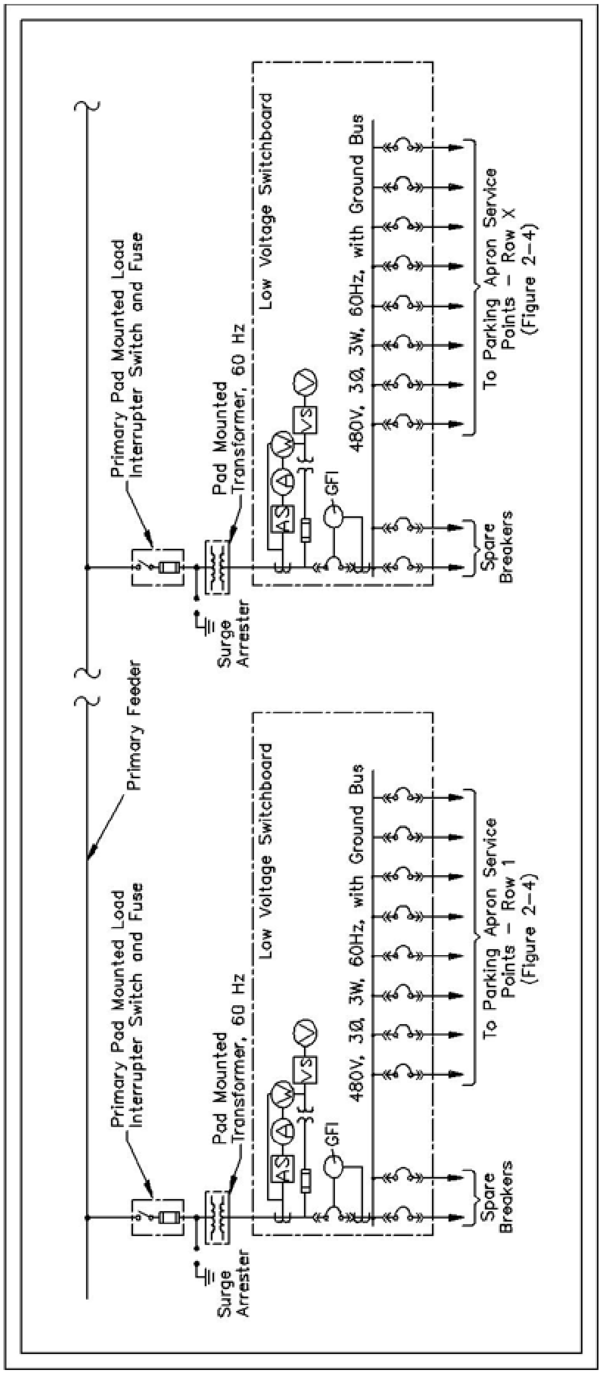


Figure 2-5 Parking Apron Service Point Arrangement / One Line

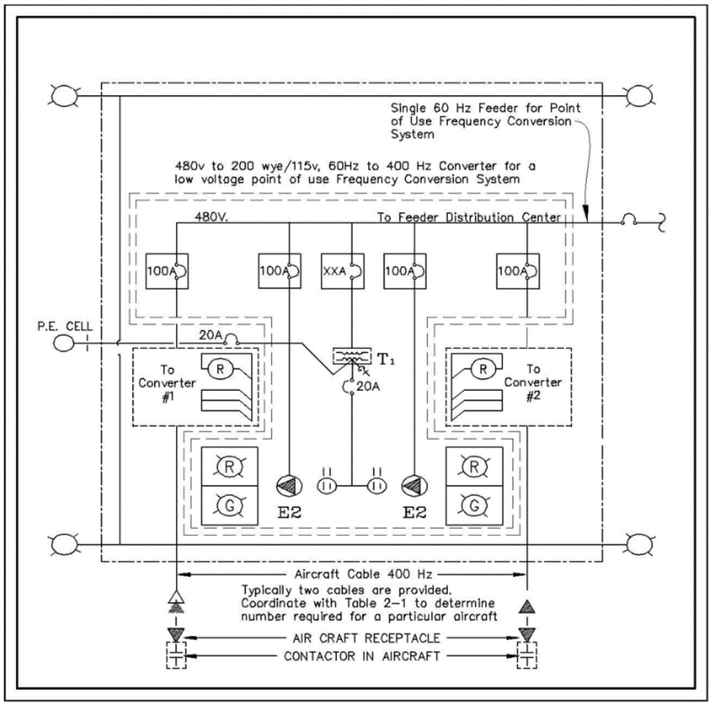
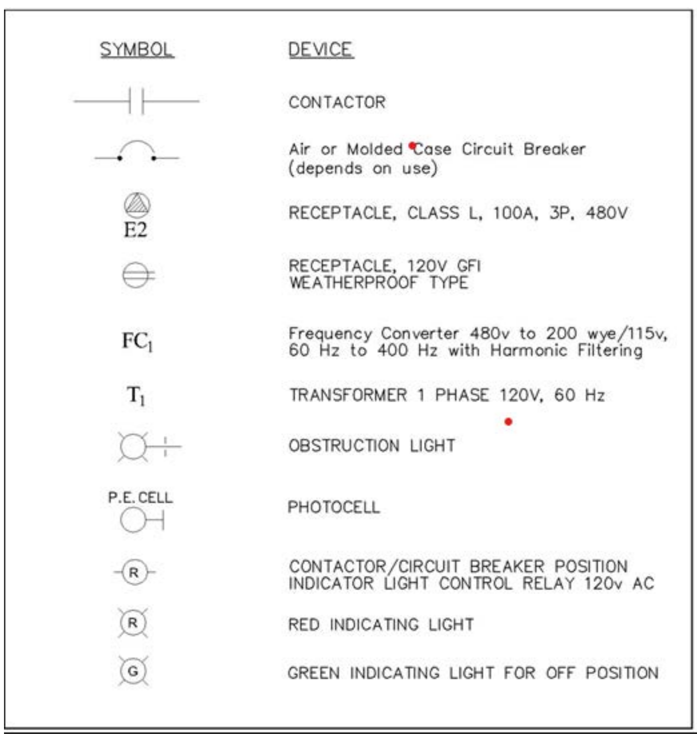


Figure 2-6 Legend



2-3.1.2 Construction.

The service point enclosures must be manufactured enclosures based on the location, and in accordance with paragraph Site Configuration. Field fabricated enclosures are not permitted. Mount the main service point enclosure assembly, and the associated converters, on a concrete base pad approximately 6 in. (152 mm) above the apron grade. Protect this entire assembly from vehicular traffic with concrete-embedded steel posts.

2-3.1.3 Electrical Equipment Components.

Provide each main service point with 60 Hz components (and the 60 Hz circuit breakers for the specialty 400 Hz or 270 VDC systems converters) as follows:

a. 60 Hz input circuit breaker(s) three-pole, 600 V. Size the input circuit breaker to include the specialty system converter loads. Operate the circuit breaker from the front of the service point enclosure. Note: all the 60 Hz breakers may be included in a panelboard / switchboard arrangement within the service point assembly.

b. Two 100 ampere and two additional, three-pole, 600 V, 60 Hz, molded case circuit breakers. Mount two breakers on the interior of each side panel. (One on each side will be used for Item c, and the second on each side will be used for the converter. Based on the new requirement for kW ratings, coordinate required ampacity of the converter breakers with at least two manufacturers.)

c. Two 100 ampere, 480 V, three-phase, four-wire, 60 Hz receptacles for Government furnished Ground Support Equipment (GSE). These receptacles are built by very few manufacturers and are identified by part numbers. Coordinate required outlet amperage (if other than 100 A) and type requirements with the users. Mount one receptacle on the exterior of each side panel.

d. One 3 kVA, one-phase, 480-120 V, 60 Hz, dry-type transformer with two-pole primary circuit breaker and a one-pole, 20-ampere secondary breaker. The transformer provides power for control, 120 V receptacles, and obstruction lights. When the mechanical system is included in the assembly, mount the transformer and the protecting breakers on the interior sheet steel barrier between the mechanical and electrical sections.

e. Two 20 ampere, 125 V, one-phase, two-pole, three-wire, 60 Hz, weatherproof receptacles with ground-fault interrupting. Mount one receptacle on each of the exterior side panels.

f. Provide obstruction warning light fixtures for each service point enclosure. Fixtures must be steady-burning red obstruction lights, FAA Type L-810. Provide in accordance with UFC 3-535-01, *Visual Air Navigation Facilities*, and FAA AC 70/7460-1. Provide fail-safe photoelectric control for the fixtures at each service island. Coordinate with the Activity to verify number required at each location. Typically, four fixtures are used, mounted near corners of the enclosure. If Activity concurs with limiting the number to two fixtures, install at opposite corners. If only one fixture is required by Activity, it must be a dual L-810 fixture.

g. Verify with Activity and Airfield Manager to determine whether or not LED fixtures are permitted.

h. Provide apron site lighting around the main service points in accordance with UFC 3-530-01, *Interior and Exterior Lighting Systems.*

i. When mechanical systems are included in the enclosure, mount one low-air-pressure warning light on the exterior panel adjacent to the mechanical system pressure gauge.

2-3.2 Converter and Cable Requirements.

Provide the converters in enclosures suitable for the exterior location of the project and in accordance with the requirements in Chapter 3.

Provide the cables in non-metallic ductbanks when underground, for the specialty systems as needed, and in accordance with the requirements in Chapter 3

CHAPTER 3 ELECTRICAL REQUIREMENTS IN HANGARS

3-1 NORMAL POWER DISTRIBUTION.

Provide normal power within Aircraft Hangars in accordance with the facility UFC 4-211-01. It is usually a 3-phase wye-connected, underground secondary service rated at 480 Volts Alternating Current (VAC). For projects outside of the United States and its territories and possessions, electric power is in accordance with UFC 3-510-01, *Foreign Voltages and Frequencies Guide.*

3-1.1 Hazardous (Classified) Locations.

Design hazardous (classified) locations including the hangar bay and adjacent spaces in accordance with NFPA 70, *National Electrical Code* requirements for hazardous locations. At a minimum, classify adjacent spaces that are not suitably cutoff as Class I Division 2 up to 18 inches (460 mm) above the floor of the hangar bay adjacent to the space.

Note: The area within 5 feet of any aircraft fuel vents and any fuel containing portion of the aircraft is Class I Division 2. For practical use and mission-flexibility, this is generally simplified to within 5 feet (1.5 m) horizontally of any aircraft surface and vertically from 5 feet (1.5 m) above the surface down to the floor.

- If a space is adjacent and communicates with a hazardous location, comply with the requirements and figures in UFC 4- 211-01.

For Navy and Marine Corps: Design all hangar bays electrically as hazardous areas for maintaining fueled aircraft regardless if the aircraft contain fuel or not. Assume all aircraft in hangar bay will enter fueled.

3-1.2 Electrical Equipment.

Comply with the facility UFC 4-211-01 for the minimum requirements for the electrical equipment enclosures in the hangars. Comply with the technical notes in the UFGSs for the equipment enclosures for converters located in the hangars.

For Army: All electrical equipment in the hangar bay is required to be in a NEMA 250 Type 3R or weather proof enclosure.

3-2 AIRCRAFT POWER DISTRIBUTION.

Aircraft have specific power requirements, including unique voltages, frequencies, and capacities. Review the aircraft requirements of the aircraft being maintained in the hangar bay to determine the appropriate services. Provide appropriate services in voltage, frequency, and capacity to service the aircraft.

Coordinate with the latest requirements in UFGS 26 35 43*, 400 Hertz (Hz) Solid State Frequency Converter* and UFGS 26 35 44*, 270 VDC Solid State Converter.* Provide permanently-mounted equipment located within the hangar bay or an adjacent space as follows:

- Permanently-mounted equipment may be installed within the hangar bay or within an adjacent space to the hangar bay. If equipment is installed in the hangar bay it may be either floor-mounted or mounted on the wall at a higher elevation. If the equipment is mounted at a higher elevation, coordinate the support of the equipment with the structural engineer. If the equipment is mounted on the floor, provide a stand for the equipment to elevate the equipment a minimum of 18 inches (0.46 m) AFF to avoid having the equipment in the Class I Division 2 hazardous space. Coordinate location of equipment to maintain the clear zone. Refer to UFC 4-211-01, paragraph 2-3: Minimum Aircraft Maintenance Bay Clearances for clear zone requirements.
- Provide a detail on the drawings that identifies the location, mounting and permitted maintenance access areas (the maintenance envelope) for each converter.
- Provide solid-state equipment for special power units.
- Permanently-mounted equipment typically has controls mounted on the face of the equipment. If the equipment is mounted at a higher elevation, or in an adjacent space, provide remote control and displays at an elevation within the hangar bay that is accessible by the user.

For Air Force:

a. Aircraft power distribution equipment is government furnished. Power distribution equipment may be provided as Service Equipment (SE) carts or permanently mounted equipment.

b. Government-furnished SE carts may be diesel powered or electrically powered. If an SE cart is diesel powered, park the SE equipment outside of the hangar bay and extend cables to the aircraft from the SE equipment. If an SE cart is electrically powered, provide a 480V, 3-phase receptacle on the wall or pedestal and extend the power from the connection to the equipment. SE carts are government furnished equipment. Coordinate the sizes and type of connection with the users and equipment available at the installation.

For Army, Navy and Marine Corps: All Converters are now required to be individual output, Point of Use (POU) converters, with each converter serving only one receptacle on an aircraft.

For Army: A combination converter (having both 400 Hz and 28 VDC outputs) is only permitted when it is specifically identified as being required on a particular project.

For Navy and Marine Corps:

a. Combination Converters, (having both 400 Hz and 270 VDC outputs, or having both 400 Hz and 28 VDC outputs) are not allowed**.**

b. Converters in hangars must be flush mounted against the wall, must not require back access for maintenance, and must comply with the “Maintenance Envelopes” identified on the project drawings.

c. Coordinate with the Navy Functional Data Sheets (FDS) and Space Types information in UFC 4-211-01 for additional information on Specialty Power Systems requirements, such as locations (like Avionics shops) where additional 400 Hz, 28 VDC, or 270 VDC services are needed.

3-2.1 Power Distribution Service Points.

Distribute aircraft power from permanently-mounted equipment located on the wall.

3-2.1.1 Wall-mounted connection points.

Different aircraft have different power requirements and connections. Match receptacle and cable type to aircraft being maintained. Provide wall-mounted connection points close to the distribution equipment. Coordinate the location of the connection points with the location of the aircraft connection point to minimize the length of the cable from the wall to the aircraft. Provide one of the following connections:

- Provide wall-mounted cable storage racks for storage of the cable. When receptacles are installed, mount receptacles above electrical hazardous location. Provide floor-mounted cable protectors from the wall across the service lane to the aircraft side of the service lane. Lay cables in the cable protector to protect cable from cross traffic while the cables are extended and in use.
- When approved by the Activity and Facilities Manager, provide wall-mounted electrically or air driven reels. Approval authority must agree to the potential additional maintenance and power quality issues related to how the power is transferred from the converter to the reel and to the cable on the reel. These additional connections and contact surfaces must be maintained. Install electric motors above the electrical hazardous location. Provide reel controls as part of the cable assembly. Coordinate motor size and type with length and weight of cable provided. If used, DOR must include reliability information from multiple manufacturers in the Basis of Design and add appropriate information to the specifications.

For Army: Cables connecting to the service point may or may not be provided as part of the service.

For Air Force:

a. Distribute aircraft power from government furnished SE carts. Government-furnished SE equipment is mobile and provides a flexible solution. The aircraft cables are typically connected to the SE cart. The equipment is owned and maintained by the maintenance mission and typically the equipment will be shared for hangar and on-ramp maintenance. A storage area may also be required for the equipment.

b. The cables connecting to the aircraft power distribution service point may or may not be provided as part of the service. Coordinate the provision of the cables with the mission owner.

For Navy and Marine Corps: Provide cables connecting to the service point as part of the service.

3-2.1.2 Permanently-Mounted Pedestal.

For Air Force, Navy and Marine Corps: Permanently-mounted pedestals are not permitted.

For Army: Provide permanently-mounted pedestals. Coordinate the connection point in the hangar floor space with the location of the aircraft. Permanently mount the pedestal to the hangar floor. Locate pedestals to avoid aircraft movements. Coordinate the location of pedestals with the clearance requirements listed in UFC 4-211-01, paragraph 2-3: Minimum Aircraft Maintenance Bay Clearances. Pedestal may have multiple mechanical, electrical, and communication services including power, compressed air, network connections, and water. Coordinate types of all service utilities to be provided on pedestal with activity. Route utility connections under the hangar floor from the wall to the pedestal. Mount all electrical utilities a minimum of 18 inches (0.46 m) AFF. Seal all electrical penetrations from the floor, per NFPA 70.

3-2.1.3 Retractable (Pop-up) Pedestal.

Retractable (Pop-up) pedestals are not permitted.

3-2.1.4 Aircraft Power Distribution Point Utility Coordination.

Other services including compressed gasses, water, and preconditioned air are required to maintain aircraft. Coordinate the location of electrical services with all other utilities.

3-3 AIRCRAFT POWER SYSTEMS.

Provide the appropriate aircraft power systems in voltage, frequency, and capacity to service the aircraft being maintained.

For Army: Special Power.

a. Use Table 3-1: Army Aviation Platform Ground Service Baseline Requirements for Service Baseline Requirements.

b. Integrate the system with the building power system and provide a complete system with all cables and connectors required to interface with the aircraft. No ground power units (carts) are allowed. Design system to provide access to each aircraft parking space without any cables or equipment passing thru the five foot clear zone around the hangar bay floor.

For Navy and Marine Corps: Refer to Table 2-1 for additional information.

Table 3-1 Aviation Platform Ground Service Baseline Requirements

GROUND SERVICE	AVIATION PLATFORM GROUND SERVICE BASELINE REQUIREMENTS							
	AHH-64A	AH-64D	UH-60A/L	UH/MH-60M, X	CH-47D	DH/MH-47E, F, G	OH-58D	ARH-70A
400 Hz 200/115 V	35 kW	35 kW	45 KW	45 kW	20 kW	40 kW	10 kW	N / A
28 VDC START	NONE	NONE	NONE	NONE	NONE	NONE	500-750A START	500-800A START
28 VDC SERVICING	NONE	NONE	NONE	NONE	300A SERVICING	300A SERVICING	200A SERVICING	200A SERVICING

3-3.1 Aircraft 400 Hertz (Hz) Service.

Design a complete, functioning 200Y/115VAC, three phase, 400 Hz power system, including converter, cables, and connectors, to support the aircraft maintenance activities. Provide Point of Use (POU) 400 Hz service in the hangar bays and in shops where 400 Hz is required by the users.

- Combination converters (having multiple 400 Hz outputs, having both “400 Hz and 28 VDC” power outputs, or having 400 Hz and 270 VDC outputs) are not permitted on Navy and Marine Corps projects. A combination converter (having both 400 Hz and 28 VDC outputs) is permitted on an Army project when it is specifically identified as being required.

- Previous versions of criteria referred to 400 Hz equipment sized only in kVA at 0.8 lagging power factor. This has changed, and designs are now required to use kW instead of kVA as the unit of power measurement for converters here and on the project drawings. This significant change in equipment designation, has been made to:

  a. Ensure that our equipment meets the full required load range, including full power at unity power factor.

  b. Eliminate the problems that have been occurring with existing equipment in the field.

  c. And to accommodate the increasing nonlinear load characteristics of Military equipment.

     - For Navy and Marine Corps documents, including their Facilities Requirements Documents (FRD)s, are being revised to coordinate with this change to kW. Army documents are in the review process. UFGS 26 35 43, *400 Hz Solid State Frequency Converter* has been rewritten to incorporate this requirement.

3-3.1.1 400 Hz Converter Sizes.

Coordinate the exact number and sizes of converters with the users supported.

For Army: Converters are sized per Table 3-1.

For Navy and Marine Corps: Provide 90 kW converters for all fixed wing aircraft and provide 45 kW converters for all rotary wing aircraft unless there are specific project design requirements approved by NAVFAC and NAVAIR. See Table 2-1. (One example, may be the direct replacement of an existing, larger kW converter),

Design the system to provide power to each aircraft parking spot. Design system to compensate for voltage drop and provide sufficient voltage at the point of service. Provide voltage drop calculations, in accordance with requirements in UFC 3-501-01, to meet the voltage requirement at the aircraft point-of-service, and to meet the requirements of the aircraft power monitor. See Appendix A for sample equations.

For Air Force: Aircraft 400 Hz systems are provided using government-furnished SE or government-furnished fixed equipment. A fixed 400 Hz system may be provided for a building, if approved by Civil Engineering (CE).

For Army, Navy and Marine Corps: 400 Hz converters, cables, and connectors are Real Property Installed Equipment (RPIE) equipment.

3-3.1.2 Aircraft 400 Hertz (Hz) Special Power Distribution Cables.

Provide 400 Hz cable in accordance with SAE AS7974 and SAE AS5756/6, consisting of six power conductors, two per phase, helically laid around one central neutral conductor and six control conductors, minimum of #18 American Wire Gage (AWG), specifically designed for 400 Hz applications.

For Army:

a. Coordinate the cable amperage and cable length between 30 and 100 ft. (9.1 to 30.5 m) with the aircraft on the project.

b. Base the size of the power conductors on the kilowatt (kW) rating of the aircraft.

c. Base the length of the cable on the distance from the distribution equipment to the aircraft location.

For Navy and Marine Corps:

a. Use the 260 Amp and 105 feet (32 meters) length options in the specification for all cable assemblies with the 90 kW converters.

b. Use the 180 Amp and 105 feet (32 meters) length for all 45 kW converters, unless the project requirements given to the designer of record specifically identify that the 90 feet (27 meters) length is sufficient.

3-3.1.3 Aircraft Cable Provision.

Coordinate how the cables are being provided for the project with the users. The cables may be part of the Military Construction (MILCON) or the cables may be equipment provided by the user. If the cables are permanently affixed to the facility distribution system, the cable is considered to be part of the MILCON. If the cables can be disconnected from the facility distribution system, the cable is provided by the user.

3-3.1.4 Aircraft Cable Interlock Circuits.

Incorporate safety requirements into the converter / cable interlock circuits. Comply with NFPA 70 E and UFC 3-560-01, which mandates the use of Standard Operating Procedures (SOPs) for electrical equipment. Confirm that any exemptions or exceptions to the safety criteria has been identified within these SOPs.

For Army, Navy and Marine Corps:

a. Provide the “split F interlock” for all new installations. This interlock is built into the cable end to ensure that the cable is not energized until it is connected to the aircraft, and that it is automatically deenergized as soon as disconnecting from the aircraft has begun. See MIL-DTL-32180 for technical information, and typical details and schematics on the operation of the interlock.

b. When the aircraft cable specification is used for existing converters, coordinate with the Activity to ensure they understand the new safety requirements being built into the new “split F interlock” cable ends, and that the Activity has the appropriate Standard Operating Procedures (SOPs) in place, per UFC 3-560-01, for the remainder of their existing equipment.

For Air Force: When involved with certain “Legacy” Air Force Aircraft, the 28 VDC may need to be changed to utilize one of the 115 V, 400 Hz phases instead. Coordinate with Activity to confirm requirements.

3-3.2 Aircraft 28 Volts Direct Current (VDC) Service.

Design a complete and functioning 28 VDC power system, including converter, cables, and connectors, to support the aircraft maintenance activities. Provide Point of Use (POU) 28 VDC service in the hangar bays and in shops where 28 VDC is required by the users.

For Army: A combination converter (having both 400 Hz and 28 VDC outputs) is permitted on an Army project when it is specifically identified as being required. This information has been incorporated as options in the UFGS 26 35 43, *400 Hertz (Hz) Solid State Frequency Converter*.

For Navy and Marine Corps: Combination converters (having multiple 28 VDC outputs, or having both “400 Hz and 28 VDC” power outputs) are no longer permitted on Navy and Marine Corps projects. Individual 28 VDC Converters are required. Contact NAVFAC Atlantic, Code DC 44 – Criteria Manager at (757) 322-4327, for a draft 28 VDC specification that can be modified for the specific project.

Coordinate the exact number and sizes of converters with the users supported. Design the system to provide power to each aircraft parking spot, when required.

For Airforce: Aircraft 28 VDC Service Distribution systems are provided using government-furnished SE cart or government furnished fixed equipment. A fixed 28 VDC system may be provided for a building, if approved by CE.

For Army, Navy and Marine Corps: 28 VDC converters, cables and connector are RPIE equipment. The use of centralized systems serving multiple aircraft are prohibited.

3-3.2.1 Aircraft 28 VDC Distribution Cables.

Provide 30 to 100 ft. (9.1 to 30.5 m) 28 VDC cable assembly, consisting of two individual power conductors banded together with non-metallic bands in accordance with SAE AS5756. Provide strain relief, and appropriate integrally molded connector in accordance with SAE AS7974. Base the size of the conductor on the kW rating of the aircraft. Base the length of the cable on the distance from the distribution equipment to the aircraft location.

Coordinate how the cables are being provided for the project with the users. The cables may be part of the Military Construction (MILCON) or the cables may be equipment provided by the user. If the cables are permanently affixed to the equipment, the cable is considered to be part of the MILCON. If the cables can be disconnected from the facility distribution system, the cable is provided by the user.

3-3.3 Aircraft 270 VDC Service.

For Air Force, Navy and Marine Corps: Design a complete and functioning 270 VDC power system, including converter, cables, and connectors, to support the aircraft maintenance activities. Provide Point of Use (POU) 270 VDC service in the hangar bays and in shops where 270 VDC is required by the users. Combination converters (having "multiple 270 VDC outputs", or having both "400 Hz and 270 VDC" power outputs) are no longer permitted.

For Air Force:

a. Coordinate the exact number and sizes of ground power units with the users supported. Design the system to provide power to each aircraft parking spot.

b. Aircraft 270 VDC systems are provided using government-furnished SE carts or government-furnished fixed equipment. A fixed 270 VDC system may be provided for a building, if approved by Civil Engineering (CE).

For Navy and Marine Corps:

a. Coordinate the exact number of ground power units with the users supported. Design the system to provide power to each aircraft parking spot.

b. The Navy and Marine Corps have standardized on one size, 72 kW for all 270 VDC converters. Coordinate with the requirements in UFGS 26 35 44, *270 VDC Solid State Converter*.

c. Aircraft 270 VDC converters, cables, and connectors are RPIE equipment.

3-3.3.1 Aircraft 270 VDC Distribution Cables.

Provide 30 to 100 ft. (9.1 to 30.5 m) 270VDC cable consisting of a single jacketed multi-conductor cable with power and controls incorporated into the cable with the appropriate connector. Base the size of the conductor on the kW rating of the aircraft. Base the length of the cable on the distance from the distribution equipment to the aircraft location.

Coordinate how the cables are being provided for the project with the users. The cables may be part of the Military Construction (MILCON) or the cables may be equipment provided by the user. If the cables are permanently affixed to the equipment, the cable is considered to be part of the MILCON. If the cables can be disconnected from the facility distribution system, the cable is provided by the user.

For Navy and Marine Corps: Refer to Table 2-1 for additional information.

3-3.4 Special Additional 60 Hz Power Service Points.

For Navy and Marine Corps: Provide special additional 60 Hz power service points in hangars as identified in the Navy Functional Data Sheets. Coordinate all requirements with users and aircraft manufacturer and dedicate adequate wall space for all equipment. The power service points may include:

a. Three-phase, 480V, 4-wire, 60 Hz, receptacles for government furnished support equipment (SE). These receptacles are built by very few manufacturers and are identified by part number. Coordinate required outlet amperage and type requirements with the users.

b. Single-phase, 120V, 60 Hz, ground fault interrupt duplex utility outlets.

c. For Triton Type IV hangars: As a minimum, provide one special receptacle for Ground Support Equipment (GSE) at each aircraft parking space (minimum four per hangar bay). The receptacle required is a 480 VAC, 100 ampere, three-phase, four-wire, 60 Hz, MIL-C-22992, Class L, Connector Size 44, with an Insert Arrangement per MS14055 Figure 5.

3-4 GROUNDING AND BONDING.

Provide grounding and bonding in accordance with UFC 3-575-01, *Lightning and Static Electricity Protection Systems*.

3-5 PHOTOGRAPHS.

Figure 3-1 Recent Converter Installations - Example 1

Figure 3-2 Recent Converter Installations (400Hz & 28 VDC) - Example 2

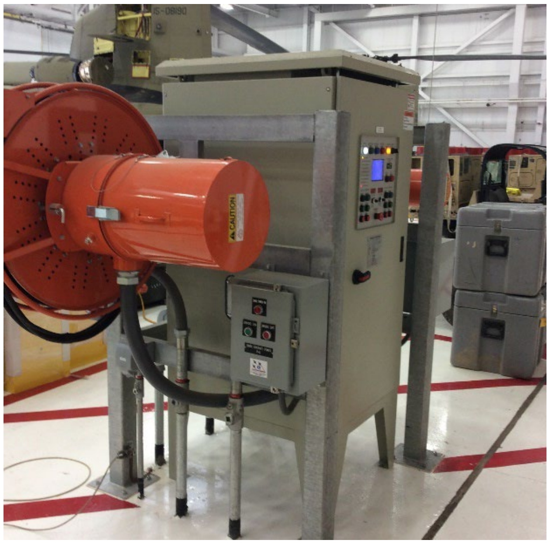


Figure 3-3   - Recent Converter Installations (270 VDC & 400 Hz) – Example 3

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APPENDIX A SUPPLEMENTAL TECHNICAL INFORMATION

A-1 CALCULATIONS.

Design analysis and documentation, including electrical calculations for Specialty Electrical Systems, are required in accordance with UFC 3-501-01 utilizing power modelling software. The standard 60 Hz calculations, complete to the incoming side of the converter, should all be covered in the Basis of Design requirements for other electrical UFCs. With Point of Use systems being required for all new designs, 400 Hz, 270 VDC and 28 VDC specialty system calculations should be limited to:

a. Converter connecter via specified cables direct to aircraft connector.

b. Converter to a cable reel, then to the aircraft.

c. Feeding from a platform mounted converter, down to the wall mounted connection points, then to the aircraft.

d. Feeding from the wall mounted converter (for Army) under the clear zone (walkway), to the pedestal mounted connection points, then to the aircraft.

Note: Future updates to this UFC will look at incorporating sample calculations with power modeling software printouts.

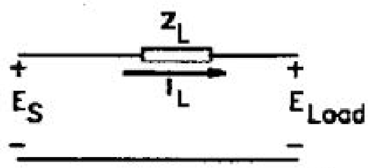
A-2 400 HZ CALCULATIONS.

The inductive contribution to the reactance voltage drop of 400-Hz systems is roughly seven times greater than that of 60-Hz systems, which necessitates certain modifications to conventional distribution and utilization system design to compensate for the increased voltage drop. The circuit diagram and formulas presented in Figure A-1 have been reproduced from the archived UFC 3-555-01N, and can be used with Table A-1 for determining 400 Hz system voltage drops.

- The minimum voltage required at the aircraft is 113 Volts.
- Therefore, maximum voltage drop allowed = 120 - 113 = 7 volts.

Table A-1 is a limited part of Table B-3 in archived UFC 3-555-01N, which was reprinted from “Actual Specifying Engineer,” February 1972. This table gives the effective A.C. resistance and inductance values for copper conductors for THHN/THWN insulations and in air, non-metallic conduits, and rigid aluminum conduits.

Figure A-1 **Simplified 400 Hz Circuit Diagram and Formulas**



E_S – Source Voltage=208Y/120

E_{Load} – Load Voltage

I_L – Line Current

Z_L – Line Impedence=R_{ac}+jwL

R_{ac} – Alternating Current Resistance

L – Inductance

w – Angular Frequency=2 x 3.14 x frequency

SIMPLIFIED CIRCUIT DIAGRAM

FORMULAS

$E_S = I_L Z_L + E_{Load}$

$E_{Load} = E_S - I_L Z_L$

Line–to–Neutral Voltage Drop= $|E_S| - |E_{Load}| = I_L\ |Z_L|$

Line–to–Line Voltage Drop= $\sqrt{3}\,(|E_S| - |E_{Load}|) = \sqrt{3}\ I_L\ |Z_L|$

NOTE: FORMULAS USING PER UNIT QUANTITIES ARE ALSO ACCEPTABLE PROVIDED ALL INFORMATION IS INCLUDED IN THE CALCULATIONS.

A-3 OTHER SYSTEM CALCULATIONS

Since FLEDS (400 Hz low voltage Flight Line Electrical Distribution Systems) and Medium Voltage 400 Hertz distribution systems are not permitted for new designs, see UFC 3-555-01N and UFC 4-211-01 for calculations that may have been used on existing systems.

Those archived UFCs also contain old sample methods for establishing a multi-facility utility demand calculation using aircraft demand loading, and for establishing a facility (Hangar) load calculation and facility transformer / service equipment sizes using converter kw loads and aircraft demand loading. However, they should be considered for informational purposes only, since they also intermix medium voltage 400 Hz and the low voltage distributed 400 Hz systems for converters that are larger than our current POU converters.

A-4 400 HZ NON-LINEAR LOAD BANK INFORMATION

In order to comply with the stringent 400 Hz non-linear load range requirements in UFGS 26 35 43, manufacturers will have to develop a means to test their converters. They must prove that they continue to meet the performance requirements when operating into a non-linear load with not less than 15 percent current Total Harmonic Distortion (THD), composed of not less than 6 percent of the third harmonic and not less than 7 percent of the 5th harmonic.

Per NAVAIR, the intent of the load description with the 15 percent current THD is to portray a 50 percent linear and 50 percent non-linear load, with a nonlinear load designed to emulate a six pulse rectifier supplying a resistive load. Figure A-2 is a sample schematic diagram that is referred to in the technical notes in UFGS 26 35 43 and has been provided by NAVAIR for manufacturer's information. If the manufacturers would like to discuss this diagram, please contact the NAVAIR POC designated in paragraph titled Regulatory Authorities in this UFC.

Figure A-2 **Example of Non-Linear Load Bank Schematic**

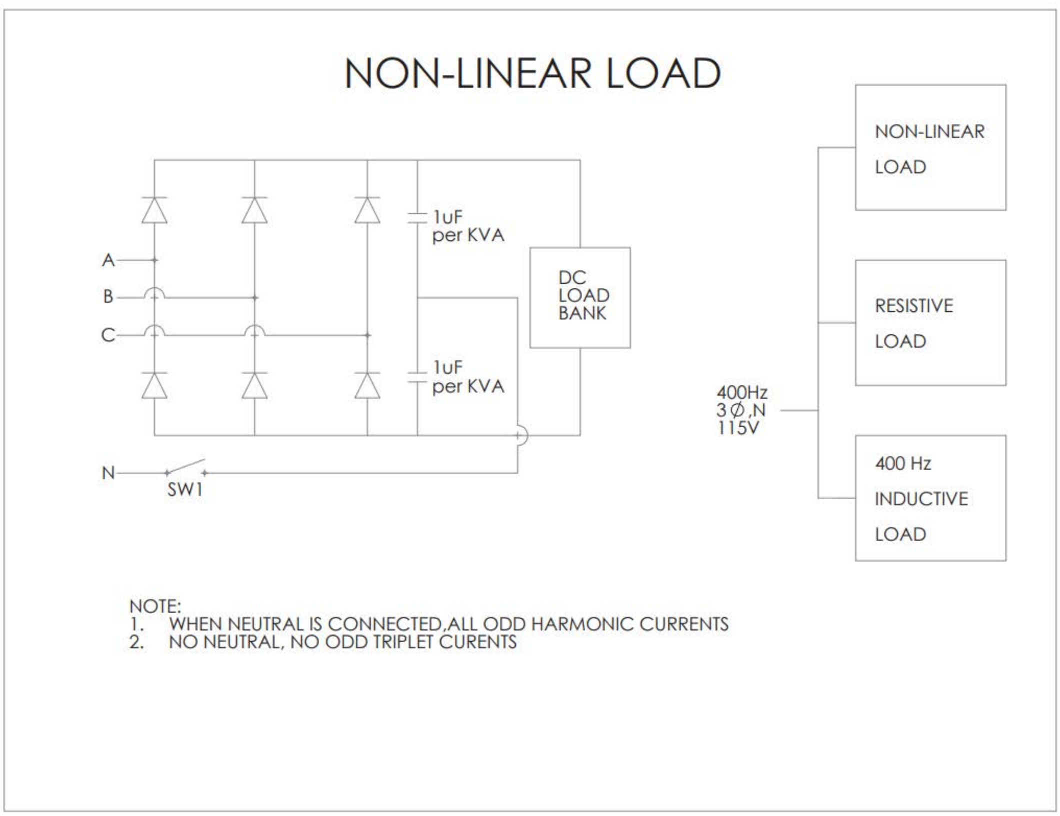


Table A-1 Effective AC Resistance and Inductance Values for THHN Copper Single Conductors at 400 Hz (Rac = microohms per ft, L = microhenries per ft)

Wire Size	In Air		Non-metallic Conduit		Rigid Alum. Conduit	
	Rac	L	Rac	L	Rac	L
#12	1970.67	0.08946	1970.67	0.10735	1970.67	0.10736
#10	1241.24	0.09131	1241.24	0.10957	1241.24	0.10957
#8	781.92	0.09403	781.92	0.11284	781.93	0.11284
#6	493.49	0.09223	493.49	0.11067	493.50	0.11067
#4	315.37	0.09317	315.37	0.11181	315.38	0.11181
#2	198.15	0.08921	198.15	0.10705	198.15	0.10705
#1	164.66	0.08788	164.66	0.10546	164.66	0.10546
#1/0	135.68	0.08675	135.68	0.10410	135.70	0.10410
#2/0	115.56	0.08506	115.56	0.10208	115.57	0.10208
#3/0	97.38	0.08346	97.38	0.10015	97.38	0.10015
#4/0	84.83	0.08263	84.83	0.09916	84.85	0.09916
250 MCM	76.68	0.08226	76.68	0.09872	76.68	0.09872
300 MCM	70.57	0.08090	70.57	0.09708	70.57	0.09708
350 MCM	64.35	0.08099	64.35	0.09719	64.36	0.09719
400 MCM	61.60	0.08015	61.60	0.09618	61.61	0.09618
500 MCM	54.79	0.07863	54.79	0.09436	54.79	0.09436
750 MCM	43.98	0.07779	43.98	0.09335	43.98	0.09335
1000 MCM	37.62	0.07684	37.62	0.09221	37.62	0.09221

Note 1: Table is a partial reprint from the 1972 February “Actual Specifying Engineer”.

Note 2: MCM is now more commonly referred to as kcmil, or thousands of circular mils.

APPENDIX B GLOSSARY

B-1 ACRONYMS

AC	Alternating Current
AFCEC	Air Force Civil Engineer Center
AWG	American Wire Gage
BIA	Bilateral Infrastructure Agreement
BOD	Basis of Design
CCR	Criteria Change Request
CE	Civil Engineering
DC	Direct Current
DoD	Department of Defense
DOR	Designer of Record
FDS	Functional Data Sheets
FLEDS	Flight Line Exterior power Distribution Systems
FPUS	Fixed Point Utility Systems
FRD	Facility Requirements Document
ft	Feet (or Foot)
GPU	Ground Power Unit
GSE	Ground Support Equipment
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
Hz	Hertz
kVA	Kilo-Volt-Ampere
LANT	NAVFAC Atlantic
lb	Pound

m	Meter
mm	Millimeter
MCM	kcmil, or thousands of circular mils
MILCON	Military Construction
NAVAIR	Naval Air Systems Command
NAVFAC	Naval Facilities Engineering Systems Command
NAWCAD	Naval Air Warfare Center Aircraft Division
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
O&M	Operation and Maintenance
POU	Point-of-Use
RFP	Request for Proposals
RPIE	Real Property Installed Equipment
SE	Service Equipment
SOFA	Status of Forces Agreements
SOPs	Standard Operating Procedures
UFC	Unified Facilities Criteria
UFGS	United Facilities Guide Specifications
U.S.	United States
V	Volt
VAC	Volts Alternating Current
VDC	Volts Direct Current

APPENDIX C REFERENCES

C-1 GOVERNMENT

DEPARTMENT OF DEFENSE

MIL-STD-704, *Aircraft Electric Power Characteristics.*

MIL-STD-3007, *Standard Practice for Unified Facilities Criteria, Facilities Criteria, and Unified Facilities Guide Specifications*.

MIL-DTL-32180, *Cable Assembly, Electrical Aircraft.*

U.S. FEDERAL AVIATION ADMINISTRATION

www.faa.gov/

FAA AC 70/7460-1, *Obstruction Marking and Lighting*

UNIFIED FACILITIES CRITERIA

www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 1-200-01, *DoD Building Code*

UFC 2-000-05N, *Facility Planning Criteria for Navy and Marine Corps Shore Installations*

UFC 3-260-02, *Pavement Design for Airfields*

UFC 3-501-01, *Electrical Engineering*

UFC 3-510-01, *Foreign Voltages and Frequencies Guide*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-530-01, *Interior and Exterior Lighting Systems*

UFC 3-535-01, *Visual Air Navigation Facilities*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-555-01N, *400 Hertz Medium Voltage Conversion/Distribution and Low Voltage Utilization Systems*

UFC 3-560-01, *Operation and Maintenance, Electrical Safety*

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UFC 4-211-01, *Aircraft Maintenance Hangars.*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs

UFGS 25 05 11, *Cybersecurity for Facility-Related Control Systems*

UFGS 26 35 43, *400 Hz Solid State Frequency Converter*

UFGS 26 35 44, *270 VDC Solid State Converter*

C-2 NON-GOVERNMENT

INTERNATIONAL ELECTROTECHNICAL COMMISSION

www.iec.ch

IEC 60529, *Degrees of Protection Provided by Enclosures*

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

www.nema.org

NEMA 250, *Enclosures for Electrical Equipment (100 Volts Maximum)*

NATIONAL FIRE PROTECTION ASSOCIATION

www.nfpa.org

NFPA 70, *National Electrical Code*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL

www.sae.org

SAE AS7974, *Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft*

SAE AS5756, *Cable, Power, Electrical, Portable*

SAE AS5756/6, *Cable, 3-Phase Power, Electric Portable, Multiconductor, 90 Degrees C, 600V, Ozone Resistant, Split phase*

UFC 3-560-01
24 July 2017
Change 3, 15 May 2023

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE: ELECTRICAL SAFETY

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

UFC 3-560-01
24 July 2017
Change 3, 15 May 2023

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE: ELECTRICAL SAFETY

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	21 Feb 2018	Paragraph 1-5
2	31 Oct 2019	Miscellaneous changes throughout document to update arc flash requirements to comply with the latest NFPA 70E version. Reference updates and changes within tables are not marked with a /2/.
3	15 May 2023	Miscellaneous changes throughout the document to update arc flash requirements to comply with the latest NFPA 70E version with the exception of 70E Article 360 Annex R

This UFC supersedes UFC 3-560-01, Electrical Safety, O&M, dated 14 April 2015, with Change 5 and all preceding changes.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
SUMMARY SHEET

Document: UFC 3-560-01, Operation and Maintenance: Electrical Safety

Superseding:

- UFC 3-560-01, *Electrical Safety, O&M*, Change 5.

  The following documents were superseded by the original issuance of UFC 3-560-01 in 2006.

- Air Force Manual 32-1185, *Electrical Worker Safety.* This manual was prepared in draft form, but was not issued.
- TM 5-682, *Facilities Engineering, Electrical Facilities Safety.*
- UFC 3-560-10N (previously MIL-HDBK-1025/10), *Safety Of Electrical Transmission And Distribution Systems*.
- Draft UFC 3-560-02, *Electrical Safety*. This document was made mandatory guidance by Air Force Engineering Technical Letter (ETL) 04-15, *Electrical Safety Guidance*

Description: This UFC 3-560-01 incorporates tri-service requirements into one unified document and provides electrical safety requirements for all electrical work activities.

Reasons for Document:

- Provide guidance for all aspects of electrical safety.
- Conform UFC criteria to recently issued industry standards.
- Clarify work requirements for unique activities.

Impact: There are cost impacts associated with the required use of personal protective equipment (PPE). The new requirements associated with working on exposed, energized circuits involve additional safety precautions. However, the following benefits will be realized.

- Electrical safety criteria are more consistent with industry standards and OSHA requirements.
- Personnel working on electrical systems have improved guidance to ensure a safer working environment.

Unification Issues:

- Paragraph 1-4.3 Service-Specific Criteria, lists service specific documents that add additional safety requirements to this UFC. In several places in this UFC these documents are referenced for the technical subject being discussed. As an example, in Chapter 8 Energized Work, in sub-paragraphs 8-5, 8-6, and 8-7 additional requirements are listed for the Navy, Air Force and Army, respectively. These requirements, in general, incorporate the documents from Paragraph 1-4.3.

- Chapter 12 Shore-to-Ship Electrical Power Connections has Navy specific criteria requirements.

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FIGURES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE.

This Unified Facilities Criteria (UFC) provides safety requirements for electrical workers. The requirements address various aspects associated with work safety for electrical workers. Wherever specific instructions are provided, the emphasis is on the job safety requirements; additional work instructions will likely be necessary related to the actual work being performed.

1-2 SCOPE.

This UFC provides safety requirements and guidance for anyone working on or near electrical components rated at 50 volts or above in facilities and related infrastructure. The scope includes electrical substations and switching stations, the associated distribution systems, and extending to electrical distribution systems inside facilities, including electrical equipment covered by UFC 3-501-01.

For the purposes of this UFC, low voltage is defined as 1,000 volts or less. Voltages higher than 1,000 volts are referred to as high voltage. Refer to the Glossary for definitions.

Note: The prior edition of this UFC designated 600 volts as the upper limit for low voltage because this voltage was considered the highest low voltage that would be typically encountered. The designation of 1,000 volts as low voltage has been chosen to be consistent with NFPA 70E and NFPA 70. However, NFPA 70E provides the same approach distances for voltages between 751 volts to 15 kV, and refers to voltage above 600 volts as medium voltage in its Annex D. NFPA 70 provides different requirements for voltages below 600 volts, between 600 and 1,000 volts, and above 1,000 volts.

1-2.1 Need.

Electrical personnel involved in operating and maintaining electrical facilities can be injured and equipment can be damaged whenever electrical systems and components are not handled safely. The adoption and enforcement of safe electrical practices will reduce the hazards to personnel.

1-2.2 Familiarity and Requirements.

Each worker must understand and apply those safety requirements of this UFC that apply to the work performed. This safety manual must be readily available to each worker for reference and study.

1-2.3 Mishap Prevention.

Mishap prevention is a basic responsibility of every worker. Personal safety, fellow workers' safety, and the general public's safety depend upon compliance with this manual's requirements. Safety takes precedence over work production.

1-2.4 Unclear Conditions.

If this UFC does not cover a specific working condition or job requirements are unclear, workers must obtain clear instructions from an authorized individual-in-charge before proceeding with the work.

1-2.5 Applicability.

1-2.5.1 Facilities and Related Infrastructure.

This UFC applies primarily to maintenance workers involved in electrical work at DoD facilities and related infrastructure. This UFC covers the authorized individual-in-charge, crew members, and qualified and unqualified electrical workers. The authorized individual-in-charge might be a supervisor, a foreman, or a lead electrical worker depending upon local policy. This UFC applies to operations, maintenance, and construction functions. It also applies to design functions when on project sites. Construction activities performed by contractors are subject to the requirements of this UFC only when required by appropriate contract documents. It is more common for contracted construction to have EM 385-1-1, *Safety and Heath Requirements*, specified.

Note: For Navy electronics personnel/operations, follow the guidance outlined in SPAWARINST 5100.9D, Navy Shore Electronics Safety Precautions.

1-2.5.2 OCONUS Locations.

Facilities located outside of the United States must also comply with the applicable host nation standards; refer to UFC 3-510-01 for additional information. Different voltages, frequencies, and grounding conventions often apply in other host nations; however, follow the design principles provided in this UFC to the extent practical.

1-2.5.3 Contingency Tactical Locations.

Although the principles of electrical safety apply to work on any electrical system, this UFC does not apply to the following:

- Forward operating base.
- Contingency operating base.
- Other temporarily manned contingency tactical locations.

Refer to service-specific documents for requirements.

1-2.5.4 Privatized Systems.

This UFC does not apply to electrical equipment and electrical systems owned **\2** and maintained **/2/** by other organizations outside DoD. Non-DoD organizations may typically be the local utility.

1-2.6 Work Type.

The type of work covered includes electrical construction, installation, maintenance, operation, repair, and testing of base and facility electrical systems.

1-2.7 Occupational Safety and Health Administration (OSHA).

Comply with OSHA requirements, as applicable.

1-3 REFERENCES.

Appendix A contains a list of references used in this UFC.

1-4 CODES, STANDARDS, AND PUBLICATIONS.

1-4.1 Applicable Documents.

Several codes, standards, and regulations apply to basic electrical practices; these documents cover electrical work rules, safety procedures, and requirements for electrical installations. Comply with all applicable provisions of the current issues of these consensus standards as follows and as noted elsewhere in this document. The applicable documents include:

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*.
- 29 CFR 1915, *Occupational Safety and Health Standards for Shipyard Employment*.
- 29 CFR 1926, *Occupational Safety and Health, Safety and Health Regulations for Construction*.
- ANSI/NETA ATS, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*.
- ANSI/NETA MTS, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*.
- IEEE C2, *National Electrical Safety Code* (NESC).
- **\2** IEEE 1584, IEEE Guide for Performing Arc-Flash Hazard Calculations.**/2/**

- NFPA 70, National Fire Protection Association (NFPA), *National Electrical Code* (NEC).
- NFPA 70B, *Electrical Equipment Maintenance*.
- NFPA 70E, *Electrical Safety in the Workplace*.

\3 *Note: Wherever NFPA 70E is referenced in this UFC, the reference refers to the* **\2** *2021* **/2/** *edition of NFPA 70E.* **/3/**

1-4.2 NFPA 70E and IEEE C2 Applicability.

For this document, specifically for arc flash related criteria issues mainly identified in Chapter 3 (Pre-Site Safety Management), and Chapter 4 (Protective Clothing and Personal Protective Equipment), the equipment operating voltage of 1,000 volts is the delineation point (demarcation point) between the two main applicable consensus standards, NFPA 70E and IEEE C2 (NESC) as follows.

1-4.2.1 NFPA 70E.

Readily accessible equipment, for all voltage levels, mounted within an enclosure (arc in a box) on grade, below grade, or in close proximity and maintained from grade, falls under the general arc flash requirements of NFPA 70E (listed in Table 4-2) and Additional Work Tasks (provided in Table 4-3).

1-4.2.2 IEEE C2.

Address aerial (overhead) systems and equipment in accordance with the general arc flash requirements of IEEE C2 (NESC) as identified by Additional Work Tasks (Table 4-6) and Table 4-7. Table 4-7 is a modified version of IEEE C2 (NESC) Table 410-2.

1-4.3 Service-Specific Criteria.

Each service has its own documents and criteria relating to occupational safety and health. Refer to the following documents as applicable for the issuing and endorsing services:

<u>Navy</u>

OPNAVINST 5100.23G CH-1, *Navy Safety and Occupational Health Program Manual*.

NAVFACINST 5100.12, *NAVFACENGCOM Safety & Health Program*.

<u>Army</u>

EM 385-1-1, *Safety and Heath Requirements*.

Department of the Army Pamphlet (DA PAM) 385-10, *Army Safety Program*.

DA PAM 385-26, *The Army Electrical Safety Program*.

Air Force

\3 DAFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards*

AFMAN 32-1065, *Grounding & Electrical Systems* **/3/**

1-5 ELECTRICAL SYSTEM MAINTENANCE AND TESTING.

NFPA 70E addresses the role of electrical system maintenance and testing as part of an electrical safety program. **\3** NFPA 70E-2021, Article 110.5 I, states, "*The electrical safety program shall include elements that consider condition of maintenance of electrical equipment and systems*." NFPA 70E-2021, Article 205.3, states, "*Electrical equipment shall be maintained in accordance with manufacturers' instructions or industry consensus standards to reduce the risk associated with failure. The equipment owner or the owner's designated representative shall be responsible for maintenance of the electrical equipment and documentation*." **/3/**

An electrical safety program does not comply with NFPA 70E if it fails to perform maintenance and testing of electrical equipment in accordance with established industry standards or manufacturer's recommendations. **\3** Apply ANSI/NETA MTS, NFPA 70B or maintenance programs that are based on these standards to the greatest extent possible or NFPA 70B for the maintenance and testing of electrical system equipment, **\1** and for additional guidance, reference **\2** TM 5-683/NAVFAC MO 116/AFJMAN 32-1083*, Facility Engineering Electrical Interior Facilities*. **/2/ /1/ /3/**

1-6 WAIVER AND EXEMPTION PROCESS.

MIL-STD 3007 provides the waiver and exemption process for deviations from this UFC.

1-7 VARIANCES FROM NORMAL SAFETY PRACTICES.

The safety requirements of this UFC apply to most commonly encountered working conditions. Occasionally, there might be a need to vary work practices from these requirements due to unusual or abnormal conditions. An example might be to permit work on energized equipment. In these cases, the authorized individual-in-charge must analyze and discuss alternatives with the crew prior to commencing work. Obtain required approvals according to local directives.

1-8 WARNINGS AND NOTES.

The following definitions apply to "Warnings," and "Notes" found throughout this UFC.

1-8.1 Warning.

An operating procedure, practice, or condition that might result in injury or death or equipment damage if not carefully observed or followed.

WARNING

1-8.2 Note.

An operating procedure, practice, or condition that is essential to emphasize.

Note: This is an example of a note.

1-9 ELECTRICAL HAZARDS.

Electrical hazards include electrical shock, electrical arc flash, and electrical arc blast. These electrical hazards are particularly dangerous because the human body usually does not sense electrical energy until contact is made and significant injury has already occurred. Workers must always be aware of the location of energized equipment and its voltage level at each job site. Additionally, workers must be aware of the possible sources of electrical feedback from other energized power sources into the work site. These hazards must be determined before starting work. Pre-job planning must include engineering guidance in understanding the system's operation and review of up-to-date single line and schematic as-built drawings. All apparel, tools, and other equipment required for worker safety must be identified and available before beginning the job.

1-9.1 Electrical Shock Dangers and Effects.

Electric shock results from setting up an electric current path within the human body. The current flows because there is a potential gradient (voltage difference) between an energized object and the grounded worker. Figure 1-1 shows potential gradients and the safe area or equipotential zone which has no potential gradient. Figure 1-2 indicates current flow paths. Table 1-1 indicates the effects of 60-hertz current on humans.

Figure 1-1. Ground Potential Gradient

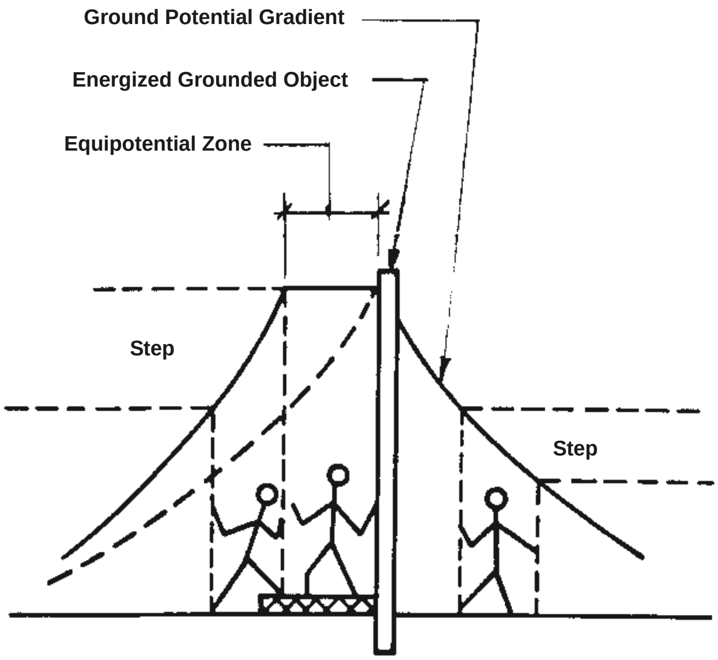
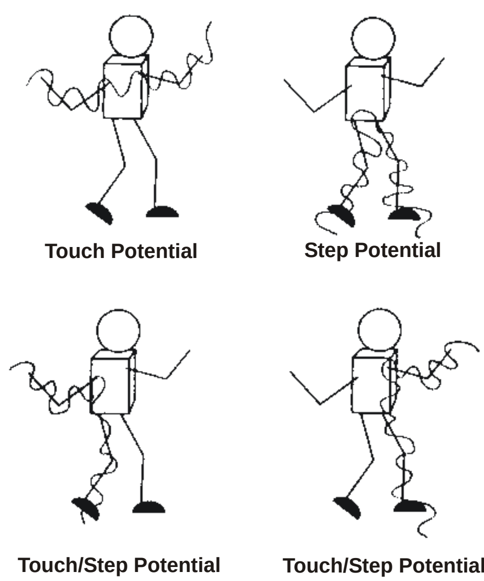


Figure 1-2. Current Path Flow



The current path will determine which tissues and organs will be damaged or destroyed. The pathway is differentiated into three groups: touch potential, step potential, and touch/step potential.

Table 1-1. Effect of 60-Hertz Current on Humans

Effect	Milliamperes	
	Men	Women[1]
Slight sensation on hand	0.4	0.3
Perception threshold	1.1	0.7
Shock, not painful and muscular control not lost	1.8	1.2
Painful shock, painful but muscular control not lost	9	6
Painful shock let-go threshold	16	10.5
Painful and severe shock, muscular contractions, breathing difficult	23	15
Ventricular fibrillation, threshold	75	75
Ventricular fibrillation, fatal (usually fatal for shock duration of 5 seconds or longer)	235	235
Heart paralysis (no ventricular fibrillation), threshold (usually not fatal; heart often restarts after short shocks)	4,000	4,000
Tissue burning (usually not fatal unless vital organs damaged)	5,000	5,000

[1]*The current values for women are lower because women typically have less body mass than men.*

1-9.2 Danger from Electrical Arc Flash and Arc Blast Hazards.

This UFC addresses arc flash criteria for electrical safety. Arcs result from the passage of electric current through air; the air failing as an insulator but serving as a conducting medium. Blasts result when the metal at the arc site expands and vaporizes. High energy arcs can be fatal even at distances of 10 ft (3.0 m) or more.

1-9.3 Workplace Dangers.

Table 1-2 indicates typical hazards that can be found in enclosures, enclosed areas, or confined workspaces. Check the applicable safety data sheets (SDS).

Table 1-2. Typical Hazards

Hazard	Source
Asbestos	Insulation, underground manholes, under houses; crawl spaces, old electric equipment, fire protecting tape, duct banks, arc chutes/shields, cables, and wiring
Polychlorinated biphenyl (PCB)	Old liquid-filled transformers, capacitors, ballasts, lead-sheathed cables
Sulfur hexafluoride (SF6)	Toxic decomposition products from electric arcs or faults acting on SF6 insulation
Combustible gases	Sewer or natural gas accumulations or from outgassing of lead-acid batteries
Carbon monoxide	Cable faults, combustion engine exhausts
Inadequate oxygen	Displaced by heavier-than-air gases
Lead	Outer sheath of lead covered conductors.

1-9.4 Health Hazards of Asbestos.

Asbestos is a known human carcinogen. Its primary route of entry to the body is by inhalation; however, exposure can occur by ingestion. Asbestos is not absorbed through the skin. The diseases caused by long term exposure to asbestos are cancer of the lungs, pleura sack surrounding the lungs, bronchus, oropharynx, stomach, and colon. Symptoms are shortness of breath, dry cough, and clubbing of the fingers. These symptoms generally do not show up for 20 years or more after initial exposure. The potential for a material containing asbestos to release breathable fibers depends on the material's degree of friability. Friable means that the material can be crumbled with hand pressure. When working around materials suspected of containing asbestos, it is important not to bump, brush or disturb the materials in any way. Wetting the materials can help to reduce the emission of fibers. Refer to Table 1-3.

Note: Employees who are not qualified to work with asbestos are not to handle or remove materials containing asbestos fibers. Refer to 29 CFR 1910.1001 (Asbestos) or 29 CFR 1926.1101 (Asbestos) for worker qualifications and requirements for handling asbestos containing materials.

Table 1-3. Precautionary Steps to Minimize Asbestos Exposure

1. Prior to disturbance, have unknown material tested for asbestos.
2. Keep unknown fibers off clothing. Wear disposable coveralls.
3. Wear proper respiratory protection: either full face or half face respirators with P-100 Filter if working with fibrous materials.
4. After working with materials, wash hands prior to eating, drinking or taking a break.

1-10 MISHAP RESPONSE.

Each worker must know what to do when a mishap occurs. Additionally, each worker must know how to report injuries and other mishaps.

1-10.1 Knowing What to Do.

Table 1-4 summarizes the first aid knowledge required of each worker. As a preplanning aid, prepare an emergency telephone number list to include the location and telephone numbers of the nearest ambulance or emergency medical treatment responders, the nearest hospital with an emergency room, the nearest helicopter evacuation service, and the nearest burn trauma center. A medical professional must evaluate all shock victims for treatment and medical follow-up.

Table 1-4. Knowing What to Do

Item	Instructions/Training
First aid/CPR	How to control bleeding and apply artificial respiration and cardiopulmonary resuscitation (CPR). How to provide pole top and manhole rescues of mishap victims. Familiarity with electric shock symptoms.
Medical provisions	Location, contents, and use of first aid kits and where located in electric line and aerial lift vehicles. How to get medical assistance.

1-10.2 Work Injuries and Mishap Reports.

Report injuries, including minor injuries, to your immediate supervisor. Every mishap involving personnel injury, property damage, or near misses must be investigated to determine the cause and the corrective action needed to prevent recurrence. Cognizant safety personnel conduct investigations. The safety staff must be notified of all mishaps that involve personnel injuries or property damage.

1-10.3 First Aid Supplies.

1-10.3.1 Storage and Inspection.

Place first aid supplies in weatherproof containers if the supplies could be exposed to the weather. Maintain each first aid kit readily available for use and inspect frequently (at least annually) to ensure expended items are replaced.

1-10.3.2 Contents.

An example of the minimal contents of a generic first aid kit is described in American National Standard (ANSI) Z308.1, *Minimum Requirements for Workplace First-Aid Kits and Supplies*. The contents of the kit listed in the ANSI standard is adequate for small worksites. When larger operations or multiple operations are being conducted at the same location, determine the need for additional first aid kits at the worksite, additional types of first aid equipment and supplies and additional quantities and types of supplies and equipment in the first aid kits.

1-10.4 Automatic External Defibrillators (AEDs).

Where emergency medical assistance is not available within four minutes, the use of AEDs may be warranted. Prior to agencies/activities purchasing AEDs, effective written programs must be established. At a minimum, address the following:

- Coordination with private sector and/or DoD medical facilities, fire departments, emergency responders.
- Training.
- Placement and availability of properly trained employees.
- Equipment maintenance.
- Legal issues.

\3 *Note: For the Air Force, refer to DAFMAN 32-1065 for requirements on AED training, including certification requirements.* **/3/**

1-11 COMMUNICATIONS.

All employees participating in a work procedure must be in constant voice contact with all other members involved in that procedure. The ability of work crew, work leader, and/or supervisor to communicate during circuit isolation, maintenance, troubleshooting, and restoration is essential. Accordingly, provide each employee with a personal communication device (radio or cellular phone) and with each assigned a unique caller identification.

1-12 ARC FLASH WARNING LABELS.

Provide arc flash warning labels on electrical equipment likely to require examination, servicing, or maintenance while energized. Some typical types of equipment include pad-mounted transformers, switchgear, switchboards, panelboards, disconnect switches, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies.

Note: Determine if the Activity has an arc flash risk assessment program, and if so, coordinate on which label format will be used.

Note: For Army projects, comply with DA PAM 385-26, The Army Electrical Safety Program, and provide arc flash labels in accordance with NFPA 70E.

Note: AutoCAD format and Adobe PDF format files are available at http://www.wbdg.org/ccb/NAVGRAPH/arc_flash_warning_labels.zip.

\2 *Note: In the 2018 update to IEEE 1584, the requirement was added to account for factors such as enclosure dimensions and electrode configurations when performing incident energy calculations. As a result, equipment such as motor control centers, which house branch circuit overcurrent protective devices within separate enclosed cubicles, may produce unique arc flash risk analysis results for each cubicle. Once the incident energy calculations have been performed for all cubicles on a piece of equipment such as this, as an alternative to applying labels to each cubicle, it is acceptable to generate a 'Worst Case' label which can be used to represent all branch circuit cubicles. 'Worst Case' branch circuit cubicle labels should only be used with the written approval of the equipment owner and/or the entity responsible for maintaining the equipment. When 'Worst Case' branch circuit cubicle labels are used, separate unique labels must still be applied to any cubicles housing the equipment's main overcurrent device(s) or tie breakers. Any 'Worst Case' branch circuit cubicle labels should be conspicuously located on the equipment and should contain wording which clearly indicates which cubicles the label applies to.* **/2/**

The following sections list the types of arc flash label formats that have been approved. These include:

- General label.
- General label referring to OSHA.
- Detailed label, compliant with NFPA 70E.
- General label that refers to a separate arc flash calculation for requirements.
- Label for equipment that has not received adequate maintenance or testing.

- Label for equipment where an arc flash calculation identifies an available incident energy greater than 40 cal/cm^2.

1-12.1 General Arc Flash Label.

Provide labels in accordance with the format shown in Figure 1-3.

Note: Do not use this label for Army projects.

Figure 1-3 Typical Arc Flash Warning Label

Note: As part of the original development of UFC 3-501-01, Electrical Engineering, and UFC 3-560-01, Operation and Maintenance: Electrical Safety, the Tri-Service Electrical Working Group (TSEWG) deliberately specified general arc flash warning labels rather than the detailed arc flash warning labels specified by NFPA 70E. The detailed label information specified by NFPA 70E was considered inappropriate for the following reasons:

- **\2** *The equipment is in poor condition.* **/2/**
- **\2** *Routine testing and maintenance does not occur or cannot be verified to have occurred.* **/2/**
- **\2** *Detailed incident energy calculations cannot reasonably be assumed to be updated on a routine basis as requirement by NFPA 70E.* **/2/**

1-12.2 General Arc Flash Label That Refers to OSHA.

OSHA requires protection from the incident energy of an arcing fault. But, neither 29 CFR 1910 nor 29 CFR 1926 require an arc flash label. As published, the OSHA requirements do not discuss labels at all. The Federal Register publication (April 11,

2014) of the revised 29 CFR Parts 1910 and 1926 discusses why OSHA does not require arc flash labels.

A general arc flash label that refers to OSHA requirements is allowed. Figure 1-4 provides an example.

Note: Do not use this label for Army projects.

Figure 1-4 General Arc Flash Label That Refers to OSHA

1-12.3 Detailed Arc Flash Label.

For new and existing installations, a detailed label is only authorized if the Activity has an arc flash risk assessment program that includes documented periodic maintenance and testing. New installations must also have been commissioned in accordance with NETA Acceptance Test Specifications.

Note: An Activity may have two distinct arc flash risk assessment programs in place: one for the medium voltage distribution (utility) part of the electrical distribution system and one for low voltage systems inside facilities.

If the following types of equipment are credited for clearing an arcing fault as part of an arc flash study, the equipment must have commissioning performed in accordance with NETA ATS if new, and periodic maintenance and testing performed in accordance with NETA MTS or NFPA 70B if existing:

- Medium voltage power circuit breakers.
- Medium voltage pad-mounted switchgear.
- Low voltage power circuit breakers.

- Overcurrent protective relays.
- Switchboards and panelboards – main circuit breaker at each location and all circuit breakers rated for 225 amperes, or higher (molded case circuit breakers and insulated case circuit breakers).
- Electronic trip units associated with the above equipment.

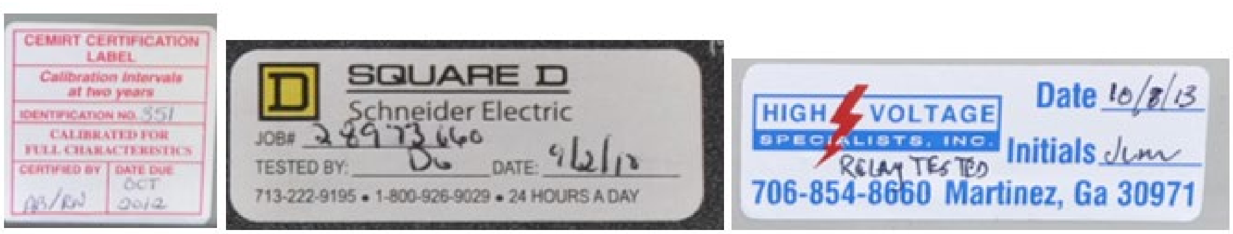
Note: Coordinate with activity to ensure funding is available for the above maintenance and testing.

1-12.3.1 Documentation of Commissioning and Maintenance/Testing.

Confirmation of commissioning and maintenance/testing consists of calibration or maintenance stickers applied to the equipment and a documented report of the maintenance and testing that was completed. Coordinate with the Activity maintenance personnel to identify the required format and content to be provided on a calibration or maintenance sticker. Figure 1-5 shows typical calibration or maintenance stickers. As a minimum, provide the following information:

- Company or organization that performed the testing.
- Date of test.
- Initials of person who performed the test.
- Date due.

Figure 1-5 Typical Calibration or Maintenance Stickers



1-12.3.2 Arc Flash Label Content.

NFPA 70E specifies the following information to be included on a detailed arc flash label:

- Nominal system voltage.
- Arc flash boundary.
- At least one of the following:

a) Available incident energy and the corresponding working distance, or the arc flash PPE category in NFPA 70E Table 130.7(C)(15)(a) or 130.7(C)(15)(b) for the equipment, but not both.

b) Minimum arc rating of clothing.

c) Site-specific level of PPE.

Note: Site-specific level of PPE is an identified requirement in NFPA 70E if it is more restrictive than item a) above. Annotate the label appropriately. This could occur based on an Activity specific issue, where the Activity is adding the additional requirement. An example of this is shown in Figure 1-8 below. **\3** [Deleted] **/3/**

In addition to the above information specified by NFPA 70E, include the following information on a detailed label:

- Equipment identification number.
- Date of arc flash calculation.

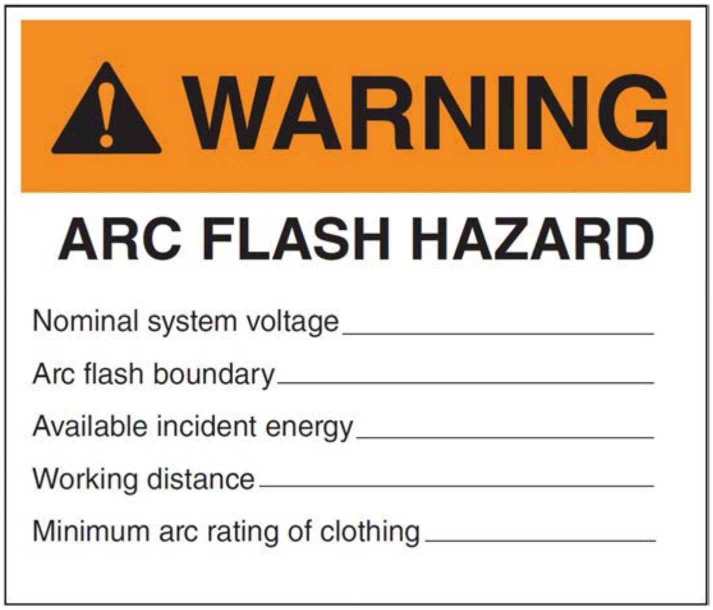
If the arc flash results can vary as a result of different operating or switching modes, include this information in the detailed label.

1-12.3.3 Arc Flash Label Examples.

\2 Figure 1-6 shows the detailed label provided by the NFPA 70E Handbook which displays the calculated available incident energy. Figure 1-7 shows a typical detailed label based on the required minimum arc rating of clothing PPE. **/2/** The arc flash label format can be modified provided that the required information is included.

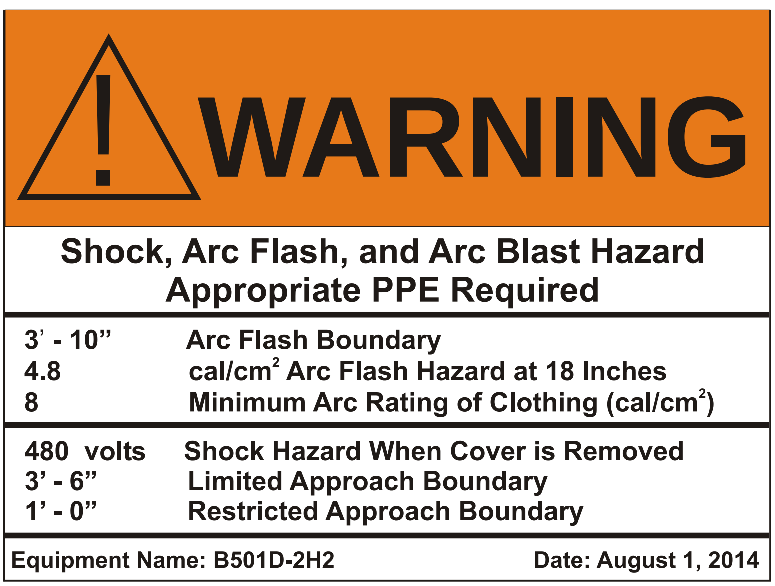
\2

Figure 1-6 NFPA 70E Handbook Arc Flash Incident Energy Warning Label



/2/

Figure 1-7 Typical Detailed Arc Flash Warning Label



1-12.3.4 Arc Flash Labels Based on NFPA 70E Tables.

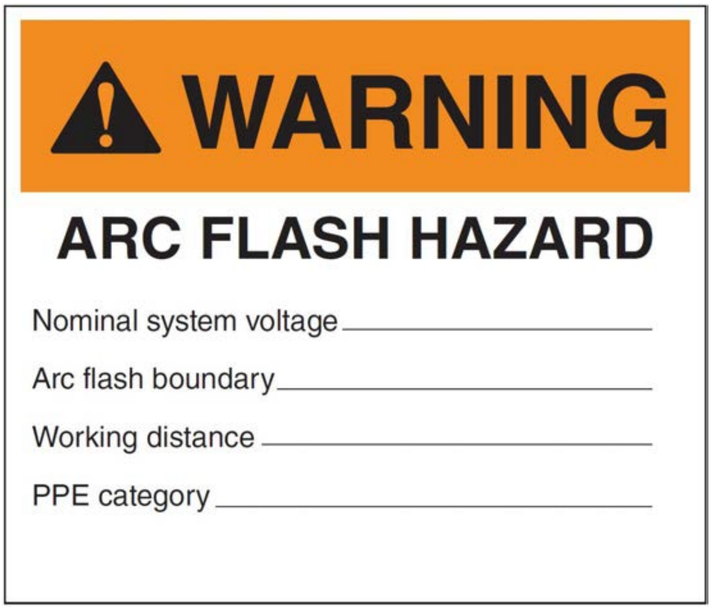
\3 Detailed labels based on NFPA 70E Table 130.7(C)(15)(a) or 130.7(C)(15)(b) can be installed if the following conditions have been verified and documented: **/3/**

- The available short circuit is less than stated in the table.
- The upstream protective device is identified and confirmed to trip within the clearing time stated in the table.

- Maintenance and testing of the upstream protective device in accordance with NETA MTS or NFPA 70B has been confirmed to be adequate and current. Typically, this equipment would have calibration or maintenance stickers applied with a documented report of the maintenance and testing that was completed.

\2 Figure 1-8 shows the detailed label provided by the NFPA 70E Handbook which displays the PPE category.

Figure 1-8 NFPA 70E Handbook Arc Flash PPE Category Warning Label



/2/

1-12.3.5 Arc Flash Label Updates.

Document the method of calculating and the data to support the information for the label. Once installed, a detailed label must be removed or replaced with a new label containing updated information under any of the following conditions:

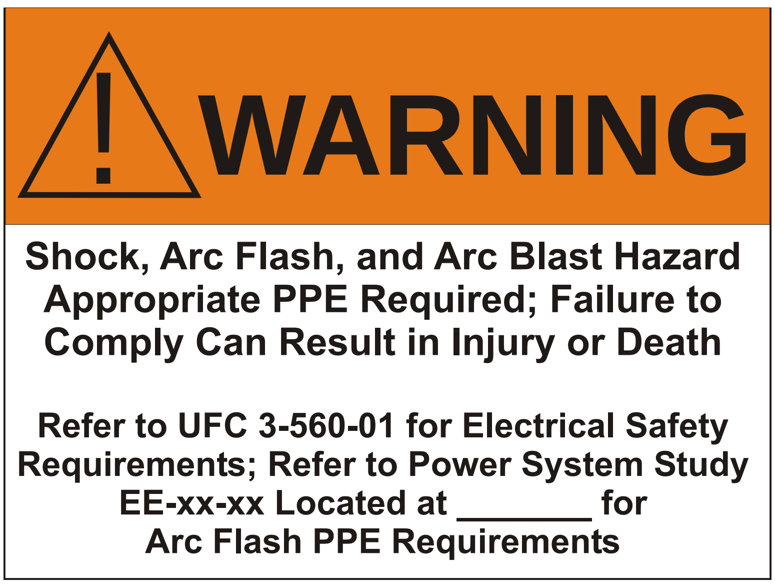
- Whenever a review of the arc flash risk assessment identifies a change that renders the label inaccurate. This includes:
    - System design changes that affect short circuit values or electrical coordination.
    - Circuit breaker trip setting changes.
- More than five years passes without maintenance and testing in accordance with NETA MTS or NFPA 70B.
- **\2** More than five years passes without a review of the arc flash risk assessment for accuracy. **/2/**

1-12.4 Arc Flash Label That Refers to a Separate Calculation.

\2 In supervised industrial installations where conditions of maintenance and engineering supervision ensure that only qualified persons monitor and service the system, instead ***/2/*** of a detailed label as specified by NFPA 70E and addressed above in Section 1-12.3, the arc flash label is allowed to refer to an arc flash calculation where the required arc flash parameters can be obtained. Figure 1-9 shows an example. The advantage of this approach is that the calculation can be periodically revised without requiring physical relabeling of the equipment. **\3** For the Air Force, the addition of a QR code for requirements is also acceptable. ***/3/***

Note: Do not use this label for Army projects.

Figure 1-9 Arc Flash Warning Label Referring to a Separate Calculation



1-12.5 Arc Flash Label for Existing Equipment Without Maintenance or Testing.

Arc flash calculation results are based on proper operation of upstream protective devices in accordance with their published time-current curves. Periodic maintenance and testing of electrical equipment is essential to confirming this proper operation. Use the standard label provided in Figure 1-10 for the following equipment locations:

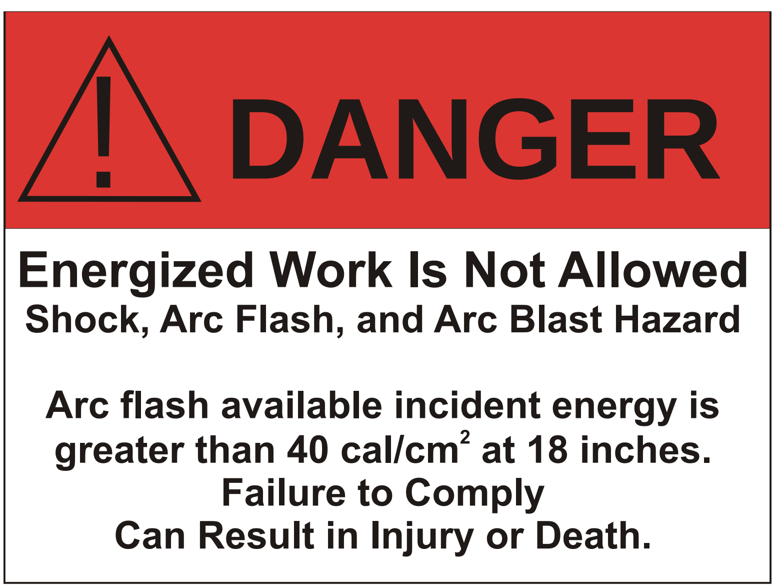
- New installations that did not include commissioning in accordance with NETA ATS.
- Existing installations without maintenance and testing in accordance with NETA MTS or NFPA 70B in the last five years.

Figure 1-10 Arc Flash Danger Label for Equipment Without Documented Maintenance and Testing

1-12.6 Arc Flash Label for Locations Identified to Be Greater Than 40 cal/cm^2.

Use a label similar to the following if the arc flash calculation identifies a location with an available incident energy greater than 40 cal/cm^2.

Figure 1-11 Arc Flash Danger Label for Locations Identified to Be Greater Than 40 cal/cm^2



CHAPTER 2 WORKER/CREW RESPONSIBILITIES

2-1 LEVELS OF RESPONSIBILITY.

Operation and maintenance of electrical distribution systems are a single work group responsibility. The same personnel will frequently perform both functions. All personnel are responsible for safety at all times. Table 2-1 lists the level of accountability for each job function.

Note: The titles and responsibilities listed in Table 2-1 are typical assignments for electrical workers at most facilities or organizations. However, titles and responsibilities might be assigned differently in accordance with local directives.

Table 2-1. Levels of Safety Accountability

Title	Accountability
Installation commander	Ultimate safety accountability
Base civil engineer	Base systems safety accountability
Electric supervisor (if assigned)	Systems safety accountability
Supervisor/lead electrical worker	Systems safety and specific work task safety
Crew members	Crew members' safety accountability is limited to doing only work for which they are qualified

2-2 ELECTRICAL WORKER QUALIFICATIONS.

Qualifications for electrical workers are normally established locally. Workers are classified as *Qualified* or *Unqualified*.

2-2.1 Qualified Persons.

\3 A qualified person shall be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method (see NFPA 70E 110.6(A)(1)). This also includes: ***/3/***

- The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment.
- The skills and techniques necessary to determine the nominal voltage of exposed live parts.
- Skills and techniques regarding how to select and use a voltage detector and phase meter.

- The clearance distances and the corresponding voltages to which the qualified person will be exposed.

2-2.2 Unqualified Person.

An unqualified person is any person who is not a qualified person.

2-2.3 Type of Training.

\3 Training can be in the classroom, interactive electronic, web-based, or on-the-job, or a combination of the two. ***/3/*** Determine the degree of training based on the risk to the employee. As a minimum, the employee must demonstrate to their supervisor or designated representatives, the capability, knowledge, and skills to understand and apply the controls required by their exposures, and that they can safely complete their assigned tasks. Each employee's possession of the necessary skills, knowledge and abilities must be determined by written or verbal tests, in conjunction with functional tests. Develop and use lesson plans or Standard Operating Procedures. Training may be contracted from outside sources, which include certified training facilities and utility companies.

Note1: Whether an employee is considered to be a "qualified person" depends upon various circumstances in the workplace. For example, it is possible and, in fact, likely for an individual to be considered "qualified" with regard to certain equipment in the workplace, but "unqualified" as to other equipment.

Note 2: An employee who is undergoing on-the-job training and who, during such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person is considered to be a qualified person for the performance of those duties.

2-2.4 Cardiopulmonary Resuscitation (CPR) and First Aid Training.

Provide first aid and CPR training to employees exposed at or above 50 volts and those trades listed in Section 4-1.1. Consider including automated external defibrillator (AED) training as part of this training. First aid training is primarily received through the American Red Cross, the American Heart Association, the National Safety Council, or other private institutions. Obtain refresher training annually to maintain CPR certifications. Train employees responsible for responding to medical emergencies in the use of an AED if the emergency response plan includes the use of this device.

When employees are performing work on or associated with exposed lines or equipment energized at 50 volts or more, persons trained in first aid and CPR must be available as follows:

- For field work involving two or more employees at a work location, ensure at least two trained persons are available. Refer to Section 3-3 for those jobs requiring at least two employees.

- For fixed work locations such as generating stations, provide a sufficient number of trained persons to ensure that each employee exposed to electric shock can be reached within 4 minutes by a trained person. However, where the existing number of employees is insufficient to meet this requirement (at a remote substation, for example), train all employees at the work location.

2-2.5 Rescue Training.

All workers engaged in electrical work must receive training in methods of release from the energized conductor and in methods of rescue from poles, structures, manholes, aerial baskets, confined spaces, and other field work areas as applicable to the facility or installation.

2-2.6 Training Documentation.

Document that each employee has received the required training. Complete this documentation when the employee demonstrates proficiency in the work practices involved and maintain the documentation for the duration of the employee's employment. Include each employee's name and dates of training in the documentation file. Verify at least annually that training is current for each employee.

2-3 SAFETY MEETINGS.

Safety meetings must consist of scheduled meetings for all personnel and job briefing/tailgate meetings as needed for specific jobs.

2-3.1 Scheduled Meetings.

Schedule safety meetings in accordance with local policy. Twice a month is recommended, but once a month is the minimum; less frequent meetings tend to de-emphasize the importance of safety. Supervisory personnel must conduct these meetings but encourage other knowledgeable individuals to conduct training on specialized topics.

2-3.2 Job Briefing/Tailgate Meetings.

Meetings at the job site prior to the commencement of work are commonly called tailgate meetings. This meeting covers all aspects of the planned work, site hazards, safety precautions to be followed, special precautions, energy source controls, and personal protective equipment. The individual in charge must conduct the job brief and must ensure that each crew member understands the precautions to be observed and the procedures to be followed. Tailgate meetings are also recommended at the beginning of each work shift for longer duration jobs so that all crew members understand what is to be done, how to accomplish the job, safety hazards present, and methods used to provide worker protection.

Refer to NFPA 70E Annex I for a typical job briefing and planning checklist. Individual services also have Standard Operating Procedures or other information that provides job briefing checklists.

2-4 WORK SITE SAFETY.

Maintaining acceptable work site safety involves proper behavior, good housekeeping, maintenance of protective measures, and avoiding unsafe actions. The following tables provide examples and are not all inclusive. Table 2-2 lists prohibited actions. Report indications of unsafe worker actions listed in Table 2-3. Verify that pre-site job requirements listed in Table 2-4 are met. Significant unsafe actions and conditions are listed in Table 2-5.

Table 2-2. Prohibited Actions

Taking chances
Playing jokes
Carelessness
Smoking
Use of intoxicants or drugs
Throwing material
Quarreling
Disobedience
Unnecessary talking or noise
Working while ill or under emotional stress

Table 2-3. Unsafe Worker Indications

Lacks information
Lacks skills
Lacks experience
Unaware of safe practices
Does not realize danger

Table 2-4. Pre-Site Job Requirements

Regular safety meetings
Job hazard analysis if safe clearance (*Chapter 6*) requires it or if energized line work (*Chapter 8*) will be done
Written work procedures covering existing conditions
Job briefing/tailgate briefings

Table 2-5. Significant Unsafe Actions and Conditions

Unsafe Actions
Operating without authority; failure to secure or warn others
Operating or working at unsafe speeds
Making safety devices inoperative without proper authorization
Using unsafe equipment (hands instead of equipment) or equipment unsafely
Taking unsafe positions or postures
Working on moving or dangerous equipment
Distracting, teasing, abusing, startling
Failing to use safe attire or personal protective devices
Failing to lock-out and tag deenergized circuits
Failure to follow established safety policies
Carelessness
Defacing identifying markings on equipment
Unsafe Conditions
Improperly guarded facilities
Defects of facilities
Hazardous arrangement or procedure
Improper ventilation
Improper illumination
Unsafe dress or apparel

2-5 JOB HAZARD ANALYSIS/JOB SAFETY ANALYSIS.

Written work procedures must be prepared for unusual or complicated work activities. Table 2-6 lists the minimum requirements for a job hazard analysis or job safety analysis.

Table 2-6. Job Hazard Analysis (JHA)/Job Safety Analysis (JSA)

Identification of the work site
Description of the work to be done
Specific hazards and how to minimize or eliminate them by use of safety equipment
Use of proper arc flash and shock hazard personal protective equipment (PPE)
Instructions covering special practices for grounding, unusual equipment and tools, and first aid requirements for hazardous materials
Sequence of major steps or a detailed step-by-step work listing
A JHA or JSA, and written standard operating procedure

2-6 SAFETY COMPLIANCE.

A requirement of employment is compliance with safety requirements. Workers must not perform work they consider unduly hazardous based on their own capabilities; they are not trained or qualified to perform; or when they are not properly protected from injury. In a case where the safety requirements are not clear, the worker must obtain direction from the authorized individual-in-charge.

2-6.1 Carelessness.

A worker must challenge a fellow worker who violates any of these rules or works in an unsafe manner and must promptly report any violations of safety requirements to the authorized individual-in-charge.

2-6.2 Interpretation.

In any case where rules are not clear ask the foreman or supervisor for an interpretation.

2-6.3 Violations.

Each safety rule must be strictly enforced. Workers failing to observe the rules can be subject to penalties. Supervisors must follow appropriate guidelines and ensure the severity of the penalty is related to the seriousness of the offense.

CHAPTER 3 PRE-SITE SAFETY MANAGEMENT

3-1 WORK LOCATION SAFETY REQUIREMENTS.

The location and the public access to the work site impose additional protective or regulatory requirements.

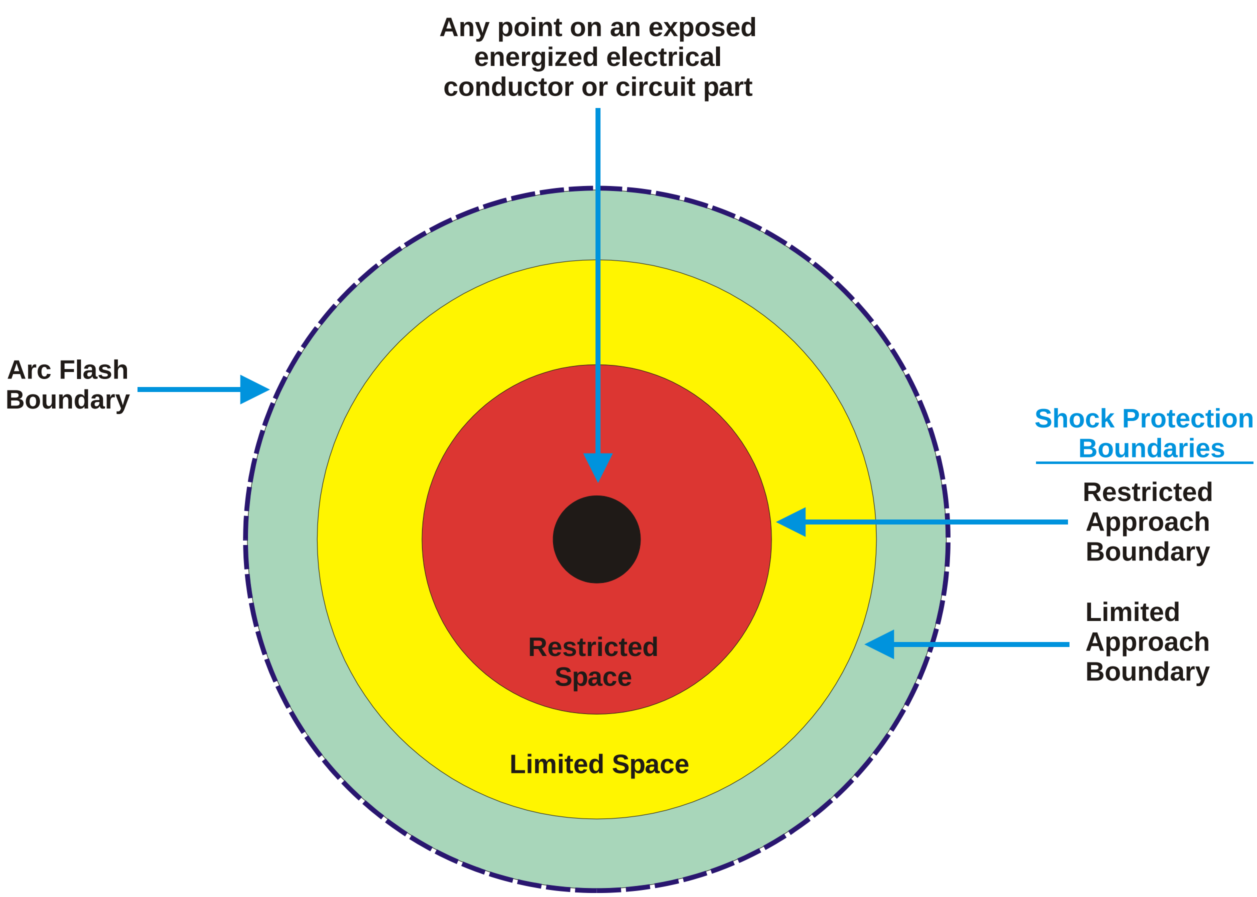
3-1.1 Working Near Energized Circuits.

Perform electrical maintenance near energized circuits with rubber blankets or other suitable guards as a safety measure. Minor work (such as cutting weeds, taking oil samples, or securing nameplate data) when done near energized apparatus or conductors located on or near the ground may be performed when workers maintain the unqualified worker minimum approach distances, as appropriate.

3-1.1.1 Minimum Approach Distances.

Figure 3-1 shows a general layout of the various approach limits. Each boundary is defined following Figure 3-1.

Figure 3-1. Approach Limits



3-1.1.1.1 Arc Flash Boundary.

The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2). Within this boundary, workers are required to wear appropriate personal protective equipment (PPE) clothing. Only qualified workers wearing appropriate PPE are permitted to be within this boundary.

3-1.1.1.2 Limited Approach Boundary.

A shock protection boundary to be crossed by only qualified persons (at a distance from a live part) that is not to be crossed by unqualified persons.

If there is a need for an unqualified person(s) to cross the limited approach boundary, a qualified person must advise him or her of the possible hazards and continuously escort the unqualified person(s) while inside the limited approach boundary. Under no circumstance is the escorted unqualified person(s) allowed to cross the restricted approach boundary.

3-1.1.1.3 Restricted Approach Boundary.

\3 An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock due to electrical arc-over, combined with inadvertent movement, for personnel working near the energized electrical conductor or circuit part. ***/3/***

3-1.1.2 Minimum Approach Distance for Unqualified Workers.

Only workers qualified by electrical training can work in areas on or with unguarded, uninsulated energized lines or parts of equipment operating at 50 volts or more. All electric lines and equipment will be treated as energized unless they are placed in an electrically safe working condition, including grounding in accordance with Chapter 7. The minimum approach distance refers to the shortest possible distance between energized electrical lines or apparatus and any part of a worker’s body and tools or material being handled.

Note: an unqualified person can enter a limited approach boundary only under the conditions stated in Section 3-1.1.1.2.

3-1.1.3 Minimum Approach Distances.

Table 3-1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding). Table 3-2 provides similar information for direct current systems.

Table 3-1. Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	Limited Approach Boundary		Restricted Approach Boundary (2) (3)
	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder
<50 V	Not specified.	Not specified.	Not specified.
50 V to 150 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 3-1:

1. *For single phase systems* ***\2*** *above 250 volts,* ***/2/*** *select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
3. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
4. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary. The arc flash boundary is determined by an arc flash analysis. Refer to Chapter 4 for PPE requirements for the intended work location.*
5. ***\2*** *Refer to NFPA 70E for AC voltages above 145 kV.* ***/2/***

Table 3-2. Qualified Worker Minimum Approach Distances – DC Systems

Nominal System Voltage Range Phase to Phase (1)	Limited Approach Boundary		Restricted Approach Boundary
	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Reduced Inadvertent Movement Adder
<50 V	Not specified	Not specified	Not specified
50 V to 300 V	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>300 V to 1 kV	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)

Notes for Table 3-2:

1. *Refer to NFPA 70E for DC voltages above 1,000 V.*

3-1.1.4 Altitude Correction for Minimum Approach Distances.

Refer to Table 3-3 for altitude correction factors for work performed at elevations greater than 3,000 ft (914 m); the minimum approach distance is determined by multiplying the distances in Table 3-1 by the appropriate correction factor from Table 3-3.

Table 3-3. Altitude Correction Factors

Altitude		Correction Factor	Altitude		Correction Factor
Feet	Meters		Feet	Meters	
3,000	900	1.00	10,000	3,000	1.20
4,000	1,200	1.02	12,000	3,600	1.25
5,000	1,500	1.05	14,000	4,200	1.30
6,000	1,800	1.08	16,000	4,800	1.35
7,000	2,100	1.11	18,000	5,400	1.39
8,000	2,400	1.14	20,000	6,000	1.44
9,000	2,700	1.17			

3-1.2 Work Location.

The location of the work will determine whether climbing or confined space training along with fall and/or respiratory protection are mandatory (refer to Chapter 4). Safety standards require protection from excessive noise and provision of minimum illumination at any applicable work site.

3-1.2.1 Noise.

Follow local procedures regarding hearing protection. Wherever hazardous noise area signs are posted, hearing protection must be used as prescribed.

3-1.2.2 Minimum Illumination.

Do not reach blindly into areas that might contain exposed energized electrical conductors or circuit parts where an electrical hazard exists. Ensure the working area has adequate illumination. Provide temporary lighting where natural or installed artificial illumination is not sufficient. Survey facility electrical equipment rooms to determine if lighting has been connected to a timer/motion control device. Ensure timers/motion control devices are disengaged prior to beginning any electrical work operations.

Where lack of illumination or an obstruction precludes observation of the work to be performed, do not perform any task within the limited approach boundary of energized electrical conductors or circuit parts operating at 50 volts or more or where an electrical hazard exists.

3-2 PUBLIC SAFETY.

Protect the public around the work area by safely guiding unqualified personnel and traffic away from workers, equipment, and excavations.

3-2.1 Warning Devices.

Locate appropriate barriers, warning signs, traffic cones, and lights at approaches to and at work areas, excavations, open manholes, parked equipment, and other hazards. Take special precautions for any areas where reduced visibility occurs, such as night operations or in fog. Immediately remove warning devices after removal of hazards and equipment. Provide flagmen if there is any doubt as to whether the warning devices will be adequate as controls, such as in areas with obstructed vehicular traffic.

3-2.2 Flagmen.

Flagmen must be used whenever there is any doubt of the effectiveness of warning devices. This often occurs on busy roadways or during commuting hours on less traveled streets. Flagmen must wear brightly colored and highly reflective warning vests.

3-2.3 Excavations.

Provide barricades around every excavation area. Keep warning barricade (cones, tape, and other items providing no physical protection) 5 ft (1.5 m) from the excavation. A protective barricade may be placed closer since it provides both a warning and physical protection. Protective barricades must have a withstand rating of at least 200 lb (90 kg) in any direction with minimal deflection. Never enter an excavation deeper than 4 ft (1.6 m) which does not have a safe access-way, which has not been inspected by a competent person before allowing an entrance, or which has equipment working next to the edge. Comply with requirements stated in *29 CFR 1926, Subpart P, (Excavations)*. Identify underground lines and services prior to starting excavations. The following tables provide additional guidance.

Table 3-4. Excavation Pre-Survey Checklist

Location	Checklist Items
Prior to leaving the shop.	1. Ensure location of underground cables has been established. 2. Verify that field sketch is available. 3. Obtain as-built/maps from facility owner(s). 4. Have subsurface facility engineering performed. 5. Conduct pre-construction meetings with facility owner(s). 6. Site and Safety Plan or Job Hazardous Analysis/Job Safety Analysis.
On the job site.	1. Check for field sketch. 2. Verify all facility marks on ground. 3. Verify all service feeds from houses or buildings. Verify all are marked or noted above ground. Draw sketch. Check for: pedestals, risers, and new trench lines. 4. Verify position of dig area to sketch. 5. Check for private facilities not marked. 6. Advise facilities owner of excavation.

Table 3-5. Performing Excavations

1. Maintain 24 in (610 mm) from marks. If digging within 24 in (610 mm), hand dig to expose and verify lines. 2. Expose all major facilities within 5 ft (1.5 m) of work area. 3. If paralleling: expose to verify location and depth of facilities every 100 ft (30.5 m). 4. Hand dig within 5 ft (1.5 m) of pedestals, risers, meters, flags, whiskers, etc. 5. Bore away from facilities. 6. Verify depth of any facilities boring across, change route or depth as required. 7. Do not place excavation dirt on locate marks, flags, whiskers, etc. 8. Support all lines exposed during excavation to avoid kinks or other damage.

Table 3-6. Backfilling

1. Prior to backfilling, contact facility owner to inspect exposed facility. 2. “Shade” all lines placed or exposed with good fill dirt. 3. Verify all fill dirt is free from rocks, cable trash, and large dirt clods. 4. No cable or personal trash may be backfilled into the trench.

Table 3-7. Damage During Backfilling of Trenching

1. If damage involves a potential risk of life, health or significant property damage, call 911 or local emergency response number.
2. All damage, including kinking or sheath damage, must be reported immediately to a supervisor and facility owner or operator.
3. Photograph the damage.
4. If a water line, other than a main, attempt to stop the damage.
5. If a gas or power line, evacuate the area, if necessary, and notify others working in the area.
6. Complete damage investigation report.

3-3 NUMBER OF WORKERS REQUIRED

All work must be performed with a sufficient number of workers to provide a safe working environment. 29 CFR 1910.269 (*Electrical power generation, transmission, and distribution*) requires more than one worker where the hazard exposure of the work is considered to be significantly reduced by the presence of additional workers. The following tables provide specific requirements:

Table 3-8. Jobs Acceptable for One Electrical Worker

1. Work on systems in an electrically safe work condition with nominal system voltages of 600 volts ac or 250 volts dc, or less.
2. Routine electrical measurements on energized systems with nominal system voltages of 600 volts ac or 250 volts dc, or less.
3. Routine operation of metal-enclosed switchgear with nominal system voltages of 600 volts ac or 250 volts dc, or less.
4. Routine operation of metal-enclosed switchgear and pad mounted switches with nominal systems voltages greater than 600 volts ac if the activity responsible can demonstrate that conditions at the site allow this work to be performed safely.
5. Routine electrical measurements or switching using gloves and live-line tools if the worker is positioned out of reach or possible contact with energized parts.
6. Emergency repair work to safeguard the general public, if previously authorized.

Table 3-9. Jobs Requiring Two Electrical Workers

Hazard Exposure	Working On
Installation, removal, or repair when working on or near lines or parts energized at:	
1. Voltages of 600 volts ac or 250 volts dc, or less.	• Installing portable monitoring equipment if it requires 1) removing covers on panels rated for greater than 240 volts or 2) disturbing circuit conductors.
2. Greater than 600 volts ac or 250 volts dc.	• Energized lines. • Deenergized lines with possible energized parts contact. • Equipment with possible energized line contact. • Mechanical equipment operation (except insulated aerial lifts) near energized parts. • Operation of insulated aerial lifts (bucket trucks). • Other work with equal or greater hazard exposure.

Table 3-10. Jobs Working In Confined Spaces That May Require More Than Two Workers

Hazard Exposure	Additional Worker Requirement
Installation, removal, or repair when working in a confined space. Manhole or vault requirements are generally classified as confined spaces.	1. An attendant with first aid and CPR training will be available on the surface in the immediate vicinity. 2. If a hazard exists within the space, or a hazard exists or is created because of traffic patterns outside the space, the attendant may not enter the confined space. 3. If the restrictions of Item 2 above do not apply, the attendant may enter the confined space to provide assistance, but only for a brief period (other than in an emergency). For extended periods of assistance, a second worker in addition to the attendant is required. For the Air Force, a minimum of three personnel must be present for manhole or vault entry.

3-4 VERIFYING SYSTEM AND EQUIPMENT PROVISIONS.

Be familiar with the electrical system to be worked on by reviewing the system's single line diagram. Check out the equipment needed such as insulating tools, hot sticks, and grounding cables.

CHAPTER 4 ARC FLASH PERSONAL PROTECTIVE EQUIPMENT (PPE)

This chapter addresses the requirements for arc flash risk assessments and the associated personal protective equipment (PPE) criteria.

4-1 PPE FOR ARC FLASH PROTECTION.

4-1.1 Applicability.

PPE that provides appropriate arc flash protection is required for all personnel working on or near exposed energized electrical equipment operating at 50 volts or more. Depending on the work location and activity, these requirements might include but are not limited to the following types of workers:

- Boiler plant operator or mechanic.
- Construction inspector.
- Electrical engineer.
- Electrical engineering technician.
- Electronic industrial controls mechanic.
- Electrical Power Controller (EPC).
- Elevator technician.
- Emergency/standby generator technician.
- Heating, ventilation, and air conditioning technician.
- High-voltage electrician.
- Industrial equipment mechanic.
- Liquid oxygen maintenance personnel.
- Low-voltage electrician.
- Maintenance mechanics.
- Mechanical engineer.
- Project manager.
- Ship-to-shore electrician.

- Utility system workers.

4-1.2 NFPA 70E PPE Summary.

\2 The PPE to be used for a piece of equipment must be determined by an arc flash risk analysis using either the incident energy analysis method or the PPE category method, but not both. Table 4-1 provides the NFPA 70E criteria for PPE as it relates to arc flash risk assessments performed using the PPE category method. Table 4-2 provides the NFPA 70E criteria for PPE as it relates to arc flash risk assessments performed using the incident energy analysis method. The results of an incident energy analysis to specify a PPE category in Table 4-1 shall not be permitted. **/2/**

Table 4-1. NFPA 70E PPE Criteria – Category Method

PPE Category	PPE
\3	Deleted **/3/**
1 (≤4 cal/cm^2)	**<u>Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (see Note 1)</u>** Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield (see Note 2) or arc flash suit hood Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **<u>Protective Equipment</u>** Hard hat (AR) Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) **\2** (see Note 3) **/2/** Heavy duty leather gloves (see Note 4) Leather footwear (AN)
2 (≤8 cal/cm^2)	**<u>Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2</u>** Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield (see Note 2) and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **<u>Protective Equipment</u>** Hard hat (AR) Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) **\2** (see Note 3) **/2/** Heavy duty leather gloves (see Note 4) Leather footwear

PPE Category	PPE
3 (≤25 cal/cm^2)	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2** Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves **\2** (see Note 4) ***/2/*** Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) **\2** (see Note 3) ***/2/*** Leather footwear
4 (≤40 cal/cm^2)	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2** Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves **\2** (see Note 4) ***/2/*** Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) **\2** (see Note 3) ***/2/*** Leather footwear

AN: as needed (optional). AR: as required. SR: selection required.

Notes:

1. *Refer to Table 4-3 for minimum PPE clothing requirements.*

2. *Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck. Use an arc-rated balaclava with an arc-rated face shield when the back of the head is within the arc flash boundary. As an alternative, an arc-rated arc flash suit hood can be worn instead of an arc-rated face shield and balaclava.*

3. ***\2*** *Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.* ***/2/***

4. *If rubber insulating gloves with leather protectors are used, additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.*

Table 4-2. NFPA 70E PPE Criteria – Incident Energy Analysis Method

Incident Energy	PPE
0-1.2 cal/cm^2	Outside the arc flash boundary and not defined by NFPA 70E. See Note 1.
1.2-12 cal/cm^2	Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy (see Note 2) Long-sleeve shirt and pants or coverall or arc flash suit (SR) Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR) (see Note 3) Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner) (AN) Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with leather protectors (SR) (see Note 4) Hard hat Safety glasses or safety goggles (SR) Hearing protection Leather footwear
>12 cal/cm^2	Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy (see Note 2) Long-sleeve shirt and pants or coverall or arc flash suit (SR) Arc-rated arc flash suit hood Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner) (AN) Arc-rated gloves or rubber insulating gloves with leather protectors (SR) (see Note 4) Hard hat Safety glasses or safety goggles (SR) Hearing protection Leather footwear

AN: as needed (optional). AR: as required. SR: selection required.

Notes:

1. *Refer to Table 4-4 for minimum PPE clothing requirements.*

2. *Arc ratings can be for a single layer, such as an arc-rated shirt and pants or a coverall, or for an arc flash suit or a multi-layer system if tested as a combination consisting of an arc-rated shirt and pants, coverall, and arc flash suit.*

3. *Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area are required by NFPA 70E Article 130.7(C)(10)(c). Where the back of the head is inside the arc flash boundary, a balaclava or an arc flash hood shall be required for full head and neck protection.*

4. *Rubber insulating gloves with leather protectors provide arc flash protection in addition to shock protection. Higher class rubber insulating gloves with leather protectors, due to their increased material thickness, provide increased arc flash protection.*

4-1.3 Minimum PPE Clothing Requirements.

Any worker whose normal job includes working on or near exposed electrical equipment must wear to work as a minimum:

- Arc-rated shirt (long-sleeve) and pants (or arc-rated coveralls) with minimum arc rating of 8 cal/cm^2 (33.47 J/cm^2).

- Cotton or natural fiber underwear (conventional short sleeve t-shirt and briefs/shorts). Do not include any organizational or other insignias or decals on t-shirts.

- Leather electrical hazard-rated (EH) footwear. *Note: High voltage linemen are not required to wear EH work footwear while climbing.* **\3** Per 70E, Table 130.5(G), footnote d, footwear other than leather or dielectric shall be permitted to be used, provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure. ***/3/***

4-1.4 Job-Site PPE Clothing Requirements.

Any employee who goes to a job site that involves working on or near exposed electrical equipment must wear all of the following (with the exception of gloves which will be dictated by the work task in Table 4-2) as a minimum:

- Arc-rated shirt (long-sleeve) and pants (or arc-rated coveralls) with minimum arc rating of 8 cal/cm^2 (33.47 J/cm^2).

- Cotton or natural fiber underwear (conventional short sleeve t-shirt and briefs/shorts). Do not include any organizational or other insignias or decals on t-shirts.

- Leather electrical hazard-rated (EH) footwear. *Note: High voltage linemen are not required to wear EH footwear while climbing*.**\3** Per 70E, Table 130.5(G), footnote d, footwear other than leather or dielectric shall be permitted to be used, provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure. **/3/**

- Safety glasses (ANSI Z87.1) with side shields. Wear safety goggles (ANSI Z87.1) over metal frame and non-safety glasses.

- Hardhat (ISEA Z89.1 Type 1 Class E approved). Long hair must be secured under the hardhat. For cold weather operations, insulated hard hat liner must be arc rated. For work tasks classified as Category 2 or higher, an insulated hard hat liner does not satisfy the requirement for a sock/balaclava worn under the face shield.

- Wear leather work gloves for work tasks classified as Category 1 or 2. Wear arc-rated gloves for work tasks classified as Category 3 or 4. Voltage rated gloves with leather protectors are equivalent to arc-rated gloves. Rubber glove protectors must not be used as work gloves.

- Hearing protection using ear-canal inserts is required whenever working within the arc flash boundary. Hearing protection is also required in accordance with local procedures and whenever the sound level exceeds 84 decibels or 140 decibels peak sound level pressure for impulse or impact noise, regardless of the exposure duration. Wear a combination of insert type and circumaural types of hearing protectors (double protection) when sound levels exceed 104 db(A).

4-1.5 Required PPE Level Per Arc Flash Risk Analysis.

Table 4-3 provides the required minimum PPE level to be worn as a function of the arc flash PPE category. **\2** Table 4-4 provides the required minimum PPE level to be worn as determined by an incident energy analysis. The results of an incident energy analysis to specify a PPE category in Table 4-3 shall not be permitted**. /2/**

Table 4-3. Required PPE Per Arc Flash Category

Arc Flash PPE Category	General PPE Description (See notes)	Required Minimum PPE Arc Rating [cal/cm^2 (J/cm^2)]
\3	[Deleted]	**/3/**
1	Comply with Section 4-1.4 for clothing requirements and Table 4-1 for face shield requirements.	8 (33.47)
2	Comply with Table 4-1.	8 (33.47)
3	Comply with Table 4-1.	25 (104.60)
4	Comply with Table 4-1.	40 (167.36)

Note 1. NFPA 70E discontinued the use of Category 0, which is defined as an incident energy of less than 1.2 cal/cm^2 (5 J/cm^2). This level of incident energy is also referred to as the arc flash boundary.

Note 2. Voltage rated gloves with leather protectors must be used in accordance with NFPA 70E and as specified elsewhere in this UFC.

Note 3. For cold weather operations, an insulated hard hat liner must be arc rated. For work tasks classified as Category 2 or higher, an insulated hard hat liner does not satisfy the requirement for a sock/balaclava worn under the face shield.

Note 4. Comply with Section 4-2.2 when operating branch circuit breakers rated for 30 amperes or less used for lighting and general-purpose receptacles.

Note 5. For Air Force military qualified electrical personnel performing Category 0 tasks, comply with Section 4-1.6.

\2\ Table 4-4. Required PPE Per Available Incident Energy

Available Incident Energy	General PPE Description (See notes)	Required Minimum PPE Arc Rating [cal/cm^2 (J/cm^2)]
0-1.2 cal/cm^2	Comply with Section 4-1.4.	8 (33.47)
1.2-8 cal/cm^2	Comply with Section 4-1.4 for clothing requirements and Table 4-2 for face shield requirements.	8 (33.47)
8-12 cal/cm^2	Comply with Table 4-2.	As determined by incident energy analysis
>12 cal/cm^2	Comply with Table 4-2.	As determined by incident energy analysis

Note 1. NFPA 70E does not provide PPE requirements for under 1.2 cal/cm2 (5 J/cm^2). This level of incident energy is also referred to as the arc flash boundary.

Note 2. Voltage rated gloves with leather protectors must be used in accordance with NFPA 70E and as specified elsewhere in this UFC.

Note 3. An insulated hard hat liner does not satisfy the requirement for a sock/balaclava worn under the face shield.

Note 4. Comply with Section 4-2.2 when operating branch circuit breakers rated for 30 amperes or less used for lighting and general-purpose receptacles.

Note 5. For Air Force military qualified electrical personnel performing 0-1.2 cal/cm^2 tasks, comply with Section 4-1.6. ***/2/***

4-1.6 Air Force Military Uniforms.

For the Air Force, refer to AFI 32-1064, *Electrical Safe Practices*, Attachment 2 for proper wear of military uniforms while working on or near exposed electrical equipment.

At forward deployed locations, Mission Oriented Protective Postures equipment may directly conflict with PPE/clothing requirements for performing electrical work on or near energized circuits. For this and other contingency or wartime operations when special chemical, biological, or radiological clothing is required, the Base Civil Engineer may waive or modify requirements in this chapter, but only after evaluating all safety alternatives with mission requirements.

4-1.7 Additional PPE Clothing Requirements.

Wear arc flash rated clothing properly inside the arc flash boundary. This includes:

- Long sleeves must be rolled down and buttoned.
- The top button of shirts, coveralls, and jackets must be fastened.
- Tuck shirts into the trousers.
- Shorts are prohibited and trousers must extend the full length of the leg.
- Garments with exposed metallic fasteners must not be worn, unless the garments are properly arc rated.
- Garments, including safety harnesses, worn over arc flash rated protective clothing must be arc flash rated.

4-1.8 Clothing Prohibitions.

The following is prohibited:

- Do not wear conductive articles of jewelry (including but not limited to cloth with conductive thread, metal frame glasses, metal headgear, wristbands, watch chains, rings, bracelets, necklaces, body jewelry and piercings) within the restricted approach boundary or where they present an electrical contact hazard with exposed energized electrical conductors or circuit parts.
- Do not wear clothing that could increase the extent of injuries when exposed to electric arcs or open flames. Clothing made from acetate, nylon, polyester, and rayon, either alone or in blends, cannot be worn as undergarments when working on or near energized equipment of greater

than 50 V. Military clothing such as DCUs, field jackets, field jacket liners, Gore-Tex jackets and pants, Gore-Tex fleece liners, nylon cold weather gloves, nylon upper combat boots, chemical warfare suits, winter parkas, winter parka pants, all are polyester blend materials and not allowed to be worn when working on or near energized equipment of greater than 50 V. Shorts are prohibited and trousers must extend the full length of the leg.

- Do not wear anything made of celluloid or other flammable plastic when working near electric arcs or open flames. This may include cap visors, collars, and cuff protectors.
- Do not wear loose clothing, dangling sleeves, or neckties when working on or near moving machinery.
- Do not wear garments equipped with metal slides or zipper fasteners unless the slide or fastener is effectively covered.
- Do not wear coveralls half-dressed where the top-half is wrapped around the waist area.
- Do not wear clothing in a way in which it was unintended to be worn, such as an arc-rated shirt tied around waist with the sleeves.

4-2 ARC FLASH RISK ASSESSMENT.

Perform and document an arc flash risk assessment in accordance with NFPA 70E, Article 130.5 or IEEE C2 Paragraph 410.A.3.a, to determine the available incident energy at the intended work location.

\2 When conducting arc flash risk assessments in accordance with NFPA 70E, incident energy calculations must be performed in accordance with the latest edition of IEEE 1584. ***/2/***

Note: Refer to Section 1-4.2 for the delineation between NFPA 70E and IEEE C2.

Include the following in an arc flash risk assessment:

a. Determine if an arc flash hazard exists. If an arc flash hazard exists, include the following in the arc flash risk assessment:

   - o Appropriate safety-related work practices.
   - o The PPE to be used within the arc flash boundary.

b. Update the arc flash risk assessment when a major modification or renovation takes place. Review the arc flash risk assessment periodically, at intervals not to exceed 5 years, to account for changes in the electrical distribution system that could affect the results of the arc flash risk assessment. Typical changes that could affect the arc flash risk assessment include:

- o System design changes that affect short circuit values or electrical coordination.
- o Protective relay and circuit breaker trip setting changes.
- o Revisions to NFPA 70E, IEEE 1584, or IEEE C2 that affect the arc flash calculation methodology or allowed assumptions in the methodology.
- o Lack of maintenance and testing for the protective equipment credited by the arc flash calculations.

c. Take into consideration the design of the overcurrent protective device and its opening time, including its condition of maintenance.

Note: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis, or the PPE category method may not provide adequate protection from arc flash hazards.

4-2.1 Arc Flash Risk Assessments Based on Tables.

If incident energy calculations cannot be performed in support of an arc flash risk assessment, utilize the following tables. A documented arc flash risk assessment must be performed for any condition not covered by these tables. **\2** Arc flash risk assessments shall be performed using Tables 4-5, 4-6, and 4-7 only as a short-term solution until an arc flash risk assessment can be performed using an incident energy analysis. Arc flash risk assessments performed using Tables 4-5, 4-6, and 4-7 are only permitted for tasks which are included in Table 4-5 and for equipment and parameters included in Table 4-6 or Table 4-7. Interpolation or extrapolation of parameters not included in these tables is prohibited. **/2/**

a. **\3** Table 4-5 has been developed utilizing NFPA 70E-2021, Table 130.5(C). **/3/** This table determines if arc flash PPE is required for the intended energized work activity.

b. **\3** Table 4-6 has been developed utilizing NFPA 70E-2021, Table 130.7(C)(15)(a). **/3/** Once it has been determined that arc flash PPE is required, Table 4-6 provides guidance regarding the PPE arc flash category.

c. **\3** Table 4-7 has been developed utilizing NFPA 70E-2021, Table 130.7(C)(15)(b). **/3/** The arc flash PPE category depends on the battery voltage and the available short circuit current.

d. Table 4-8 addresses specific service SOPs. Table 4-8 takes precedence over Tables 4-5, 4-6, and 4-7 for any conflicts (interpretation or comparisons) between the tables.

e. Table 4-9 provides the arc flash PPE requirements for overhead distribution work and is based on IEEE C2. Refer to the notes below Table 4-9 for additional information.

f. Tools used as part of the task must be rated for the line-to-line voltage of the energized equipment.

Table 4-5. Arc Flash Hazard Identification

Task	Equipment Condition	Likelihood (see Note)
• Reading a panel meter while operating a meter switch. • Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers. • Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access. • Examination of insulated cable with no manipulation of cable. • **\3** [Deleted] ***/3/*** • For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack. •	Any	No

• For ac systems, work on energized electrical conductors and circuit parts, including voltage testing. • **\3** Operation of a CB or switch the first time after installation or completion of maintenance in the equipment. **/3/** • For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing. • Removal or installation of CBs or switches. • Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers. • Application of temporary protective grounding equipment, after voltage test. • Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts. • Insertion or removal of individual starter buckets from motor control center (MCC). • Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed. • Insertion or removal of plug-in devices into or from busways. • Examination of insulated cable with manipulation of cable. • Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center. • Insertion or removal of revenue meters (kW-hour, at primary voltage and current). • **\3** Insertion or removal of covers for battery intercell connector(s). **/3/** • For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source. • Opening voltage transformer or control power transformer compartments. • Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV. • Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	Any	Yes
• Operation of a CB, switch, contactor, or starter.	Normal	No

Task	**Equipment Condition**	**Likelihood (see Note)**
• Voltage testing on individual battery cells or individual multi-cell units. • Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts. • Opening a panelboard hinged door or cover to access dead front overcurrent devices. • Removal of battery nonconductive intercell connector covers.		
• Maintenance and testing on individual battery cells or individual multi-cell units in an open rack • Insertion or removal of individual cells or multi-cell units of a battery system in an open rack. • **\3** Arc-resistant equipment with the DOORS CLOSED and SECURED. And where the available fault current and fault clearing time docs do not exceed that of the arc-resistant rating of the equipment in one of the following conditions: • (1) Insertion or removal of individual starter buckets • (2) Insertion or removal (racking) of CBs from cubicles • (3) Insertion or removal (racking) of ground and test device • (4) Insertion or removal (racking) of voltage transformers on or off the bus **/3/**	Abnormal	Yes

Note: The two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies "No" as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. ***\3*** *Where this table identifies "Yes" as an estimate of likelihood of occurrence, it means that additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in NFPA 70E 2021, Article 110.5(H).* ***/3/***

\3\

Table 4-6. Arc Flash PPE Category Classifications for Alternating Current (AC) Systems on Grade

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 V and below. Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec. (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.).	1	19 in (485 mm)
Panelboards or other equipment rated >240 V and up to 600 V. Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec. (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.).	2	3 ft (900 mm)
600-V class motor control centers (MCCs). Parameters: Maximum of 65 kA short-circuit current available; maximum of 0.03 sec. (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	5 ft (1.5 m)
600-V class motor control centers (MCCs). Parameters: Maximum of 42 kA short-circuit current available; maximum of 0.33 sec. (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	14 ft (4.3 m)
600-V class switchgear (with power circuit breakers or fused switches) and 600 V class switchboards. Parameters: Maximum of 35 kA short-circuit current available; maximum of up to 0.5 sec. (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	20 ft (6 m)
Other 600-V class (277 V through 600 V, nominal) equipment. Parameters: Maximum of 65 kA short circuit current available; maximum of 0.03 sec. (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	5 ft (1.5 m)
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV. Parameters: Maximum of 35 kA short-circuit current available; maximum of up to 0.24 sec. (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.).	4	40 ft (12 m)

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Metal-clad switchgear, 1 kV through 15 kV. Parameters: Maximum of 35 kA short circuit current available; maximum of 0.24 sec. (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	40 ft (12 m)
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.) Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4 4	12 m (40 ft) 12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment Arc-resistant equipment 1 kV through 15 kV Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment	N/A N/A	N/A N/A

/3/

Note 1. Refer to NFPA 70E for additional limitations regarding the use of the above table.

\3

Table 4-7. Arc Flash PPE Category Classifications for Direct Current (DC) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Storage batteries, dc switchboards, and other dc supply sources Parameters: 100 V ≤ Voltage ≤ 250 V Maximum arc duration and working distance: 2 sec @ 455 mm (18 in.)		
Available fault current < 4 kA	2	900 mm (3 ft)
4 kA ≤ Available fault current < 7 kA	2	1.2 m (4 ft)
7 kA ≤ Available fault current < 15 kA	3	1.8 m (6 ft)
Storage batteries, dc switchboards, and other dc supply sources Parameters: 250 V < Voltage ≤ 600 V Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)		
Available fault/ current < 1.5 kA	2	900 mm (3 ft)
1.5 kA ≤ Available fault current < 3 kA	2	1.2 m (4 ft)
3 kA ≤ Available fault current < 7 kA	3	1.8 m (6 ft)
7 kA ≤ Available fault current < 10 kA	4	2.5 m (8 ft)

/3/

Note 1. Refer to NFPA 70E for additional limitations regarding the use of the above table.

Note 2. Obtain the available short circuit current for a particular battery from the manufacturer or the manufacturer's manual for the battery. If this information is not available, estimate the available short circuit current for a lead acid battery from the battery performance data sheet as 10 times the 1-minute ampere capability of the cell (at 77°F (25°C) to 1.75 V per cell).

Table 4-8. Additional Work Tasks and Associated PPE Requirements

Voltage	Task	Modifications and Clarifications to NFPA 70E Tables	V-Rated Gloves	V-Rated Tools
< 600 V	Overhead line work, including lighting.	Comply with Section 4-1.4 and arc-rated safety harness (see Note 1)	Y	Y
> 600 V	Overhead line work (specific tasks of gang-operated switch operation, phasing/voltage/current testing, installing or removing safety grounds, and installing/removing mechanical type live-line clamps/stirrups) at hot stick distance (> 6 ft (2 m)).	Comply with Section 4-1.4 and arc-rated safety harness with lanyard	Y	Y (Note 2)
> 600 V	Overhead line work (specific tasks of disconnect switch operation, fused cutout operation, and replacing fuses) at hot stick distance (> 6 ft (2 m)).	Category 2 and arc-rated safety harness with lanyard	Y	Y (Note 2)
< 600 V	Underground line work (excluding underground structures), including lighting.	Comply with Section 4-1.4	Y	Y
> 600 V	Underground structures (manhole or vault) with no known problems: Routine cable inspection without touching or otherwise disturbing cables.	Comply with Section 4-1.4 and arc-rated safety harness with lanyard	Y	Y
> 600 V	Underground structures (manhole or vault) with no known problems: Splicing deenergized cables in structure with energized cables.	Comply with Section 4-1.4 and arc-rated safety harness with lanyard. Any work task associated with adjusting, moving, or disturbing energized cables requires that power be secured (circuit opened) prior to beginning the task. See Chapter 10 for additional guidance.	N	N
> 600 V	Operating (open/close) SF6, vacuum and air pad-mounted switches (dead front).	Category 2	Y	N

Voltage	Task	Modifications and Clarifications to NFPA 70E Tables	V-Rated Gloves	V-Rated Tools
> 600 V	Operating (open/close) SF6, vacuum and air pad-mounted switches (live front) at hot stick distance (> 4 ft (1.25 m)).	Category 2	Y	Y (Note 2)
> 600 V	Operating (open/close) oil switches.	Must remotely operate from >20 ft (6.1 m) and comply with Section 4-1.4.	Y	N
> 600 V	Oil fused cutouts.	Category 2 Must deenergize upstream before operating cutout.	Y	N
> 600 V	Operating (open/close) oil immersed loadbreak 3-phase gang operated or single-phase pad mount transformer switches at hot stick distance and removal of load-break elbows from various equipment (> 4 ft (1.25 m)).	Category 2	Y	Y (Note 2)
> 600 V	Phasing circuits from grade (ground) at hot stick distance (> 6 ft (2 m)).	Category 2	Y	Y (Note 2)
> 600 V	Overhead series lighting at hot stick distance (> 6 ft (2 m)).	Category 2	Y	Y (Note 2)
> 600 V	Fusing: Operation of fused cutouts (or replacing fuses in fused cutouts) mounted inside a vault or building at hot stick distance (> 4 ft (1.25 m)).	Category 4	Y	Y (Note 2)
> 600 V	Fusing: Replacing fuses in pad mounted transformers or pad mounted switches at hot stick distance (> 4 ft (1.25 m)).	Category 2 Must deenergize transformer before replacing fuses.	Y	Y (Note 2)
> 600 V	Disconnecting /shorting/and grounding capacitor banks at hot stick distance (> 4 ft (1.25 m)).	Category 4	Y	Y (Note 2)
< 600 V	Ship to shore – voltage testing, testing shore power receptacle cover interlock switches and shore power receptacle interlock switches.	Category 4	Y	N

Voltage	Task	Modifications and Clarifications to NFPA 70E Tables	V-Rated Gloves	V-Rated Tools
> 600 V	Ship to shore – voltage testing, application of safety grounds at hot stick distance (> 4 ft (1.25 m)).	Category 4	Y	Y (Note 2)
> 600 V	Hi-potential testing.	Comply with Section 4-1.4.	Y	N
> 600 V	Application of safety grounds from grade (ground) at hot stick distance (>6ft (2m)) in outdoor substations.	Category 4	Y	Y (Note 2)
> 600 V	Spiking a deenergized cable to ground with a remote hydraulic spiking tool. See Note 3.	Comply with Section 4-1.4.	N	N
> 600 V	Cutting a deenergized cable with a remote hydraulic guillotine cutter. See Note 3.	Comply with Section 4-1.4.	N	N

Note 1. Treat voltage of circuits (less than 600 V) as that of the highest voltage occupying one or more poles on which the circuit is run.

Note 2. Live-line tools (minimum length as indicated) must be used.

Note 3. For manhole work, keep workers outside manhole for this task. For direct buried cables, keep workers more than 20 ft (6.1 m) away from task.

Table 4-9. Requirements for Aerial (Overhead) Systems and Equipment

Phase-to-Phase Voltage (kV)	Fault Current (kA)	Category 0	Category 2
		Maximum Clearing Time (cycles)	Maximum Clearing Time (cycles)
1.1 to 15	5	320.0	2,134.0
	10	125.0	830.0
	15	69.0	460.2
	20	44.7	297.7
15.1 to 25	5	189.6	1264.0
	10	78.0	519.8
	15	45.2	301.0
	20	30.2	201.0
25.1 to 36	5	141.3	942.0
	10	59.7	398.0
	15	35.4	235.7
	20	24.0	160.0
36.1 to 46	5	107.4	716.0
	10	46.1	307.0
	15	28.3	188.5
	20	20.2	134.7

Note 1. These calculations are based on open air phase-to-ground. This table is not intended for phase-to-phase arcs or enclosed arcs (arc in a box).

Note 2. These calculations are based on a 72-inch distance from the arc to the employee and arc gaps as follows: 1 kV to 15 kV = 5.08 cm (2 in), 15.1 kV to 25 kV = 10.16 cm (4 in), 25.1 kV to 36 kV = 15.24 cm (6 in), 36.1 kV to 46 kV = 22.86 cm (9 in). See IEEE 4.

Note 3. These calculations were derived using a commercially available computer software program. Other methods are available to estimate arc exposure values and may yield slightly different but equally acceptable results.

Note 4. The use of the table in the selection of clothing is intended to reduce the amount of injury but may not prevent all burns.

Note 5. The table identifies Category 0 and Category 2 levels. Refer to Section 4-1.5 for associated PPE requirements.

Note 6. The maximum clearing time applies to the upstream protective device(s) that provides circuit protection for the intended work location.

4-2.2 Facility Manager Authorized Tasks.

Facility Managers and Building Monitors are permitted to perform the following tasks on switchboards and panelboards rated for less than 600 volts while wearing a minimum of 8 cal/cm^2 (33.47 J/cm^2) coveralls, leather gloves, and safety glasses:

- Opening and closing circuit breakers rated for 30 amperes or less for the purpose of circuit identification and panelboard labeling, including ground fault circuit interrupter and arc fault circuit interrupter testing.

- Operating SWD or HID rated circuit breakers used for lighting control.

Resetting a branch circuit breaker rated for 30 amperes or less used for lighting and general-purpose receptacles after a known equipment or circuit overload and the overload has been removed. If circuit breaker fails to close or immediately trips after resetting, call a qualified electrical worker to investigate.

Note: If the reason for a tripped circuit breaker cannot be determined to be because of an overload, do not reclose the circuit breaker. Call a qualified electrical worker to investigate.

4-2.3 Arc Flash PPE Requirements for Low Voltage Control Circuits.

Arc flash PPE clothing is optional for work on control circuits rated for 120 volts, or less, if the control circuit is provided with upstream fusing rated for 30 amperes or less. The restricted approach boundary is “Avoid Contact” at 150 volts or less and voltage rated gloves are optional for work near 120-volt control circuits. Personnel working on these energized control circuits are required to be trained and designated as a qualified electrical worker in accordance with Section 2-2 for the activities that might be performed on an energized control circuit.

The following are examples of systems that might include these low-voltage control circuits:

- Elevator systems.

- HVAC systems.

- Fire alarm systems.

- Diesel generator control circuits.

- SCADA control circuits.

CHAPTER 5 WORK AREA PROTECTIVE EQUIPMENT AND TOOLS

This chapter addresses the work area protective equipment that supports electrical construction and maintenance, and the associated requirements for their inspection and use. Refer to manufacturer's specific instructions when available.

5-1 INSPECTION OF APPAREL, TOOLS, AND MATERIALS HANDLING EQUIPMENT.

All apparel, tools, and equipment used on the job must comply with this UFC, as well as the applicable service and OSHA requirements. Regular inspections are also necessary to prevent the use of defective items on the job. The authorized individual-in-charge may, regardless of ownership, prohibit the use of any equipment on the job which could be considered unsafe. Complete inspections as follows:

- An initial inspection of tools brought on the job by a new worker must be made by the authorized individual-in-charge. Use is permitted only if the tools are in good condition and conform to requirements of this UFC.
- Inspections of tools and equipment used by an individual worker may be made by the authorized individual-in-charge at any time.
- Before a job is started, each worker must inspect protective apparel, tools, ladders, scaffolds, ropes, and other materials handling equipment to be used. All items must be suitable for their intended uses and in good material condition.
- Use of employee-owned test equipment is prohibited.

Consider the following when selecting and using apparel:

- Maintenance of the garment – some garments may be marked for professional cleaning/dry cleaning only with home/shop laundry prohibited.
- Durability – ability and process to remove stain/oils.
- Wear ability – sizing.
- Repair – procedures utilizing proper materials.
- Intended use – based upon arc flash analysis and manufacturer's recommendations.
- Projected life of the product.
- Limitations of the garment – limited washings, as specified by the manufacturer.

- Training.

- Take care to ensure all garments meet and are labeled in accordance with ASTM F1506, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*.

5-2 RUBBER PROTECTIVE EQUIPMENT.

Rubber protective equipment consists of gloves, sleeves, blankets, and insulator hoods. Ensure all items meet or exceed the requirements of the applicable ASTM F18 series standards.

5-2.1 Job Requirements.

The authorized individual-in-charge must determine the necessary type and amount of protective equipment required on the job. Inspect rubber goods before use. Destroy any item found to be defective. Each line truck and service/trouble truck that is required to carry protective equipment, must carry enough protective equipment rated at or above the voltages that could be encountered.

Keep rubber goods inside of a bag, box, or container designed for and used exclusively for them. Transport rubber goods in a manner protected from light, temperature extremes, excessive humidity, ozone, and other injurious substances and conditions. Transport rubber goods in their natural shape, not folded, creased, inside out, compressed, or in any manner that will cause stretching or compression.

5-2.2 Use of Rubber Protective Equipment.

Rubber or other approved protective equipment must be used on all conductors or energized parts, which could be contacted by a worker climbing to or reaching from a work position. Rubber or other approved protective equipment must be rated for the voltage encountered. Table 5-1 provides the OSHA 29 CFR 1910.137 voltage and proof test requirements for rubber insulating equipment. Table 5-2 provides the rubber insulating equipment test intervals.

Table 5-1. Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Proof Test (AC Volts)	Retest Voltage (DC or AC – Average)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	2,500	10,000	1 (25)
0	Red	1,000	5,000	20,000	1 (25)
1	White	7,500	10,000	40,000	1 (25)
2	Yellow	17,000	20,000	50,000	2 (50)
3	Green	26,500	30,000	60,000	3 (75)
4	Orange	36,000	40,000	70,000	4 (100)
1 – Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.					

Observe the following precautions:

- Position protective equipment to protect workers against unforeseen hazards such as slipping, cutting out, leaning back, or falling.

- Protective equipment must be placed by working from a level below the wires or insulators on the pole or structure, beginning with those nearest the climbing space, and covering the live parts in the order of their distance away from the climbing space.

- Cover other points of contact, such as grounded guys, equipment, and secondary wires to provide complete protection.

- The removal of protective equipment must be done with equal care, working below the level of wires and insulators. The order of removal must be the reverse of the order of placement.

5-2.3 Use of Rubber Gloves.

Wear rubber gloves with leather protectors suitable for the purpose when climbing or working on installations or structures in the vicinity of live circuits, or in the vicinity of any wire or equipment that may become energized by remote or accidental means. Observe the following:

- Do not use rubber gloves without leather protector gloves over them.

- Before putting on rubber gloves, give each glove an air test to detect cuts and weak spots. This is accomplished by rolling up the glove tightly beginning at the gauntlet end. Listen and feel for air escaping through the palm, thumb, or fingers. Gloves that show weak spots or air leakage must be destroyed. It is recommended that one or more fingers of a defective glove be immediately cut off to ensure no other worker inadvertently uses the glove.

- Liners are available for use inside the rubber gloves to absorb perspiration.
- Use only the gloves assigned, except in case of emergency.
- Keep sleeves of wearing apparel tucked inside the cuffs of the rubber gloves.
- Put on rubber gloves (and sleeves if needed) before being within reach of the restricted approach boundary of the energized conductors.
- Do not remove gloves or sleeves until out of reach of the restricted approach boundary of energized conductors.

Note: Work involving overhead work in a bucket truck is treated differently regarding when to put on and remove rubber gloves. Put on rubber gloves before bucket departure from the cradle and do not remove rubber gloves until the bucket has been returned to the cradle.

5-2.4 Use of Rubber Sleeves.

Wear rubber sleeves whenever there is a possibility of arms coming within the restricted approach boundary specified in Table 3-1. Rubber sleeves are normally worn in conjunction with rubber glove work. Wear rubber sleeves when performing energized-line pole or bucket work within contact distance of an energized line.

5-2.5 Care and Inspection of Rubber Protective Equipment.

Inspect rubber protective equipment before each day's use and immediately following any incident that can reasonably be suspected of having caused damage. Protective equipment must not be stored in a sharply bent position or exposed to the sun's rays, light, or heat.

5-2.5.1 General Care.

Wipe dry all protective equipment before storing. Protect it from contact with oil, paint, creosote, kerosene, gasoline, acids, and other harmful materials. Rubber protective equipment must be turned in to an experienced testing laboratory for cleaning, inspection, and electrical tests. Shorter inspection periods must be considered where equipment is used frequently. Refer to Table 5-2 for required test intervals.

5-2.5.2 Care of Rubber Gloves.

When not in use, rubber gloves must be carried in glove bags. When in use, take the following precautions:

- Rubber gloves must be washed when tested at an approved laboratory and kept free from embedded foreign matter.
- Powder specifically designed for protective rubber gloves can be used after washing rubber gloves to avoid skin irritation and to prevent the rubber from sticking together.
- Store rubber gloves with the fingers up to allow perspiration to drain/dry from the gloves.

5-2.5.3 Care of Rubber Blankets and Sleeves.

Roll, never fold, rubber blankets and sleeves. When being rolled, their surfaces must be brushed clean to prevent dirt from becoming embedded in the surface of the rubber. Do not wear climbers when standing on rubber blankets.

5-2.5.4 Inspection of Rubber Blankets and Sleeves.

Inspect rubber blankets and sleeves immediately before each use. Items with cracks, holes, snags, blisters, or other defects must be discarded.

5-2.5.5 Inspection of Insulator Hoods.

Inspect hoods immediately before use. Examine hoods before each use to ensure that there are no defects and determine if they are suitable for further use.

5-2.5.6 Care of Insulator Hoods.

Line hoods must be air dried. Store hoods in compartments so that no part is strained or distorted.

5-2.6 Test Intervals for Rubber Protective Equipment.

Rubber protective equipment must be subjected to periodic electrical tests. Table 5-2 provides the OSHA 29 CFR 1910.137 required test intervals for rubber insulating equipment. Consider shorter inspection periods where equipment is used frequently.

Table 5-2. Rubber Insulating Equipment Test Intervals

Type of Equipment	Test Frequency
Rubber insulating covers	Upon indication that insulating value is suspect
Rubber insulating blankets	Before first issue and every 12 months thereafter
Rubber insulating gloves	Before first issue and every 6 months thereafter
Rubber insulating sleeves	Before first issue and every 12 months thereafter

Note: If the insulating equipment has been electrically tested, but not issued for service, it may not be placed into service unless it has been electrically tested within the previous 12 months. For rubber insulating gloves, the following examples describe when gloves must be removed from service or retested:

- *Gloves tested on January 1, 2016, and issued after six months in storage on July 1, 2016. The gloves must be removed from service by January 1, 2017. This is both 6 months from the issue date and 12 months from the test date.*

- *Gloves tested on January 1, 2016, and issued shortly after on February 1, 2016. The gloves must be removed from service by August 1, 2016. This is 6 months from the issue date but less than 12 months from the test date.*

- *Gloves tested on January 1, 2016, and issued later in the year on October 1, 2016. The gloves must be removed from service by January 1, 2017. This is only 2 months from the issue date but 12 months from the test date.*

5-3 INSULATED HAND TOOLS AND HANDLING EQUIPMENT.

When working near exposed energized conductors or circuit parts, use insulated tools or handling equipment if the tools or handling equipment might contact such conductors or parts. If the insulating capability of insulated tools or handling equipment is subject to damage, protect the insulating material during storage.

5-4 LIVE-LINE (HOT-LINE) TOOLS.

Live-line tools are only as safe as their continued care and inspection make them. ANSI/IEEE 516 and ASTM F3121/F3121M-16 provide additional information on maintenance and testing. ANSI/IEEE 935 is the guide to be used for tool terminology.

5-4.1 Manufacture.

Tools must be manufactured to meet ASTM F18 series specifications as appropriate to the device and material. The insulating tool portion must be made of fiberglass-reinforced plastic (FRP). FRP must be used as it does not absorb moisture, is impervious to oil-borne materials and solvents, is stronger, and is a better insulator than wood. Like any insulator, FRP must be kept clean and dry to maintain its insulating ability. Use only live-line tools that have a manufacturer's certification as having been tested to meet the following minimum acceptance requirements:

5-4.1.1 FRP.

A FRP tool must have withstood 100,000 V ac per ft (305 mm) of length for 5 minutes.

5-4.1.2 Wood.

Wooden tools are not authorized for use.

5-4.2 Authorized Types of Tools.

All tools must be FRP tools. Replace existing wooden tools with new FRP tools.

5-4.3 Records.

Records must be maintained for all live-line tools to demonstrate satisfactory accomplishment of laboratory and shop testing.

5-4.4 Tool Cleaning Before Use.

A live-line tool must be wiped clean before each day's use and visually inspected for cleanliness and a glossy surface. Clean live-line tools with a clean absorbent paper towel or cloth and then wipe with a clean, dry cloth (a silicone-treated cloth is also permitted). Never use cloths that have been washed in harsh solvents, soap, or detergents. Residues could be left on the tool that may be conductive. Abrasives could damage the surface gloss of the tool (thus permitting water to "wet-out" or "sheet" on the surface of the tool if later exposed to rain or heavy fog). If the surface of the tool is not glossy, or any contamination is present after wiping that could adversely affect the insulating qualities of the tool, the tool must be removed from service and tested before being returned to service.

5-4.5 Tool Inspection After Cleaning and Before Use.

After each cleaning and before use, a live-line tool must be visually inspected for defects. If any defect is present that could adversely affect the insulating qualities of the tool, the tool must be removed from service and tested before being returned to service. The following field observations warrant removing a tool from service:

- Evidence of an electrically overstressed tool, such as: electrical tracking; burn marks; or blisters caused from heat.

- Evidence of a mechanically overstressed tool, such as: damaged, bent, warped, worn, or cracked components; deep cuts, scratches, nicks, gouges, dents or delamination in the tool surface; or deterioration of the tool's glossy surface.

5-4.6 Other Conditions for Removal from Service.

A live-line tool must be removed from service if one or more of the following conditions are detected:

- It fails to pass an electrical wet test during laboratory, shop, or field-testing.

- If a tingling or fuzzy sensation is felt when the tool is in contact with energized conductors or hardware.

- If a tool has been dropped from a significant height (such as from an overhead line or a structure) or subjected to impact such that internal structural damage is suspected.

5-4.7 Returning a Tool to Service.

A tool may not be returned to service until the tool has been examined, cleaned, and repaired (if necessary), and electrically tested.

5-4.8 Waxing.

Waxing is not necessary after every use but only as needed. Use cleaning and waxing kits manufactured for live-line tools and follow directions for their use. All live-line tools must be electrically tested under wet conditions before being returned to service after any waxing.

5-4.9 Repairs and Refinishing.

Only competent personnel must make repairs, including any necessary refinishing. Generally, if there is no roughness on the surface and the live-line tool meets electrical tests, there is no need for repair. Small surface ruptures and small voids beneath the surface may need repair and refinishing. Refinishing of FRP tools typically includes abrasive smoothing of the surface and application of a clear epoxy coat. FRP tools must be electrically wet tested before returning to service after repair or refinishing.

5-4.10 Wet Electrical Testing.

FRP tools must be submitted to a wet electrical test at not more than 2-year intervals, and after any repair or refinishing. This test must be performed over the entire working length of the tool. Use of either of two procedures is acceptable to complete these tests:

- Laboratory testing in accordance with ASTM F3121/F3121M-16. FRP tools require an application of 75,000 V (ac) per ft (305 mm) for one minute.
- Shop or field testing using calibrated test equipment, such as the Hubbell Chance Wet/Dry Hot Stick Tester.

5-4.11 Precautions for Shop or Field Testing.

Follow the manufacturer's instructions and comply with the following precautions:

- Use demineralized water (such as sold in local grocery stores), if available. Otherwise use clean water of conductivity of 3.0 micromho-centimeters or less at room temperature.
- Support the tool in a horizontal position during the test.
- Avoid over-wetting. Use a mist applicator (such as a laundry-type spray bottle) and spray the test section until drops just start to run down the surface. If too much water is sprayed on the tool, water can collect in a line of drops at the undersurface, producing a false rejection because of flashover or high leakage current.
- Take overlapping readings from one end of the tool to the other but do not slide the tester on the tool. Lift up the tester before moving it. This can prevent streaks that can cause a false rejection.
- Rotate the tool 90 degrees and again test the tool from end to end. Continue in this manner until four different positions around the tool circumference have been tested.

5-4.12 Transportation.

Live-line tools must be transported with care and protected from mechanical damage. Exposure to inclement weather must be avoided. Containers must prevent damage to insulating surfaces from abrasive surfaces and bumping motions, and to minimize contamination buildup. In house fabricated containers made from PVC pipe and fittings provide excellent protection for live line tools. Special PVC fittings are also available from vendor for this purpose.

5-4.13 Storage.

Live-line tools transported on vehicles can be stored in bins or racks. If possible, avoid locations subject to temperature changes because this can permit the formation of condensation. Place tools in protective covers that are furnished with the tools. Store tools in bins and racks, constructed to prevent damage to insulating surfaces, away from dirt, moisture, and sunlight (and other sources of ultraviolet light). In house fabricated containers made from PVC pipe and fittings provide excellent protection for live line tools. Special PVC fittings are also available from vendors for this purpose.

5-4.14 Use of Live-Line Tools.

When using live-line tools, workers must use voltage rated gloves and not place their hands closer than is necessary to energized conductors or equipment or to the metal parts of the tool, and in no case closer than the restricted approach boundary specified in Table 3-1. Additional requirements on the use of live-line tools include:

- If tools used have quick-change heads, they must not be used without a “quick change safety clip”.
- Approved blocks, ropes, slings, and other tackle used in live-line tool work must not be used for any other purpose and must be kept clean, dry and free from contamination.
- Live-line tools being used to spread or raise conductors must be securely fastened and must not be held by workers except as necessary to secure or release them.
- Live-line tools must be hung on a hand line or approved tool hanger, if possible. Do not hang a tool on a conductor or bond wire.
- Never lay live-line tools on the ground. When brought to the worksite, place tools on portable racks or lay them on clean, dry tarpaulins or plastic sheeting.
- Do not use live-line tools in rain or heavy fog except in an emergency as directed by the authorized individual-in-charge. In no case must they be used when conditions permit formation of rivulets of water along the tool. After completing the job, make sure the tools are wiped dry before returning them to storage.

5-5 SKIN PROTECTION.

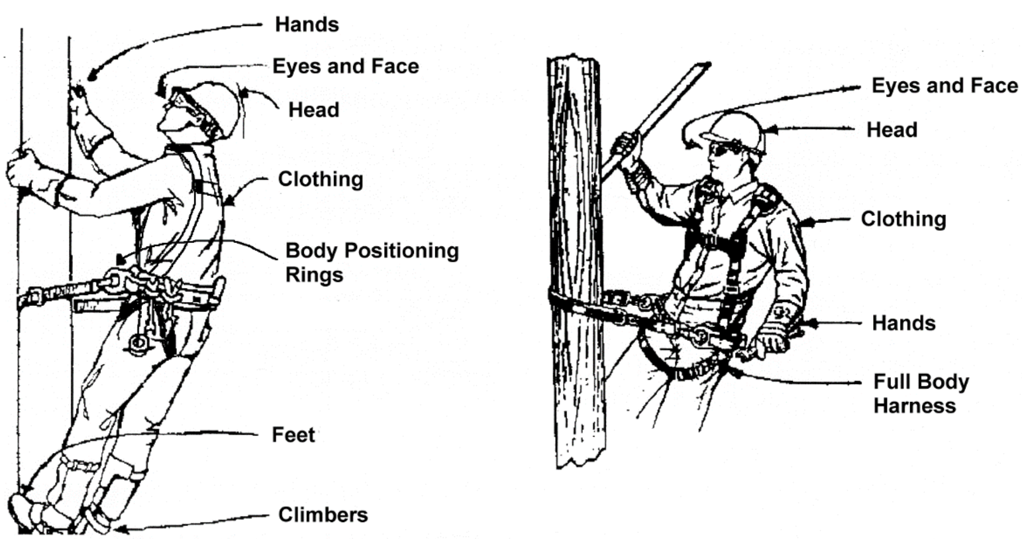
Provide protection for the worker’s skin from toxic and irritant substances where there is a possibility, they can occur at the job site. Ensure workers prevent injury by wearing suitable protective clothing. Keep protective ointments, proper cleaners for the skin, and appropriate first aid remedies on hand. Ensure protective ointments are not of a type that can damage rubber protective apparel. Keep emergency water sources on hand for flushing of irritant substances which could spill on the body, such as battery acid when working in a battery room. Keep sun-blocking ointments on hand when working outdoors.

5-6 POLE/TREE CLIMBING AND FALL PROTECTION.

5-6.1 Personal Protective Equipment.

Pole and tree climbing requires additional personal protective equipment to prevent falls. Items appropriate for work on a wood pole are shown in Figure 4-2.

Figure 4-2. Personal Protective Equipment for Working on a Pole



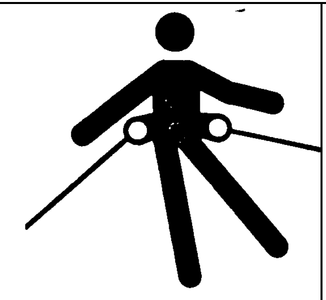
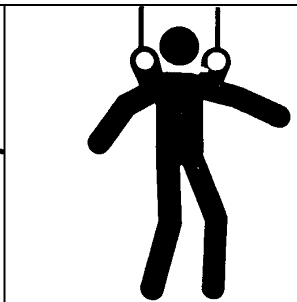
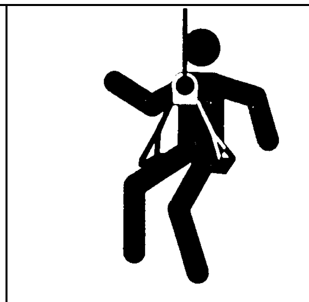
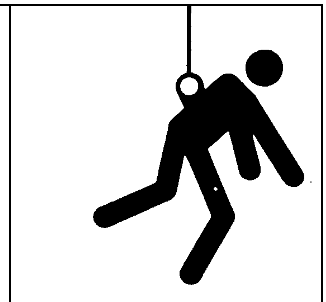
5-6.2 Climbing Personal Protective Equipment.

Use climbers meeting ASTM F887, *Specifications for Personal Climbing Equipment*.

5-6.3 Fall Protection Personal Protective Equipment.

Use of fall protection equipment is required in all instances while climbing or changing positions on poles or towers. Four types of fall protection are used to handle various fall situations as shown in Figure 4-3. Fall arrest equipment is effective only if adequate anchoring has been identified by a qualified person.

Figure 4-3. Types of Fall Protection

			
Positioning Rings on Full Body Harness	Retrieval	Suspension	Fall arrest
Leaves hands free while positioning a worker.	Allows emergency retrieval from a confined space.	Leaves hands free and supports a worker.	For arresting a fall from an elevated position.
Use on wood pole.	Use in a manhole.	Use on structures.	With anchor points.

Positioning, retrieval, and suspension fall protection must support worker's weight plus any additional load. This type of protection does not provide fall arrest. Fall arrest must be added if it is determined that there is a fall arrest anchor point capable of meeting fall arrest requirements. Fall arrest protection requires an anchor point capable of supporting 5,000 lb (2,250 kg) plus a connection device. Protection must provide an adequate free fall distance of 6 ft (1.8 m) or with a deceleration unit a fall distance of 9.5 ft (2.8 m).

5-7 ELECTRICAL TESTING DEVICES.

Electrical testing devices are necessary to ensure maintenance of electric lines can be accomplished safely. This section covers testers that are considered necessary for normal safety considerations. Always use testing devices in accordance with the manufacturer's recommendations, and with the appropriate personal protection. Live-line tools may also be needed.

Note: For the Air Force, proximity voltage detectors are not to be used solely to verify deenergized conditions. Direct contact voltage meters must be used. Capacitive voltage test point meters are considered direct contact voltage meters when used in accordance with the manufacturer's criteria. **\3** The exceptions in NFPA 70E 120.5(7) can be considered. **/3/**

5-7.1 Electrical Testing Device Calibration.

Maintain a calibration program which assures that all applicable testing devices are maintained within rated accuracy. Ensure the accuracy is traceable to the National Institute of Standards and Technology. Maintain a testing device calibration frequency schedule not to exceed 12 months. Provide visible dated calibration labels on all test equipment. Keep up-to-date records that indicate dates and test results of the electrical devices calibrated.

When a device is not being used for NETA type testing, then as an exception to annual certification, the following apply:

- Analog low-voltage multimeters are not allowed.
- Digital multimeters, such as a Fluke, used to verify the absence or existence of voltage do not require annual certification. However, if the device shows any signs of defective operation including failure of any segment of a display element, immediately remove it from service. If the device is sent out for repair, obtain a calibration certification before placing it back in service.
- Meters used for a specific purpose, such as voltage detectors, ampere meters, or phase check meters, do not require annual certification. However, if the device shows any signs of defective operation including failure of any segment of a display element, immediately remove it from service. If the device is sent out for repair, obtain a calibration certification before placing it back in service.

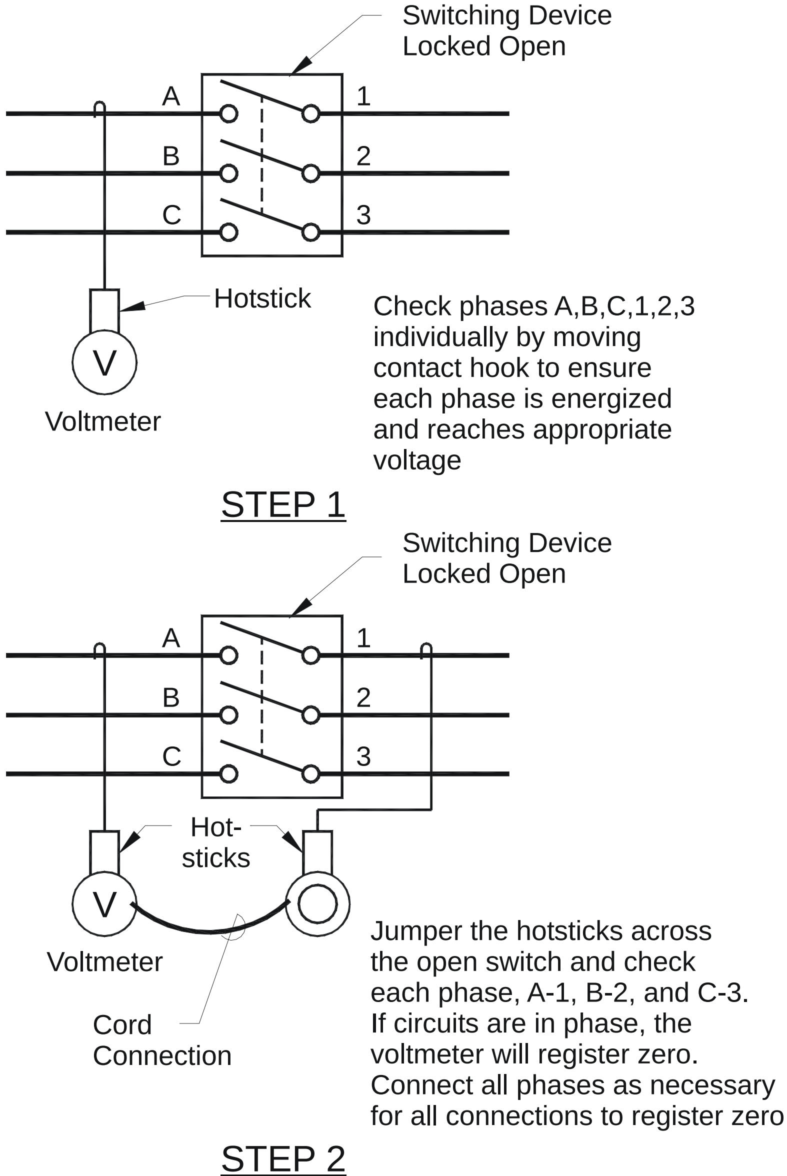
5-7.2 Voltage Detectors.

Voltage detectors (meters) are used to determine whether the line or device is energized or deenergized. The user must understand how to select the proper voltage detector (meter) for the application and where and how the detectors can be used. Some detectors cannot be used to detect or measure voltages on cables with metallic sheaths or semiconductor coatings. Some detectors cannot be used on ungrounded circuits or to detect lower voltages.

5-7.3 Phasing Testers.

Use phasing testers to determine the phase relationships and approximate voltages on energized lines and cables. Prior to paralleling two circuits, determine the correct connection for each conductor by checking the voltage level between that conductor and all other conductors. The voltage across corresponding lines or phases must be zero. A typical phasing tester consists of two high-resistance units on hot sticks connected through a voltmeter. Refer to Figure 5-2 for connections. If potential transformers are available, a voltmeter can be used to measure voltages by connecting a voltmeter between the two sides. If the lines are in phase, the voltmeter will register zero.

Figure 5-2. Phasing Check Using Hot-Stick Phasing Testers



5-7.4 Line Fault Locators.

Use line fault locators on underground lines up to 34.5 kilovolts to determine the location of line faults.

5-7.5 Insulator Testers.

Use insulator testers to measure the potential across each insulator in a suspect string of cap and pin insulators. They can be used without interrupting service.

5-7.6 Leakage-Current Monitors.

The leakage current that can occur from overcurrent conditions on insulated ladder and truck booms must be monitored for worker safety. Leakage current flows along the surface of tools or equipment due to the properties of the device's surface and surface deposits. The permissible leakage current on aerial lifts is one microampere per kilovolt ac or 0.5 microamperes per kilovolt dc. Adverse weather conditions derate the normal dielectric quality of air which results in a greater leakage current. Periodic testing is required. The use of a monitor on an aerial lift providing a continuous display of leakage current is recommended. Set the monitor to sound an alarm at a pre-set leakage current level to alert workers of danger.

5-7.7 Combustible Gas/Oxygen Detectors.

Portable monitors provide visual and audible warnings of explosive atmospheres and/or low oxygen levels which often occur in confined spaces. A continuous reading is given of any gas concentration ranging from 0 to 100 percent of the lower explosive level (LEL) and 0 to 25 percent of the oxygen level. A detector can be used to check battery rooms where ventilation is suspect. Determine if a hazardous atmosphere exists before entering a confined space. Hazardous atmospheres include: a contaminant concentration 10 percent or more of its lower flammability limit; oxygen concentration less than 19.5 percent by volume; and oxygen concentration more than 23 percent by volume, particularly if oil mist or other combustible materials are present.

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CHAPTER 6 ENERGY CONTROL (LOCKOUT/TAGOUT)

6-1 SERVICE-SPECIFIC CRITERIA

Comply with the energy control (lockout and tagout) requirements specified in the following documents:

Navy

OPNAVINST 5100.23G CH-1, *Navy Safety and Occupational Health Program Manual*.

Army

EM 385-1-1, *Safety and Health Requirements*.

Department of the Army Pamphlet (DA PAM) 385-10, *Army Safety Program*.

DA PAM 385-26, *The Army Electrical Safety Program*.

Air Force

\3 DAFMAN 91-203, *Air Force Occupational Safety Fire and Health Standards*

AFMAN 32-1065, *Grounding & Electrical Systems* **/3/**

6-2 ADDITIONAL CRITERIA FOR ELECTRICAL EQUIPMENT

Refer to Appendix J for additional information regarding lockout/tagout for electrical equipment.

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CHAPTER 7 TEMPORARY PROTECTIVE GROUNDING

7-1 TEMPORARY GROUNDING.

Temporary grounding is provided to protect workers engaged in deenergized electric line maintenance. In addition, lines and equipment are protected. Unsafe potentials can occur on the line from static charge buildup, induced voltages through magnetic and capacitive coupling from nearby energized lines, and accidental energizing of the line. The temporary grounding will cause an inadvertently energized line to become deenergized through the action of ground fault relays and will drain off induced voltages. Provide protective grounds with an impedance low enough to cause immediate operation of protective devices in case of accidental energizing of the lines or equipment. Further information on temporary grounding may be found in IEEE Standard 1048, *Guide for Protective Grounding of Power Lines*, and IEEE 1246, *Guide for Temporary Protective Grounding Systems Used in Substations*.

For 600 volts and below, temporary grounding must be installed on lines and equipment to be worked on, unless the authorized individual-in-charge determines that temporary grounding is not practical. The authorized individual-in-charge must explain to the work crew the reasons for not installing temporary grounding. If it is not practical or possible to install temporary grounding then other methods of protection must be provided, such as circuit breakers racked out to the disconnected position, removal of fuses from disconnect switches, disconnect conductors from terminals to isolate the circuit or equipment being worked on, or other methods.

7-1.1 Testing.

Test the line to be sure it is deenergized before installing protective grounds.

WARNING

Place protective grounds on the disconnected lines or equipment to be worked on in accordance with 29 CFR 1910.269(n), Grounding for Protection of Employees. However, if it can be demonstrated that installation of a ground is impracticable or that the conditions resulting from the installation of a ground would present greater hazards than working without grounds, the lines and equipment may be treated as deenergized provided all of the following conditions are met.

1. The lines and equipment have been deenergized.
2. There is no possibility of contact with another energized source.
3. The hazard of induced voltage is not present.

7-1.2 Installation Criteria.

A good temporary ground provides adequate current-carrying capacity and a low-resistance path to the reference ground and is connected at the proper points with clean tight joints. If the temporary ground is not installed correctly, a worker might feel secure but not actually be protected. When connecting grounds to conductors, maintain the minimum approach distances specified in Table 3-1 from energized lines, using live-line tools as required. Place grounds as close to the equipment/work as practical to minimize the inductive voltage loop formed by the ground cable and the worker. To avoid hazardous touch and step potentials, persons on the ground within the work area must stay at least 10 ft (3.0 m) from any protective grounds or devices, and from vehicles bonded to them. If this is not feasible, workers must wear insulated footwear or use other protective measures to minimize the hazard.

7-1.3 Temporary Grounding System Components.

Use system application (overhead, underground, substation) sets with ASTM F 855, *Temporary Grounding Systems to be Used on De-Energized Electric Power Lines and Equipment*, grounding jumpers (clamps, ferrules, and 600 volt jacketed elastomer flexible cable). Store in accordance with the requirements for electrical tools and rubber protective equipment. Assemble grounding sets and jumpers in a workbench environment and test annually using an instrument specifically designed to test grounding equipment.

7-1.3.1 Clamps.

Use the alloy (copper or aluminum) matching the conductor or device to which it is attached and meeting or exceeding the current-carrying capacity of the associated cable. Use smooth jaw clamps on buses to avoid surface marring. Use serrated clamp jaws to bite through corrosion products for attachment to conductors or metal products. Self-cleaning jaws are recommended for use on aluminum. Never use live-line clamps for grounding.

7-1.3.2 Cable.

Cables will be preferably ASTM F855, Type I, of a minimum 2/0 AWG copper and be able to withstand the available fault currents for 15 cycles for substation use and for 30 cycles for line use. Sharp bends and continuous flexing of cable can break conductor strands. Excessive cable lengths must be avoided as this increases resistance, and twists and coils also reduce their current-carrying capacity. As a general rule, limit the length of grounding cables to 30 ft (9 m) for line use and 40 ft (12 m) for substation use. Derate the Table 7-1 fault current capability by 10 percent when using multiple ground cables (which must all be of the same size and length). Verify cables prepared by facility personnel for grounding applications are highly flexible and rugged.

Table 7-1. Maximum Fault Current Capability for Grounding Cables[1]

Cable Size (AWG)	Fault Time (Cycles)	RMS Amperes (Copper)
2/0	15 30	27,000 20,000
3/0	15 30	36,000 25,000
4/0	15 30	43,000 30,000

[1]These current values are the "withstand rating" currents for grounding cables and cables as per *ASTM F 855*. These values are about 70 percent of the fusing (melting) currents for new copper conductors. They represent a current that a cable is capable of conducting without being damaged sufficiently to prevent reuse.

7-1.3.3 Ferrules.

Use ASTM F855, Type IV (stud copper base compression type) when installed on grounding cables by facility personnel. Use ferrules with a filler compound vent hole at the bottom of the cable so that employees can visually check that the cable is fully inserted into the ferrule. Install clear heat shrink over a portion of the ferrule to minimize strand breakage caused by bending. In all cases, follow the manufacturer's recommendations. Do not use aluminum alloy ferrules as they will not provide a lasting snug fit. Check for tightness periodically.

7-1.3.4 Grounding Cluster Bar.

Use to connect phase and neutral conductor jumper cables to the selected method of providing a ground electrode. Cluster bars must have an attached bonding lead. Provide temporary ground rods as stated in Table 7-2.

Table 7-2. Temporary Ground Rod Minimum Requirements

1. Single rod installed to a depth of 5 ft (1.5 m) below grade. • A minimum 5/8 in (16 mm) diameter bronze, copper, or copper-weld rod at least 6 ft (1.8 m) long. • A 6 ft (1.8 m), screw-type ground rod, consisting of a minimum 5/8 in (16 mm) diameter copper-weld shaft with a bronze auger bit and bronze T-handle, tightly connected to the rod.
2. Additional rods to provide a total of 5 ft (1.5 m) below grade where required. • Install 6 to 8 ft (1.8 to 2.4 m) apart while maintaining the 10 ft (3.0 m) step and touch potential clearance. • Bond all rods together prior to installing other electrode connections.

7-1.4 Equipotential Zone.

All metal within reach must be at the same (zero or minimum) potential with reference to ground in order to safely protect the workers. Install and connect grounding and bonding conductors in a proper manner to provide an equipotential zone of protection for workers.

7-1.5 Ground Connection and Electrodes.

Temporary grounds must be connected to the permanent ground of the structure or pole, to another grounding electrode or grounded conductor. This may be the neutral conductor, or an overhead ground wire, or the station ground, or one or more temporarily driven ground rods, driven so at least 6 ft (1.8 m) of the ground rod is in contact with moist soil. Additionally, any metallic object that is a good conductor, such as an anchor rod or permanent ground rod, which extends several feet into the ground, may be used for the connection if sufficiently low ground resistance is determined. When connecting to a metal pole or structure, always verify it has an unbroken connection to its permanent ground rod. In areas accessible to unqualified persons, provide a barricade for the ground rod as a physical and visual barrier to prevent anyone from approaching within the minimum approach distances specified in Table 3-1.

7-2 TEMPORARY GROUNDING OF SUBSTATION CURRENT-CARRYING EQUIPMENT COMPONENTS.

Ground deenergized current-carrying components of substation equipment before approaching them within the minimum distances specified in Table 3-1. Place grounds as close to the equipment/work as practical to minimize the inductive voltage loop formed by the ground cable and the worker. Special precautions are needed during oil handling. Refer to Figure 7-1, and Tables 7-3 and 7-4. Refer to Table 7-5 if oil handling is involved.

Figure 7-1. Substation Temporary Grounding

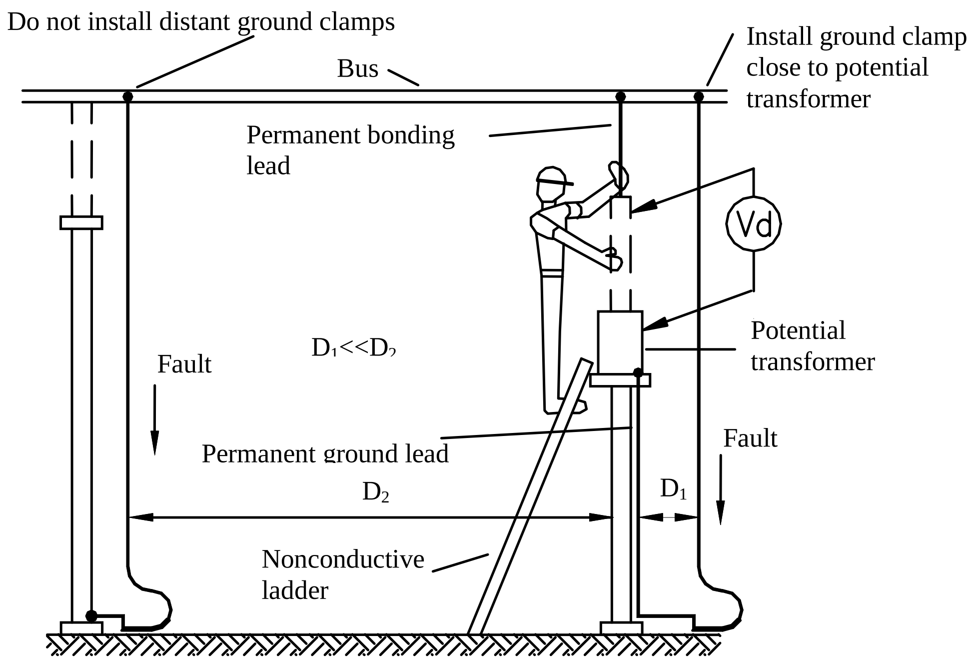


Table 7-3. Substation Protective Grounding Procedures

1	Check validity of permanent equipment grounds.
2	Install a protective ground cable and bond to a grounded structure member or to a common copper equipment bushing lead for equipment being worked on.
3	Apply personal protective grounds before working within Table 3-1 minimum approach distances on substation equipment including: • Bushings • Buses • Capacitors • Circuit breakers • Instrument transformers • Power transformers • Switches • Surge arrestors

Table 7-4. Grounding of Substation Equipment

1	Grounds must be in place before a tank is opened and the insulating medium (oil/gas) is changed. This does not apply to sampling when using a sampling valve.
2	Switches may not be used to maintain personal ground continuity except when the switch is specifically designed for that purpose.
3	Allow at least 5 minutes between opening of the capacitor switching devices and the closing of the ground switch on a fully charged capacitor bank. wait at least 5 minutes after the ground switch is closed before installing protective grounds. Maintain a capacitor bank deenergized for at least 5 minutes before re-energizing it. Include the time limits required for these maneuvers in switching orders involving capacitor banks.
4	Disconnect and discharge surge arrestors using grounding cables.
5	Do not work on grounding transformers unless they are in an electrically safe work condition. Isolate phase reactors from all energized sources and ground them before starting work on them.
6	Disconnect bushing leads from bushing terminals as necessary to permit equipment testing that requires the equipment to be ungrounded. Use a hot stick to connect test equipment and re-establish the ground as soon as the test is completed. Following an applied potential test (“Hi-Pot”), ensure the ground remains in place for a period at least two times the duration of the test period. Follow the manufacturer’s recommendations for work clearances and grounding instructions for the test equipment
7	Install separate grounds for each isolated section of the deenergized circuit if a hazard exists when working in a deenergized area of a substation where there are one or more physical breaks in the electrical circuit.

Table 7-5. Grounding of Equipment During Oil Handling

1	Bond apparatus tanks, conductive hoses, pumping or filtering equipment, drums, tank cars, trucks, and portable storage tanks to the station ground mat. Connect the vehicle end first and disconnect it last to prevent possible arcs near the vehicle.
2	Bond exposed conductors, such as transformer or circuit breaker bushings, or coil ends or transformers where bushings have been physically removed, to the same grounding point.

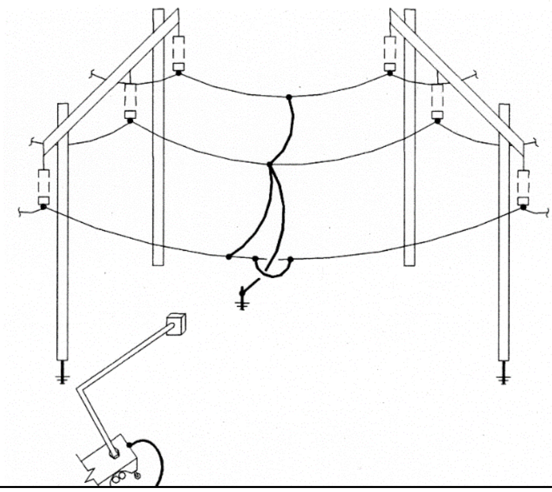
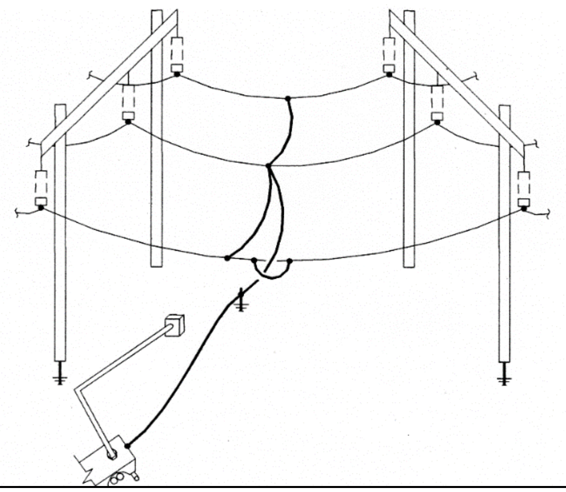
7-3 AERIAL LIFT TRUCK VEHICLE GROUNDING.

Ground and bond each vehicle being used at the job site when any parts of it will come within the minimum approach distances of Table 3-1. When in transit or when parked with no load and all booms lowered, the vehicle may be ungrounded if it is located outside the restricted approach boundary. Ensure the workers and the vehicle operator are aware of step and touch potential hazards near vehicles as well as near permanent and temporary ground rods and electrodes. Diggers, cranes, and other work vehicles must be bonded, if practical, to the common temporary or permanent ground electrode provided when performing work on deenergized circuits. Ground vehicles in accordance with Table 7-6 and Figure 7-2.

Table 7-6. Procedures for Grounding Insulated and Uninsulated Aerial Lift Trucks

Grounding	Procedure
Insulated boom vehicles	Bond the vehicle to a separate driven ground rod located about midway on one side and as close to the vehicle as practical. If possible, keep insulated vehicles and their ground rods at least 10 ft (3.0 m) away from the structure grounding system to minimize step and touch potentials. If workers can simultaneously contact two or more separately grounded systems, the systems will be bonded together.
Uninsulated boom and other electrical work vehicles	Bond the uninsulated boom and all other vehicles directly involved in electrical work to the grounded system using a grounding cable rated for the maximum available fault current.
Tensioning vehicles	Vehicles used to pull and hold tension on the conductor or overhead ground wire must be properly bonded to a structure ground or a temporary ground rod. Stay on the vehicle or at least 10 ft (3.0 m) away from the vehicle ground when possible.

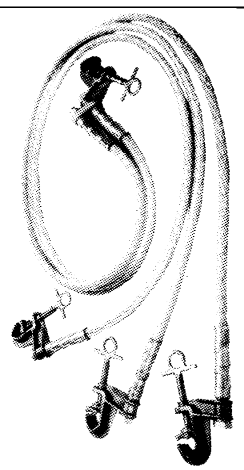
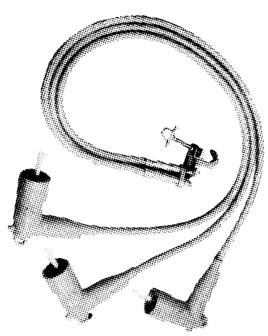
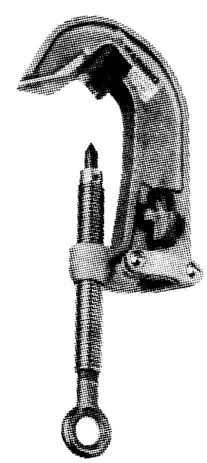
Figure 7-2. Insulated and Uninsulated Aerial Lift Vehicle Grounding Connections

	
Insulated aerial lift	Uninsulated aerial lift

7-4 TEMPORARY GROUNDING OF UNDERGROUND LINES.

Ground all possible sources of power (including transformer backfeed). If the application of grounds is considered to increase the work hazard, then the grounding method will require additional evaluation and approval in accordance with Chapter 8. Install protective grounds at equipment terminations or ground by spiking cable (using an approved tool) prior to work on the cable. Use approved ground sets of the type shown on Figure 7-3.

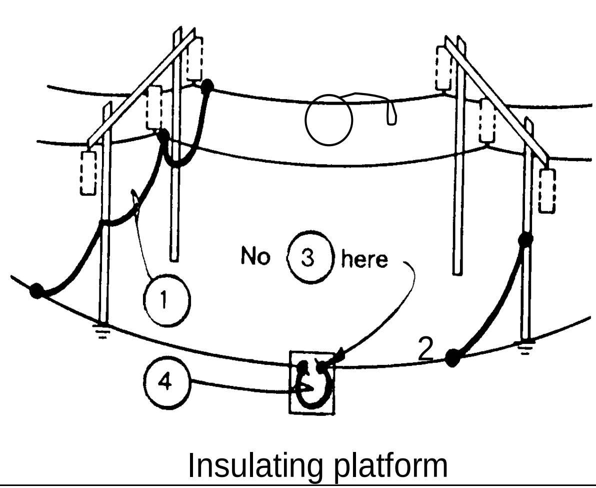
Figure 7-3. Underground System Grounding Sets

			
1-1.2 Live-front pad-mount equipment grounding set	Elbow grounding set	Cable spiking grounding jumper	Cable clamps with a penetrating grounding spike

7-5 OPENING OR SPLICING DEENERGIZED CONDUCTORS.

Conductors may be spliced at ground level, from aerial lift equipment utilizing ground mats (uninsulated aerial lifts), or from insulating platforms (insulated aerial lifts). Grounding for conductive or insulating platforms is shown on Figure 7-4. Install all grounding jumpers with hot sticks. Ground any mobile equipment. Stay 10 ft (3.0 m) away from grounded items and step onto equipment or platforms as quickly as possible to minimize any adverse step and touch potentials.

Figure 7-4. Using a Conductive or Insulating Platform for Opening/Closing Deenergized Overhead Conductors



1. Three-phase ground all conductors and structure on one side of the work.
2. Single-phase ground work on conductor and structure on the other side of the work.
3. Ground conductive platform but not insulating platform.
4. Maintain integrity of conductor connection.

7-6 GROUNDING FOR STRINGING AND REMOVING LINES.

Locate grounds to meet requirements of Table 7-7 and Figure 7-5. After conductor pulling, locate grounds in accordance with Table 7-8. Stay 10 ft (3.0 m) away from grounded items and step onto equipment or platforms as quickly as possible to minimize any adverse step and touch potentials.

Figure 7-5. Composite Stringing/Removing Temporary Protective Grounds on Overhead Conductor Lines

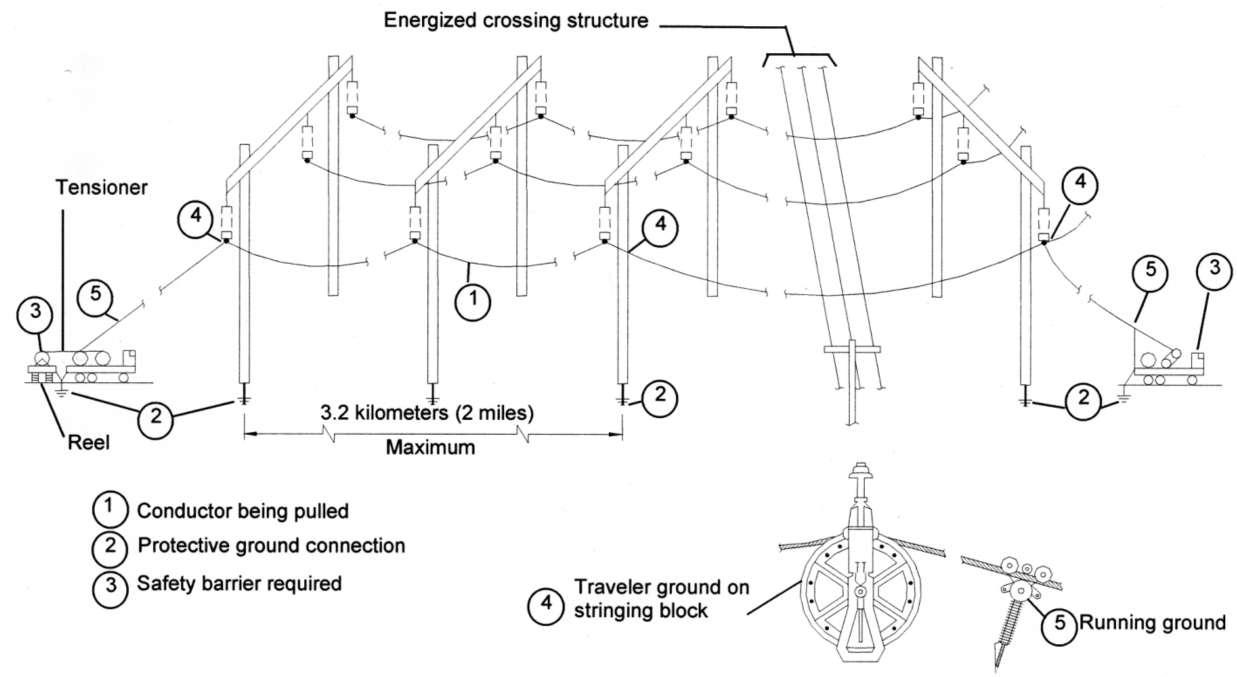


Table 7-7. Stringing/Removing Conductor Ground Locations

1	Ground all stringing equipment such as reel stands, pullers, tensioners, and other devices.
2	Provide a safety barrier around the equipment.
3	Install a running ground between pulling and tensioning equipment and their adjacent structures. *Note: "Running grounds" only work on bare conductors. If using insulated conductors (aerial cable or tree wire for example), the pulling cart and the tensioning cart will need to be grounded and all personnel working are required to wear voltage rated gloves.*
4	Ground stringing blocks at first and last structures, and at least every 2 miles (3.2 km) in between.
5	Ground stringing blocks at each structure on both sides of an energized circuit being crossed. If the design of the circuit interrupting devices protecting the lines so permits, the automated reclosing feature of those devices must be made inoperative and tagged out.

Table 7-8. Conductor Ground Location After Pulling

1	Ground at each structure next to intermediate dead ends of the stringing operation.
2	Ground at each structure where and while work (including clipping-in) is being performed on or near the conductor.
3	Remove grounds as the last phase of finished aerial installation.

7-7 TEMPORARY GROUNDING OF AERIAL LINES.

Ground by installing an overhead distribution grounding set. The grounding set provides a parallel low-level (milliohm) resistance path which limits the current flow through the worker to a very low (safe) value (milliamperes) thus limiting the potential across the worker to a safe value. If the ground resistance were in series with the worker life-endangering currents could flow through the worker under fault conditions. Avoid any ground connection which could provide violent whipping from wind action. Double-point grounds are sometimes utilized but single-point (equipotential) grounding is the preferred method. If double-point grounding is necessary, install the temporary grounds at least one span away from the work site because the grounding cables may violently move during a fault condition.

7-8 PLACEMENT OF GROUNDS.

Install grounds as close as possible to the work. Temporary grounding connection/removal procedures will be in accordance with Table 7-9. Never approach closer than distances specified in Table 3-1 until after the line/equipment has been isolated, deenergized, tested, and properly grounded. Afterwards, avoid coming closer than 10 ft (3.0 m) to minimize the hazard from step and touch potentials. Such potential differences occur from items such as down guys, ground rods, maintenance vehicles, and structure legs or ground wires during the period in which they are bonded to temporary grounds. When it is absolutely necessary to work on or near these features, use bonded conductive or insulated platforms, or approved insulated footwear to minimize the hazard from step and touch potentials. Bond separately grounded systems together if they can be simultaneously contacted.

Table 7-9. Temporary Grounding Connection/Removal Procedures

1	Select a ground electrode using either an established ground at the structure or a temporarily driven ground rod. Minimize the impedance and do not introduce a hazardous potential difference.
2	Test the deenergized line/equipment for voltage by an approved tester. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily. The test also determines if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage backfeed.
3	Visually inspect ground equipment. Check mechanical connections for tightness. Clean clamp jaws and conductor surfaces. Clean not earlier than 5 minutes before connection using a wire brush attached to a live-line tool. Use of self-cleaning equipment is also acceptable.
4	Make the ground end clamp of each grounding cable the first connection made and the last to be removed. Hot sticks will be used if the grounded system and worker are at different potentials.
5	The conductor-end clamps of each grounding cable will always be connected last and removed first by hot sticks. Apply to the nearest conductor first and proceed outward or upward until all phases have been connected. Remove in reverse order. The practice of physically holding the temporary grounding cable with gloved hand while attaching the temporary ground connector, in order to lighten the weight on the head of the stick, is strictly prohibited. The practice of holding the hot stick near the head of the hot stick to lighten the weight on the head of the stick is also prohibited. Instead, have a co-worker assist in installing heavy cables by holding the cable with another hot stick, or by using a “shepherd hook” with a pulley and a nonconductive rope to hoist the grounding cable into position.

CHAPTER 8 ENERGIZED WORK

8-1 WORK ON ENERGIZED CIRCUITS.

Do not work on energized electrical circuits operating at 50 V or more except when required to support a critical mission, prevent human injury, or protect property.

In all instances of work on energized electrical circuits, workers must be qualified for energized line work, and all required protective equipment and special tools must be available at the work site. OSHA 29 CFR 1910.333 limits work on live energized electrical equipment as follows: "*Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*."

WARNING

Only workers qualified by electrical training can work in areas on or with unguarded, uninsulated energized lines or parts of equipment operating at 50 V or more. All electric lines and equipment will be treated as energized unless deenergized, locked, tagged, and tested for no voltage. In addition, provide grounding in accordance with Chapter 7. Maintain the specified minimum approach distances specified in Table 3-1 based on the voltage range. The arc flash boundary distance requires the wearing of arc rated clothing. No energized work can be performed during adverse weather conditions (ice storms, high winds, and electric storms) unless there is an emergency and the work has been approved by the designated authority. Any relaxation of these electrical safety requirements in the interest of mission continuation places both the electrical workers and the mission at risk.

8-2 EXAMPLES OF ENERGIZED WORK.

Tables 8-1 and 8-2 provide examples of energized work activities that might be performed. Comments are provided in the tables regarding each energized work activity.

Table 8-1. Typical Energized Work Activities on Interior Electrical Systems

Activity on Energized Electrical Equipment	Comments
Circuit switching (on or off) – low voltage.	This is considered by NFPA 70E as normal operation of electrical equipment.
Circuit switching (on or off) – medium voltage.	This is considered by NFPA 70E as normal operation of electrical equipment.
Troubleshooting – low voltage.	This is considered by NFPA 70E as an activity that does not require an energized electrical work permit.
Troubleshooting – medium voltage.	This is considered by NFPA 70E as an activity that does not require an energized electrical work permit.
Voltage testing – low voltage.	This is considered by NFPA 70E as an activity that does not require an energized electrical work permit.
Voltage testing – medium voltage.	This is considered by NFPA 70E as an activity that does not require an energized electrical work permit.
Remove bolted covers of energized equipment – low voltage.	This is the type of activity that might require an energized electrical work permit.
Remove bolted covers of energized equipment – medium voltage.	This is the type of activity that might require an energized electrical work permit.
Install or remove data logger from a low voltage panel.	This is the type of activity that might require an energized electrical work permit and is a good candidate for a Standard Operating Procedure.
Racking power circuit breakers manually (in or out) – low voltage.	This is the type of activity that might require an energized electrical work permit and is a good candidate for a Standard Operating Procedure.
Racking power circuit breakers manually (in or out) – medium voltage.	This is the type of activity that might require an energized electrical work permit and is a good candidate for a Standard Operating Procedure.
Racking power circuit breakers with remote mechanism (in or out) – low voltage.	A case could be made that this is not energized work in that the employee is a safe distance away from the work activity.
Racking power circuit breakers with remote mechanism (in or out) – medium voltage.	A case could be made that this is not energized work in that the employee is a safe distance away from the work activity.

Activity on Energized Electrical Equipment	Comments
Conductor termination into energized panel or switchboard.	This activity does not satisfy the OSHA requirement of "…*unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*".
Replace lighting ballasts while energized.	This activity does not satisfy the OSHA requirement of "…*unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*".
Replace lighting fixtures while energized.	This activity does not satisfy the OSHA requirement of "…*unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*".
Installing receptacles while energized.	This activity does not satisfy the OSHA requirement of "…*unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*".
Circuit breaker installation into energized panel – low voltage.	This activity does not satisfy the OSHA requirement of "…*unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations*".
Batteries and Backup Power Systems	
Stationary battery maintenance.	This is the type of activity that might require an energized electrical work permit or a Standard Operating Procedure.
Stationary battery replacement, including individual cells or modules.	This is the type of activity that might require an energized electrical work permit or a Standard Operating Procedure.
Automatic transfer switches – inspection and exercising while energized.	This is the type of activity that might require an energized electrical work permit or a Standard Operating Procedure.
UPS inspection and maintenance	This is the type of activity that might require an energized electrical work permit or a Standard Operating Procedure.

Table 8-2. Typical Energized Work Activities on Exterior Electrical Systems

Activity on Energized Electrical Equipment	Comments
Overhead Distribution	
Opening or closing gang-operated air break switches	Routine activity that can be controlled by a Standard Operating Procedure.
Opening or closing single pole switches	Routine activity that can be controlled by a Standard Operating Procedure.
Opening or closing fused cutouts, including refusing.	Routine activity that can be controlled by a Standard Operating Procedure.
Voltage testing, phase rotation testing, and current measurements.	Routine activity that can be controlled by a Standard Operating Procedure. Voltage testing is also part of applying temporary grounding equipment.
Replace pole-mounted equipment, including cross-arms, conductors, transformers, switches, surge arresters, etc.	Routine activity for an electric utility. Not a routine activity at most military installations.
Underground Distribution	
Opening or closing switches, VFIs, or fused compartments on pad-mounted switchgear.	Routine activity that can be controlled by a Standard Operating Procedure.
Removing or inserting load break elbows.	Routine activity that can be controlled by a Standard Operating Procedure.
Voltage testing, phase rotation testing, and current measurements.	Routine activity that can be controlled by a Standard Operating Procedure. Voltage testing is also part of applying temporary grounding equipment.

Activity on Energized Electrical Equipment	Comments
Electrical Manholes and Vaults	
Entry into manhole containing energized circuits for insulated cable examination.	Arc flash calculation methodology does not address the unique configuration of an electrical manhole in which an arcing fault occurs inside a small, enclosed space that also contains the worker. Additional precautions are necessary. An IEEE interpretation dated 14 January 2009, regarding IEEE C2 (National Electrical Safety Code) Rule 410A3, confirms that the phrase "on or near energized parts or equipment" applies to energized insulated conductors inside manholes. IEEE C2 Rule 443 does allow a qualified employee, working alone, to enter a manhole where energized cables or equipment are in service for the purpose of inspection, housekeeping, taking readings, or similar work if such work can be performed safely.
Entry into manhole containing energized circuits for circuit installation/relocation.	See above.
Spicing electrical conductors.	See above.

8-3 ENERGIZED ELECTRICAL WORK PERMIT.

8-3.1 Normal Operation of Electrical Equipment.

Normal operation of electrical equipment, such as circuit breaker operation, does not require an energized electrical work permit if all the following conditions are met:

- The equipment is properly installed. The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards (such as NFPA 70) and the manufacturer's recommendations,

- The equipment is properly maintained. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards, such as NFPA 70B or NETA MTS.

- All equipment doors are closed and secured.

- All equipment covers are in place and secured.

- There is no evidence of impending failure. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, or deterioration.

8-3.2 Prohibitions to Energized Work.

Energized work is prohibited for the following conditions:

- Energized work on equipment or systems with a nominal voltage above 34.5 kV.

- Energized work on medium voltage systems that have not received adequate maintenance and testing.

- Energized work on low voltage systems that have not received adequate maintenance and testing.

An energized electrical work permit is not authorized if there is no assurance that the electrical distribution system is capable of responding as required to overcurrent or arc flash events.

8-3.3 Energized Electrical Work Permit.

An energized electrical work permit is required under the following conditions:

- When work is performed within the restricted approach boundary.

- When an employee interacts with the equipment when conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists. An example of this condition is racking (inserting or removing) a circuit breaker into or out of an energized switchgear bus.

Determine appropriate safety-related work practices before any person is exposed to the electrical hazards involved by using both shock risk assessment and arc flash risk assessment. Only qualified persons are permitted to work on electrical conductors or circuit parts that have not been put into an electrically safe work condition. Energized electrical work permits must be prepared in advance in accordance with NFPA 70E and, as a minimum, include:

- Description of the circuit and equipment to be worked on and their location.

- Justification for why the work must be performed in an energized condition.

- Description of safe work practices to be employed.

- Results of the electrical task risk assessment, which includes:
    - o Results of the shock risk assessment, including voltage level, limited approach boundary, restricted approach boundary, and necessary personal protective equipment.
    - o Results of the arc flash risk assessment, including 1) available incident energy at the intended working distance or arc flash PPE category, 2) necessary PPE to protect against the hazard, and 3) arc flash boundary.
- Means employed to restrict the access of unqualified persons from the work area.
- Evidence of completion of a job briefing, including a discussion of any job-specific hazards
- Energized work approval.

Appendix B provides an example of an electrical task risk assessment checklist that can be used in support of preparing the energized electrical work permit.

8-3.4 Exemptions to Energized Electrical Work Permit.

An energized electrical work permit is not required if a qualified person is provided with and uses appropriate safe work practices and PPE under the following conditions:

- **\3** Testing, troubleshooting, or voltage measuring.
- Thermography, ultrasound, or visual inspections if the restricted approach boundary is not crossed. **/3/**
- Access to and egress from an area with energized electrical equipment if no electrical work is performed and the restricted approach boundary is not crossed.
- General housekeeping and miscellaneous non-electrical tasks if the restricted approach boundary is not crossed.

8-4 STANDARD OPERATING PROCEDURES FOR ENERGIZED ELECTRICAL WORK PERMITS.

8-4.1 OVERVIEW.

Standard Operating Procedures (SOPs) are recommended as a means of satisfying the energized electrical work permit requirements of this UFC. The preferred work approach is to establish an electrically safe work condition by deenergizing the equipment before allowing work. However, there are routine activities on the primary distribution system that involve energized work.

Done properly, an energized electrical work permit is a time-consuming detailed evaluation of the work to be done and the safety precautions that are required to ensure the work is performed safely. For specified tasks, an SOP is a pre-approved energized electrical work permit that can simplify the preparation for an energized work activity while still complying with mandated regulations and industry standards.

8-4.1.1 SOP Limitations.

SOPs are recommended for electrical-related work activities that might be performed routinely. Unusual or non-routine work activities that involve working on or near energized electrical equipment require an energized electrical work permit.

An SOP is a pre-approved energized electrical work permit rather than a detailed technical procedure. The SOP assumes that the qualified electrical worker is proficient in the technical aspects of the designated work activity and the SOP focuses on the safety aspects that would be typically included in an energized electrical work permit.

8-4.1.2 Items to Address in an SOP.

Develop SOPs by a risk assessment based upon job hazard analyses (JHA) using Operational Risk Management (ORM) principles. Include the following in an SOP:

- The purpose of the SOP.
- References and definitions appropriate for the work activity.
- The hazards that will be avoided by using the SOP.
- Specific procedures that will be used to reduce/minimize/eliminate the hazards.
- Potential energy sources, including limits of approach.
- Specific required training/certifications.
- Number of required employees.
- Rescue procedures and equipment.
- Potential incident energy level exposure.
- Appropriate personal protective equipment (PPE) such as arc rated clothing, face shields, and electrical gloves for exposure level.
- Management approvals.

Include an electrical task risk assessment as part of the SOP development in support of its specified work scope and associated electrical safety requirements. Refer to the appendices for examples of SOPs that might be appropriate for working on the primary distribution system. These sample SOPs are provided for reference; modify them as necessary for the installation, the allowed work practices, and the qualifications of the personnel.

8-5 APPLICABILITY FOR THE NAVY.

8-5.1 Navy Energized Electrical Work Permit.

For the Navy, all energized work requires written, job specific procedures approved, in writing, by the Commanding Officer/Executive Officer and considered necessary to support a critical mission, prevent human injury, or protect property. “Gloving” above 600 volts is not authorized for Navy personnel. In addition, Navy personnel are not authorized to perform energized overhead distribution (pole line) work above 600 volts with the following exceptions (these exceptions must be performed as required in the task specific SOP, which includes using the appropriate PPE and live line tools):

a. Comply with Section 4-1.4 and arc rated safety harness with lanyard:

- Gang operated switch operation.
- Phasing tests.
- Voltage tests.
- Current tests (with hook sensing head ammeter).
- Installing and removing temporary protective grounds.
- Installing and removing mechanical stirrups and live-line clamps.

b. Comply with Category 2 and arc rated safety harness with lanyard (*Note: Where limited visibility, due to environmental conditions (night time, rain, wind) will possibly create a greater hazard, a face shield is not mandatory. Remainder of PPE (including safety goggles and balaclava with hardhat), is required*):

- Disconnect switch operation.
- Opening or closing fused cutouts.
- Replacing fuses.

8-5.2 NAVFAC Standard Operating Procedures (SOPs).

Develop SOPs based upon job hazard analyses (JHA) using Operational Risk Management (ORM) principles. SOPs must ensure compliance with the codes, standards and regulations identified in Section 1-4. Address the purpose of the SOP, the hazards that will be avoided by using the SOP, specific procedures that will be used to reduce/minimize/eliminate the hazards, potential energy sources, specific required training/certifications, rescue procedures and equipment, and appropriate personal protective equipment (PPE) such as arc rated clothing, face shields, and electrical gloves.

8-5.3 SOP Priority.

Priorities for the development of SOPs are:

- The hazard may cause death, serious injury, or loss of a facility.
- May cause major injury, severe illness, or major property damage.
- May cause minor injury, minor illness, or minor property damage.

8-5.4 SOP Approval and Training.

Following completion of the JHA and development of the SOP, route SOPs through the appropriate chain-of-command and the Activity Safety Office for review and approval. Upon completion of this process, train employees on the SOP and maintain a training record by the supervisor.

SOPs that have been issued by NAVFAC Activities are available for review at the Enterprise Safety Applications Management System (ESAMS) at the following:

https://esams.cnic.navy.mil/ESAMS_GEN_2/LoginESAMS.aspx.

8-6 APPLICABILITY FOR THE AIR FORCE.

\3 For the Air Force, all energized work must be authorized by the authority referenced in AFMAN 32-1065, *Grounding & Electrical Systems*, and considered necessary to support a critical mission, prevent human injury, or protect property. Energized electrical work permits are required in advance of work and require as a minimum those items contained in AFMAN 32-1065. ***/3/*** "Gloving" above 600 volts is not authorized for Air Force personnel.

8-7 APPLICABILITY FOR THE ARMY.

For the Army, all energized work must be authorized in accordance with DA PAM 385-26, *The Army Electrical Safety Program*.

8-8 CATEGORIES OF WORK.

The approved work procedures to be used for work on energized circuits depend on the potentials at which the worker operates. These include:

8-8.1 Workers at Ground Potential.

Workers located on a structure supporting the conductor, on other work platforms, or standing on the ground (earth) remain essentially at ground potential when using tools and equipment. Apply the lockout/tagout program with temporary grounding to ensure that an appropriate ground potential and equipotential work zone is maintained.

8-8.2 Workers at Intermediate Potential.

Workers are isolated from grounded objects by insulating means, such as an aerial lift, an insulating ladder or platform, or insulating mat and they work with insulated tools and equipment. Specific approval is required for this work.

8-8.3 Workers at Line Potential.

Workers are bonded to the energized device on which work is to be performed and are insulated from grounded objects and other energized devices that are at a different potential. This is commonly known as the barehand technique and is prohibited.

8-9 ENERGIZED WORK RULES.

With the use of various types of aerial equipment and live-line tools, it is possible to perform many operations in the maintenance of overhead distribution lines while these lines are energized. Exact compliance with safety precautions is particularly important for energized work, and personnel engaged in this type of work must be trained and qualified in the procedures and the use of tools and equipment. Trained personnel must be familiar with ANSI/IEEE 516, *Guide for Maintenance Methods on Energized Powerlines*, and ANSI/IEEE 935, *Guide on Terminology for Tools and Equipment to Be Used in Live Line Working*. The “Lineman’s and Cableman’s Handbook” also provides pictorial data on many of the tools, equipment, and techniques used for energized work operations.

8-9.1 Permitted Work.

Energized work must not be performed at any facility without written authorization.

8-9.2 Personal Protective Equipment and Clothing.

Refer to Chapter 4 to determine the protective equipment and clothing that will be required.

8-9.3 Statement of Qualifications.

Each worker authorized to perform work on energized lines or equipment must be qualified and covered by a written statement that indicates the highest voltage on which the individual is authorized to work. Local policy must establish who can issue the statement of qualification. Electricians in upgrade training must work under the direct supervision of a qualified person.

8-9.4 Work Methods for Voltage Levels.

Energized work methods and the minimum approach distances must be in accordance with this UFC. For overhead line work, use the approved energized work methods given in Table 8-1 while maintaining the minimum approach distances given in Table 3-1. Use insulated (rubber) goods meeting the requirements of ASTM F 18 standards with color coding meeting the requirements of Table 5-1. Use leather protectors over rubber gloves. Use insulating tools meeting the requirements of Table 8-2 and insulating plastic guard equipment meeting the requirements of Table 8-3. The use of live-line tools without gloves to detect tool deterioration is prohibited. Use voltage-rated gloves with live-line tools. Review instructions and regulations detailing correct use and maintenance of such tools/equipment as a part of the work procedures. At least two workers, fully qualified for the voltage range (including other conductors within reach), must be available. See exceptions in Table 3-9.

Table 8-1. Approved Energized Overhead Line Work Methods by Voltage Class

Nominal AC Voltage Level	Work Method
Up to 600 volts	Use of live-line tools from electrically insulated aerial lift bucket or platform (intermediate protection) or use of live-line tools from structure mounting or an aerial lift bucket (ground potential).
>600 to 7.5 kilovolts	Use of live-line tools from electrically insulated aerial lift bucket or platform (intermediate protection) or use of live-line tools from structure mounting or an aerial lift bucket (ground potential).
>7.5 to 15 kilovolts	Use of live-line tools from electrically insulated aerial lift bucket or platform (intermediate protection) or use of live-line tools from structure mounting or an aerial lift bucket (ground potential).
>15 to 36 kilovolts	Use of live-line tools from an electrically insulated aerial lift bucket (intermediate potential).
>36 to 70 kilovolts	This work can only be performed by personnel specifically trained in the hazards associated with voltages in this range.
>70 to 230 kilovolts	This work can only be performed by personnel specifically trained in the hazards associated with voltages in this range.

Table 8-2. Insulating Tools for Electrical Workers

Standards			
ASTM F711, Specification for Fiberglass Reinforced Plastic (FRP) Rod and Tube Used in Live-Line Tools. *ASTM F3121/F3121M-16, Standard Guide for In-Service Maintenance and Electrical Testing of Hand-Held Live-Line Insulating Tools (Fiberglass-Reinforced Plastic (FRP)).*			
Minimum Test Values			
Tool Material	**OSHA Acceptance[1]**	**IEEE In-Service[2]**	**Use**
Fiberglass reinforced plastic (FRP)	100 kV/ft (0.3 m)	75 kV/ft (0.3 m)	Preferred[3]

Notes for Table 8-2:

1. *Test values manufacturers must certify for acceptance by buyer.*
2. *Test values required after acceptance and tested after use in the field.*
3. *All new tools will be FRP. Replace wood live-line tools with FRP tools immediately; permanently remove the wood tools from service and destroy.*

Table 8-3. Insulating Overhead Line Plastic Guards/Platforms for Electrical Workers

<table>
<tr><th colspan="7">Standards</th></tr>
<tr><td colspan="7">ASTM F-712, Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers</td></tr>
<tr><td colspan="7">ASTM F-968, Specification for Electrically Insulating Plastic Guard Equipment for Protection of Workers</td></tr>
<tr><td colspan="7">ASTM F-1564, Specification for Structure Mounted Insulating Work Platforms for Electrical Workers</td></tr>
<tr><th colspan="7">Common Classifications for Plastic Guards</th></tr>
<tr><th colspan="2">Installation</th><th>Conductors</th><th colspan="2">Structure/Apparatus</th><th colspan="2">Special</th></tr>
<tr><td colspan="2">• Attached hot stick
• Eye for removable hot stick
• Rope loop or equivalent for gloving or hot stick</td><td>• Line guards
• Line guard connectors
• Insulator covers
• Deadend covers
• Bus guards
• Bus “T” guards</td><td colspan="2">• Pole guards
• Ridge pin covers
• Switchblade covers
• Arm guards
• Cutout covers
• Crossarm guards</td><td colspan="2">• Shape
• Size
• Attachment
• More stringent electrical requirements</td></tr>
<tr><th colspan="7">Guard Rating for Accidental Brush Contact</th></tr>
<tr><th></th><th colspan="2">Maximum Use Rating kV (60 Hz)</th><th colspan="3">Proof Test Withstand Voltage (In-Service Testing)</th><th></th></tr>
<tr><th>Class</th><th>Phase-to-Phase[1]</th><th>Phase-to Ground</th><th>Phase-to-Ground kV 60 Hz</th><th>Phase-to-Ground kV dc</th><th>Duration, Minutes</th><th>Criteria</th></tr>
<tr><td>2</td><td>14.6</td><td>8.4</td><td>13.0</td><td>18</td><td>1</td><td rowspan="5">No flashover other than momentary as a result of too close spacing of electrode</td></tr>
<tr><td>3</td><td>26.4</td><td>15.3</td><td>24.0</td><td>34</td><td>1</td></tr>
<tr><td>4</td><td>36.6</td><td>21.1</td><td>32.0</td><td>45</td><td>1</td></tr>
<tr><td>5</td><td>48.3</td><td>27.0</td><td>42.0</td><td>60</td><td>0.5</td></tr>
<tr><td>6</td><td>72.5</td><td>41.8</td><td>64.0</td><td>91</td><td>0.25</td></tr>
</table>

Notes for Table 8-3:

1. *Cover-up materials are tested at values greater than the maximum use phase-to-ground values. The maximum use phase-to-phase values relate to guarded-phase-to-guarded-phase. The units are not rated for bare-phase-to-guarded-phase potentials.*

8-9.5 Pre-Work Procedures.

Do not start work until the requirements of Table 8-4 have been completed.

Table 8-4. Pre-Work Procedures – Overhead Line

1. Determine existing conditions and complete a job hazard analysis (see Chapter 2).
2. Determine the voltage rating of circuits to be worked on, distances to other energized lines, and location of work. Evaluate the following: a. If aerial lift equipment can be used. b. What personnel qualifications are needed for the work. c. If special equipment, tools, or hazard protection are needed.
3. Prepare a written standard operating procedure.
4. Obtain energized work approval/permit (permissible work for all services is discussed in Chapter 8).
5. Review work and safety precautions with the crew before work begins (including tailgate briefing).
6. Inspect tools/equipment before starting work.

8-9.6 General Job-in-Progress Procedures.

Observe the precautions given in Table 8-5 before proceeding with the procedures provided in Table 8-6.

Table 8-5. Energized Work Precautions – Overhead Line

1. Check that circuit automatic reclosing devices have been made inoperative and tagged out while work is being performed. For the Navy, use a Special Instruction tag or a Hold tag.
2. Do not allow items of a voltage class lower than required for the work to be available to the workers at the work site.
3. Exercise special care when working in the proximity of equipment such as fuses, surge arresters, and similar equipment, or where conductor checks indicate burns or other defects in conductors, tie wires, and insulators. Procedures may require that some equipment be bypassed for the duration of the work.
4. Comply with adverse weather and number of qualified worker requirements.

Table 8-6. Voltage Level Work Procedures – Overhead Line

600 Volts and Below
1. Ground vehicles and aerial lifts in the vicinity of the work site.
2. Cover with approved protective equipment, or isolate with suitable barriers, energized phase and neutral wires, ground wires, messengers, and guy wires in the vicinity of the work. Apply covering to the nearest and lowest conductor first and remove in reverse order. Refer to Chapter 7.
3. Refer to Table 8-3 for work methods.
4. Rubber gloves with leather protectors will be worn when entering the restricted approach boundary of Table 3-1and removed only after leaving that area.
5. Protective equipment and vehicle grounds will be removed at the end of each workday.
6. Perform work on only one conductor at a time.
7. Tape or otherwise protect splices. Secure loose ends of conductors.
601 to 15,000 Volts
1. Ground vehicles and aerial lifts in the vicinity of the work site.
2. Cover with approved protective equipment, or isolate with suitable barriers, energized phase and neutral wires, ground wires, messengers, and guy wires in the vicinity of the work. Apply covering to the nearest and lowest conductor first and remove in reverse order. Refer to Chapter 7.
3. Use approved live-line tools where required by Table 8-3.
4. Rubber gloves with leather protectors will be worn when entering the restricted approach boundary of Table 3-1and removed only after leaving that area.
5. Protective equipment and vehicle grounds will be removed at the end of each workday.
6. Work performed must be under the direct supervision of a qualified work leader devoting full time and attention to the workers and the safety of their work.
7. Perform work on only one conductor at a time, although it is recognized that three-phase lifting tools may be used.
Above 15,000 to 230,000 Volts
1. Except for the replacement of fuses and switching, work on energized lines or apparatus at this voltage range must be performed by personnel specifically trained in the hazards associated with voltages in this range. Follow the requirements of Table 8-3.
2. Energized work above 36,000 volts will be done by personnel specifically trained in the hazards associated with voltages in this range.

CHAPTER 9 SUBSTATIONS AND SWITCHGEAR

9-1 SUBSTATION WORK.

9-1.1 Purpose of Substation.

A substation provides a protected area for switching power circuits and may include transforming power from one voltage to another. For the purposes of this UFC, substation refers to substations and switching stations. A substation presents an inherent safety hazard because usually only some portions of the substation apparatus can be deenergized for maintenance. For safe operation and maintenance, a thorough knowledge of the substation, including aerial and underground line connections, is necessary. Systems are designed to be safe to operate if maintained properly. Operating safely requires maintenance to be done in a manner that eliminates risks and requires knowledge of the work area, its hazards, and its design basis.

9-1.2 Diagrams and Schematics.

Electrical diagrams and schematics of the substations must be available and up to date. Diagrams and schematics must be studied to understand the operation of the systems and the location and connections of all circuits. Protective devices, alarms, and interlocking circuits all are intended to protect the system. The electrical worker must understand where, why, how, and when blocking protective devices can maintain safe working conditions.

9-1.3 Engineering Guidance.

Diagrams and schematics must be kept up to date under the supervision of the facility's engineering staff. Engineering staff guidance must be sought when performing maintenance on complex systems. Engineering input is mandatory if the maintenance work involves additions or changes to the power and control systems involved.

9-1.4 System Operation.

System single line diagrams must be permanently mounted at each substation. When Safe Clearance switching operations are performed, mimic buses on switchgear can be helpful as a visual indication of the lines or equipment being operated.

9-1.4.1 Protective Devices.

Protective devices within the system, such as relays, circuit breakers, and fuses, must retain, respectively, their correct coordination settings or be of the proper size and type. Always record previous data so that unintended changes in system coordination are not made.

9-1.4.2 Alarms.

System alarms, if blocked during maintenance, must be returned to their correct operating condition at the completion of the maintenance.

9-1.4.3 Interlocking.

Interlocking is used to maintain proper electrical operation in the case of a circuit loss or switching change. Interlocking provisions must be fully understood so to eliminate the danger of electrical feedback from another source, possible paralleling of two unsynchronized sources, or other unsafe operations. Interlocks, if bypassed during maintenance, must only be done by qualified persons, and must be returned to their correct operating condition at the completion of the maintenance.

9-1.5 Abnormal Conditions.

Maintenance accomplished after the occurrence of fault conditions that interrupted normal service imposes higher than usual maintenance risks. Faulty energized equipment and lines must always be placed in an electrically safe work condition before any work is done. All abnormal operating equipment and electrical components must be deenergized, locked and tagged tested, and grounded or isolated (whichever is applicable).

9-1.6 Defective Equipment.

Electrical apparatus found to be in a dangerous condition or not working properly must be removed from service immediately and tagged. Subsequently, a complete report on the defective equipment must be provided by the worker to the authorized individual-in-charge, the same day if feasible. Perform the following:

- Defective equipment removed from service, such as: distribution, potential, and current transformers; capacitors; and surge (lightning) arresters must positively be identified by an authorized and qualified individual before they are put in storage. Existing defective equipment in storage or at any other location must also be clearly identifiable.

- Identify defective equipment by painting a large red “X” on the body (not on the top) of the equipment. The red X must remain on such equipment until it has been repaired or until it has been properly disposed of. Local policy may dictate use of their preferred defective equipment identification marking.

- It must be considered a serious neglect of duty, and willful disobedience of instructions for a worker to deface in any way the identification marking on defective equipment or to place such equipment in service while so identified. The worker in charge of repairing any piece of defective equipment must be the only person authorized to remove the defective markings, and then only after all repairs have been made and the equipment has passed all required testing.

9-2 SWITCHING.

Opening or closing a power switch can expose the electrical worker to some degree of hazard. A mishap might occur if a switch is closed when a fault is still present on the line. To prevent a mishap, the authorized individual must prepare a switching sequence and identify all load isolation requirements. All switches operated in the switching sequence must be correctly identified. The electrical worker will review the manufacturer's operation manual for any switch that is unfamiliar, and all safety steps listed in the operation manual will be accomplished before opening or closing the switch.

WARNING

Switches can fail during switching operations, creating arc flash hazards. Wear arc rated clothing and/or switching suits during these operations in accordance with Chapter 4 requirements.

For the Navy, switching operations above 600 volts require a Switching Order. Switching operations include changing the position of circuit breakers, fused equipment, switches, and other devices.

9-2.1 Air Switches.

Many air switches cannot be opened if there is a load on the line, a large magnetizing current from a transformer, or a heavy charging current from an unloaded transmission line. Understand the interrupting capability of each switch being operated.

9-2.1.1 Disconnect Switches.

Disconnect switches of the non-load break-type must not be used to interrupt loads and magnetizing currents, unless an engineering review has determined the disconnect switch can safely interrupt the actual current. Switch sticks will be used when necessary to provide the minimum working and clear hot stick distances. Assume disconnect switches are of the non-load break-type unless you have positive proof otherwise. Operate non-load break-type switches on the following basis:

- Disconnect switches can be used to open an energized line when not under load.
- Disconnect switches can be used to open sections of deenergized lines where these lines parallel other high-voltage lines. Use caution because induced voltages can build up in the deenergized line and create dangerous switching conditions.

- Evaluate the hazard before using disconnect switches to open a tie line or to break two parallel high-voltage lines.

9-2.1.2 Airbreak Switches.

Gang-operated airbreak switches equipped with arcing horns may be rated for load-break operation, or they may only be rated for interrupting the magnetizing current of transformers or the charging current of lines, or to make and break line parallels. Operates these switches as follows:

- Provide ground mats for the operator to stand on for all substation airbreak switches when operating. Either fixed or portable small iron-mesh mats must be used. The mats must be electrically connected to the operating rod and the substation ground grid to equalize the ground gradient and prevent any potential differences in case of insulation failure or flashover.

- Appropriate arc flash rated personal protective equipment, rubber gloves, and hot sticks must be used when operating airbreak switches.

- The hinges of airbreak switches must be sufficiently stiff (and kept in this condition) so that after the blades have been turned into the open position they will not accidentally fall back on their line-side energized clips.

- The switch must be inspected after it has been opened to see that all blades have opened the proper distance. Single-throw airbreak switches must be opened to the maximum amount. Double-throw airbreak switches must be opened so that the blades clear both sides of the switch by the same amount.

- Install locks on all airbreak switch-operating mechanisms. Airbreak switches will be kept locked except when opening or shutting the switch.

9-2.1.3 Interrupter Switches.

Interrupter switches are designed to be opened under load. Metal-enclosed interrupter switches have sometimes been used in place of circuit breakers as a more economical switching method.

9-2.1.4 Inching.

The method of opening manually operated non-load break-type disconnects in a gradual manner is called inching, when the operator believes there is no load current. If a small arc occurs from the charging current, it has been assumed that a cautious opening would allow the arc to be broken; however, inching is dangerous and is prohibited.

9-2.2 Oil Switches.

The consequences of operating a faulty oil switch or closing into a faulted circuit with an oil switch are likely to be catastrophic and, often fatal. Switching procedures will be used to make sure that no energized oil switch is operated while workers are in the vicinity. Unless the switch has been equipped for remote operation (at least 20 ft (6.1 m)) away, the switch must be completely deenergized by an upstream device before switching. The switch must be locked out and tagged out before allowing maintenance. In addition, do not operate any energized high-voltage oil switch unless routine maintenance has been performed within the past year.

The switch must be deenergized at the nearest upstream device following the lockout/tagout procedures of Chapter 6. Once maintenance has been performed on the switch, the switch can be considered operational following the guidelines of this section. Oil switches must incorporate a mechanical stop to prevent inadvertent operation to ground. Any abnormalities or defects discovered in any oil switch must be reported to an authorized individual.

9-2.3 SF_6 Switches.

Follow all precautions specified by the manufacturer. Inspect the switch before operating it for any signs of degradation, such as low SF_6 pressure or signs of SF_6 leakage (accumulation of powder around seals). Verify that the SF_6 pressure gauge is in the green zone before operating the switch; operating a switch with low SF_6 pressure can result in internal flashovers that will damage the equipment and cause personal injury. Before energizing the switchgear for first use, verify that the shipping caps on all bushings and bushing wells have been replaced with elbows or insulated protective covers or plugs. The switchgear must be deenergized and grounded prior to conducting any maintenance, SF_6 sampling, or SF_6 filling procedures.

9-2.4 Oil-Filled Vacuum Switches.

Follow all precautions specified by the manufacturer. Inspect the switch before operating it for any signs of degradation, such as oil leakage; operating a switch without oil can result in internal flashovers that will damage the equipment and cause personal injury. Before energizing the switchgear for first use, verify that the shipping caps on all bushings and bushing wells have been replaced with elbows or insulated protective covers or plugs. The switchgear must be in an electrically safe work condition prior to conducting any maintenance, oil sampling, or oil filling procedures.

9-3 FUSES.

WARNING
Fuses might fail during handling if energized, creating arc flash hazards. Wear arc rated clothing or switching suits when changing energized fuses in accordance with Chapter 4 requirements.

9-3.1 Characteristics.

A fuse is a single-phase device. Fuses can be subject to partial melting or damage by currents that might not have been of sufficient magnitude to blow the fuse.

9-3.2 Fuse Handling.

Fuses must normally not be handled, except when they need to be replaced. Pull them briskly and remove completely. Use safety glasses and face shields when replacing fuses in primary fuse cutouts, do not use your free arm in an attempt to shield your eyes from possible flashes. The worker changing the fuses must stand firmly on a level surface. Where operating in an elevated position, the worker will be secured with a safety lanyard/harness to prevent a slip and fall if there is a flash. Use live-line tools to remove energized fuses. Whenever possible, deenergize the circuit before removing a fuse.

9-3.3 Operation of Energized Fuses.

Open all lines protected with energized fuses in the same manner as for air switches. Deenergize non-load-break type installations. For load-break installations, wait for a short time after fuse replacement in order to allow the fuse to interrupt any fault condition that might remain prior to the fuse replacement.

9-3.4 Open Fuse Holder.

Do not leave outdoor fuse holders open for an extended period of time. Water damage/moisture or warping could make closing them dangerous or degrade their protective ability.

9-3.5 Closed-Position Fuse Locking.

Follow the fuse or switch manufacturer's instructions, as appropriate, to be sure that the fuse is securely locked, latched, and held fast in a closed position.

9-3.6 Bypassing.

Do not bridge fuses or fuse cutouts internally.

9-4 ENERGY STORING PROTECTIVE DEVICES.

9-4.1 Electrical Charge.

WARNING

Protective devices such as surge arresters, choke coils, and capacitors store electrical charges as a byproduct of their protective mechanism. **\3** This stored charge must be discharged to ground and tested per NFPA 2021 70E 120.4(B)(6) before such devices can be considered deenergized. ***/3/*** Always wear appropriately rated personal protective equipment, including eye/face protection when deenergizing or energizing these devices., and use appropriate PPE in accordance with Chapter 4 requirements.

9-4.2 Surge Arresters.

A surge arrester limits overvoltages and bypasses the related current surge to a ground system that absorbs most of the energy. An overvoltage condition can be caused by a fault in the electrical system, a lightning strike, or a surge voltage related to load switching. All surge arrester equipment must be considered as loaded to full circuit potential, unless it is positively disconnected from the circuit. Be sure the permanent ground conductor is intact before any work is performed.

- High-voltage substation and at-grade surge arresters must always be provided with screens or fences to prevent possible contact while parts of the surge arresters may be live. The screen or fence must have a gate large enough to permit the removal of individual units. The gate must be provided with a lock and an authorized person must keep the key.

- Surge arresters must never be touched or approached, unless they are completely disconnected from all live lines and live equipment, and all parts have been discharged to ground and effectively grounded.

- Horn gap switches must be fully opened and completely separated from all live lines and equipment whenever it is necessary to work near a surge arrester.

- If the first attempt to disconnect a surge arrester is unsuccessful, wait 2 or 3 minutes before making another attempt so not to cause an internal fault.

9-4.3 Choke Coils.

Choke coils are inductors that operate in a manner similar to surge arresters, except that they operate on over-frequency rather than over-voltage.

9-4.4 Capacitors.

Capacitors consist of an electrical condenser housed in a suitable container. Power capacitors are used to provide power factor correction. Coupling capacitors are used for coupling communication circuits to metering circuits. Because capacitors can hold their charge, they are not electrically deenergized immediately after being disconnected from an energized line. Capacitors on electric lines must be provided with discharge devices to discharge the voltage to 50 V or less, within 5 minutes after the capacitors have been completely disconnected from the circuit. Wear appropriate levels of PPE identified in Chapter 4.

- Discharge circuits are intended to discharge capacitors after the circuit is deenergized. Since there could be no indication that the circuit is burned out or otherwise not functioning, always assume capacitors are fully charged until tested.

- Line capacitors removed from service for any purpose must be considered at full or higher voltage, until the terminals have been shorted together and discharged by an approved method. Do not short terminals until capacitors have been deenergized for at least 5 minutes to allow time for the voltage level to reduce.

- It is not safe to use fuses or disconnect switches to disconnect large capacitor banks (above 60 kilovolt-reactive single-phase, or 180 kilovolt-reactive three-phase). Circuit breakers or switches designed specifically for this purpose must be used.

- After disconnecting all capacitor banks, wait 5 minutes. Short together and ground all terminals; ensure the neutral is grounded. All operations must be performed using rubber gloves and a hot stick.

- Grounds and terminal shorts on capacitors must be left on until the work is completed.

- Barricade the work area as a safety measure for other workers, when working on or testing capacitors in the shop.

- Capacitors made before 1979 usually contained PCBs. Follow precautions for hazardous materials if the case is ruptured or any liquid is visible on the outside of the case.

9-4.5 Coupling Capacitors.

These capacitors have a high impedance, which results in a long discharge period. This characteristic of coupling capacitors is typically overlooked, which makes them particularly hazardous to personnel if not properly grounded. To minimize shock hazard, follow the precautions below:

- A coupling capacitor must always have a shorting wire installed.
- During maintenance, a grounding wire must be connected to each exposed metal terminal that a worker could contact. Grounding wires must be left in place for the entire duration of maintenance.

9-5 INSTRUMENT TRANSFORMERS.

9-5.1 Potential (Voltage) Transformers (PT).

PTs provide a means of obtaining a low voltage from a higher voltage circuit. They are designed and selected to operate within certain accuracy limits and burdens. Replacement transformers must have characteristics identical with the original units. The case and one of the windings of the low-voltage side of voltage transformers must always be grounded before energizing the transformer.

Be aware of the following hazards inherent in the maintenance and removal of these units:

- If the secondary windings are inadvertently shorted together when the primary windings are energized, a very high current will flow causing the windings to quickly overheat. This may also create an arc flash hazard to anyone in the vicinity of the transformer.
- On most modern switchgear, a drawout arrangement automatically disconnects and grounds the transformers when access to the fuses is necessary.
- On older obsolete switchgear, fuse replacement is potentially dangerous when the primary circuit to the transformer remains energized. Follow these additional safety precautions.
    - The authorized individual-in-charge will give specific instructions for replacing a blown primary winding fuse on a potential transformer located within switchgear and whenever it is not possible to use a standard 6 ft (1.8 m) fuse puller.
    - If a circuit breaker or sectionalizing switch is not installed to isolate a potential transformer, the worker must report the situation to the authorized individual-in-charge before replacing the fuse. The authorized individual-in-charge will arrange for deenergizing the primary circuit. Replacing a primary fuse when the potential transformer is not isolated is particularly hazardous and requires specific approval.
    - When disconnecting the primary service to the transformer, verify the absence of voltage using a suitably rated voltmeter (a handheld test meter with a high-voltage probe is not acceptable). Lamps can be

used in addition; however, note that a non-illuminated lamp, connected on the low-voltage side of a voltage transformer, is not an adequate indication that the primary side of the transformer is deenergized.

    - The secondary fuses must also be removed before replacing the primary fuse, and then reinstalled before the transformer is reenergized.

- While the transformer is deenergized, the worker must visually inspect for obvious symptoms of trouble such as a smoked or burned case, a damaged bushing, or a damaged fuse holder.

9-5.2 Current Transformers (CT).

WARNING

The most serious hazard associated with the maintenance of CTs occurs when the secondary side is opened while the primary side is energized. This causes a very high voltage to develop in the secondary winding, which both stresses the insulation and presents an extreme personnel hazard. The secondary circuit of a current transformer must never be opened while the primary side is energized; however, the secondary leads can be shorted together without damage to the transformer.

Before opening the secondary circuits of any energized current transformer, the secondary leads must be shorted together and grounded. The location of the short and ground is preferably located at the transformer secondary terminals but can be at any point between the current transformer and the location at which the secondary circuit is to be opened.

Current transformer cases and secondary circuits must be grounded before energizing any current transformer.

9-6 POWER TRANSFORMERS AND REGULATORS.

9-6.1 Transformers (Power and Distribution).

Consider all transformers energized and at full voltage unless they are disconnected from primary and secondary wires or disconnected from the primary wires and all phases shorted together and grounded. The secondary neutral normally is sufficient as a ground, provided that there is a grounding conductor interconnected with the common neutral, the transformer case, and a ground electrode. Always check continuity of the ground connection.

WARNING

Do not remove transformer covers or handhole plates or allow any work to be done on the inside of transformers until the following instructions have been completed.

Observe the following precautions:

- When transformers are installed or replaced, check the secondary terminals for correct voltage and for phase rotation (if applicable).
- When transformers are installed, and before they are energized, the ground connection must first be made to the case and to the neutral, when applicable.
- When removing transformers, case and neutral grounds must be disconnected last.
- When working on or near an energized three-phase, wye-connected transformer, or transformer bank, verify the transformer neutral is properly grounded.
- Never operate no-load (or manual) tap changers when the transformer is energized. Only load-tap-changing (LTC) type tap changers can be operated when the transformer is energized. When reenergizing a transformer after changing the position of manual tap changers, maintain the minimum approach distances specified in Table 3-1 with all required personal protective equipment until it is determined the internal switching was successful.
- If necessary to relieve pressure on a transformer, the pipe plug, pressure relief device, or inspection cover plate must be loosened slowly so the internal pressure of the transformer can dissipate gradually.
- Pressure relief valves must never be opened when there is precipitation or high humidity, except on failed transformers and when re-fusing.
- Never draw an oil sample, open a pressure relief valve, or otherwise open a transformer when there is an internal vacuum on an energized transformer. Doing so can cause an explosion.
- Transformers or tanks must not be entered unless forced ventilation or an air supply is used to maintain a minimum oxygen level of 19.5 percent by volume in the work area.
- Energized pad-mounted transformers and associated equipment must be locked or otherwise secured when unattended.

9-6.2 Voltage Regulators.

Voltage regulators are normally installed with bypass and disconnect switches. Never open or close a regulator bypass switch, unless the regulator is set on its neutral position and the control switch is open, or the automatic control feature is inactivated in accordance with the manufacturer's recommendations.

When regulators are maintained as spares in substations, their bushings must be short-circuited and grounded.

9-7 METALCLAD SWITCHGEAR.

Operate and maintain metalclad switchgear according to manufacturer's instructions and the guidance provided in this section. Perform the following prior to drawout (rack out) of a circuit breaker operating mechanism. Always rack out the switchgear breaker whenever there is work on the circuit originating from that switchgear breaker.

- In a confined space, such as pier vaults, the switchgear must be deenergized. Ground where possible. In other than confined spaces and vaults, consider deenergizing the switchgear from an upstream location. Utilize remote racking mechanisms when available, to rack breakers in and out. Wear appropriate PPE in accordance with Chapter 4.

- Open the circuit breaker.

- Discharge the stored-energy mechanism, if provided.

- Check that protective interlocks are functioning to protect against closed-position circuit breaker rack out.

- Ensure that all workers in the vicinity know the circuit breaker is being racked out.

- Access to switchgear terminals through portholes for maintenance in circuit breaker cells is limited to the following.

    - When both sets of terminals in a cell are deenergized (i.e., line and load, or bus to bus).

    - After both sets of terminals are deenergized, access to switchgear terminals through the portholes is permitted for cleaning, inspecting, and routine maintenance of terminals and bushings.

- A manufacturer-approved ground and test device can be used for access to terminals for procedures such as the application of protective grounds, phase identification on deenergized circuits, or phasing tests on live circuits. Use of this device avoids the hazardous operation of opening and shutting the shutters of a high-voltage switchgear cell. It can be an extremely hazardous device if not used according to manufacturer's instructions. Such devices are not permitted for Navy installations.

- o Do not install the device with ground cables already connected. Connect ground cables after installing the device.
- o Shut all access doors on the device while installing and removing the device. Use padlocks on any door where studs are intended to remain energized, and access is not needed for testing.
- o After installing the device, verify by using a voltage detector that exposed studs are deenergized.

- For the Navy, a manufacturer-approved grounding breaker can be used for access to the terminals for procedures of connecting temporary protective grounds to ground the main bus, ground the incoming lines or ground both the main bus and the incoming lines.
- For the Navy, phasing tests on circuits must be accomplished by using ground ball studs on outgoing cable termination pads or synchronizing check controls in conjunction with ground ball studs on outgoing cable termination pads. It is no longer permissible to conduct phasing tests using the shutters of a high-voltage switchgear cell. Retrofit existing equipment during preventive maintenance cycles.

9-8 STATIONARY BATTERIES.

9-8.1 Basis for Safety Requirements.

Batteries and DC system components are different from AC electrical system equipment. Batteries contain acid, which is harmful to skin and eyes, and the electrical shock hazards associated with DC power can be more severe than those associated with AC power for equivalent voltages and currents. Only authorized personnel who have been familiarized, trained, and qualified on battery fundamentals and maintenance procedures are allowed to perform maintenance-related activities on a battery.

In addition to substation applications, the requirements of this section apply to all stationary battery applications, including engine starting, UPS, and other backup power applications.

9-8.2 Applicable Industry Standards.

The following industry standards provide the most complete safety standards for stationary batteries and DC systems. Refer to the appropriate document for the type of battery used in a particular application.

- IEEE 450, *Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*.

- IEEE 484, *Installation Design, and Installation of Vented Lead-Acid Batteries for Stationary Applications*.

- IEEE 1106, *Installation Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*.

- IEEE 1187, *Installation Design, and Installation of Valve Regulated Lead-Acid Batteries for Stationary Applications*.

- IEEE 1188, *Maintenance, Testing and Replacement of Valve Regulated Lead-Acid Batteries for Stationary Applications*.

- IEEE 1578, *Stationary Battery Spill Containment and Management*.

- **\3** NFPA 2021 70E, *Electrical Safety in the Workplace,* Chapter 2, Article 240*, Batteries and Battery Rooms*. ***/3/***

9-8.3 Protective Equipment.

The following equipment must be available for the safe handling of the battery and protection of personnel:

- Safety glasses with side shields, goggles, and/or face shields.

- Acid-resistant gloves.

- Protective aprons and safety footwear.

- Portable or stationary water facilities for rinsing eyes and skin in case of contact with acid electrolyte.

- Class C fire extinguisher.

- For lead acid batteries, bicarbonate of soda to neutralize any acid spillage (1 lb/gal or 0.1 kg/L of water).

- Adequately insulated tools.

- Lifting devices of adequate capacity, when required.

9-8.4 Safety Precautions.

> **WARNING**
>
> Stationary batteries generate a direct current (DC) voltage, which is particularly dangerous with respect to electrical safety. Exercise extreme caution whenever working on battery systems.

Observe the following safety precautions:

- Wear proper safety clothing to prevent contact with acid or live electrical connections. Whenever working on or near batteries, wear a rubber apron and rubber gloves. Ensure goggles and face shields are available for personnel.
- Use only insulated tools in the battery area to prevent accidental shorting across battery connections. Never lay tools or other metal objects on cells; shorting, explosion, or personal injury could result. As a general rule, ensure the length of the exposed metal for any tool is less than the distance between the positive and negative posts of each cell.
- Wear only nonconductive hard hats near batteries. Metal hard hats can fall across the battery terminals or connections and create short circuits.
- Remove all jewelry, wristwatches, or clothing with metal parts that could come into contact with the battery terminals.
- Do not make or break series connections within an operating group of cells. Before proceeding, open the battery system circuit breaker to minimize the possibility of arcing.
- Vented lead acid, vented nickel cadmium batteries and valve-regulated lead acid (VRLA) batteries can generate hydrogen gas that, in sufficient concentrations, can be explosive if ignited. Never bring burning materials such as lighted matches, cigarettes, or sparks of any kind near the battery. Avoid the use of spark-producing equipment near batteries. Residual gases can remain within cells during storage and shipment. Smoking is not permitted in battery rooms or near stationary batteries. Always take these precautions while handling batteries.
- Ensure that the exit from the battery area is unobstructed.
- Minimize access to the battery by personnel unaware of battery safety precautions.
- Ensure that the battery area is suitably illuminated.

- Keep the battery and adjacent area clear of all tools and other foreign objects.

- Avoid static buildup by having personnel contact ground periodically while working on batteries.

9-9 INSULATING OIL HANDLING OPERATIONS.

Place oil insulated equipment in an electrically safe work condition before starting any oil handling procedure. Observe the following additional precautions during oil filtering, oil reclaiming, and other oil-handling operations:

- Always place potential and current transformers in an electrically safe work condition before taking oil samples.

- Have appropriate types and sizes of fire extinguishers readily available.

- Once all equipment has been placed in an electrically safe work condition and insulating oil handling operations is to begin, don an approved disposable coverall. Use extreme caution to ensure that oil does not contaminate arc-rated PPE. Immediately remove from service arc-rated PPE that has become contaminated.

CHAPTER 10 UNDERGROUND LINES

This chapter applies to work in manholes, vaults, and handholes; work on duct lines, trenches, and underground cables; and work on ground-mounted and underground equipment associated with underground electrical lines.

Note: An IEEE interpretation, dated 14 January 2009, regarding IEEE C2 (National Electrical Safety Code) Rule 410A3, confirms that the phrase "on or near energized parts or equipment" applies to energized insulated conductors inside manholes. IEEE C2 Rule 443 does allow a qualified employee, working alone, to enter a manhole where energized cables or equipment are in service for the purpose of inspection, housekeeping, taking readings, or similar work if such work can be performed safely.

10-1 AUTHORIZED WORK ACTIVITIES INSIDE CONFINED SPACES CONTAINING ENERGIZED ELECTRICAL CIRCUITS.

Deenergize all equipment inside an underground structure (including manholes and vaults) operating at high voltage levels before allowing entry into the underground structure. This includes insulated conductors. If the equipment inside the manhole cannot be deenergized, apply the guidance provided in the following sections. If a cable in an underground structure has one or more abnormalities that could lead to or be an indication of an impending fault, the defective cable must be deenergized before any employee can enter the manhole.

Note: Abnormalities such as oil or compound leaking from cable or joints, broken cable sheaths or joint sleeves, hot localized surface temperatures of cables or joints, or joints that are swollen beyond normal tolerance are presumed to lead to or be an indication of an impending fault.

An arc flash event inside an electrical manhole or vault is considered potentially more severe than arcing faults in equipment above grade. IEEE 1584 provides arc flash analysis methods for two configurations: a three-phase arc in open air and a three-phase arc in a box in which the worker is located just outside the box. For work inside an electrical manhole, the IEEE 1584 methodology, as well as an NFPA 70E alternate method, does not apply, in that the worker is located within the box, which is not a configuration covered by IEEE 1584. An arc flash risk assessment must consider that, if an arcing fault occurs, the electrical worker will be located within the plasma cloud inside a constrained environment.

10-1.1 Inspection-Only Access in Manholes Containing Energized Circuits.

Note: Entry into a manhole or vault containing energized circuits is not permitted for inspection activities if problems are suspected inside the manhole, such as conductor damage associated with a short circuit.

Note: Standing water is permitted for inspection activities provided that the standing water level is below energized and installed conductors and associated cable rack arm.

Inspection-only access to a manhole or vault containing energized circuits can be authorized by an energized electrical work permit or a standard operating procedure (SOP) for the purpose of examining insulated cable, equipment, or accomplishing other inspections not requiring touching or disturbing the energized conductors or equipment. The following are examples of the types of activities that are considered inspection-only access:

- Manhole and sump inspection.
- Sump cleaning.
- Inspection of conductors and splices, without touching or disturbing the conductors.
- Inspection of any equipment installed in the manhole.
- Installation of conduit plugs on spare conduits, provided that conductors inside the manhole will not be touched or disturbed.

Comply with Table 4-6 Additional Work Tasks and Associated PPE Requirements for the minimum PPE for this activity. Before entering, visually confirm that the manhole can be entered, and the intended activity can be accomplished without disturbing energized conductors.

10-1.2 Work Inside Manholes Containing Energized Circuits.

Note: Entry into a manhole or vault containing energized circuits is not permitted for work activities if problems are suspected inside the manhole, such as conductor damage associated with a short circuit.

Note: Standing water is permitted for the specified work activities provided that the standing water level is below energized and installed conductors and associated cable rack arm.

Note: Reracking energized conductors is not permitted. The circuits must be deenergized before the conductors can be disturbed.

Access to a manhole or vault containing energized circuits to perform specific work activities can be authorized by an energized electrical work permit or a standard operating procedure (SOP). The following are examples of the types of work that can be performed:

- Removing conduit plugs.
- Spare conduit inspection using fish tape, boroscope, or other devices.

- Splicing deenergized conductors. When splicing deenergized conductors, confirm that an 18-inch (0.5-meter) safe working distance from other energized conductors or equipment can be maintained during the work.

- Pulling new conductors in spare conduits.

- Removing abandoned (deenergized) circuits, including associated equipment, if nearby energized circuits are not disturbed.

Comply with Table 4-6 Additional Work Tasks and Associated PPE Requirements for the minimum PPE for this activity. Before entering, visually confirm that the manhole can be entered, and the intended activity can be accomplished without disturbing energized conductors.

10-1.3 All Other Work Inside Manholes Containing Energized Circuits.

Note: Standing water is permitted for the specified work activities provided that the standing water level is below energized and installed conductors and associated cable rack arm.

All other work not covered by Section 10-1.1 or 10-1.2 require a job-specific energized electrical work permit in accordance with Chapter 8. In addition to the requirements provided in Chapter 8, include the following in the energized electrical work permit:

- Description of manhole and its configuration.

- Description of planned work activities.

- Electrical shock and arc flash risk assessment.

  Note: Electrical analysis software packages that perform arc flash calculations do not account for an electrical manhole configuration in which the electrical worker is inside an enclosed area rather than standing adjacent to an enclosure. Increase the arc flash PPE requirements by a minimum of one (1) arc flash hazard category above the arc flash calculation result.

- Required PPE.

- Minimum number of qualified electrical workers.

- Means to restrict unqualified persons from the work area.

- Rescue plan.

10-1.4 Switching Activities Inside Manholes Containing Energized Circuits.

Do not switch or rack energized equipment in or out of switchgear in an underground structure. Observe the following:

- Secure, whenever feasible, all electrical power prior to start of work in electrical vaults, manholes and other confined or enclosed spaces.
- When absolutely not feasible to secure the power in these locations, refer to Chapter 8 for requirements.

10-2 CABLE PULLING.

Observe the following:

- Do not handle pull-wires or pulling-lines within reaching distance of blocks, sheaves, winch drums, and take-up reels.
- Do not remain in a manhole during pulling operations.
- Do not use wire rope to pull cable in a duct already occupied by conductors.
- Use a nonmetallic duct fishing wire or device when fishing ducts containing energized conductors.
- Always fish ducts in the direction that presents the least hazard. Consider stationing a worker at each end when fishing ducts.

10-3 BURIED ELECTRICAL CABLES.

Observe the following:

- Use area utility maps to locate existing buried cables and nearby utilities as accurately as possible. Locate/scope for buried cables along any intended digging areas. Obtain digging permits, as required.
- Use extreme care when excavating near or exposing direct-burial electric underground cables. If the depth of all direct-burial cables is definitely known, power digging equipment can be used for excavating all but the last 12 in (305 mm) of cover over the cables. The remaining cover must be removed by use of hand-digging tools with FRP handles. Where the depth of direct-burial cables is not established, power-digging equipment must not be used, except to break and remove the surface pavement.
- Do not use probe rods or bars to locate any underground direct-burial cables.

- Take extreme care to avoid damaging the cable insulation when uncovering direct-burial cables.

- Protect all exposed cables against damage in a work area with boards or other nonconductive materials. Utilize suitable nonflammable protective material when it is necessary to weld adjacent to cables.

- Do not stand, sit, kneel, or lean on unprotected direct-burial cables.

CHAPTER 11 LOW-VOLTAGE INTERIOR SYSTEMS

11-1 WORKING ON INDOOR EQUIPMENT.

11-1.1 Restricted Space.

Be alert that older installations might not meet current NEC clearance and entrance requirements for electrical rooms. Where installations do not conform to current NEC/OSHA requirements, additional safety precautions and instruction must be provided to maintenance workers. Give special attention to the guarding of live parts where current NEC clearances are not met. Ensure that unobstructed emergency exit routes are provided.

11-1.2 Grounding Systems.

Verify that existing permanent electrical system grounds are adequate for personnel protective grounding and provide additional temporary grounding as necessary.

11-1.3 Disconnection of Power Sources.

Be sure to check single line diagrams and verify that all inputs and interconnections to any electric power source are locked and tagged open. Verify single line diagram connections with the actual line connections of the applicable equipment.

11-1.4 Related Building Systems.

Do not disable or work on any fire protection and fire alarm systems without prior notification and approval of the local fire department. If the room’s ventilation system is affected by the work, ensure that adequate temporary ventilation is provided.

11-2 LOW-VOLTAGE SYSTEMS.

Complete any work with only qualified electrical workers with training and experience on low-voltage circuits. Electrical workers must be familiar with NFPA 70 requirements and must have work experience with low-voltage systems. Inform the foreman when installations do not meet the requirements of applicable codes and standards. Electrical workers must understand electrical safety requirements for low-voltage systems. In many cases, contract personnel or specially trained workers will repair complex controls and special equipment.

11-2.1 Overview.

Consult the manufacturer's instruction manual if available for the apparatus before starting work.

Unless specifically approved in accordance with Chapter 8, work is not permitted on energized circuits. Use temporary ground wires to drain off induced voltages and currents from live circuits, stored energy devices, and equipment metal guards before starting work.

11-2.2 Battery Room Hazards.

The battery safety rules provided in Section 9-8 apply to low-voltage systems.

11-2.3 Fire Alarm Systems.

Maintaining fire alarm systems with their appropriate safety requirements requires special training and must be in accordance with UFC 3-601-02, *Operations and Maintenance: Inspection, Testing and Maintenance of Fire Protection Systems*. Workers must have completed one or more of the following certifications or specialized training.

- Factory trained and certified, or
- Certified by the National Institute for Certification in Engineering Technologies (Fire Alarm Systems), or
- Certified by the International Municipal Signaling Association (Fire Alarm Systems), or
- Certified by state or local authority, or
- Trained and qualified by an organization listed by a nationally recognized testing laboratory for the servicing of fire alarm systems.

11-2.4 Solid-State Equipment.

Adjustable-speed motor controllers, frequency converters, and uninterruptible power supply (UPS) equipment are complex solid-state devices that must generally be maintained by manufacturers or specially trained contract personnel. Facility personnel are not normally trained for such work. Even after initial training, maintenance work is usually done on such an infrequent basis that workers must not be considered qualified. Facilities with these installations must contain cautionary labeling to warn workers of the electric shock dangers involved in operating and maintaining these types of equipment.

11-2.5 Low-Voltage Work Precautions.

Observe the following:

- Assume all parts of an electric circuit are energized until an electrically safe working condition has been established.

- Use only insulated hand tools when working on equipment where the tool could contact an energized source of 50 V or higher.

CAUTION

Older plastic or rubber coated tools are often not certified by the manufacturer for insulating ability, and the coating is only provided as a comfort feature for the user. If the tool has not been tested, it must be assumed to not meet OSHA requirements for use of insulated hand tools.

- Unless specific permission is provided, no work will be performed on energized electrical circuits or equipment operating at more than 50 V phase-to-phase. Follow the safe clearance requirements of Chapter 6. If work is performed on live energized circuits, select the appropriate personal protective equipment in accordance with the criteria provided in Chapter 4.

- When working on or near energized circuits, workers must stand on a dry surface.

- If using fish tape near energized parts, cover live parts with rubber equipment.

- If working near running machinery, use extreme care and provide barricades, if necessary.

- Place all tools clear of machinery before starting machinery. Never use a wrench on running machinery.

- Provide adequate illumination.

- Wear safety goggles when soldering joints or tinning lugs on connectors.

- Remove tripping hazards before starting work and do not work on slippery surfaces.

- Tape or cover bare or exposed places on one energized conductor before exposing another energized conductor. Never leave joints or loose ends of wire untapped or otherwise unprotected.

- An open knife switch can be hazardous because of the exposure to live parts and because of the arc formed when the switch is opened. Only use knife switches that are enclosed in grounded metal cabinets having the control lever operable from outside the cabinet. Install a knife switch so that the blades are deenergized when the switch is open and oriented so that gravity will not tend to close the switch.

- Provide fuses and circuit breakers in accordance with NFPA 70, properly sized to protect the downstream conductors and equipment. Substitution of conductors for fuses is not permitted. Remove fuses only after opening the upstream disconnect device. Use an insulated fuse puller. Use an insulated fuse puller and PPE in accordance with Chapter 4.

- Use properly grounded portable electric tools, particularly in damp locations or near grounded equipment or piping. Do not open a ground connection to a water pipe or ground rod until the ground wire has been disconnected at the equipment.

11-3 ROTATING MACHINERY.

11-3.1 Hazards of Rotating Machinery.

Ensure guards are provided to protect workers from accidental contact with live electrical parts, rotating parts, and hot machine surfaces. Be aware that rotation can loosen grounding connections, hold-down bolts, and fray flexible or cord connections. Be alert to sparking of brushes and insulation failures that may cause flame or molten metal to be ejected from open type motors or generators. Interior electrical work often must be done in close proximity of rotating electrical equipment such as motors and generators. Do not operate rotating machinery without protective guards.

11-3.2 Motors and Generators.

After work has been performed on circuits to rotating machines, check direction of rotation. Always take positive steps to ensure that rotating equipment under repair cannot be set into motion.

Follow appropriate mechanical safety precautions if operating a generator, including:

- Ensure engine coolant is at the proper level and has the proper amount of antifreeze. Make sure engine lubricant and fuel are at the proper levels. Check hoses for good condition.

- Ensure engine air requirements for combustion are met. Check air filters and cleaners for cleanliness and good condition.

- Verify the engine, generator, and related equipment are clean. Keep oil-soaked rags out of the generating facility to avoid a fire hazard.

CHAPTER 12 SHORE-TO-SHIP ELECTRICAL POWER CONNECTIONS

12-1 CONNECT/DISCONNECT SERVICES.

Shore Electric Utility Systems are utilized to provide dockside electrical service (Shore Power) to Ships operating in a cold iron mode. Shore Power Electric Utilities which connect and disconnect services, with the associated cable assemblies and cable maintenance, are provided as a reimbursable activity. Cable assemblies include all necessary components to allow connection from Facility Shore Power receptacles to Ship's or Submarine's Shore Power receptacles but may also require use of ship owned lug and bolt cable adapter assemblies, often called pigtails. The specific requirements and performance responsibilities for shore-to-ship connects are provided in Section 12-2. The step-by-step procedures for ship connects, infra-red testing of connections, and ship disconnects are developed at the local level following this UFC. Refer to Naval Engineering Training and Operating Procedure and Standard (NETOPS) #29, *Shore-to-Ship Power Connect and Disconnect Procedures*, for additional information.

SOPs that have been issued by NAVFAC Activities are available for review at the Enterprise Safety Applications Management System (ESAMS) at the following:

https://esams.cnic.navy.mil/ESAMS_GEN_2/LoginESAMS.aspx

12-2 SPECIFIC SHORE-TO-SHIP ELECTRICAL SYSTEM SAFETY.

This section covers connection of portable power cables to shore electrical outlet assemblies and ship electrical buses. Connection is a divided responsibility between the Shore Electrical Supervisor (ES) and the Ships Electrical Officer (EO)). Follow the Standard Operating Procedure (SOP) established by the Shore ES as identified in Section 12-1.

12-2.1 Unusual Shore-to-Ship System Hazards.

The additional risks posed by shore-to-ship power cable connections include:

- Split personnel shore/ship responsibilities for electrical safety.
- Portable power cable and outlet safety assurance.
- Electrical equipment accessibility and working space.
- An ungrounded, adequate, and correctly phased electrical power input.
- Minimizing any parallel operations.

12-2.2 Split Personnel Responsibilities.

It cannot be overemphasized how important standard operating procedures are in eliminating the hazards of split responsibilities between shore and ship. Training of both shore and ship personnel is necessary to assure safety while connecting and disconnecting cables between a pier and a ship.

12-2.3 Portable Power Cable and Outlet Safety Assurance.

> **WARNING**
> Harsh waterfront environments provide salt spray, high humidity, and cold temperature conditions. All of these result in more rapid deterioration of permanent installations. Portable power cables, if not adequately barricaded are subject to damage from the wheels of vehicles used in industrial operations and improper handling. Families welcoming returning service members, DoD personnel, and contractors working on piers may not understand or recognize the dangers these energized shore power cables installed in accessible positions poses to the public.

12-2.4 Electrical Equipment Accessibility and Working Space.

> **WARNING**
> Electrical equipment in under-pier vaults that is not readily accessible might not meet current NEC working space requirements.

12-2.5 Readily Accessible.

> **WARNING**
> The NEC defines ready accessible as capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, or other such devices. Therefore all workers in vaults must satisfy all confined space requirements.

12-2.6 Working Space.

The NEC defines working space as sufficient access provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment. Working space in vaults has been provided in accordance with the NEC requirements applying at the time the vault was built. As with all safety aspects affecting both the general public and maintenance workers, safety requirements have become more rigorous over the years. Although current NEC requirements do not apply to vaults built to previous NEC editions, compare the NEC current requirements with actual working space provisions.

Each activity must evaluate the comparisons as to their effect on workers safety and provide SOP's as necessary to assure safe working conditions.

12-3 SPECIALIZED SHORE-TO-SHIP SYSTEM TRAINING.

Train all employees whose job requires providing shore power services to understand the purpose and function of the hazardous energy control program, and the hazards they face. Verify that they demonstrate a working level knowledge of all process steps and applicable references, and complete site-specific training as required.

Qualification training for the operation, maintenance, and testing of the shore power systems includes:

- Power cable/connector assemblies and extensions.
- Cable phasing and paralleling methods.
- Lock-out/tag-out procedures.
- Switching operations.
- Maintaining electrical safe working conditions.

12-4 SHIP'S MAIN ELECTRICAL SERVICE COMPONENTS.

The specific safety requirements given apply to the cable assemblies from the pier's electrical outlet assemblies (commonly called "turtlebacks" on Mil-C receptacle systems, and "Connection Stations" on single pole panel mount connector systems) to the ship's electrical bus. There are other components of the shore's high-voltage electrical distribution system used to supply substations that in turn supply the pier electrical outlet assemblies. The safety requirements for the pier electrical outlet assemblies that supply line side components are covered by earlier sections. Because they are provided for ships power in addition to permanent pier electrical loads, these components are also described here to enable a clearer understanding of the dockside electrical distribution system.

12-4.1 Shore High-Voltage Distribution System.

The facility's primary electrical distribution system normally operates in the high-voltage range between 5 kV and 35 kV. For permanent pier service, dual primary feeders from the shore's primary system is preferred. Pier systems can also be furnished with single feeders. These feeders serve substations, which step down the distribution system's primary voltage to the required secondary voltage for ships electrical service of 13.2 kV, 4.16 kV or 480 volts.

12-4.2 Pier Substations.

Substations might consist of above ground installed on the top of a pier or units installed in vaults located under the pier. Vault substations are fed by shielded power cables installed in electrical duct. Above deck substations are skid-mounted and are supplied by either shielded power cables installed in duct or mine power cable installed on the pier connected to the electrical distribution system via cable coupler plugs to coupler receptacles in electrical connection outlet assemblies. Both types of substations may include one or more primary fused switches or be fed from a pad mount switchgear vacuum fault interrupter switch way, the step-down transformer, and secondary circuit breakers supplying the pier electrical outlet assemblies for ship-to-shore power cables. The following figures show these component elements.

Figure 12-1. Electrical Connection Outlet Assembly with a 15 kV Receptacle

Figure 12-2. Close-Up of Electrical Connection Outlet Assembly

Figure 12-3. Inside a Pier Vault Housing a Substation

Figure 12-4. Skid-Mounted Substation

Figure 12-5. Skid-Mounted Substation with Single-Pole Connections

Figure 12-6. Double-Deck Pier Switchgear

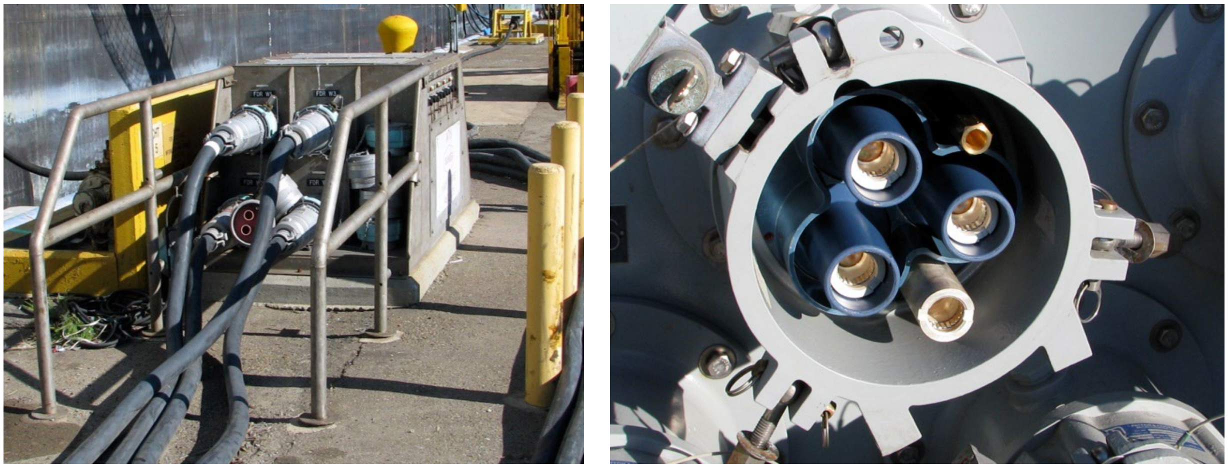
12-4.3 Ship-to-Shore Pier Electrical Outlet Assemblies.

Ships service is from pier electrical outlet assemblies that contain either multiples of single pole or three-pole, 500-ampere receptacles rated either for 450 volts ships service, 4.16 kV ships service, or 15-kV ships service as appropriate to the pier's ship electrical service requirement. Receptacles may be interlocked with their associated substation secondary circuit breaker for safety reasons. Figures 12-7 and 12-8 show three-pole outlet assemblies for 480 volt and 4.16 kV services respectively. Figure 12-9 shows the newer design for medium voltage electrical outlet assemblies.

Figure 12-7. 480 Volt Pier Electrical Outlet Assembly Without Cable Connections

Figure 12-8. 4.16 kV Pier Electrical Outlet Assembly and Outlets – Existing Installations

Figure 12-9. 4.16 kV Pier Electrical Outlet Assembly and Outlets – Newer Designs



12-4.4 Shore-to-Ship Power Cables and Connectors.

Portable shore-to-ship power cables are rated 8000 volts for operating at 4160 volts, three-phase, three-wire, ac or 600 volts for operating at 450 volts, three phase, three-wire ac. Both 4160 V and 480 V shore power systems are ungrounded (the transformer neutrals are isolated from ground).

Note: Splices are not allowed in 4.16 kV power cables. Figures 12-10 through 12-13 show examples of cables in place and various connections.

Figure 12-10. 480 Volt Pier Electrical Outlet Assembly and Cable Connections

Figure 12-11. 480 Volt Shore-Cable to Ship-Cable with Single-Pole Connection

Figure 12-12. 480 Volt Shore-Cable to Ship-Cable Plug and Receptacle Connection In Place

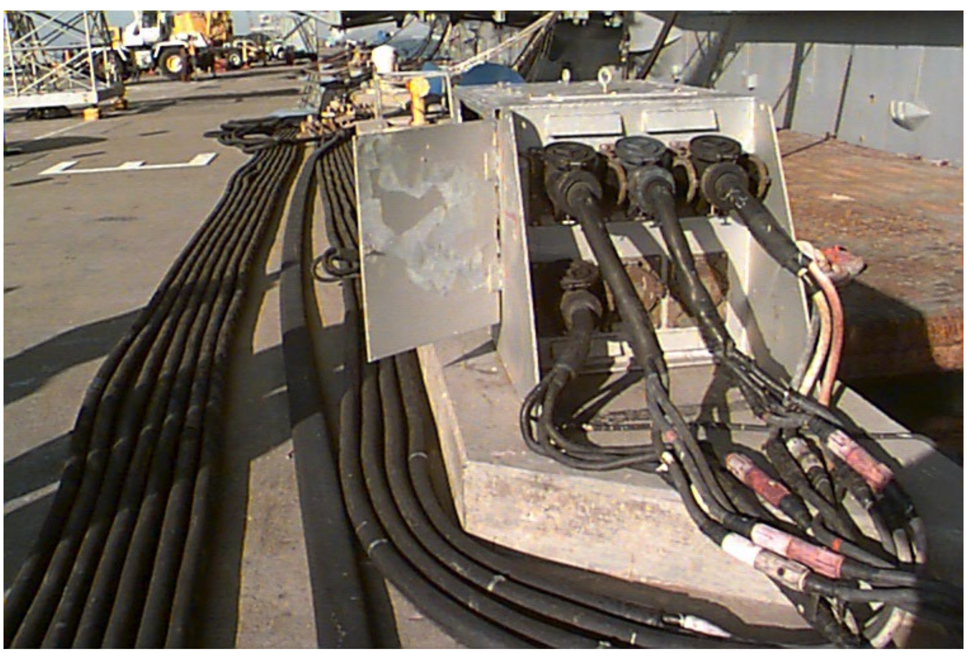


Figure 12-13. 480 Volt Shore-Cable to Ship-Cable Splice Connection in Place

12-4.5 Pier High-Voltage (4,160 Volt) Electrical Outlet Assemblies.

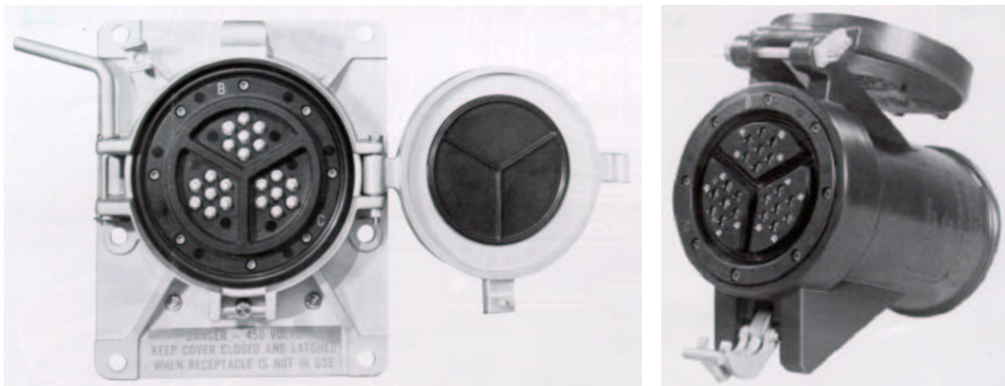
This assembly utilizes a three pole, 500-ampere, 4,160 volt receptacle with a matching plug. Units have the Mine Health Safety Administration approval, are provided with a safety interlock, and have been modified to remove a ground cable connector. Refer to Figure 12-14.

Figure 12-14. High-Voltage Shore Receptacle

12-4.6 Low-Voltage Terminations.

The system provides a 480 volt, three-phase, three-wire, ungrounded 60 hertz source to the ship. Refer to Figure 12-15.

Figure 12-15. Low-Voltage (480 Volt) Shore Receptacle



APPENDIX A REFERENCES

Note: *The most recent edition of referenced publications applies, unless otherwise specified.* [1]

AIR FORCE PUBLICATIONS

\3 AFMAN 32-1065, *Grounding & Electrical Systems*

DAFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards* **/3/**

DEPARTMENT OF DEFENSE PUBLICATIONS

\2 TM 5-683/NAVFAC MO 116/AFJMAN 32-1083, *Facility Engineering Electrical Interior Facilities* **/2/**

TSEWG TP-15: Electrical Technical Paper: *Arc Flash Calculations and Detailed Arc Flash Warning Labels.*

UFC 3-501-01, *Electrical Engineering*

U.S. NAVY PUBLICATIONS

OPNAVINST 5100.23G CH-1, *Navy Safety and Occupational Health Program Manual*.

NAVFACINST 5100.12, *NAVFACENGCOM Safety & Health Program*.

Naval Engineering Training and Operating Procedure and Standard (NETOPS) #29, *Shore-to-Ship Power Connect and Disconnect Procedures*.

U.S ARMY CORPS OF ENGINEERS PUBLICATIONS

Engineer Memorandum (EM) 385-1-1, *Safety and Health Requirements Manual*.

Department of the Army Pamphlet (DA PAM) 385-10, *Army Safety Program*.

DA PAM 385-26, *The Army Electrical Safety Program*.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

[1] Addresses for Non-Government standards organizations:

1. American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036
2. ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959
3. Institute of Electrical and Electronics Engineers, 3 Park Avenue, New York, NY 10016
4. International Safety Equipment Association, 1901 North Moore Street, Arlington, VA 22209-1762
5. National Fire Protection Association, One Batterymarch Park, P.O. Box 9101, Quincy, MA 02269
6. Underwriter's Laboratories, Inc., 333 Pfingston Road, Northbrook, IL 60062

Note: Many ANSI documents are sponsored or co-sponsored by other organizations, such as IEEE. Some ANSI documents are listed with the sponsoring organization.

ANSI/NETA ATS, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*.

ANSI/NETA MTS, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*.

ANSI/SIA A92.2, *Vehicle-Mounted Elevating and Rotating Aerial Devices.*

ANSI/SIA A92.3, *Manually Propelled Elevating Aerial Platforms.*

ANSI/SIA A92.5, *Boom Supported Elevating Work Platforms.*

ANSI/SIA A92.6, *Self-Propelled Elevating Work Platforms.*

ANSI Z308.1, *Minimum Requirements for Workplace First-Aid Kits and Supplies*.

ASTM INTERNATIONAL

ASTM F18-Series, *Standard on Electrical Protective Equipment for Workers*.

ASTM F711, *Specification for Fiberglass Reinforced Plastic (FRP) Rod and Tube Used in Live-Line Tools*.

ASTM F855, *Specifications for Temporary Grounding Systems to be Used on De-energized Electric Power Lines and Equipment*.

ASTM F887, *Specifications for Personal Climbing Equipment*.

ASTM F1506, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*.

ASTM F3121/F3121M-16, *Standard Guide for In-Service Maintenance and Electrical Testing of Hand-Held Live-Line Insulating Tools (Fiberglass-Reinforced Plastic (FRP))*.

FEDERAL HIGHWAY ADMINISTRATION

Manual on Uniform Traffic Control Devices (MUTCD)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2, *National Electrical Safety Code.*

IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated Up To 38 Kv for Internal Arcing Faults*

IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*.

IEEE 450, *Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*.

IEEE 484, *Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.*

IEEE 516, *Guide for Maintenance Methods on Energized Power-lines.*

ANSI/IEEE 935, *Guide on Terminology for Tools and Equipment to Be Used in Live Line Working.*

IEEE 1106, *Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*.

IEEE 1187, *Installation Design and Installation of Valve Regulated Lead-Acid Batteries for Stationary Applications*.

IEEE 1188, *Maintenance, Testing and Replacement of Valve Regulated Lead-Acid Batteries for Stationary Applications.*

IEEE 1246, *Guide for Temporary Protective Grounding Systems Used in Substations*.

IEEE 1578, *Stationary Battery Spill Containment and Management*.

IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*.

INTERNATIONAL SAFETY EQUIPMENT ASSOCIATION (ISEA)

ISEA Z89.1 *Industrial Head Protection.*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70, *National Electrical Code*.

NFPA 70B, *Electrical Equipment Maintenance*.

NFPA 70E, *Electrical Safety in the Workplace.*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Note: The following OSHA regulations can be downloaded from *www.osha.gov*.

29 CFR 1910, *Occupational Safety and Health, General Industry Standards*.

29 CFR 1915, *Occupational Safety and Health Standards for Shipyard Employment.*

29 CFR 1926, *Occupational Safety and Health, Safety and Health Regulations for Construction*.

APPENDIX B ELECTRICAL TASK RISK ASSESSMENT CHECKLIST

Appendix B provides an example checklist in support of the risk assessments specified by NFPA 70E. An energized electrical work permit requires a shock risk assessment and an arc flash risk assessment. Table B-1 provides an example checklist. The format and method of documentation is optional; however, any electrical task risk assessment must address the topics listed in Table B-1. References to numbered sections and tables (such as Section 4-2 or Table 4-7) apply to sections and tables in this UFC. References to lettered sections (such as Section C) apply to sections within the Electrical Task Risk Assessment Checklist.

Table B-1 Electrical Task Risk Assessment Checklist

Section A, Task Identification					
Facility Location:					
Equipment:					
Scope of Work/Task:					
Work Order No.					
Submitter:		**Submitter Signature:**		**Date:**	
Section B, General					
	*Mark **"Y"** or **"N"** as appropriate*				
No.	**Item**	**Yes**	**No**	**Instructions**	
1.	Is the equipment operating at 50 volts or more or is a shock hazard present?			*If **No**, hazard analysis is not required.* *If **Yes,** proceed to Line 2.*	
2.	Is the required working distance available?			*If **Yes**, proceed to Line 3.* *If **No**, do not proceed. Additional risk assessment is required before any work is performed.*	
3.	Is the working space clear?			*If **Yes**, proceed to Line 4.* *If **No**, do not proceed. Additional risk assessment is required before any work is performed.*	
4.	Was an incident energy analysis performed?			*If **Yes**, proceed to Section C* *If **No**, proceed to Line 5*	
5.	Is the equipment properly installed and maintained and there is no evidence of impending failure?			If ***Yes***, arc flash PPE may not be required if doors are, and will remain, closed and secured and if covers are, and will remain, secured in place. If work will be performed on exposed energized electrical equipment as stated in Section 8-3.3, proceed to Section C. If ***No***, arc flash PPE is required, proceed to Section C.	
Section C, Shock Information – All Methods *Refer to Table 3-1 or Table 3-2, as applicable, as well as Table 3-3.*					

6.	Phase voltage:		*Establish the shock boundaries*
	Limited Approach Boundary:		*Proceed to Lines 7 and 8.*
	Restricted Approach Boundary:		
7.	Are rubber insulating gloves required for the task?		*Proceed to Section D if an incident energy analysis has been or needs to be performed. Proceed to Section E if using the Arc Flash PPE Category (Table) method.*
8.	Are insulated or insulating hand tools required for the task?		
Completed By:		**Signature:**		**Date:**	

Section D, Arc Flash Information – Incident Energy Analysis Method (Default Method)
(*To Be Completed by Engineering Personnel if Unknown or Not Previously Analyzed)*

9.	Incident energy: ___ Working Distance: ___		*Include at least one and establish the arc flash boundary. Working distance must be provided with incident energy determination. Note method used:* • **\3** *Section 4-2 (Based on NFPA 70E 2021, Article 130.5) for interior electrical equipment or for exterior pad-mounted equipment.* **/3/** • *Section 4-2 and Table 4-7 (Based on the National Electrical Safety Code) for overhead distribution.*
	Level of PPE:		
	Minimum Arc-Rating of Clothing:		
	Arc Flash Boundary:		
Completed By:		**Signature:**		**Date:**	

Section E, Arc Flash Information – Arc Flash PPE Category Method
(*To Be Completed by Engineering Personnel if Unknown or Not Previously Analyzed)*
Use Tables 4-5 through 4-9 as applicable

10.	Determine the available fault current and clearing times for the task			
	Available Fault Current:		Overcurrent Device Clearing Time:	
	*Mark **"Y"** or "**N**" as appropriate*			
11.	Do the available fault current and clearing times for the task exceed the maximum allowed by Table 130.7(C)(15)(a) or 130.7(C)(15)(b)?		*If **Yes**, an incident energy analysis is required. Complete Section D.* *If **No**, proceed to Line 12*	
12.	Arc Flash Boundary:			
	Arc Flash PPE Category:		Working Distance:	
Completed By:		**Signature:**		**Date:**	

<table>
<tr><th colspan="6">Section F, Confirmation of Adequate Maintenance and Testing of Overcurrent Protective Devices Credited by the Incident Energy Analysis Method or Arc Flash PPE Category Method</th></tr>
<tr><td>13.</td><td colspan="3"></td><td colspan="2">List the overcurrent protective devices that have been credited by the arc flash analysis.</td></tr>
<tr><td>14.</td><td colspan="3"></td><td colspan="2">Confirm that the above overcurrent protective devices have received adequate maintenance and testing, including the calibration dates or explain why maintenance and testing are not required, such as for protection by upstream fuses.</td></tr>
<tr><td>Completed By:</td><td></td><td>Signature:</td><td></td><td>Date:</td><td></td></tr>
<tr><th colspan="6">Section G, Arc-Rated Clothing and Other PPE Information – All Methods</th></tr>
<tr><td>15.</td><td>Minimum arc rating in cal/cm^2 for protective clothing and other PPE</td><td colspan="2"></td><td colspan="2">Establish the required arc-rated clothing and other PPE</td></tr>
<tr><td colspan="4"></td><td colspan="2">In the block to the left, list the required arc-rated clothing and other PPE. Note which method used:
Incident Energy Analysis Method:
\3\ Section 4-2 (Based on NFPA 70E 2021, Article 130.5) /3/
Incident Energy Analysis Method for Overhead Distribution: Section 4-2 and Table 4-9 (Based on the National Electrical Safety Code)
PPE Category Method: \3\ Section 4-2.1 (Based on NFPA 70E 2021, Article 130.7(C)(15)) /3/</td></tr>
<tr><td>Completed By:</td><td></td><td>Signature:</td><td></td><td>Date:</td><td></td></tr>
</table>

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APPENDIX C SAMPLE SOP – VOLTAGE AND CURRENT DIAGNOSTIC MEASUREMENTS

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

1.0 **Purpose.**

This procedure defines the requirements for measuring voltage and current, monitoring the performance of electrical systems with data loggers, and confirming correct phase rotation. Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

This procedure can also be used as part of circuit lockout/tagout to confirm that a circuit has been deenergized.

2.0 **Applicability.**

This procedure applies to personnel that are designated as a qualified person with respect to working on or near electrical equipment rated at 50 volts or above.

3.0 **References.**

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 **Definitions.**

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

\3\ Balaclava (Sock Hood). An arc-rated head-protective fabric that protects the neck and head except for a small portion of the facial area.

Boundary, Arc Flash. The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2). ***/3/***

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Low-Voltage. Any voltage below 1,000 V.

Medium Voltage. Voltages above 1,000 and ranging to 72,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

\3\ Shock Hazard. A source of possible injury or damage to health associated with current through the body caused by contact or approach to exposed energized electrical conductors or circuit parts. **/3/**

Unqualified Person. A person who is not a qualified person.

\3\ Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on":

> **Diagnostic (testing)** is taking readings or measurements of electrical equipment, conductors, or circuit parts with approved test equipment that does not require making any physical change to the electrical equipment, conductors, or circuit parts.
>
> **Repair** is any physical alteration of electrical equipment, conductors, or circuit parts (such as making or tightening connections, removing or replacing components, etc.). **/3/**

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Document all training.

6.0 Required Approach Distances.

Table 1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding). Table 2 provides similar information for direct current systems.

Table 1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	**Arc Flash Boundary**	**Limited Approach Boundary**		**Restricted Approach Boundary (3) (4)**
	From Phase to Phase Voltage (5), (6)	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Includes Standard Inadvertent Movement Adder**
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 1:

1. *For single phase systems* **\2** *above 250 volts,* **/2/** *select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary.*
6. **\2** *Refer to NFPA 70E for AC voltages above 145 kV.* **/2/**

Table 2. Qualified Worker Minimum Approach Distances – DC Systems

Nominal System Voltage Range	Limited Approach Boundary	Restricted Approach Boundary
	Exposed Fixed Circuit Part	**Includes Reduced Inadvertent Movement Adder**
<50 V	Not specified	Not specified
50 V to 300 V	3 ft 6 in (1.0 m)	Avoid contact
>300 V to 1 kV	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)

Notes for Table 2:

1. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
2. *Only qualified workers wearing appropriate PPE are permitted to be within the limited approach boundary and the arc flash boundary. The arc flash boundary is determined by calculation.*
3. ***\2** Refer to NFPA 70E for DC voltages above 1 kV. **/2/***

7.0 **Personal Protective Equipment.**

Comply with UFC 3-560-01 for PPE requirements. Perform the following:

1. Review electrical task risk assessment for this SOP for the potential incident energy level.
2. Select PPE equipment to exceed calculated potential incident energy level.

Voltage-rated gloves with leather protectors (Table 3) are required for work inside the restricted approach boundary or when handling live-line tools. Select as follows:

Table 3 Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	1 (25)
0	Red	1,000	1 (25)
1	White	7,500	1 (25)
2	Yellow	17,000	2 (50)
3	Green	26,500	3 (75)
4	Orange	36,000	4 (100)

Notes for Table 3: Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.

8.0 **Low-Voltage Electrical Measurements – Voltage and Current.**

Take electrical measurements in accordance with the following procedure:

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members, if applicable.

2. Select voltage-rated gloves with leather protectors using Table 3. Inspect voltage-rated gloves and leather protectors before use.

3. Select and inspect the tools and devices to be used for the electrical measurements. Ensure that all are rated for the voltage to be tested.

4. Check the arc flash label installed at the location where electrical measurements will be taken. **\2** Before starting work, obtain and wear the correct arc-rated PPE rated at or above the incident energy or arc flash hazard category listed on the arc flash label, with a minimum rating of 8 cal/cm^2 or Category 2 respectively. ***/2/***

5. Open the cabinet or enclosure where electrical measurements will be taken. Ensure PPE is worn properly before exposing energized electrical circuits. Wear voltage-rated gloves with leather protectors before entering the restricted approach distance. Only voltage-rated gloves with leather protectors are allowed inside the restricted approach distance.

6. Test the meter with a known energized source. Confirm the meter is operational and displaying correctly.

7. Apply the voltage leads of the meter to the test point on the system or device being tested to check for voltage. Check voltage on all phases.

8. If testing for current, position the meter's ammeter sensor so that the wire(s) or conductor(s) to be tested pass through the sensor. Document the current reading and repeat for all phases.

9. If voltage testing was performed to verify a deenergized circuit as part of a lockout/tagout procedure, test the meter again with a known energized source.

10. When testing is complete, restore the equipment to normal and return all devices (test equipment, PPE, and voltage-rated gloves) to their protective containers. Confirm that all tools and test equipment that were used are accounted for. If covers were removed as part of gaining access to the equipment, confirm that the covers are fully secured with no missing screws.

9.0 **Medium-Voltage Electrical Measurements – Voltage and Current.**

This procedure applies to all systems with a voltage above 600 volts. Take electrical measurements in accordance with the following procedure:

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members, if applicable.

2. Select voltage-rated gloves with leather protectors using Table 3. Inspect voltage-rated gloves and leather protectors before use.

3. Select and inspect the tools and devices to be used for the electrical measurements. Ensure that all are rated for the voltage to be tested. Confirm that live-line tools (hot sticks) have been wet tested within the last 2 years. Inspect tools before use.

4. Check the arc flash label installed at the location where electrical measurements will be taken. **\2** Before starting work, obtain and wear the correct arc-rated PPE rated at or above the incident energy or arc flash hazard category listed on the arc flash label, with a minimum rating of 8 cal/cm^2 or Category 2 respectively. ***/2/***

5. Open the cabinet or enclosure where electrical measurements will be taken. Ensure PPE is worn properly before exposing energized electrical circuits. Wear voltage-rated gloves with leather protectors before entering the restricted approach distance. Only the voltage-rated gloves with leather protectors are allowed inside the restricted approach distance.

6. Test the meter with a known energized source or test medium. Confirm the meter is operational and displaying correctly.

7. Apply the tip of the touch meter to the test point on the system or device being tested to check for voltage. Check voltage on all phases.

8. If testing for current, attach the clamp-on/inductive type ammeter to the insulated hot stick. Position or move the meter's ammeter sensor so that the wire(s) or conductor(s) to be tested pass through the sensor. Document the current reading and repeat for all phases.

9. If voltage testing was performed to verify a deenergized circuit as part of a lockout/tagout procedure, test the meter again with a known energized source.

10. When testing is complete, restore the equipment to normal and return all devices (test equipment, PPE, and voltage-rated gloves) to their protective containers. Confirm that all tools and test equipment that were used are accounted for. If covers were removed as part of gaining access to the equipment, confirm that the covers are fully secured with no missing screws.

10.0 **Low-Voltage Data Logging Electrical Measurements.**

Take electrical measurements using a data logger in accordance with the following procedure:

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members, if applicable.

2. Select voltage-rated gloves with leather protectors using Table 3. Inspect voltage-rated gloves and leather protectors before use.

3. Select and inspect the tools and devices to be used for the electrical measurements. Ensure that all are rated for the voltage to be tested. Inspect the current transformers (CTs)/clamp-on leads that will be used for testing; confirm the leads are in good condition and are fully insulated.

4. Check the arc flash label installed at the location where electrical measurements will be taken. **\2** Before starting work, obtain and wear the correct arc-rated PPE rated at or above the incident energy or arc flash hazard category listed on the arc flash label, with a minimum rating of 8 cal/cm^2 or Category 2 respectively. ***/2/***

5. Open the cabinet or enclosure where electrical measurements will be taken. Ensure PPE is worn properly before exposing energized electrical circuits. Wear voltage-rated gloves with leather protectors before entering the restricted approach distance. Only the voltage-rated gloves with leather protectors are allowed inside the restricted approach distance.

6. Determine where all leads will be attached.

7. Apply the voltage leads to the selected exposed energized phases.

8. Attach the CT clamp-on leads around the selected conductors.

9. After all leads are connected and confirmed to be in place, start the data logger to start monitoring.

10. While data logging is in progress, close and secure the cabinet or enclosure where the data logger leads are connected. If the cabinet or enclosure cannot be sealed because of its configuration, place warning signs around the equipment and secure the area to prevent unauthorized access.

11. When testing is complete, perform Steps 1 through 5 and reopen the cabinet or enclosure to allow access to the data logger and its leads. Stop the data logger and remove the voltage and CT clamp-on leads.

12. Close the cabinet or enclosure where measurements were taken.

13. When testing is complete, restore the equipment to normal and return all devices (test equipment, PPE, and voltage-rated gloves) to their protective containers. Confirm that all tools and test equipment that were used are accounted for. If covers were removed as part of gaining access to the equipment, confirm that the covers are fully secured with no missing screws.

11.0 **Low-Voltage Phase Rotation Checks.**

Take phase rotation measurements in accordance with the following procedure:

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members, if applicable.

2. Select voltage-rated gloves with leather protectors using Table 3. Inspect voltage-rated gloves and leather protectors before use.

3. Select and inspect the tools and devices to be used for the electrical measurements. Ensure that all are rated for the voltage to be tested.

4. Check the arc flash label installed at the location where electrical measurements will be taken. **\2** Before starting work, obtain and wear the correct arc-rated PPE rated at or above the incident energy or arc flash hazard category listed on the arc flash label, with a minimum rating of 8 cal/cm^2 or Category 2 respectively. ***/2/***

5. Open the cabinet or enclosure where electrical measurements will be taken. Ensure PPE is worn properly before exposing energized electrical circuits. Wear voltage-rated gloves with leather protectors before entering the restricted approach distance. Only the voltage-rated gloves with leather protectors are allowed inside the restricted approach distance.

6. Confirm presence of voltage in accordance with Paragraph 8 above.

7. If possible, deenergize the circuit or equipment before connecting the phase rotation meter leads. Attach the leads of the phase rotation meter to the exposed energized conductors.

8. Press the meter's actuating button, check for proper phase rotation, and release.

9. If possible, deenergize the circuit or equipment before disconnecting the phase rotation meter leads. Remove the leads.

10. When testing is complete, restore the equipment to normal and return all devices (test equipment, PPE, and voltage-rated gloves) to their protective containers. Confirm that all tools and test equipment that were used are accounted for. If covers were removed as part of gaining access to the equipment, confirm that the covers are fully secured with no missing screws.

12.0 **Medium-Voltage Phase Rotation Checks.**

This procedure applies to all systems with a voltage above 600 volts. Take phase rotation measurements in accordance with the following procedure:

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members, if applicable.

2. Select voltage-rated gloves with leather protectors using Table 3. Inspect voltage-rated gloves and leather protectors before use.

3. Select and inspect the tools and devices to be used for the electrical measurements. Ensure that all are rated for the voltage to be tested. Confirm that live-line tools (hot sticks) have been tested within the last 6 months. Inspect tools before use.

4. Check the arc flash label installed at the location where electrical measurements will be taken. **\2** Before starting work, obtain and wear the correct arc-rated PPE rated at or above the incident energy or arc flash hazard category listed on the arc flash label, with a minimum rating of 8 cal/cm^2 or Category 2 respectively. ***/2/***

5. Open the cabinet or enclosure where electrical measurements will be taken. Ensure PPE is worn properly before exposing energized electrical circuits. Wear voltage-rated gloves with leather protectors before entering the restricted approach distance. Only the voltage-rated gloves with leather protectors are allowed inside the restricted approach distance.

6. Confirm presence of voltage in accordance with Paragraph 9 above.

7. Use two personnel to hold the hot sticks for phase rotation checks. Perform dry run, with PPE, without touching the energized source. This step is performed to confirm that there is sufficient access for the task and that the two crewmembers can coordinate their movements.

8. Apply the touchmeters to the test points on the system being tested to check for proper phasing. Check all phases.

9. When testing is complete, restore the equipment to normal and return all devices (test equipment, PPE, and voltage-rated gloves) to their protective containers. Confirm that all tools and test equipment that were used are accounted for. If covers were removed as part of gaining access to the equipment, confirm that the covers are fully secured with no missing screws.

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APPENDIX D SAMPLE SOP – WORKING ON STATIONARY BATTERY SYSTEMS

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

1.0 **Purpose.**

This procedure defines the requirements for working on or near stationary battery systems and applies to the following activities:

- Battery or cell inspections.
- Battery or cell maintenance or testing.
- Battery or cell replacement.

Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

This procedure applies to stationary battery systems consisting of either nickel cadmium batteries, vented lead acid batteries, or valve-regulated lead acid (VRLA) batteries. It applies to batteries installed on battery racks or installed inside cabinets, including UPS systems.

Batteries and dc system components are different from ac electrical system equipment. Lead acid batteries contain a sulfuric acid electrolyte, which is harmful to skin and eyes, and the electrical shock hazards associated with dc power can be more severe than those associated with ac power for equivalent voltages and currents.

Batteries and cells are always energized and a fully charged stationary battery contains a tremendous amount of energy. A short circuit between the battery or cell terminals can produce explosive fault currents.

Only authorized personnel who have been familiarized and trained on battery fundamentals and maintenance procedures should be allowed to perform maintenance activities on a battery.

2.0 **Applicability.**

This procedure applies to personnel that are designated as a qualified person with respect to working on or near electrical equipment rated at 50 volts or above, including working on stationary battery systems.

3.0 **References.**

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*

- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*

- NFPA 70E, *Electrical Safety in the Workplace*

4.0 Definitions.

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

Battery. Two or more cells connected to form one unit for producing electric energy at the required voltage and current levels.

Battery Rack. A structure used to support a group of cells.

Boundary, Arc Flash. The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2).

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

Cell. An electrochemical device, composed of positive and negative plates, separator, and electrolyte, that is capable of storing electrical energy; when encased in a container and fitted with terminals, it is the basic component of a battery.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrolyte. The conducting medium in which the flow of electric current takes place by the migration of ions. For example, the electrolyte for a lead-acid cell is an aqueous solution of sulfuric acid.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Valve-Regulated Lead-Acid (VRLA) Cell. A lead-acid cell that is sealed with the exception of a valve that opens to the atmosphere when the internal gas pressure in the cell exceeds the atmospheric pressure by a pre-selected amount. VRLA cells provide a means of recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption.

Vent. A normally sealed mechanism which allows the controlled escape of gases from within a cell.

Vented Cell. A lead-acid cell in which the gaseous products of electrolysis and evaporation are allowed to escape to the atmosphere as they are generated. A vented cell is also referred to as a flooded cell.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on": Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Only authorized personnel who have been familiarized and trained on battery fundamentals and maintenance procedures should be allowed to perform maintenance or work activities on a battery.

Document all training.

6.0 Required Approach Distances.

Table 1 lists the minimum approach distances from exposed direct current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table 1. Qualified Worker Minimum Approach Distances – DC Systems

Nominal System Voltage Range	Limited Approach Boundary	Restricted Approach Boundary
	Exposed Fixed Circuit Part	Includes Reduced Inadvertent Movement Adder
<50 V	Not specified	Not specified
50 V to 300 V	3 ft 6 in (1.0 m)	Avoid contact
>300 V to 1 kV	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)

Notes for Table 1:

1. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
2. *Only qualified workers wearing appropriate PPE are permitted to be within the limited approach boundary and the arc flash boundary. The arc flash boundary is determined by calculation.*
3. ***\2** Refer to NFPA 70E for DC voltages above 1 kV. **/2/***

7.0 Personal Protective Equipment.

Comply with UFC 3-560-01 for PPE requirements. Wear Class 0 voltage rated gloves with leather protectors for DC voltages 600 volts and below. Select arc-rated PPE in accordance with the PPE category specified in Table 2.

T able 2. Arc Flash PPE Categories for Direct Current Systems

Equipment	PPE Category	Arc Flash Boundary
Storage batteries, dc switchboards, and other dc supply sources Parameters: 100 V ≤ Voltage < 250 V Maximum arc duration and working distance: 2 sec @ 18 in.		
Short-circuit current < 4 kA	2	3 ft
4 kA ≤ short-circuit current < 7 kA	2	4 ft
7 kA ≤ short-circuit current < 15 kA	3	6 ft
Storage batteries, dc switchboards, and other dc supply sources Parameters: 250 V < Voltage ≤ 600 V Maximum arc duration and working distance: 2 sec @ 18 in.		
Short-circuit current < 1.5 kA	2	3 ft
1.5 kA ≤ short-circuit current < 3 kA	2	4 ft
3 kA ≤ short-circuit current < 7 kA	3	6 ft
7 kA ≤ short-circuit current < 10 kA	4	8 ft

Note: Apparel that can be expected to be exposed to battery electrolyte must meet both of the following conditions:

1. *Be evaluated for electrolyte protection in accordance with ASTM F1296, Standard Guide for Evaluating Chemical Protective Clothing.*

2. *Be arc-rated in accordance with ASTM F1891, Standard Specification for Arc Rated and Flame Resistant Rainwear, or equivalent.*

Note: Obtain the available short circuit current for a particular battery from the manufacturer. If this information is not available, estimate the available short circuit current from the battery performance data sheet as 10 times the 1-minute ampere capability of the cell (at 77°F (25°C) to 1.75 V per cell) for lead-acid batteries.

8.0 Safety Precautions.

The following sections provide basic safety precautions for working around lead acid batteries and dc equipment.

8.1 Personal Safety General Precautions.

Batteries are inherently dangerous; they can generate lethal currents and contain acidic or caustic electrolyte. Take the following personnel safety measures should be take whenever working around batteries or other dc system equipment.

1. Lead acid batteries contain a sulfuric acid electrolyte that can cause burns and other serious injury. Avoid any skin contact with the electrolyte. In the event of skin contact with the electrolyte, flush immediately and thoroughly with water. If the electrolyte comes into contact with eyes, flush immediately with water and seek medical assistance. Be familiar with how to use emergency eyewash equipment, which should always be close at hand.

2. Neutralize sulfuric acid electrolyte spills on clothing or other material with a bicarbonate of soda (baking soda) solution (1 pound of bicarbonate of soda per gallon of water). Apply the solution to any spills until bubbling stops and rinse with clean water.

3. Whenever working with battery electrolyte, wear a rubber apron and rubber gloves. Ensure goggles and face shields are available.

4. Batteries can generate hydrogen gas. Never bring burning materials such as matches, cigarettes, or sparks of any kind near the battery. Avoid the use of spark-producing equipment near batteries. Residual gases can remain within cells during storage and shipment. Take these precautions at all times while handling batteries.

5. Use only insulated tools in the battery area to prevent accidental shorting across battery connections. Never lay tools or other metal objects on cells; shorting, explosion, or personal injury could result. As a general rule, the length of the exposed metal for any tool should be less than the distance between the positive and negative posts of each cell.

6. Remove all jewelry, wristwatches, or clothing with metal parts that could come into contact with the battery terminals.

7. Do not make or break series connections within an operating group of cells. Before proceeding, open the battery system circuit breaker to minimize the possibility of arcing.

8. Ensure that the exit from the battery area is unobstructed.

9. Do not overheat anticorrosion grease when preparing it for battery terminations. Some compounds have a flash point as low as 90°F. Follow the manufacturer's instructions carefully.

10. Minimize access to the battery by personnel unaware of battery safety precautions.

8.2 Equipment Safety General Precautions.

The previous section summarized safety precautions applicable to personnel. Improper handling or maintenance can also damage the battery. The following summarizes common considerations for the battery.

1. Install stationary batteries only on racks designed for the types of cells to be installed. Follow the manufacturer's guidance with regard to the design and material of the battery rack.

2. Do not lift any cell by its terminal posts. Use a lifting belt, spreader board, or other device approved by the manufacturer to move cells; internal cell damage can result if the cells are mishandled.

3. Do not adjust or tamper with seal nuts around cell posts, if installed.

4. Never use solvents or unapproved greases on cells or connections. Solvents can attack and even crack the plastic cell case. Unapproved greases can also attack plastic materials on the cell. Use only clean water and the proper neutralizing compound, as necessary, to clean the battery racks and containers.

5. Do not use a steel brush, brass brush, emery cloth, sandpaper, steel wool or metal file to clean cell posts and connectors; these tools can damage the lead plating.

6. Keep battery tops clean and neutralize any spilled electrolyte to minimize the possibility of electrical shock and short circuit, and to reduce rack corrosion.

7. Use two insulated wrenches when checking the connection torque to minimize stress on the connection hardware.

8. Unless required by the manufacturer for the particular battery design, do not remove flame arrestors. Use the filling funnel to add water or check the electrolyte.

9. Provide proper support for cables connected to cell terminals. Excessive strain from improper cable arrangements can damage cell terminal posts and seals.

10. Do not use cables as handles. This practice can stress the termination points and cause terminal post seal leakage.

9.0 Working on Stationary Battery Systems.

Perform work on or around a stationary battery in accordance with the following procedure:

1. Conduct pre-job brief; include unique precautions for working on battery and DC systems. Confirm communication is established with all crew members, if applicable.

2. Select required PPE in accordance with Table 2. Ensure all personnel are wearing required PPE.

3. Wear Class 0 voltage-rated gloves with leather protectors if working within the restricted approach boundary for battery systems rated for 300 volts or higher. Inspect voltage-rated gloves and leather protectors before use.

4. Select and inspect the tools and devices to be used for work. Ensure that all tools are insulated.

5. Perform work in accordance with the pre-job brief.

   Note: Depending on the work to be performed, a separate procedure might be required. This SOP addresses only the safety considerations for working on or near battery systems.

6. When work is complete, restore the equipment to normal and return all devices (tools, test equipment, PPE, and voltage-rated gloves) to their protective containers. Confirm that all tools and test equipment that were used are accounted for. If covers were removed as part of gaining access to the equipment, confirm that the covers are fully secured with no missing screws.

APPENDIX E SAMPLE SOP – INSERTING OR REMOVING (RACKING) CIRCUIT BREAKERS TO/FROM AN ENERGIZED BUS

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

1.0 **Purpose.**

The following is a sample SOP for racking circuit breakers in and out of switchgear. The following activities are covered by this SOP.

- Manually racking circuit breakers out of switchgear.
- Manually racking circuit breakers into switchgear.
- Racking circuit breakers out of and into switchgear using a remote racking mechanism.

The process of racking a drawout circuit breaker into and out of the connected position is one of the most frequent exercises that exposes an operator to risk. A malfunction during this operation has the potential for catastrophic consequences to equipment and personnel. Supervised, closed door circuit breaker racking is a fundamental recognized safety practice. Furthermore, older breakers are more complex and vulnerable to mechanical failures that create safety problems.

Manual racking refers to switchgear circuit breaker removal or insertion using a hand-operated racking device while standing in front of the circuit breaker. Given the potential risk, Category 4 (40 cal/cm^2) PPE and voltage-rated gloves with leather protectors are specified for this activity.

Remote racking refers to switchgear circuit breaker removal or insertion using a remote racking mechanism that allows the operator to stand up to 25 feet away from the circuit breaker; Figure 1 shows an example of one type of unit. Remote racking reduces the risk of circuit breaker racking and standard Category 2 (8 cal/cm^2) clothing is specified for this activity.

Figure 1. Remote Racking Mechanism

Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

2.0 Applicability.

This procedure applies to personnel that are designated as a qualified person with respect to working on or near electrical equipment rated at 50 volts or above.

3.0 References.

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 Definitions.

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

\3\ Boundary, Arc Flash. The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2). ***/3/***

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Inserting (Racking In) Circuit Breaker. The act of inserting a breaker into its cell, effectively placing it into a position to control or connect the electrical supply to the load connections mounted in the rear of the cell.

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Low-Voltage. Any voltage below 1,000 V.

Medium Voltage. Voltages above 1,000 and ranging to 72,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Test Position. Breaker position for testing the breaker operation during maintenance. When in the test position, the breaker is not connected to the line or load side stabs (bus).

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on": Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing, or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Personnel using this procedure must also be trained in circuit breaker racking, either manually or with a remote racking mechanism if available.

Document all training.

6.0 Required Approach Distances.

Table 1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Note: Racking operations are not performed with the qualified electrical worker next to exposed energized parts. The equipment to be racked out is dead-front design. However, because of the higher risk associated with racking operations, observe these approach distances and wear the PPE specified in Section 7.

Table 1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	**Arc Flash Boundary**	**Limited Approach Boundary**		**Restricted Approach Boundary (3) (4)**
	From Phase to Phase Voltage (5), (6)	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Includes Standard Inadvertent Movement Adder**
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 1:

1. *For single phase systems* ***\2*** *above 250 volts,* ***/2/*** *select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary.*
5. ***\2*** *Refer to NFPA 70E for AC voltages above 145 kV.* ***/2/***

7.0 **Personal Protective Equipment (PPE).**

Comply with UFC 3-560-01 for PPE requirements, as well as the additional requirements specified in the sections below.

7.1 **PPE for Manual Racking.**

Review electrical task risk assessment for this SOP for the potential incident energy level to confirm there are no locations with an incident energy rating above 40 cal/cm^2. Wear the following arc-rated clothing, minimum of 40 cal/cm^2, while performing manual racking operations:

Note: Some locations where racking will be performed will be rated for an incident energy of less than Category 4 (40 cal/cm^2) or lower. Category 4 clothing is specified for this activity because of the unique risk posed by this activity,

Note: The following PPE is required regardless of whether the circuit breaker compartment door is open or closed during racking.

- Arc-rated flash suit pants and jacket.
- Arc-rated flash suit hood.
- Leather electrical hazard rated (EH) work shoes/boots.
- Hearing protection.
- Voltage-rated gloves with leather protectors.

Select voltage-rated gloves with leather protectors (Table 2) based on the line-to-line voltage rating of the switchgear. Select as follows:

Table 2 Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	1 (25)
0	Red	1,000	1 (25)
1	White	7,500	1 (25)
2	Yellow	17,000	2 (50)
3	Green	26,500	3 (75)
4	Orange	36,000	4 (100)

Notes for Table: Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.

7.2 PPE for Remote Racking.

Remote racking operations will be performed with the qualified electrical worker located well outside the limited approach boundary and the arc flash boundary, which reduces the risk associated with this activity. Comply with UFC 3-560-01 for minimum arc flash clothing requirements.

8.0 Manual Racking.

8.1 Manual Racking – Breaker Removal (Rack Out) from an Energized Bus.

Perform the following steps:

1. Conduct pre-job brief and identify/confirm the circuit breaker(s) that will be operated and racked. Confirm communication is established with all crew members, if applicable.

2. Check the electrical task risk assessment for this SOP for the location where racking will occur. If the arc flash incident energy exceeds Category 4 (40 cal/cm^2) at the stated working distance, stop work. The switchgear must be deenergized and placed in an electrically safe work condition before racking is allowed.

3. Ensure personnel that will perform manual racking operations are wearing PPE required by Section 7.

4. Open the circuit breaker to be racked out, using a remote-control device if available.

5. Rack out the circuit breaker using the racking tool.

   Note: Count the number of revolutions required to fully rack out the circuit breaker. Use this number as a guide in the future when racking the circuit breaker back in.

6. If circuit breaker removal is part of a lockout/tagout procedure, complete the lockout/tagout. If desired for additional confirmation of lockout/tagout, pull the control power fuses for the circuit breaker.

8.2 Manual Racking – Breaker Insertion (Rack In) to an Energized Bus.

Perform the following steps:

1. Conduct pre-job brief and identify/confirm the circuit breaker(s) that will be operated and racked. Confirm communication is established with all crew members, if applicable.

2. Check the electrical task risk assessment for this SOP for the location where racking will occur. If the arc flash incident energy exceeds Category 4 (40 cal/cm^2) at the stated working distance, stop work. The switchgear must be deenergized and placed in an electrically safe work condition before racking is allowed.

3. Ensure personnel that will perform manual racking operations are wearing PPE required by Section 7.

4. Remove any lockout/tagout tags and locks, if applicable. If removed, replace the control power fuses for the circuit breaker.

5. Open the compartment and confirm that the circuit breaker is squarely aligned in the cell and is seated into the starting position. Visually confirm that the circuit breaker is open.

6. Rack the circuit breaker into the cell using the racking tool.

   Note: Count the number of revolutions required to fully rack in the circuit breaker. This should be the same number as was required to rack out the circuit breaker.

7. Visually confirm the circuit breaker is racked in.

8. If needed for system operations, close the circuit breaker, using a remote-control device if available.

9. Open the circuit breaker compartment door and visually confirm that the circuit breaker is closed.

9.0 **Remote Racking.**

9.1 **Remote Racking – Breaker Removal (Rack Out) from an Energized Bus.**

Perform the following steps:

1. Conduct pre-job brief and identify/confirm the circuit breaker(s) that will be operated and racked. Confirm communication is established with all crew members, if applicable.

2. Check the electrical task risk assessment for this SOP for the location where racking will occur. If the arc flash incident energy exceeds Category 4 (40 cal/cm^2) at the stated working distance, stop work. The switchgear must be deenergized and placed in an electrically safe work condition before racking is allowed.

3. Ensure personnel that will perform remote racking operations are wearing PPE required by Section 7.

4. Open the circuit breaker to be racked out, using the remote-control device.

5. Align the remote racking mechanism in front of the circuit breaker and connect to the circuit breaker racking rod.

6. Set up to operate the remote racking mechanism in accordance with the manufacturer's instructions.

7. Ensure all personnel in the area are a minimum of 20 feet away from the circuit breaker to be racked.

8. Rack out the circuit breaker using the remote racking mechanism.

9. If circuit breaker removal is part of a lockout/tagout procedure, complete the lockout/tagout.

9.2 **Remote Racking – Breaker Removal (Rack Out) from an Energized Bus.**

Perform the following steps:

1. Conduct pre-job brief and identify/confirm the circuit breaker(s) that will be operated and racked. Confirm communication is established with all crew members, if applicable.

2. Check the electrical task risk assessment for this SOP for the location where racking will occur. If the arc flash incident energy exceeds Category 4 (40 cal/cm2) at the stated working distance, stop work. The switchgear must be deenergized and placed in an electrically safe work condition before racking is allowed.

3. Ensure personnel that will perform racking operations are wearing PPE required by Section 7.

4. Remove any lockout/tagout tags and locks, if applicable. If removed, replace the control power fuses for the circuit breaker.

5. Open the compartment and confirm that the circuit breaker is squarely aligned in the cell and is seated into the starting position. Visually confirm that the circuit breaker is open.

6. Align the remote racking mechanism in front of the circuit breaker and connect to the circuit breaker racking rod.

7. Set up to operate the remote racking mechanism in accordance with the manufacturer's instructions.

8. Ensure all personnel in the area are a minimum of 20 feet away from the circuit breaker to be racked.

9. Rack the circuit breaker into the cell using the remote racking mechanism.

10. Visually confirm the circuit breaker is racked in.

11. If needed for system operations, close the circuit breaker, using a remote-control device if available.

12. Open the circuit breaker compartment door and visually confirm that the circuit breaker is closed.

APPENDIX F SAMPLE SOP – FUSED CUTOUTS: OPENING, CLOSING, OR REPLACING FUSES

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

The following is a sample SOP for operating overhead distribution fused cutouts or replacing fuse links inside cutouts. Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

1.0 **Purpose.**

This procedure defines the requirements for opening fused cutouts, closing fused cutouts, or replacing fuse links in fused cutouts on the overhead distribution system.

2.0 **Applicability.**

This procedure applies to personnel that are designated as a qualified person with respect to working on or near primary overhead distribution systems.

3.0 **References.**

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 **Definitions.**

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm^2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

\3\ Balaclava (Sock Hood). An arc-rated head-protective fabric that protects the neck and head except for a small portion of the facial area.

Boundary, Arc Flash. The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2). ***/3/***

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Fused Cutout. A pole mounted interrupting device, equipped with fuses, that provides a method for de-energizing and protecting downstream electrical equipment.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Low-Voltage. Any voltage below 1,000 V.

Medium Voltage. Voltages above 1,000 and ranging to 72,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on": Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method. For this SOP, this includes working inside an elevated bucket, handling of live-line tools, and pole-top rescue.

Document all training.

6.0 Required Approach Distances.

Table 1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table 1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	**Arc Flash Boundary**	**Limited Approach Boundary**		**Restricted Approach Boundary (3) (4)**
	From Phase to Phase Voltage (5), (6)	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Includes Standard Inadvertent Movement Adder**
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 1:

1. *For single phase systems* ***\2*** *above 250 volts,* ***/2 /****select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary.*
6. ***\2*** *Refer to NFPA 70E for AC voltages above 145 kV.* ***/2/***

7.0 **Personal Protective Equipment.**

Comply with UFC 3-560-01 for PPE requirements.

De-energizing equipment before opening equipment is the preferred work procedure. If mission prohibits de-energizing equipment:

1. Review electrical task risk assessment for this SOP for the potential incident energy level.

2. Select PPE equipment to exceed calculated potential incident energy level.

Voltage-rated gloves with leather protectors (Table 2) are required for work inside the restricted approach boundary or when handling live-line tools. Select as follows:

Table 2 Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	1 (25)
0	Red	1,000	1 (25)
1	White	7,500	1 (25)
2	Yellow	17,000	2 (50)
3	Green	26,500	3 (75)
4	Orange	36,000	4 (100)

Notes for Table: Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.

8.0 <u>Opening a Fused Cutout.</u>

Perform the following steps:

Note: If the overhead distribution circuit overcurrent protection includes reclosing ability, disable upstream reclosing before starting work. Enable reclosing after work is complete.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.

2. If possible, remove load from the fused cutouts by opening the secondary main breakers in all facilities supplied through the fused cutouts.

3. Select voltage-rated gloves with leather protectors using Table 2. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work inside the bucket.

4. Select and inspect the live-line insulated tool (hot stick) to be used for the work. Confirm that hot sticks have been wet tested within the last 2 years. Ensure that all tools are rated for the voltage to be worked on.

5. Position the insulated bucket truck in a position as far as possible from active traffic lanes. Place cones, barricades, and traffic markers as appropriate. Turn on all warning flashers and yellow beacons (day and night).

6. Enter and maneuver the bucket close enough to reach the fused cutouts with the insulated tool without having to reach or lean outside of the bucket.

7. Grasp the hot stick with both hands and insert the working end into the pull handle on the individual fused cutout. Pull it open in one smooth motion.

8. Open the remaining fused cutouts by the same process described above.

9. If changing the fuse(s), use the hot stick to lift and remove the fuse cartridge from the fused cutouts. To install the replacement fuse cartridge, pick up the fuse cartridge with the working end of the hot stick, position the fuse, and drop into place in the fused cutout.

10. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

9.0 **Closing a Fused Cutout.**

Perform the following steps:

Note: If the overhead distribution circuit overcurrent protection includes reclosing ability, disable upstream reclosing before starting work. Enable reclosing when work is complete.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.

2. If possible, remove load from the fused cutouts by opening the secondary main breakers in all facilities supplied through the fused cutouts.

3. Select voltage-rated gloves with leather protectors using Table 2. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work inside the bucket.

4. Select and inspect the live-line insulated tool (hot stick) to be used for the work. Confirm that hot sticks have been wet tested within the last 2 years. Ensure that all tools are rated for the voltage to be worked on.

5. Position the insulated bucket truck in a position as far as possible from active traffic lanes. Place cones, barricades, and traffic markers as appropriate. Turn on all warning flashers and yellow beacons (day and night).

6. Enter and maneuver the bucket close enough to reach the fused cutouts with the insulated tool without having to reach or lean outside of the bucket.

7. Grasp the hot stick with both hands and insert the working end into the pull handle on the individual fused cutout. Lift and push closed in one smooth motion.

8. Close the remaining fused cutouts by the same process described above.

9. If changing the fuse(s), use the hot stick to lift and remove the fuse cartridge from the fused cutouts. To install the replacement fuse cartridge, pick up the fuse cartridge with the working end of the hot stick, position the fuse, and drop into place in the fused cutout.

10. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

11. If load was removed from the fused cutouts by opening the secondary main breakers in facilities supplied through the fused cutouts, restore power to the facilities by closing the secondary main breakers.

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APPENDIX G SAMPLE SOP – CONNECTING/DISCONNECTING LOADBREAK ELBOWS

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

The following is a sample SOP for connecting or disconnecting load break elbows on an energized bus. Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

1.0 **<u>Purpose.</u>**

This procedure defines the requirements for or connecting or disconnecting load break elbows on an energized circuit.

2.0 **<u>Applicability.</u>**

This procedure applies to personnel that are designated as a qualified person with respect to working on or near primary underground distribution systems.

3.0 **<u>References.</u>**

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 **<u>Definitions.</u>**

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

\3\ Balaclava (Sock Hood). An arc-rated head-protective fabric that protects the neck and head except for a small portion of the facial area. **/3/**

Boundary, Arc Flash. The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2).

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Elbow. A connector component for connecting a power conductor to a bushing, designed so that when assembled with the bushing, the axes of the conductor and bushing are perpendicular.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Insulated Cap. An accessory device designed to electrically insulate, electrically shield, and mechanically seal a bushing insert or integral bushing.

Insulated Parking Bushing. An accessory device designed to electrically insulate, electrically shield, and mechanically seal a power cable terminated with an elbow and to be installed into a parking stand.

Live Line Tool. An insulated tool that electrically insulates the worker from the energized conductor and provides physical separation from the device being operated.

Loadbreak Connector. A connector designed to close, and interrupt rated load current or less on energized circuits under rated conditions.

Low-Voltage. Any voltage below 1,000 V.

Medium Voltage. Voltages above 600 and ranging to 72,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Separable Insulated Connector. A fully insulated and shielded system for terminating an insulated power conductor to electrical apparatus, other power conductors, or both, and designed such that the electrical connection can be readily made or broken by engaging the connector at the operating interface.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of “working on”: Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing, or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Document all training.

6.0 Required Approach Distances.

Table 1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table 1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	**Arc Flash Boundary**	**Limited Approach Boundary**		**Restricted Approach Boundary (3) (4)**
	From Phase to Phase Voltage (5), (6)	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Includes Standard Inadvertent Movement Adder**
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 1:

1. *For single phase systems* ***\2*** *above 250 volts,* ***/2/*** *select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary.*
6. ***\2*** *Refer to NFPA 70E for AC voltages above 145 kV.* ***/2/***

7.0 **Personal Protective Equipment.**

Comply with UFC 3-560-01 for PPE requirements.

De-energizing equipment before opening equipment is the preferred work procedure. If mission prohibits de-energizing equipment:

1. Review electrical task risk assessment for this SOP for the potential incident energy level.

2. Select PPE equipment to exceed calculated potential incident energy level.

Voltage-rated gloves with leather protectors (Table 2) are required for work inside the restricted approach boundary or when handling live-line tools. Select as follows:

Table 2 Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	1 (25)
0	Red	1,000	1 (25)
1	White	7,500	1 (25)
2	Yellow	17,000	2 (50)
3	Green	26,500	3 (75)
4	Orange	36,000	4 (100)

Notes for Table: Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.

8.0 **Precautions.**

Maneuver loadbreak connectors with a fully insulated “shot gun” live-line type tool; the live-line tool length is optional provided that the resulting working distance is less than or equal to that assumed in the electrical task risk assessment developed for this SOP. Ensure the working area is clear of obstructions or contaminants that might interfere with the operation of the connector or cause it to fall into the exposed bushing well. The operating position should allow establishing a firm footing and enable grasping the live-line tool securely, while maintaining positive control over the movement of the loadbreak connector before, during, and directly after the operating sequence. Because of the control, speed, and force required to engage or disengage an elbow, certain operating positions are more advantageous than others. If there are any concerns regarding an adequate position for handling a loadbreak connector, the operation must be practiced first on a de-energized circuit.

The following lists additional precautions and limitations for handling loadbreak connectors on an energized circuit:

- Limit work to dry weather conditions. Do not operate loadbreak connectors during wet conditions.
- Loadbreak connectors can be operated inside manholes only if the work can be accomplished with the qualified electrical worker standing outside the manhole at grade.
- Operation (connecting or disconnecting) loadbreak connectors inside a manhole with the qualified electrical worker standing inside the manhole is prohibited.
- Making a connection into a suspected fault is prohibited. De-energize the circuit prior to connection.
- If a fault occurs during connection or disconnection, replace the elbow connector and the bushing.
- Never connect an energized load break elbow into a transformer that has not been tested for proper operation.
- Never connect loadbreak elbow type surge arresters into an energized transformer or circuit.
- Never use a loadbreak connector to switch energized capacitors.
- Check the appropriate manufacturer's operating instructions to confirm the device(s) is rated for energized operation, either connecting or disconnecting.

9.0 Loadbreak Operation (Connecting) at Grade.

Perform the following steps:

Note: This operation might be performed as part of a switching order. If so, then coordinate the Activity with the rest of the switching order.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.
2. Select voltage-rated gloves with leather protectors using Table 2. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work.
3. Select and inspect the live-line insulated tool (hot stick) to be used for the work. Confirm that hot sticks have been wet tested within the last 2 years. Ensure that all tools are rated for the voltage to be worked on.
4. Ensure the area is clear of obstructions or contaminants that might interfere with the operation of the connector.

5. Open the equipment where the loadbreak connector operation will be performed.

6. Prepare the bushing for the elbow connector by removing the insulated cap. Attach the live-line tool to the insulated cap pulling eye and remove from the bushing.

7. Securely fasten a shot gun live-line tool to the load break connector pulling eye.

Note: This procedure assumes that the loadbreak connector is on an insulated parking bushing on the apparatus parking stand before work starts.

8. Without exerting any pulling force, slightly rotate the connector to break any surface friction prior to disconnection from the insulated parking bushing on the apparatus parking stand.

9. After establishing a firm footing and positive control of the elbow connector, withdraw the elbow from the insulated parking bushing on the apparatus parking stand with a fast, firm, and straight motion, while being careful to avoid the ground plane.

10. Place the elbow connector receptacle area over the bushing plug and insert the elbow male contact (arc flower portion) into the bushing until a slight resistance is felt. Immediately push the elbow into the locked position with a fast, firm, and straight motion. Apply sufficient force to engage the internal lock on the elbow connector and bushing interface.

11. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

10.0 **Loadbreak Operation (Disconnecting) at Grade.**

Perform the following steps:

Note: This operation might be performed as part of a switching order. If so, then coordinate the Activity with the rest of the switching order.

1. Conduct pre-job brief. Ensure all personnel are wearing required PPE. Confirm communication is established with all crew members.

2. Select voltage-rated gloves with leather protectors using Table 2. Inspect voltage-rated gloves and leather protectors before use. Wear voltage-rated gloves with leather protectors while performing all work.

3. Select and inspect the live-line insulated tool (hot stick) to be used for the work. Confirm that hot sticks have been wet tested within the last 2 years. Ensure that all tools are rated for the voltage to be worked on.

4. Ensure the area is clear of obstructions or contaminants that might interfere with the operation of the connector.

5. Open the equipment where the loadbreak connector operation will be performed.

6. Place the insulated parking bushing on the apparatus parking stand.

7. Firmly tighten a shot gun live-line tool to the loadbreak connector pulling eye.

8. Without exerting any pulling force, slightly rotate the connector to break any surface friction prior to disconnection.

9. After establishing a firm footing and positive control of the elbow connector, withdraw the elbow from the bushing with a fast, firm, and straight motion, while being careful to avoid the ground plane.

10. Place the connector on the insulated parking bushing and secure.

11. When work is complete, return all equipment (PPE, live-line tools, and voltage-rated gloves) to their protective containers. Confirm that all tools that were used are accounted for.

APPENDIX H SAMPLE SOP – ELECTRICAL MANHOLE/VAULT ENTRY

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

1.0 **Purpose.**

This procedure defines the requirements for work performed inside electrical manholes and vaults. Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

Arc flash calculation methodology does not address the unique configuration of an electrical manhole in which an arcing fault occurs inside a small, enclosed space that also contains the worker. Additional precautions are necessary.

An IEEE interpretation dated 14 January 2009, regarding IEEE C2 (National Electrical Safety Code) Rule 410A3, confirms that the phrase “on or near energized parts or equipment” applies to energized insulated conductors inside manholes. IEEE C2 Rule 443 does allow a qualified employee, working alone, to enter a manhole where energized cables or equipment are in service for the purpose of inspection, housekeeping, taking readings, or similar work if such work can be performed safely.

In some instances, it can be difficult to deenergize all circuits inside a manhole when accomplishing repair or installation activities because of the number of circuits inside the manhole. Accordingly, this SOP provides guidance regarding the type of work activities permitted inside manholes containing energized circuits.

2.0 **Applicability.**

This procedure applies to personnel that are designated as a qualified person with respect to working on or near electrical equipment rated at 50 volts or above.

3.0 **References.**

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 **Definitions.**

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

Arc Rating. The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (EBT) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or EBT, whichever is the lower value.

\3\ Boundary, Arc Flash. The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2). **/3/**

Boundary, Limited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Electrically Safe Work Condition. A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Incident Energy. The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Low-Voltage. Any voltage below 1,000 V.

Medium Voltage. Voltages above 1,000 and ranging to 72,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of "working on": Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing, or replacing components, etc.).

5.0 **<u>Training and Qualification Requirements.</u>**

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Document all training.

6.0 **<u>Required Approach Distances.</u>**

Table 1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table 1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	Arc Flash Boundary	Limited Approach Boundary		Restricted Approach Boundary (3) (4)
	From Phase to Phase Voltage (5), (6)	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 1:

1. *For single phase systems* ***\2*** *above 250 volts,* ***/2/*** *select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary.*
6. ***\2*** *Refer to NFPA 70E for AC voltages above 145 kV.* ***/2/***

7.0 **Personal Protective Equipment.**

Comply with UFC 3-560-01 for PPE requirements. Review the electrical task risk assessment for this SOP for the potential incident energy level.

Voltage-rated gloves with leather protectors if energized circuits can be or will be touched. Select as follows:

Table 2 Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Color Label	Maximum Use (AC Volts)	Minimum Distance[1] in Inches (Millimeters)
00	Beige	500	1 (25)
0	Red	1,000	1 (25)
1	White	7,500	1 (25)
2	Yellow	17,000	2 (50)
3	Green	26,500	3 (75)
4	Orange	36,000	4 (100)

Notes for Table: Wear leather protectors over rubber gloves. Minimum distance is the minimum length that the exposed rubber glove must extend beyond the leather protector.

7.0 <u>Electrical Manhole Entry.</u>

7.1 <u>Access for Inspection Only – No Known Problems.</u>

Note: Entry into a manhole containing energized circuits is not permitted for inspection activities if problems are suspected inside the manhole, such as conductor damage associated with a short circuit.

Note: A small amount of standing water is permitted for inspection activities.

The following activities are allowed:

1. Manhole and sump inspection.
2. Sump cleaning.
3. Inspection of conductors and splices, without touching or disturbing the conductors.
4. Inspection of any equipment installed in the manhole.
5. Installation of conduit plugs on spare conduits.

Perform the following steps:

1. Conduct pre-job brief. A minimum of two qualified persons are required for this activity. Confirm communication is established with all crew members, if applicable.

2. Follow all requirements for confined space entry.

3. Ensure qualified persons are wearing PPE required by Section 6.

4. Open the electrical manhole or vault. Before entering, visually confirm that the manhole can be entered, and the activity can be accomplished without disturbing energized conductors.

5. One qualified person is required to remain outside the electrical manhole or vault.

6. One or more qualified persons are allowed to enter and perform the allowed activities.

7.2 **Authorized Work Inside Manholes Containing Energized Circuits.**

Note: Entry into a manhole containing energized circuits is not permitted for inspection activities if problems are suspected inside the manhole, such as conductor damage associated with a short circuit.

Note: No standing water is permitted for work.

Note: Reracking energized conductors is not permitted. The circuits must be deenergized before the conductors can be disturbed.

The following activities are allowed:

1. Removing conduit plugs.

2. Spare conduit inspection using fish tape, boroscope, or other devices.

3. Splicing deenergized conductors. When splicing deenergized conductors, confirm that an 18-inch (0.5-meter) safe working distance from other energized conductors or equipment can be maintained during the work.

4. Pulling new conductors in spare conduits.

5. Removing abandoned (deenergized) circuits, including associated equipment, if nearby energized circuits are not disturbed.

Perform the following steps:

1. Conduct pre-job brief. A minimum of two qualified persons are required for this activity. Confirm communication is established with all crew members, if applicable.

2. Follow all requirements for confined space entry.

3. Ensure qualified persons are wearing PPE required by Section 6.

4. Open the electrical manhole or vault. Before entering, visually confirm that the manhole can be entered, and the planned work activity can be accomplished without disturbing energized conductors.

5. One qualified person is required to remain outside the electrical manhole or vault.

6. One or more qualified persons are allowed to enter and perform the allowed planned work activities.

7.3 **Other Work Inside Manholes Containing Energized Circuits.**

Other work not covered by Section 7.1 or Section 7.2 require a job-specific energized electrical work permit. Include the following in the energized electrical work permit:

1. Description of manhole and its configuration.

2. Description of planned work activities.

3. Electrical shock and arc flash risk assessment.

   Note: Electrical analysis software packages that perform arc flash calculations do not account for an electrical manhole configuration in which the electrical worker is inside an enclosed area rather than standing adjacent to an enclosure. Increase the arc flash PPE requirements by a minimum of one (1) arc flash hazard category above the arc flash calculation result.

4. Required PPE.

5. Minimum number of qualified electrical workers.

6. Means to restrict unqualified persons from the work area.

7. Rescue plan.

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APPENDIX I SAMPLE SOP – PROHIBITED ENERGIZED WORK ACTIVITIES

This appendix is optional and provides a typical SOP. Refer to Section 8-4 for requirements associated with SOPs.

This SOP is an example of how to prohibit certain electrical work activities if the system cannot be deenergized. Modify this SOP as appropriate for the installation, the allowed work practices, and personnel qualifications.

1.0 **Purpose.**

This procedure defines the requirements for the following activities:

- Replacing ballasts on lighting circuits.
- Replacing or installing low-voltage receptacles.
- Installing a molded case circuit breaker into a panelboard or switchboard.

The associated electrical systems must be deenergized before performing any of the above activities. The basis for this limitation includes:

Replacing lighting system ballasts, installing receptacles, or inserting molded case circuit breakers while energized do not meet the minimum safety criteria established by OSHA for working on energized electrical circuits. OSHA 29 CFR 1910.333 limits work on live energized electrical equipment as follows:

"Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is not feasible due to equipment design or operational limitations."

Performing the above listed tasks on energized electrical systems do not meet the OSHA criteria.

The procedures provided in this SOP for replacing lighting system ballasts, installing receptacles, or inserting molded case circuit breakers into a panelboard or switchboard are based on first deenergizing the circuit. If the area occupants do not allow the circuit(s) to be deenergized, then the procedures specify to stop work and notify your supervisor that the work will need to be rescheduled.

2.0 **Applicability.**

This procedure applies to personnel that are designated as a qualified person with respect to working on or near electrical equipment rated at 50 volts or above.

3.0 References.

- 29 CFR 1910, *Occupational Safety and Health, General Industry Standards*
- Unified Facilities Criteria (UFC) 3-560-01, *Operation and Maintenance: Electrical Safety*
- NFPA 70E, *Electrical Safety in the Workplace*

4.0 Definitions.

De-energized. Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Electrical Hazard. A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

Exposed (as applied to energized electrical conductors or circuit parts). Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Low-Voltage. Any voltage below 1,000 V.

Medium Voltage. Voltages above 1,000 and ranging to 72,500 V.

Qualified Person. One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Unqualified Person. A person who is not a qualified person.

Working On (energized electrical conductors or circuit parts). Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of “working on”: Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

5.0 Training and Qualification Requirements.

Personnel using this procedure must be trained and qualified in the following:

Emergency response training. Contact release. First aid, emergency response, and resuscitation.

Qualified Person Employee training. A qualified person must be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

Document all training.

6.0 Required Approach Distances.

Table 1 lists the minimum approach distances from exposed alternating current energized parts within which a qualified worker may not approach without the use of personal protective equipment appropriate for the potential electrical hazards or place any conductive object without an approved insulating handle, unless certain other work techniques are used (such as isolation, insulation, shielding, or guarding).

Table 1 Qualified Worker Minimum Approach Distances – AC Systems

Nominal System Voltage Range Phase to Phase (1)	Arc Flash Boundary	Limited Approach Boundary		Restricted Approach Boundary (3) (4)
	From Phase to Phase Voltage (5), (6)	Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder
50 V to 150 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	Avoid contact
>151 V to 750 V	(2)	10 ft 0 in (3.0 m)	3 ft 6 in (1.0 m)	1 ft 0 in (0.3 m)
>750 V to 15 kV	(2)	10 ft 0 in (3.0 m)	5 ft 0 in (1.5 m)	2 ft 2 in (0.7 m)
>15 kV to 36 kV	(2)	10 ft 0 in (3.0 m)	6 ft 0 in (1.8 m)	2 ft 9 in (0.8 m)
>36 kV to 46 kV	(2	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	2 ft 9 in (0.8 m)
>46 kV to 72.5 kV	(2)	10 ft 0 in (3.0 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>72.5 kV to 121 kV	(2)	10 ft 8 in (3.3 m)	8 ft 0 in (2.5 m)	3 ft 6 in (1.0 m)
>121 kV to 145 kV	(2)	11 ft 0 in (3.4 m)	10 ft 0 in (3.0 m)	3 ft 10 in (1.2 m)

Notes for Table 1:

1. *For single phase systems* ***\2*** *above 250 volts,* ***/2/*** *select the range that is equal to the system's maximum phase to ground voltage times 1.732.*
2. *The arc flash boundary is determined by an arc flash analysis.*
3. *The restricted approach boundary is defined as the distance between energized parts and grounded objects without insulation, isolation, or guards.*
4. *The restricted approach distance applied to hot sticks is the distance between a worker's hand and the working end of the stick.*
5. *Only qualified workers wearing appropriate PPE are permitted to be within the arc flash boundary.*
6. ***\2*** *Refer to NFPA 70E for AC voltages above 145 kV.* ***/2/***

7.0 **Personal Protective Equipment.**

Comply with UFC 3-560-01 for PPE requirements.

8.0 **Lighting Ballast Replacement**

Replace a ballast on a lighting circuit as follows:

1. Deenergize the associated lighting circuit before starting work.
2. If the area occupants do not allow lighting to be deenergized while replacing one or more lighting ballasts, stop work. Inform the area occupants that work will be rescheduled by your supervisor. Inform your supervisor that lighting ballasts were not replaced. The supervisor will work with the area occupants to establish a future date when the lighting system can be deenergized for a short period for ballast replacement.
3. After the lighting system has been deenergized, replace the lighting ballasts.
4. Comply with fall protection requirements while working.
5. After the ballasts have been replaced, restore power to the lighting circuit. Confirm lighting fixtures appear to be operating normally.

9.0 **Receptacle Installation.**

Install a low-voltage receptacle as follows:

1. Deenergize the associated electrical circuit before starting work.
2. If the area occupants do not allow the electrical circuit to be deenergized, stop work. Inform the area occupants that work will be rescheduled by your supervisor. Inform your supervisor that the scheduled work was not completed. The supervisor will

work with the area occupants to establish a future date when the electrical system can be deenergized for a short period for receptacle installation.

3. After the electrical system has been deenergized, install the receptacle(s) as specified.

4. After the receptacles have been installed, restore power. Confirm the circuit(s) appears to be operating normally.

10.0 **<u>Circuit Breaker Installation.</u>**

Install a molded-case circuit breaker into a panelboard or switchboard as follows:

1. Deenergize the associated panelboard or switchboard before starting work.

2. If the area occupants do not allow the electrical circuit to be deenergized, stop work. Inform the area occupants that work will be rescheduled by your supervisor. Inform your supervisor that the scheduled work was not completed. The supervisor will work with the area occupants to establish a future date when the electrical system can be deenergized for a short period for circuit breaker installation.

3. After the electrical system has been deenergized, install the circuit breakers as specified.

4. After the circuit breakers have been installed, restore power. Confirm the circuit appears to be operating normally.

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APPENDIX J LOCKOUT/TAGOUT GUIDANCE

This appendix is optional and provides typical lockout/tagout guidance that is applicable to electrical systems. Refer to Chapter 6 for requirements.

Occupational Safety and Health Organization programs address energy control (lockout and tagout) for a variety of potential hazards, including non-electrical hazards. NFPA 70E addresses energy control specifically targeted towards electrical systems and is recommended as a reference for lockout/tagout programs for electrical equipment. The following sections provide additional information associated with lockout/tagout for electrical systems.

J-1 SAFE CLEARANCE (SWITCHING ORDER) AND LOCKOUT/TAGOUT PROCEDURES

The basic safety rule governing safe clearance and lockout/tagout procedures is that all conductors and equipment are considered energized until:

- All sources of electrical energy (verified by checking applicable up-to-date drawings, diagrams, and identification tags) have been disconnected or otherwise prevented from energizing the equipment or circuits being worked on.
- A qualified person has operated the equipment operating controls or otherwise verified that the equipment cannot be restarted.
- And a qualified person used test equipment to test the circuit elements and electrical parts of equipment to which employees will be exposed and verified that the circuit elements and equipment parts are deenergized. The test also determines if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage backfeed even though specific parts of the circuit have been deenergized and presumed to be safe.

Even with safe clearance and lockout/tagout procedures applied, all lines (circuits) and apparatus must be tested for no voltage and grounded with approved grounding methods. This will reduce the voltage across the worker to the lowest practical value possible in case the line or equipment being worked on is accidentally energized. Table J-1 summarizes the sequence of events associated with lockout and tagout. If the lines (circuits) or equipment cannot be grounded, due to its design or other restrictions, it must be isolated. As part of safe working practices, the lockout/tagout process requires a circuit be deenergized, tested dead, isolated, tested dead, locked out, tagged, and grounded.

Table J-1 Lockout/Tagout Sequence

Steps to Place a Circuit in an Electrically Safe Work Condition	
1	Notify all affected workers of hazards, their control, and any possible stored energy.
2	Prior to shut down, check voltage to ensure test meters are working properly.
3	Shut down the system by isolation of energy sources. System is made inoperative.
4	Secure all energy source shutdown methods by lockout/tagout/tryout of controls. Tryout refers to verification of successful lockout/tagout.
5	Release any stored energy and verify such release.
6	Verify by testing that the system is deenergized (no voltage). Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily. The test also determines if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage backfeed.
7	Test meter on known source to ensure testing meters are working properly. Do not use a meter's "self-check" feature to verify the test meter is working properly in lieu of using a known source.
8	Provide temporary grounding.
Steps to Reenergize a Circuit	
1	Inspect the work area for an operationally intact system and remove nonessential items.
2	Notify all affected workers that system will be reenergized and warn them to stand clear.
3	Remove temporary grounding.
4	Remove lockout/tagout devices.
5	Visually determine that all affected workers are clear of the circuit.
6	Check voltage and phasing before re-energizing system.
7	Proceed with restoring service.

J-1.1 Development of Procedures.

Establish safe clearance and lockout/tagout procedures at each base or facility. Each service has documents controlling this process; refer to Section 6 for a list of documents.

J-1.2 Lockout.

If a device is listed on the Safe Clearance and is capable of being locked out, then apply a lock. Release any stored energy and verify such release. Use of only tagout and not lockout must be justified on the Safe Clearance. This might occur when the device is not physically configured to accept and cannot be adapted for a lockout device. In these cases, the Safe Clearance must include provisions for other means to provide a level of safety equivalent to that obtained by a lockout.

J-1.3 Tagouts.

Apply Danger (red) tags to prohibit changing the position of devices by unauthorized persons. All energy-isolating devices must be provided with a Danger tag, even those locked out. Use a Danger tagout for each Safe Clearance. Use Caution (yellow) tags in connection with a Safe Clearance to provide precautions necessary before operation of a switch or other device. Out-of-Order tags are not used as part of a Safe Clearance. If used, green tags indicate placement of a ground on a circuit or equipment. Tags and tag ties must be nonreleasable, with a minimum strength of no less than 50 lb (23 kg).

J-1.4 Preparation of the Safe Clearance Form (Switching Order).

The details and the person preparing the Safe Clearance must include:

- Details of blocking, switching, tags, and locks. A second worker who is at least classified as an electrical journeyman must check this information. This check must be done before beginning any switching. Enter details in their proper sequence, reading down the form. Include any switch operations (such as opening or shutting) necessary to transfer load or put other equipment into operation.

- Supplemental direction, if necessary, to be provided to the crew involved in the work to ensure their understanding of boundaries of coverage of the Safe Clearance.

J-1.5 Issue (Approval) of the Safe Clearance Form (Switching Order).

Only designated persons must be authorized to issue (approve) Safe Clearances for work by qualified personnel. These persons must be designated in writing in accordance with local procedures. The designated person in issuing (approving) a Safe Clearance must ensure that the following objectives have been met:

- Inclusion of the correct switching and equipment operations sequence.

- Provisions are included to discharge and ground capacitors and other sources of stored electrical energy that might endanger personnel.

- Provisions are included to discharge or block the release of stored non-electric energy (such as springs) in any device that could cause electric circuits to re-energize.

- Selection of a qualified worker who is authorized to receive the approved Safe Clearance and then perform the required switching and operations.

The qualified worker must have previously been approved in writing as one authorized to receive a Safe Clearance.

- Arrangements have been made for any necessary interruption of service, such as notifying users and notifying the utility company supplying power to the facility. Notifications to the utility company must be given to the person designated by the utility company to receive such information. In the event this individual cannot be reached, the nearest system operating or load dispatching office of the company must be informed.

J-1.6 Safe Clearance Form Description.

Detailed information follows section by section, for completing the Safe Clearance form.

J-1.6.1 Record Number.

A consecutive number must be assigned from records maintained in the appropriate (locally designated) office.

J-1.6.2 Other Clearance Numbers.

When feasible, only one safe clearance should be issued. If more than one safe clearance will be issued, or more than one crew assigned to the work, one authorized individual-in-charge must be responsible for all the crews and supervise the receipt of all safe clearances and the removal of lockouts and tagouts. Additionally, if more than one safe clearance is to be issued on the same line or equipment, show the serial numbers of the other clearances in the upper right-hand box.

J-1.6.3 Issued By, Time, and Date.

Provide the name and signature of the person issuing the Safe Clearance and time and date of issuance. This person is often the electrical supervisor.

J-1.6.4 Issued To.

Fill in the name of the person receiving the Safe Clearance. Safe Clearances must be issued only to workers authorized to receive them. A list of all such workers must be kept in the office that contains Safe Clearance records. The worker receiving a Safe Clearance is responsible for checking all lockouts and tagouts, especially being assured that all points of possible feed, including stored-energy devices, are open, locked out, and provided with correct tagouts.

J-1.6.5 Line/Equipment Involved.

Give a brief description of the lines or equipment on which work is to be performed. This information is prepared prior to issuance of the Safe Clearance.

J-1.6.6 Details of Blocking and Tagging.

Step-by-step instructions and supplemental information are provided relative to hanging tags and installing lockouts. This information is prepared prior to issuance of the Safe Clearance.

J-1.6.7 Time Applied.

Progressing downward in proper sequence of the form, fill in the actual time each step of the details is performed.

J-1.6.8 Released By, Time Released, and Date Released.

Provide the name and signature of the person releasing the Safe Clearance. This is usually the authorized individual-in-charge for the job. The person releasing a Safe Clearance is responsible for making sure that all workers and temporary grounds are clear and that the line or equipment is ready to return to service.

Note: Switching operations, and removal of lockouts and tagouts are not yet approved or accomplished at this point.

J-1.6.9 Accepted By.

Provide the name and signature of the person accepting the release of the Safe Clearance. This is often the same person that issued the Safe Clearance. If more than one Safe Clearance is issued for the same equipment or location, this person is also responsible for ensuring all Safe Clearances are released before any change is made in lockouts or tagouts. Once accepted, removal of lockouts and tagouts may be authorized, and switching operations may be performed to restore the line or equipment to service.

J-1.6.10 Time Removed.

Beginning with the last detail of switching, lockout, and tagout on the Safe Clearance, perform the reverse operation, progressing upward on the form, and enter the time each operation is performed. For instance, if a detail of switching, lockout, and tagout reads “Switch ‘A’ open and hang danger tag” the opposite operation is “remove danger tag and Switch ‘A’ shut.” Do not operate the equipment or perform any switching operation after removing your danger tag if it is still tagged with another danger tag.

Note: If lockouts and tagouts have been installed for more than one Safe Clearance on the same equipment or line, perform no switching operations until releases have been accepted for all Safe Clearances.

J-1.6.11 Notification.

Return the completed Safe Clearance form to the office that retains Safe Clearance records.

J-1.7 Lockout and Tagout Precautions.

J-1.7.1 Single Blade Stick-Operated Disconnect Switches.

A single blade, stick-operated disconnect switch cannot be mechanically blocked open and ordinarily is not capable of being locked out. In this case, a danger tag hung on each phase would normally be considered an acceptable provision for electrical safety. Suitable tag holders, made of insulating material and designed for installation with a hot stick, must be used on single blade stick-operated disconnect switches, fused cutouts, open jumpers, and similar visible line breaks.

J-1.7.2 Gang-Operated Switches.

Gang-operated switches are normally designed to be locked open and a single danger tag must be tied on the locked switch. Tag must be secured with minimum 50-pound pull-rated tie.

J-1.7.3 Overhead Lines.

On overhead lines, a visible line break must be provided at all points of possible feed. An opened circuit breaker is not normally acceptable in lieu of a visible line break on overhead systems and must be used only when it is not feasible to remove the line side leads from the circuit breaker bushings and it is not possible to provide a visible line break near the circuit breaker. If a circuit breaker is used for electrical isolation, the circuit breaker must be mechanically blocked or locked open, and a danger tag tied on the circuit breaker. Additionally, the authorized individual-in-charge must ensure workers are particularly careful in determining that the line is actually deenergized. Also, temporary grounds must be installed on overhead systems as close as possible to the worker. Tag must be secured with minimum 50-pound pull-rated tie.

J-1.7.4 Underground Lines.

On underground systems, it is often not feasible to provide a visible line break. For these systems, use of a circuit breaker or subway disconnect switch locked or blocked mechanically in the open position and provided with a danger tag is acceptable. The authorized individual-in-charge must ensure workers are particularly careful in determining that the line is actually deenergized. Also, temporary grounds must be installed on underground system as close as possible to the worker.

J-1.7.5 Fused Cutouts.

Fuse cutouts must be blocked or locked in the open position, the fuse block removed, and the clamp provided with a Danger tag.

J-1.7.6 Normally Open Switches.

A Caution tag must be hung on a normally open switch if it has been closed to tie two lines together prior to taking a line out of service. For example, a normally open switch might be closed to provide an alternate source for a line that is downstream of the intended work location. The position of the switch with the Caution tag must not be changed without prior approval of the authorized individual-in-charge. When all work is completed, this Caution tag will be removed as part of returning the system to its normal operating lineup. If the position of the switch with the Caution tag is to remain in the changed position (the normally open point in the system has moved to another location), the Safe Clearance must be updated with the new position and the date and time the change was made. Update system documentation to reflect the modified system configuration. Tag must be secured with minimum 50-pound pull-rated tie.

J-2 ENERGY CONTROL (LOCKOUT/TAGOUT).

J-2.1 Low-Voltage Levels.

Maintain the minimum approach distances given in Table 3-1 and wear appropriate personal protective equipment until the lines and equipment are positively proven to be in an electrically safe working condition. Safe Clearance procedures apply to low-voltage levels. Lines and equipment must be positively proven to be in an electrically safe work condition before work is begun. A locally approved voltage detector may be used for this test in conjunction with a direct contact voltmeter. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily. Determine by test if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage backfeed. A meter's "self-check" feature cannot be used to verify the test meter is working properly in lieu of using a known source. All energized conductors or equipment within reach of workers must be covered with insulating material or approved rubber protective equipment. Temporary grounding must be installed on lines and equipment to be worked on, unless the authorized individual-in-charge determines that temporary grounding is not practical. The authorized individual-in-charge must explain to the work crew the reasons for not installing temporary grounding. If it is not practical or possible to install temporary grounding then other methods of protection must be provided, such as, circuit breakers racked out to the disconnected position, removal of fuses from disconnect switches, disconnect conductors from terminals to isolate the circuit or equipment being worked on, or other methods. When pulling in new conductors near energized conductors, the new conductors must be provided with temporary grounds, and treated as if energized until the work is complete. Always treat bare wire communication conductors and neutrals on power poles as energized lines and use appropriate personal protective equipment.

J-2.2 High-Voltage Levels.

Maintain the minimum approach distances given in Table 3-1 and wear appropriate personal protective equipment until the lines and equipment are proven to be in an electrically safe work condition. Use a locally approved voltage detector for this purpose. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily. Determine by test if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage backfeed. A meter's "self-check" feature cannot be used to verify the test meter is working properly in lieu of using a known source. If an energized conductor is not available for the check, the detector may be checked on a spark plug of a running gasoline-powered engine. Commercially available spark testing devices can also be used. Include the following:

- Confirm that reactors and connected equipment are in an electrically safe work condition.

- Discharge surge arresters and stored energy devices in accordance with manufacturer's recommendations or local instructions.

After the lines or equipment have been proven to be in an electrically safe work condition, install a cluster mount ground on the pole the worker is working. When installing temporary grounds, make the earth connection first and then connect to the conductor or equipment. Use a hot stick when making the connection to the conductor due to the hazard of static discharge. When removing temporary grounds disconnect the earth connection last. Refer to Section 7 for additional grounding information.

APPENDIX K GLOSSARY

Abbreviations and Acronyms:

ac—Alternating Current

AED—Automatic External Defibrillator

AFCEC—Air Force Civil Engineer Center

AFI—Air Force Instruction

AHJ—Authority Having Jurisdiction

ANSI—American National Standards Institute

AR—Arc Rated

ASTM—American Society for Testing and Materials

AWG—American Wire Gauge

BIL—Basic Impulse Insulation Level

cal/cm^2—Calories per centimeter squared

CFR—Code of Federal Regulations

cm—Centimeter

CPR—Cardiopulmonary Resuscitation

CT—Current Transformer

dB—Decibel

dc—Direct Current

DoD—Department of Defense

EM—Electromagnetic

EMS—Emergency Medical Service

ER—Engineering Regulation

FRP—Fiberglass-Reinforced Plastic

ft—Feet or foot

HID—High Intensity Discharge

HQ—Headquarters

HVAC—Heating, Ventilating, and Cooling

Hz—Hertz

I—Amperes

IEEE—Institute of Electrical and Electronics Engineers

in—inch

ISEA – International Safety Equipment Association

J—Joules

J/cm^2—Joules per centimeter squared

JHA—Job Hazard Analysis

JSA—Job Safety Analysis

kg—Kilogram

kW—Kilowatts

kWh—Kilowatt Hours

kV—Kilovolts

kVA—Kilovolt-Amperes

L—Liter

lb—Pound

LEL—Lower Explosive Level

m—Meter

MDF—Main Distribution Frame

MI—Mineral Insulated

MIL HDBK—Military Handbook

mm—Millimeter

MOV—Metal Oxide Varistor

MTS—Maintenance Testing Specifications

NAVFAC—Naval Facilities

NEC—National Electrical Code

NEMA—National Electrical Manufacturers Association

NESC—National Electrical Safety Code

NETA—International Electrical Testing Association

NFPA—National Fire Protection Association

O&M—Operations and Maintenance

ORM— Operational Risk Analysis

OSHA—Occupational Safety and Health Administration

PCB—Polychlorinated Biphenyl

PPE—Personal Protective Equipment

PT—Potential Transformer

R—Resistance

RE—Remote

RMS—Root-Mean-Square

SDS—Safety Data Sheet

SF_6—Sulfur Hexafluoride

SOP—Standard Operating Procedure

SWD—Switching Duty

TM—Technical Manual

UFC—Unified Facilities Criteria

UPS—Uninterruptible Power Supply

US—United States

USACE—U.S. Army Corps of Engineers

V—Volt

VAC—Volts Alternating Current

VDC—Volts Direct Current

VRLA—Valve-Regulated Lead Acid

W—Watts

X—Reactance

X/R—Ratio of Reactance to Resistance

Terms:

Note: The terms listed here are provided for clarification of the design criteria provided in this UFC. Refer to IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, for additional electrical-related definitions.

Accessible, Readily (as applied to equipment)— Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to actions such as to use tools, to climb over or remove obstacles, or to resort to portable ladders, and so forth.

Ampacity—The current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

Approved—Acceptable to the authority having jurisdiction.

Arc Duration—The time span of an arc from initiation to extinction, usually specified as a number of cycles of current, typically 60 Hz or 50 Hz.

Arc Energy—The total energy discharged to a surrounding area by an electric arc.

Arc Rating—The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm^2 and is derived from the determined value of the arc thermal performance value or energy of breakopen threshold. Arc rated clothing or equipment indicates that it has been tested for exposure to an electric arc. Flame resistant clothing without an arc rating has not been tested for exposure to an electric arc. All arc rated clothing is also flame resistant.
Arc Thermal Protective Value—For protective clothing is the minimum incident thermal energy that causes the onset of a second-degree burn based on the energy transmitted through the clothing.

Authority Having Jurisdiction (AHJ)— An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Authorized Person—A person approved or assigned by a supervisor to perform a specific duty or duties or to be at a specific location or locations at the job site.

Available Short-Circuit Current—The maximum current that the power system can deliver through a given circuit point to any negligible impedance short circuit applied at the given point, or at any other point that will cause the highest current to flow through the given point.

Barehand Work—A technique of performing work on live parts, after the employee has been raised to the potential of the live part.

Barricade—A physical obstruction such as tape, cones, or structures intended to provide a warning about and to limit access to a hazardous area.

Barrier—A physical obstruction that is intended to prevent contact with equipment or energized electrical conductors, or to prevent unauthorized access to a work area.

Blocking—Placing a switch in the open or closed position and mechanically ensuring the position of the switch cannot be accidentally changed.

Bolted Fault—The highest magnitude short circuit current for a particular fault location. The impedance at the fault location is usually very low or zero for a bolted fault.

Bonding—A reliable connection to assure electrical conductivity. In terms of grounding, the permanent joining of metallic parts to form an electrically conductive path to assure electrical continuity with the capacity to conduct safely any current likely to be imposed.

Bonding Conductor—A conductor used specifically for the purpose of bonding.

Boundary, Arc Flash—The distance from an arc source (energized exposed equipment) at which the potential incident heat energy from an arcing fault on the surface of the skin is 1.2 cal/cm^2 (5 J/cm^2). Within this boundary, workers are required to wear protective clothing, such as arc rated shirts and pants and other PPE. This boundary was previously referred to as the Flash Protection Boundary by NFPA 70E.

Boundary, Limited Approach—An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.

Boundary, Restricted Approach—An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

Cardiopulmonary Resuscitation (CPR)—An emergency medical procedure which includes opening and maintaining an airway, providing ventilation through rescue breathing, and providing artificial circulation through the use of external cardiac compression.

Circuit Breakers Incorporating Ground Fault Protection—Circuit breakers that perform all normal circuit breaker functions and also trip when a current to ground exceeds some predetermined value.

Circumaural—ear protection type that covers the outer/external part of the ear.

Clearing Time—The total elapsed time between the beginning of an overcurrent and the final interruption of the circuit at rated voltage. For a fuse, the clearing time is considered the sum of the melting time and the arcing time. For a breaker, the clearing time is the elapsed time between the actuation of a release device and the instant of arc extinction on all poles of the primary arcing contacts.

Conductor—A material (usually a wire, cable, or bus bar) for carrying an electric current. *Note: This term is used only with reference to current carrying parts which are sometimes alive (energized)*.

Cycle—One cycle equals 1/60th of a second for 60 Hz current, or 1/50th of a second for 50 Hz current.

Dead Front—Without live parts exposed to a person on the operating side of the equipment.

Deenergized—Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Earth Ground—An electrical connection to earth obtained by a grounding electrode system.

Electrical Hazard—A dangerous condition such that contact, or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

Electrically Safe Work Condition—A state in which a conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Emergency Lighting System—A system capable of providing minimum required illumination specified in NFPA 101, *Life Safety Code*, Section 5.9. It includes the lighting units, related backup power source(s), and required connections.

Energized—Electrically connected to, or is, a source of voltage.

Energized Work—Work on or near (e.g., part of tools being used or worker's body less than restricted approach boundary) energized or potentially energized lines (i.e., grounding, live-tool work, hotstick work, gloving, and bare hand work).

Equipment—A general term, including fittings, devices, appliances, luminaires, apparatus, machinery, and the like, used as a part of, or in connection with, an electrical installation.

Equipment – Climbing—Includes body belts, safety and climber straps, climbers, and ladders.

Equipment – Electrical Inspecting and Testing—Electrical and mechanical devices such as voltmeters, ammeters, ohmmeters, phase meters, and similar devices.

Equipment – Mobile and Portable Large Equipment—Relatively large equipment items easily transported for maintenance, which must include line trucks, aerial lift trucks, motor-generator sets, pole hole diggers, and similar apparatus.

Equipment – Protective— Includes rubber gloves, matting, blankets, insulator hoods, and sleeves, in addition to barricades and warning devices.

Equipment Grounding Conductor—The conductor used to connect the non-current carrying parts of conduits, raceways, and equipment enclosures to the grounded conductor (neutral) and the grounding electrode at the service equipment (main panel) or secondary of a separately derived system, such as an isolation transformer.

Exposed (as applied to energized electrical conductors or circuit parts)—Circuit is in such as position that, in case of failure of supports or insulation, contact with another circuit may result. Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts that are not suitably guard, isolated, or insulated.

Gloving—A method of performing maintenance on energized electrical conductors rated above 600 volts and equipment whereby a worker or workers, wearing specially-made and tested insulating gloves, with or without sleeves, and using cover-up equipment while supported by the structure or insulated aerial lift equipment, work(s) directly on the energized electrical conductor or equipment.

Ground—A conducting connection, either intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of relatively large extent that serves in place of the earth.

Grounded (Grounding)—Connected (connecting) to ground or to a conductive body that extends the ground connection.

Grounded Neutral—A point of an electrical system that is intentionally connected to ground.

Grounded, Solidly— Connected to ground without inserting any resistor or impedance device.

Ground-Fault Circuit Interrupter—A device intended for the protection of personnel that functions to deenergize a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply input.

Heat Flux—The thermal intensity of an arc that is incident by the amount of energy transmitted per unit area and per unit of time, measured in calories per square centimeters per second ($cal/cm^2/sec$).

High Voltage—For the purposes of this UFC, high voltage is defined as above 1,000 volts. IEEE 100 defines a high voltage system with a rms voltage above 72,500 volts.

I^2t—Heating caused by current as a function of time.

Incident Energy— The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Job Hazard Analysis (JHA)—see Job Safety Analysis.

Job Safety Analysis (JSA)—A method for studying a job in order to identify hazards or potential hazards associated with each step or task involved. Additionally, it is used to develop controls or solutions to eliminate or mitigate those hazards identified. Also, referred to as a Job Hazard Analysis (JHA).

Listed—Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Live (Energized or exposed)— “Hot” electrically connected to a source of potential difference or electrically charged to have a potential significantly different from the earth in the vicinity. The terms “live” or “hot” are sometimes used in place of the term “current carrying” where the intent is clear to avoid repetition of the longer term.

Live Front—With live parts exposed to a person on the operating side of the equipment.

Live-Line Tool—A type of insulating tool used in various operations of energized work. This includes hot sticks.

Live Parts—Energized conductive components.

Low Voltage System—An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 V.

Mishap—An unplanned or unsought event or series of events that results in death, injury, or occupational illness or damage to or loss of equipment or property.

Medium Voltage System—An electrical system having a maximum rms ac voltage of 1,000 to 72,500 volts. For the purposes of this UFC, any voltage above 1,000 volts is referred to as “high voltage.”

Qualified Person—One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.

Risk Assessment—An overall process that identifies hazards, estimates the potential severity of injury or damage to health, estimates the likelihood of occurrence of injury or damage to health, and determines if protective measures are required.

Supervisor—Refers to the supervisor of “employees or workers” as used in this instruction. Generally, includes the supervisor responsible for exterior electrical systems, the zone supervisor or foreman, and the infrastructure support element supervisor. Titles are necessary to assign specific responsibilities to a specific individual.

Shock Hazard—A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

Switch, Isolating—A switch intended for isolating an electric circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means.

Tagging—Placing a safety tag directly on a circuit opening device or equipment for additional safety to ensure it is not used or its position altered.

Tags—Temporary signs (usually attached to a piece of equipment or part of a structure) to warn of existing or immediate danger.

Unqualified Person— Any person who is not a qualified person.

Voltage—The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the circuit concerned.

Working On (Energized Electrical Conductors or Circuit Parts)—Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing. There are two categories of “working on”: Diagnostic (testing) is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; repair is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

UFC 3-570-01
28 November 2016
Change 1, 14 January 2019

UNIFIED FACILITIES CRITERIA (UFC)

CATHODIC PROTECTION

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 3-570-01
28 November 2016
Change 1, 14 January 2019

UNIFIED FACILITIES CRITERIA (UFC)

CATHODIC PROTECTION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location
1	14 Jan 2019	Paragraphs 1-2, 1-4, 1-7, 2-2 and 2-3

This UFC supersedes UFC 3-570-02A, dated March 2005 and 3-570-02N dated January 2004.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 3-570-01, *Cathodic Protection*

Superseding: UFC 3-570-02A, *Cathodic Protection*, March 2005
UFC 3-570-02N, *Electrical Engineering Cathodic Protection*, Jan 2004

Description: This UFC provides general design guidance for cathodic protection (CP) systems. This UFC applies to all Army, Navy, and Air Force service elements and contractors.

Reasons for Document:

- Update the format of the manual (more of a policy and guidance manual instead of a technical cookbook on design) and unify UFC 3-570-02A and UFC 3-570-02N.

- Incorporate policy, guidelines, and procedures previously identified in Engineering Technical Letters and Interim Technical Guidance Documents.

- Provide additional guidance to the Project Design Engineer (PDE) in managing CP design contracts and guidance on commissioning of CP systems.

- Incorporate information regarding new technologies and update obsolete technical information.

Impact:

- Clarifies policy where CP must be provided. Provides more guidance to the PDE managing a CP Architect-Engineer (A-E) design contract to help improve designs. Previously, the manual only described technical requirements for the actual designers. Helps ensure CP provided where necessary and properly designed to ensure economical long-term facility/structure life cycle cost.

Unification Issues

- \1\Para 2-2 Structures for which CP is Mandatory. Navy has relaxed this for some structures and requires these structures to be evaluated for CP requirements.

- Para 2-3 Navy has relaxed the mandatory requirement that DoD CP systems reviewers be certified. /1/

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides policy and design requirements for cathodic protection (CP) systems. This document provides the minimum design requirements, and must be utilized in the development of plans, specifications, calculations, and Design/Build Request for Proposals (RFP).

UFC 3-501-01, *Electrical Engineering*, provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-570-01 for Cathodic Protection requirements. Refer to UFC 3-501-01 for design analysis, calculation, and drawing requirements.

1-2 APPLICABILITY.

Compliance with this UFC is mandatory for Department of Defense (DoD) facilities located on or outside of DoD installations, whether acquired by appropriated or non-appropriated funds, or third party finance and constructed.

\1\For Navy projects, third party financed and constructed projects are not required to meet this UFC's requirements except for provision and extension of Navy-owned or Government-owned systems and infrastructure that are extended to the third party's site. /1/

1-3 GENERAL BUILDING REQUIREMENTS.

UFC 1-200-01, *General Building Requirements*, provides applicability of model building codes and government-unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, sustainability, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

\1\For Navy projects, the reference date is set by the contract or RFP date. /1/

1-5 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

1-6 CYBERSECURITY.

All control systems (including systems separate from an energy management control system), remote monitoring units, and automated data collection units must be planned, designed, acquired, executed and maintained in accordance with UFC 4-010-06; and as required by individual Service Implementation Policy.

1-7 RECONCILIATION WITH OTHER UNIFIED FACILITIES CRITERIA.

The CP requirements and criteria in this document will be reconciled with CP requirements and criteria in other UFCs so that the required criteria are located in a single location; the other UFCs and criteria documents will refer to UFC 3-570-01. In the event there is a conflict between these criteria and other criteria in another document, these criteria govern. The documents listed in Table 1-1 are known to be affected by the requirements and criteria in this document.

Table 1-1. UFC Documents Requiring Reconciliation of CP System Requirements and Criteria

DOCUMENT	TITLE
UFC 3-230-01	Water Storage, Distribution and Transmission
UFC 3-460-01	Design: Petroleum Fuel Facilities
UFC 3-460-03	Operation and Maintenance: Maintenance of Petroleum Systems
UFC 3-570-06	Operation and Maintenance: Cathodic Protection Systems
UFC 4-150-07	Maintenance and Operation: Maintenance of Waterfront Facilities
UFC 4-151-10	General Criteria for Waterfront Construction
UFC 4-152-01	Design: Piers and Wharves

CHAPTER 2 CATHODIC PROTECTION SYSTEM PLANNING

2-1 INTRODUCTON.

In accordance with DoD Instruction 5000.67, *Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure*, consider corrosion prevention and control (CPC) as an integral part of the design, construction, sustainment, restoration and maintenance of all DoD infrastructure. Utilize CP systems to reduce corrosion of buried or submerged metallic structures, thus reducing the probability of failure and concomitant environmental, operational, safety, and economic repercussions. Petroleum, oil and lubricant (POL) systems, waterfront structures, and utility systems have been found to be the most critical facilities in terms of a combination of risk from corrosion, the need for continuous direct support of base operations, and the life cycle cost effectiveness of utilizing appropriate corrosion control systems.

CPC requirements development, pre-design surveys, system designs, and acceptance surveys must be accomplished under the supervision of one of the following individuals:

- NACE International certified Corrosion Specialist or Cathodic Protection Specialist with a minimum of five years of experience in the applicable CP system being designed.
- Where the qualification requirements are more restrictive or more stringent than any one of the above requirements, an appropriately certified person as required by applicable state/local laws, regulations, or requirements (primarily for underground storage tanks).

2-2 STRUCTURES FOR WHICH CP IS MANDATORY.

Regardless of soil or water corrosiveness, provide both CP systems and protective coatings for the following buried or submerged metallic structures:

- Petroleum, Oil, and Lubricants (POL) pipelines
- Underground POL/gas storage tanks, piping, and ancillary items
- Underground hazardous substance storage tanks
- Natural Gas and Propane Pipelines, including metallic components of non-metallic lines
- Fire protection water storage tanks
- Interior of all steel water distribution storage tanks, including the interior of elevated tank risers
- Oxygen Pipelines
- Other facilities with hazardous products as identified by the major commands, major claimants, or other competent authorities

\1\For Army and Air Force projects, CP for the following structures and systems is mandatory. For Navy projects, the following structures and systems are not considered mandatory by this UFC, but may be mandatory by specific system UFC or other documents. Evaluate these structures for CP by the paragraph titled Other Structures for Which Cathodic Protection must be Evaluated:

- Oil/water separators and all associated metallic fittings in contact with soil
- New Waterfront Structures
- Piping or water lines used with fire protection water storage tanks, including metallic components of non-metallic lines (i.e., PIV's, fire hydrants, change of direction devices, valves, metallic sections under building slabs and elsewhere, etc.)
- Metallic water distribution pipelines (including steel, ductile and cast iron pressurized piping) buried under concrete slabs (building foundations, runways, taxiways, parking aprons, wharf decks, and similar)
- Metallic components of force mains
- Sewage lift stations (all metallic components in contact with soil or liquids)
- Underground heat distribution and chilled water piping in metallic conduit/1/

2-2.1 POL Facilities and Structures.

Provide CP systems along with other corrosion control measures such as protective coatings and materials selection for all POL liquid fuel pipelines and storage facilities following the provisions of Code of Federal Regulations (CFR) Title 49 Chapter 1, Part 195, Transportation of Liquids by Pipeline, and CFR Title 40 Chapter 1, Part 112, Oil Pollution Prevention. Overseas installations must comply with the requirements of the Host Nation standards, DoD Overseas Environmental Baseline Guidance Document (OEBGD), and related specific Area Governing Standards. Coordinate CP system design with other POL related requirements in UFC 3-460-01.

2-2.2 Underground Storage Tank System.

Provide CP systems along with other corrosion control measures such as protective coatings and materials selection for all steel underground storage tank (UST) systems in accordance with CFR Title 40 Part 280, Technical Standards and Corrective Action for Owners and Operators of Underground Storage Tanks. By definition, the underground storage tank system includes the storage tank and associated piping. In addition, comply with State and Local government laws that may dictate additional or more stringent requirements. Overseas installations must comply with the requirements of the Host Nation standards, DoD OEBGD, and related specific Area Governing Standards. Ensure that UST CP systems are designed by a certified CP Specialist.

2-2.3 Natural Gas Pipe Lines.

Provide CP systems along with other corrosion control measures such as protective coatings and materials selection for all metallic natural gas pipelines in accordance with the provisions of CFR Title 49 Chapter 1, Part 192, Transportation of Natural and Other Gas by Pipeline.

2-2.4 Waterfront Structures.

Provide CP systems in conjunction with other protective measures such as proper material selection, protective coatings, and encasement, for the following submerged metallic waterfront structural systems:

- Steel sheet pile bulkheads along the waterfront or waterway
- Steel bearing piles for piers and wharves
- Steel fender piles for piers and wharves
- Submerged mooring components

Specify the proper type and size of galvanic or impressed current anodes to meet the desired CP system life. Do not specify magnesium anodes as the primary CP system for structures immersed in salt water.

2-2.5 Buried or Submerged Steel Utility Piping.

For all other steel utility piping, provide CP systems and bonded protective coatings on buried or submerged steel utility piping in which the electrolyte (soil or water) resistivity is less than 30,000 ohm-cm at the installation depth at any point along the piping installation.

2-2.6 Ductile or Cast Iron Utility Piping.

For all other ductile or cast iron utility piping and fittings, provide CP systems and protective coatings on buried or submerged new ductile or cast iron pipe in which the electrolyte resistivity is less than 30,000 ohm-cm at the installation depth at any point along the piping installation. Do not use unbonded protective coatings such as loose polyethylene wraps. Additionally, provide joint bonding for all ductile and cast iron installations. For non-metallic pipe with ductile or cast iron fittings, provide CP systems and protective coatings on buried or submerged new ductile or cast iron fittings in which the electrolyte resistivity is less than 30,000 ohm-cm.

\1\For Navy projects, the use of unbonded protective coatings, such as loose polyethylene wraps, is not prohibited. /1/

2-2.7 Potable Water Storage Tanks.

Provide CP and protective coatings for the interior submerged surfaces of potable water storage tanks, including bolted panel tanks in accordance with National Sanitation Foundation (NSF) Standard 61. Include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with an impressed current CP (ICCP) system, if specified, and NSF Standard 61. For bolted panel storage tanks, require the contractor to ensure all panels of a bolted panel storage tank are electrically continuous.

2-2.8 Fire Protection Water Storage Tanks.

Fire protection water storage tanks are mission critical facilities and must be properly protected against corrosion. Provide an ICCP system for the interior submerged surfaces of all fire protection water storage tanks, including bolted panel tanks. When the backfill beneath an on-grade tank is corrosive, provide an ICCP system for the exterior bottom of the on-grade tank. Include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with the ICCP system. For bolted panel storage tanks, require the contractor to ensure all panels of a bolted panel storage tank are electrically continuous.

\1\For Navy projects, allow ICCP or sacrificial anode (GCP) systems for fire protection water storage tanks. /1/

2-3 OTHER STRUCTURES FOR WHICH CATHODIC PROTECTION MUST BE EVALUATED.

Evaluate the economic feasibility of providing CP systems for the following buried or submerged systems:

- Gravity sewer lines
- Existing steel waterfront structures
- Reinforcing steel in concrete
- New or existing cast or ductile iron potable water lines (unless installed under a concrete slab) in soils with resistivity greater than 30,000 ohm-cm along its entire length
- Exterior bottom of on-grade steel water storage tanks
- Buried hydraulic elevator cylinders
- Other buried/submerged metallic structures not covered above

Installation of CP systems on these types of structures must be based on life-cycle economics. The overall corrosion protection system must include a combination of CP systems, protective coatings, proper material selection, encasement, or other methods. CP system requirements determined by non-DoD personnel (e.g., A/E's, private contractors, private consultants, etc.) must first be reviewed by a DoD qualified Corrosion Engineer or DoD NACE International certified cathodic protection specialist who subsequently recommends government approval prior to implementation.

\1\For Navy projects, delete the requirement that all CP system requirements be reviewed by a DoD Qualified Corrosion Engineer or DoD NACE International certified cathodic protection specialist. When available, DoD qualified CP personnel must be used for review. /1/

2-4 PROTECTIVE COATINGS SPECIFICIED IN CONJUNCTION WITH CATHODIC PROTECTION.

Protective coatings to be applied to a new metallic structure in conjunction with CP must have the minimum characteristics as described in NACE International SP0169 and the appropriate UFGS. Coordinate the coating type and requirements with the CP system being specified. Utilize the appropriate protective coating UFGS and supplement the UFGS requirements, as necessary, with the minimum coating characteristics indicated in NACE International SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*. Do not delete the CP requirements simply because it is not compatible with a particular coating.

2-5 ISOLATION OF COPPER WATER PIPES FROM FERROUS PIPES.

Dielectrically isolate copper water service lines from ferrous pipe in accordance with the requirements in NACE International SP0286, *Electrical Isolation of Cathodically Protected Pipelines*, unless not economically practicable. Where not practicable, design the CP system to include protection of both the copper and ferrous piping.

2-6 CP PROJECT PLANNING.

2-6.1 General CP Requirements.

Include CP system requirements as a separate line item in project documentation for the construction of new or the repair/upgrade of existing metallic structures as required by paragraphs 2-1 and 2-2. Cathodic protection systems are often not included in a project design because they are not appropriately identified in the project planning documents. Addition of these requirements later in the process often results in funding problems and other delays. Coordinate CP system requirements with the appropriate service CP subject matter expert or Major Command Corrosion Engineer. Refer also to the best practices in Appendix B.

2-6.2 Environmental/Site Concerns.

Identify environmental and site concerns. Prepare proper environmental Categorical Exclusions (CATEX), or if necessary, Environmental Impact Assessments (EIA) documentation prior to project execution. Refer also to paragraph 3-3.5.

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CHAPTER 3 DESIGN REQUIREMENTS

3-1 INTRODUCTION.

This chapter identifies CP system technical design requirements and defines the data that must be developed to establish engineering design bases and to evaluate the proper type of CP system(s) to be provided.

3-2 APPLICABLE CODES AND REGULATIONS.

In addition to the policy in Chapter 2, ensure that the CP system design complies with the legal requirements in any of the applicable codes, regulations, and other documents:

- CFR Title 40 Chapter 1, Part 112, *Oil Pollution Prevention*
- CFR Title 40 Part 280, *Technical Standards and Corrective Action for Owners and Operators of Underground Storage Tanks*
- CFR Title 49, Chapter 1, Part 192, *Transportation of Natural and Other Gas by Pipeline*
- CFR Title 49, Chapter 1, Part 195, *Transportation of Liquids by Pipeline*
- Department of Defense, *Overseas Environmental Baseline Guidance Document* and the appropriate regional/country Final Governing Standards.
- State or locality laws and regulations with more stringent CP requirements than the Federal laws and regulations.

Design agents doing Air Force designs will also comply with the requirements in Air Force Instruction 32-1054, *Corrosion Control*.

3-3 SYSTEM DESIGN.

Design CP systems in accordance with the policy in Chapter 2, applicable codes and regulations in paragraph 3-2, and the requirements of this section. Refer also to the best practices and lessons learned in Appendix B.

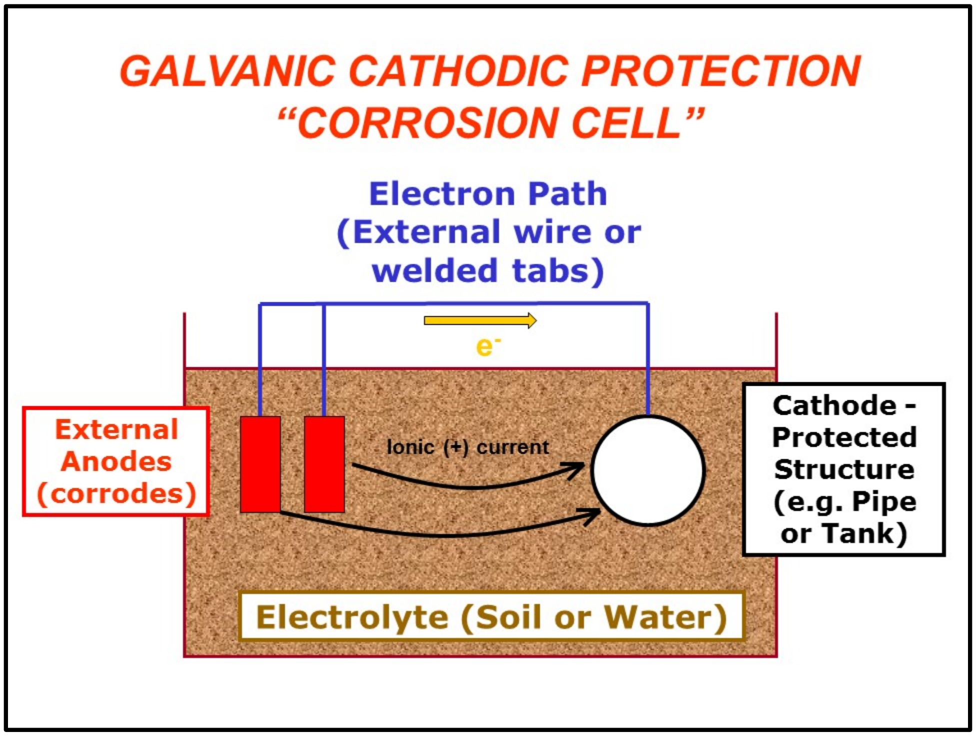
3-3.1 Two types of CP systems.

Select the CP system type, sacrificial anode (GCP) or ICCP, based on feasibility and cost. An economic analysis may be necessary to determine the system with the best life-cycle cost. In general, systems with small stable current requirements (0.5 Amp or less per 100 linear feet of structure) are more likely to be protected using sacrificial anode type systems. Those structures with larger current requirements (1 amp or more per 100 lineal feet of structure), or where the current requirements vary considerably with time, are more likely to require ICCP systems.

3-3.1.1 Galvanic (Sacrificial) Anode Systems.

A galvanic (sacrificial) anode CP system is essentially a controlled electrochemical cell. Figure 3-1 illustrates such a system. The structure becomes the cathode in the electrochemical cell, and corrosion that would have occurred on the structure being protected is mitigated due to the corrosion of the anode. The anode is consumed in the process but can usually be replaced when consumed. Anode life of 10 to 15 years is common, although lifetime can be limited by other factors such as mission requirements or mechanical damage.

Figure 3-1 Schematic Illustration of a GCP System

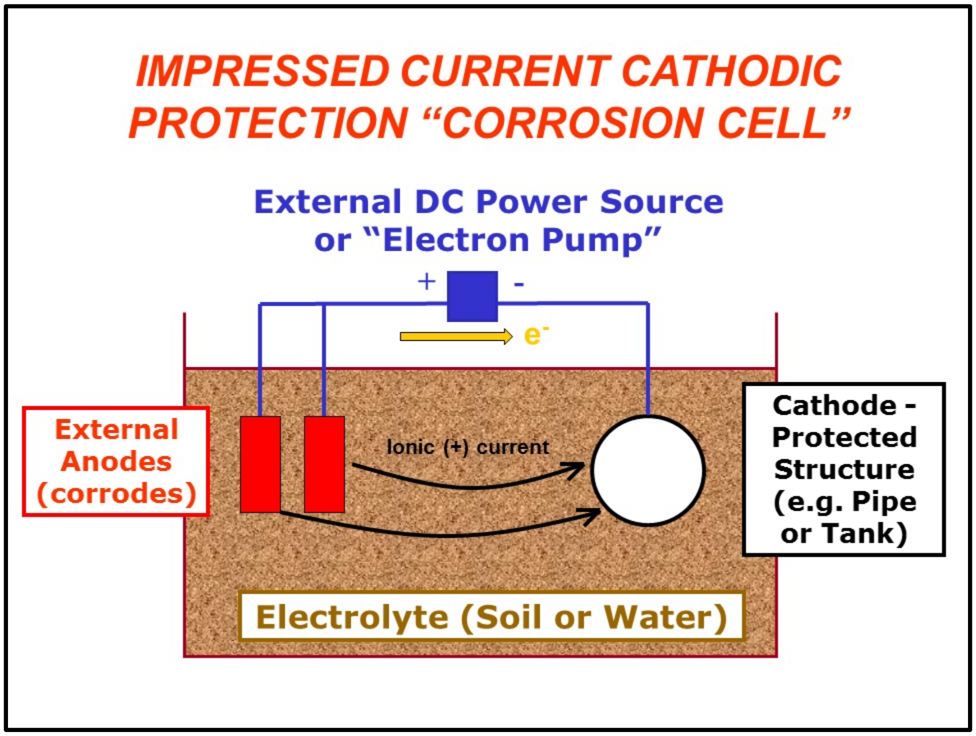


The structure and ancillary components intended for protection by sacrificial anodes must be electrically continuous. Conversely, other buried metals electrically continuous with the structure to be protected, but are not intended to be protected by the CP system, must be electrically isolated from the protected structure.

3-3.1.2 Impressed Current Systems.

Impressed current CP systems are also essentially controlled electrochemical cells. However, in the ICCP system, a supply of direct electrical current is used to develop the potential difference between the anode and the structure being protected as Figure 3-2 illustrates. The direct current source supplies current from the anode through the electrolyte to the surface of the structure being protected. Like sacrificial anodes, ICCP anodes are also consumed, although typically at a much lower consumption rate. Anode life of 20 to 25 years is common; although similar to GCP systems, lifetime can be limited by other factors such as mission requirements or mechanical damage.

Figure 3-2 Schematic Illustration of an ICCP System



As with GCP systems, the structure and ancillary components intended for protection by ICCP systems must be electrically continuous. Conversely, other buried metals electrically continuous with the structure to be protected, but are not intended to be protected by the CP system, must be electrically isolated from the protected structure.

3-3.2 Field Surveys and Tests.

Conduct a field survey to determine site conditions required to adequately design a CP system. Perform specific investigations and field tests at the proposed installation site(s) to evaluate as a minimum:

- Electrolyte corrosivity (resistivity, pH, etc.)
- CP system current requirements
- Suitable anode bed locations, including geological concerns
- Available electrical power
- Location of rectifiers
- Overall terrain around the structure (location of test stations)
- Easement issues for structures located off station
- Possible environmental concerns
- Constructability issues (physical and operational)

- Location of existing nearby CP systems and potential stray current concerns. Review of a published Base Corrosion Control Plan.
- Security restrictions that may impact cost
- Communication with local Corrosion Coordinating Committees for structures located off station

3-3.3 Availability of AC Power (ICCP Systems).

During the site survey, determine the availability of alternating current (AC) power at the site as the cost of installing new AC power service may be an important factor in determining whether a sacrificial or ICCP system is the more practical solution for the specific application. Where practicable, locate the ICCP rectifier nearby a building with available AC power and comply with applicable fire safety codes.

Design required electrical service in accordance with UFC 3-501-01. The electrical service design must be accomplished under the supervision of a registered professional electrical engineer.

3-3.4 Environmental/Site Concerns.

Consider the numerous environmental and safety concerns that may significantly impact the selection of CP system type, materials specified, system component installation procedures and controls, design document preparation, and the overall cost of the project. Consult with environmental and safety personnel during the early stages of design to identify the concerns and allow ample time for the designer to address these concerns. The following are some examples:

3-3.4.1 Hazardous Material.

Identify existing hazardous material at the proposed project site. These should be identified in the required environmental documents.

3-3.4.2 Archaeological/Historic Preservation Requirements.

Identify archaeological/historic preservation requirements and limitations at the proposed project site. This should also be identified in the required environmental documents.

3-3.4.3 Federal, State and Local Regulations.

Review and comply with Federal, state and local regulations that may affect the CP system installation. Some states have specific regulations regarding the design and installation of CP systems for underground storage tanks.

3-3.4.4 Mercury-Containing Anodes.

Avoid specifying mercury-containing aluminum alloy anodes. Consult with local/state regulators regarding concerns about the use of zinc anodes in certain situations.

3-3.4.5 Water Storage Tanks.

Specify anodes and other related components in water storage tanks that comply with National Sanitation Foundation/American National Standards Institute (NSF/ANSI) Standard 61.

3-3.4.6 Issues That May Impact Construction/Installation.

Address issues that may impact the construction/installation process, particularly, the drilling or excavation for installation of the anodes:

- Address requirements and specify procedures and controls when hazardous material is encountered.
- Address requirements and specify procedures and controls when drilling into the ground water table. Specify controls for preventing cross contamination of ground water aquifers.
- Specify construction site controls to prevent pollution of the environment.
- Specify safety requirements applicable to the site and specific installation.

Review the appropriate UFGS sections for environmental and safety requirements to ensure the applicable concerns are addressed. Provide design documents to the base/DoD installation environmental and safety personnel for review to ensure the requirements are properly addressed.

3-3.5 Electrical Continuity.

Determine locations and provide bonding to ensure electrical continuity of all buried metallic structures that are intended to be protected by the CP system. All electrically discontinuous section(s) of the structure(s) to be protected must be properly bonded into the system to ensure adequate protection. Common causes of electrical discontinuities include:

- Dresser couplings.
- Mechanical pipe section connections such as found in ductile iron pipe.
- Plastic valves and fittings.
- Non-metallic sections of pipeline (new, existing or future installation).
- Improper bonding (or lack of bonding) on joints, flanges or previously installed dielectric isolation unions or flanges.

If electrical discontinuities cause the pipeline system to be too fragmented, and continuity bonding is not feasible, consider providing multiple smaller separate CP systems for the electrically discontinuous sections of structure. Some isolated sections of pipelines may be small enough to use a GCP system, but the designer must consider possible interference problems on these sections.

3-3.5.1 Tracer Wires on Plastic Pipe.

When plastic pipe is used to replace or extend existing pipe, exothermically weld an insulated No. 8 American Wire Gage (AWG) copper wire to the existing steel pipe and run the wire along the full length of the plastic pipe for continuity and locator tracing purposes. As this may not always be technically feasible; alternatively, install tracer wires/tapes/devices directly above the plastic pipe at a depth that will be detectible by current detection equipment and technologies.

3-3.6 Identification of Other Structures in the Area.

Locate existing or planned Tburied or submerged structures. Determine if the other structures will impact or be impacted by the planned CP system. Identify the location of such structures in the design documents for interference testing during commissioning. Locate new CP anode beds to minimize the possibility of interference, while providing the best current distribution possible. Although resistivity is an important factor in anode bed location, the location of other structures in the area is just as important.

3-3.6.1 Pipeline Crossings.

For a new pipeline installation, require/specify a minimum clearance of twelve inches between all pipelines lines at crossings. If practicable, specify 24 inches of clearance. Indicate that direct contact between crossing or adjacent pipelines must be avoided. Also where practicable, specify installation of insulating mats between pipelines at crossings if substantial earth currents are detected in the area or if a newly coated line is crossing a poorly coated or uncoated line.

3-3.6.2 Cathodic Protection Interference.

Stray currents, also called interference, result from external electromotive forces and can greatly accelerate corrosion. Stray current corrosion can be caused by voltage gradients (current flow) resulting from DC transit systems, HVDC Transmission systems, DC welding, telluric earth currents, and CP systems. The amount of corrosion caused is directly proportional to the amount of DC current flowing in the electrolyte. Steel corrodes at a dissolution rate of about 20 pounds per ampere-year. CP systems can impress large amounts of current from their anodes, through the electrolyte, to the cathode. When a metallic structure not connected to or not intended to be protected by the CP system (referred to as the “foreign” structure) is immersed in the same electrolyte in the vicinity of the protected structure, it is subjected to stray current corrosion because of the electromotive force being applied through that electrolyte, and can undergo extremely severe corrosion without proper mitigation.

Provide test stations with provisions for bonding at all crossings for stray current interference testing and mitigation. Specify any additional appropriate methods and procedures to mitigate stray currents. Contact the users (owners, if not government owned) of the existing pipelines and inform them of the planned project. As any solutions to problems at pipeline crossings require cooperative efforts, effective coordination is essential. Identify coordination points of contact on the design drawings, particularly if non-government owned structures are impacted. For off base locations, Corrosion Coordinating Committees have been established in many areas to facilitate coordination of such efforts.

3-3.7 Electrical Isolation.

Determine locations and provide electrical isolation from buried metallic structures that are not intended to be protected by the CP system. Electrical isolation is essential to minimizing current requirements for both GCP and ICCP systems and ensuring the intended structure can be adequately protected. Also provide insulating joints to isolate sections of structures so that each section can be protected separately when necessary (e.g. a pipeline with multiple road crossings). For POL pipelines, provide surge arrestors across the electrical isolation device per UFC 3-460-01.

3-3.8 Connecting Electrical Wires and Cables.

Specify proper selection of cable size and type of insulation for ampacity, mechanical strength and electrically safe, reliable system operation. Use only copper cables in any CP installation. The DC output connecting cables used between the various components of CP systems are vital to the proper performance of the system. Any break in the primary circuit will result in failure of the system. Breaks in the auxiliary connections such as those used to test the system will also result in difficulties in proper adjustment and inspection of the system. See also paragraphs 4-2.4 and 4-3.3.

3-3.9 Connections and Splices.

Wire splices and connections are a source of undesirable circuit resistance and are a weak point in the reliability of the system as they often fail due to either corrosion or mechanical damage. Wire splices are not permitted in the following situations:

- Submerged GCP and ICCP anode lead wires or anode header cables
- Buried individual GCP and ICCP anode lead wires. Provide anodes with lead wires of sufficient length to reach an anode junction box/test station
- Buried sections of anode header cables unless specific site conditions or mission requirements prohibit the installation of an anode junction box/test station
- Buried sections of structure lead wires/header cables in highly corrosive environments

Keep connections to an absolute minimum and specify types of connections that have low resistance, high reliability, and good resistance to corrosion. See also paragraph 4-4.2.

3-3.10 Hazards Associated with Cathodic Protection.

3-3.10.1 Explosive Hazard Concerns.

Design both ICCP and sacrificial anode CP systems to comply with the regulations governing the hazardous area where flammable liquids or explosive gasses may be present. Such areas include, but are not limited to:

- Fuel storage farms
- Fuel terminals and fueling areas
- Refineries
- Ammunition depots
- Manholes (sewer gas)

Cathodic protection rectifiers used in such applications must be special oil-immersed explosion-proof types, or must be located outside of the hazardous area. In addition, all connections must be made in explosion-proof housings, and electrical conduits entering the housings properly sealed.

3-3.10.2 Bonding for Electrical Safety.

Provide electrical bonding points to prevent static discharge as required for safety where ships, vehicles, or aircraft are fueled or loaded. Any voltage gradient in the soil can result in a potential difference between structures located at different points, resulting in dangerous arcing. Cathodic protection systems are one source of such voltage gradients. Normal electrical bonding methods used in such circumstances is sufficient to mitigate this hazard. Voltage gradients caused by CP systems can also cause arcing during pipeline repairs when the pipeline is severed. Specify that a temporary bond be provided across the area to be cut to prevent this hazard before cutting a pipeline.

3-3.10.3 Installation Work near High Voltage Power Lines.

Installation work around high voltage power lines constitute a safety hazard from either direct contact with the power lines or induced voltage from these power lines. If the potential for such occurrences exists at the project site, then include provisions in the design documents addressing these concerns during construction.

3-3.10.4 Induced Alternating Current Concerns.

Alternating current (AC) can be induced on underground or aboveground components of CP systems, as well as large structures being protected in the vicinity of AC electrical transmission lines. This is particularly true if the structure is well coated or isolated from the ground, and the probability and intensity of induced current increases the more the pipeline is oriented parallel to the AC transmission lines. Pipelines using the same right-of-way as the AC transmission lines are particularly susceptible to induced AC voltages. In addition to causing corrosion damage, these voltages can be dangerous to personnel who may come in contact with the structure or CP system.

Identify the location of the AC transmission lines during the design of CP systems and assess the effects of induced currents. Where practicable, avoid placement of CP system components and test stations in areas where induced currents may exist. Provide the appropriate combination of safety features to mitigate the effects of induced current for equipment that must be located within induced current areas and prevent electric shock to maintenance personnel such as.

- Electrical test stations and cabinets with a lockable dead front
- Gradient control mats around pipeline appurtenances engineered to provide safe (15 volts or less) touch-and-step voltages during both load and fault conditions
- Grounding systems for pipeline appurtenances and nearby independent isolated metallic structures
- Distributed galvanic anodes connected to the pipeline as part of the grounding system
- High resistivity crushed stone around pipeline appurtenances (use in conjunction with grounding/gradient control system)

Include induced current safety precautions and test procedures in the specifications for CP system commissioning field surveys or other electrical tests in the vicinity of AC transmission lines

3-3.10.5 CP Systems Near Communication Equipment.

Electrical filters are used to both increase the efficiency of the rectifier by reducing alternating current ripple and to reduce interference with communications equipment. Efficiency filters can increase the efficiency of single-phase bridge type rectifiers by 10 to 14 percent and their use must be based upon a first cost versus operating (power) cost basis. Efficiency filters are not commonly used with three-phase rectifiers as the alternating current ripple in these units is inherently lower.

Specify noise interference filters where operational requirements mandate their use. Verify requirements with the user during the design survey. Where necessary, retrofit noise interference filters into an existing rectifier when noise problems are encountered and are significantly affected by turning the unit on and off.

3-3.11 Special Requirements.

Identify any special requirements in the proposed CP system description such as the need for remote monitoring units, automated data collection units, unique structure or procedural features that may impact the CP system design, operation, or maintenance. Refer to paragraph 4-5 and the best practices in Appendix B. These special requirements will impact the construction cost.

All control systems, remote monitoring units, and automated data collection units must be planned, designed, acquired, executed and maintained in accordance with DoD Instruction 8500.01 and DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

3-3.12 Easement Issues.

Easements are usually not an issue since most projects are located on-installation where easements are not necessary. In the case of CP systems for distribution pipelines and other structures located off-installation, identify easement issues as early as possible during the design process if not already addressed during the planning stages. Obtaining easements can be a long legal process; therefore, should be identified as early as possible before the start of construction. Involve installation real estate personnel for assistance. Ensure easement issues are well documented and the documents kept on file in the event property owners contest the location of the CP equipment years after installation.

3-3.13 CP System Protection Criteria.

Design all CP systems to provide protective levels according to the requirements and criteria for adequate protection identified in the NACE International standards appropriate for the structure(s) being protected.

3-3.14 System Maintainability.

Identify operation and maintenance (O&M) requirements for the end users early on in the design process as end user O&M capabilities may impact the CP system design. Refer to UFC 3-570-06. The following paragraphs briefly summarize the general O&M requirements and design features that facilitate O&M:

3-3.14.1 GCP Systems.

Conduct structure-to electrolyte (S/E) potential tests semiannually (or at least annually as a minimum) to determine adequacy of the CP system. Read and record potential reading at all established test points. Inspect junction boxes and test boxes. Tighten wire connections and perform minor repairs as necessary. Test insulating joints annually.

3-3.14.2 ICCP Systems.

Inspect each rectifier monthly (bimonthly as a minimum), to ensure the system is operating. Read and record rectifier input and output voltage and current readings. Inspect, clean, and tighten output wire connections. Conduct structure-to electrolyte (S/E) potential tests quarterly (or at least annually as a minimum) to determine adequacy of the CP system. Read and record potential reading at all established test points. Adjust or repair rectifiers if test potentials indicate inadequate protection. Test insulating joints annually.

3-3.14.3 Design Requirements to Facilitate O&M.

Specify CP system features and configuration that will save time by making it easier for base facilities management personnel to operate, maintain, adequately test, and troubleshoot the CP system, and ensure adequate CP is being provided to the intended structure throughout the life cycle of the system. The capability for maintaining the CP system at the installation may affect the decision on the type of CP system to be installed. Examples of features, configuration, and design considerations include but are not limited to:

- Location of CP equipment where they will be readily maintainable
- Provision of equipment cabinets suitable for the environment
- Provision of an adequate number of test stations in readily accessible areas. Where possible avoid test station installation in the middle of roads. Without sufficient test stations and test access, a system may be impossible to accurately evaluate for adequacy of protection
- Provision of test stations that preclude maintenance personnel from having to enter confined spaces
- Specification of time saving features such as remote monitoring and automated data collection units where feasible
- Identification of the location of all CP equipment and test points on the design drawings
- Specifications that include training of base maintenance personnel by the contractor and/or manufacturer
- Specifications that include provision of maintenance manuals to the base maintenance personnel by the contractor and/or manufacturer

Refer also to the best practices in Appendix B-8.

3-3.15 Design Submittals.

Project managers or Architects/Engineers-in-charge should contact the service CP system Technical Expert or Major Command Corrosion Engineer regarding the CP system design during the various project phases, and upon request, provide the design documents for review. Design submittals must include the following as a minimum:

3-3.15.1 Design Basis.

The Design Basis must include a narrative description of the proposed CP system and rationale for selecting the type of system, electrolyte (soil, water, etc.) corrosivity data, CP system current requirement test data (if applicable), and all design calculations. The design basis shall also address the anticipated CP system maintenance requirements for the installation.

3-3.15.2 Drawings.

Drawings must include CP system one line diagrams, locations of all CP equipment (anodes, rectifiers, test stations, etc.), stray current test points, installation details, dielectric insulating fittings, and electrical continuity bond connections.

3-3.15.3 Specifications.

Specifications must describe all CP system equipment and installation procedures; acceptance testing procedures including static (native) potentials, initial and final system potentials, and interference tests; special contractor qualifications; and applicable reference standards.

3-3.16 Design Build.

Design build contracts are generally based upon performance specifications. Successful application of CP for the system life will be significantly dependent upon the requirements detailed in the request for proposal (RFP). The contractor selected is responsible to design a CP system that will meet the RFP requirements. Requirements that are too general and are not explicit in performance will result in the installation of a minimum system that will not perform over the anticipated system life. Typically, the contractor’s warranty is one-year, while the system design life is typically 15 - 25 years. Include the following CP system requirements in the RFP:

3-3.16.1 CP Requirements.

Include CP system requirements in the performance technical specifications. If necessary, mark-up guide specifications (UFGS) with prescriptive requirements where a particular system type or specific features are required based on experience

3-3.16.2 CP System Life.

Require a minimum CP system life of 15 - 20 years for GCP systems and 20 -25 years for ICCP systems, unless specific mission requirements or overarching project requirements dictate otherwise.

3-3.16.3 CP System Maintainability.

Require the contractor to address CP system maintainability. Many bases may have a limited ability to readily maintain the CP system.

3-3.16.4 CP System Commissioning.

Require the contractor to provide explicit CP system commissioning requirements. Require commissioning reports be sent to qualified base/installation government personnel for review.

3-3.16.5 CP System Warranty Testing.

Require the contractor to test and maintain the CP system(s) for first year. Include requirements for test data submission to the government.

3-4 DESIGN FOR CONSTRUCTABILITY.

Cathodic protection systems must be properly installed in order for effective protection to be achieved. Problems during construction and installation do occur, and many are due to unforeseen conditions. In some cases, these issues may already be known by installation personnel and it would be beneficial to identify these during the early stages of the design process.

3-4.1 Identification of Issues During Design Field Survey.

During the design field survey, identify and resolve issues that may impact the ability to construct the CP system. Evaluate the following as a minimum:

- Site conditions differing from those shown on installation development maps and as-built drawings. Specify CP system component locations to avoid interference from existing structures
- Site conditions may also be a significant factor in the determination of the type of system selected and the materials used for the components of the system
- Site conditions that may impact construction safety. Coordinate with the installation construction management office/safety officer for any site specific requirements
- Environmental/ archaeological concerns
    - Pollution prevention considerations
    - Preservation of historical structures or site conditions
    - Excavation, drilling and other permits
- Communication with installation personnel regarding
    - Operational requirements that may impact site access, materials of construction, installation or schedule.
    - Future construction at or nearby the project site that may affect the location of the CP system components
    - Security or operational requirements that may impact personnel/construction equipment access and construction schedule (e.g. inside of a shipyard controlled access area)
    - Easement issues if located off-base

The appropriate UFGS sections contain sections that generally address many of the above issues, and site conditions may require the designer to modify these sections for a particular site. Provide copies of the design submissions to installation personnel, including the local construction management office, to ensure that the requirements have been adequately addressed.

3-4.2 Prevention of Damage to Existing Structures/CP System Components.

Include requirements for the contractor to pay particular attention to maintaining the condition of the coating on the structure and maintaining the structural continuity and isolation required for proper CP system operation when working around existing structures. If the coating on a structure is damaged and not repaired, CP requirements will increase dramatically, and the new or existing CP system for the structure may not function properly. Damage to/removal of existing continuity bonds or dielectric isolating devices are common causes of inadequate protection or interference on nearby pipelines that can cause accelerated corrosion damage.

3-4.3 Commissioning.

Specify adequate commissioning procedures so that the system is energized and fully tested to ensure its proper operation before being accepted from the contractor. The cathodic protection UFGS listed below provide detailed commissioning and testing procedures that must be considered and tailored for the specific system being designed.

- UFGS 26 42 13.00 20, Cathodic Protection by Galvanic Anodes
- UFGS 26 42 14.00 10, Cathodic Protection System (Sacrificial Anode)
- UFGS 26 42 15.00 10, Cathodic Protection System (Steel Water Tanks)
- UFGS 26 42 17.00 10, Cathodic Protection System (Impressed Current)
- UFGS 26 42 19.00 20, Cathodic Protection by Impressed Current
- UFGS 26 42 22.00 20, Cathodic Protection System for Steel Water Tanks

Proper commissioning by qualified personnel ensures the system is properly operating from the onset and helps identify system deficiencies, both design and construction, that should be corrected before the system is accepted. A properly commissioned system will help simplify maintenance and operation, and commissioning test data can be used as a baseline for future operation and troubleshooting. See also Appendix B-11.

3-4.3.1 General Commissioning Requirements.

Require the CP systems to be tested and inspected by the Contractor's corrosion engineer/CP Specialist in the presence of the Contracting Officer's corrosion protection/ CP engineer or approved representative. Also require the contractor to record test data, including date, time, and locations of testing and submit a report to the Contracting Officer. Specify that the contractor shall correct, at his expense, all deficiencies in the materials and installation observed by these tests and inspections, and must pay for retests made necessary by the corrections.

3-4.3.2 Required Tests.

Commissioning testing must include the following measurements as a minimum:

- Baseline Potential Tests

- Insulation Joint Testing
- Electrical Continuity Testing
- Rectifier System Testing (ICCP systems)
- Permanent Reference Electrode Calibration (if included in the design)
- Pipe Casing Testing (if applicable)
- Energized Potential Tests
- Interference Testing (If ICCP system is specified or exists nearby)

Refer to the detailed requirements and procedures in the UFGS identified in Paragraph 3-4.3.

3-4.3.3 Warranty Period Testing.

For most CP systems, specify the contractor also conduct periodic testing during warranty. Refer to the detailed requirements and procedures in the UFGS identified in Paragraph 3-4.3.

CHAPTER 4 CATHODIC PROTECTION SYSTEM COMPONENTS

4-1 INTRODUCTION.

There are two main types of CP systems, GCP or ICCP, and they can be applied many different ways to cathodically protect different types of structures. There are many different types and sizes of anodes for either type of CP system that can be installed either horizontally or vertically. Since CP is applied to prevent corrosion of a wide variety of structures in a variety of environments, each situation will require special consideration. There are fundamental requirements that should be followed in each case, and the method of application of CP to a particular structure depends upon unique design factors.

4-2 GALVANIC ANODE SYSTEMS.

Specify GCP systems where economically practical unless specific site conditions or mission requirements require the use of an ICCP system. GCP systems generally require less maintenance efforts than ICCP systems; however, this may not be true for extensive piping systems with numerous distributed anode connection points. The design must consider the DoD installation’s ability to maintain and operate the system specified.

Do not specify GCP systems where the electrolyte resistivity is more than 30,000 ohm-cm, on large/extensive bare or poorly coated storage tank and distribution pipeline structures, or on structures that cannot be practically electrically isolated from all other structures, unless specific site conditions or mission requirements prohibit the use of a GCP system. Do not specify GCP systems for the exterior bottoms of aboveground (on-grade) fuel storage tanks with a clean sand backfill and a secondary containment liner unless specific site conditions or mission requirements prohibit the use of an ICCP system.

4-2.1 Anodes.

Specify the type and size of GCP anode that will provide the optimum performance based upon site conditions, electrolyte characteristics, system life, and economic feasibility. The minimum GCP design life is 15 years unless mission or operational requirements dictate otherwise (e.g. a particular structure will be in service for less than 15 years). The design basis and calculations must provide clear rationale for the anode selection and must address:

- Anode life
- Anode current output
- Specific environmental conditions that may impact performance
- Material costs
- Installation costs

Specify the proper type and size of GCP anodes to meet the desired CP system life for structures immersed in seawater or brackish water. Do not specify magnesium anodes as the primary CP system for structures immersed in salt water.

4-2.1.1 Zinc Anodes.

Zinc anodes are most commonly used in immersion service either in fresh or salt water. They are also occasionally used in the protection of buried structures when soil or water resistivity is low and special circumstances are encountered. Do not use zinc anodes where the soil or water resistivity is greater than 2,000 ohm-cm. Ensure that the proper type of zinc anode is specified. Two zinc anode compositions are commonly available; a standard alloy formulated for use in fresh water and soil, and an alloy specially formulated for use in seawater.

In some fresh waters, the potential between steel and zinc can reverse at temperatures above 140 degrees F, in which case, the steel will act as anode and corrode to protect the zinc. Do not specify zinc anodes to protect steel in such cases (e.g. do not use zinc anodes to protect a steel hot water storage tank).

4-2.1.2 Magnesium Anodes.

Magnesium anodes are most commonly used in soils with higher resistivity and fresh or brackish water immersion service. Do not use magnesium anodes for waterfront structures immersed in sea water, as they do not have a favorable economic life in such environments. Also, do not use magnesium anodes in soil where the soil resistivity is less than 2,000 ohm-cm unless determined to be more feasible for the specific soil conditions. In such cases, ensure that sufficient anode quantities are provided to meet the desired design life.

Ensure that the proper type of magnesium anode is specified. Two compositions are commonly available; a standard alloy and a high-purity (high potential) alloy. Specifications should include provisions that prohibit contractors from inter-mixing the anode types, particularly if the high potential anode is specified.

4-2.1.3 Aluminum Anodes.

Specify aluminum anodes for structures immersed in salt water, brackish water or other low resistivity or high chloride aqueous environments such as sewage effluent unless specific conditions are more favorable to zinc anodes. Specify only the indium activated (Type III) aluminum anodes. Do not specify anodes containing mercury unless specific site conditions or mission requirements dictate their use.

Do not use aluminum anodes for GCP systems for the interiors of potable water tanks. They have been used in past installations in cold climates, but are no longer preferred.

4-2.2 Backfill.

Specify anodes pre-packaged by the manufacturer in backfill consisting of a mixture of hydrated gypsum, bentonite, and sodium sulfate for GCP anodes that will be installed in soil. Besides providing a uniform resistivity environment which reduces the self-corrosion rate, the backfill is hygroscopic and will absorb moisture from the surrounding soil to lower the resistivity and improve the anode current output.

4-2.3 Connecting Wires.

For sacrificial anode CP systems, the electrical currents are usually quite low, and the size of the conductors is normally more a function of mechanical strength than of ampacity or resistance. In systems where sacrificial anodes are used in groups as remote anode beds, the currents can be larger and the voltage drop in the cable must be considered. Calculate the most economic wire size with No. 12 AWG or foreign equivalent being the minimum size wire that must be used.

4-2.3.1 Wire and Cable Insulation.

Specify high molecular weight polyethylene (HMWPE) insulated stranded copper cable for anode leads and structure leads, with the wire appropriately sized for current carrying capacity, mechanical strength, and total CP circuit resistance. Wire size must conform to the requirements in the National Electrical Code (NEC). For submerged applications or chemical environments, specify the appropriate insulation that bests resists deterioration in that environment.

Test station wires carry only very small currents and insulation requirements are not critical, but should be selected to match the environment. Specify stranded copper wires, No. 12 gauge AWG with thermoplastic (THW), cross-linked polyethylene (RHW or USE), or HMWPE insulation for this application unless otherwise dictated by economics or site conditions.

4-3 IMPRESSED CURRENT SYSTEMS.

4-3.1 Anodes.

Specify the type and size of ICCP anode that will provide the optimum performance based upon site conditions, electrolyte characteristics, system life, and economic feasibility. The design basis and calculations must provide clear rationale for the anode selection. The minimum design life is 25 years unless mission or operational requirements dictate a shorter economic life.

4-3.2 Backfill.

Provide special carbon backfill, referred to in the industry as coke breeze, in the anode hole for soil applications. Some specific backfill requirements are as follows:

4-3.2.1 Backfill Specific Gravity.

Specify backfill with the appropriate specific gravity for the type of anode hole so that the particles will settle and compact themselves. Where applicable, include procedures for installing and tamping the backfill in lifts to avoid voids and bridging in the anode hole. Where tamping is not practicable, specify calcined petroleum coke backfill for its spherical shaped particles that can better settle into the hole and compact itself.

4-3.2.2 Backfill Particle Size.

Specify backfill with the appropriately sized particles for optimum contact between the anode and backfill for the type of installation being designed. At the same time, consider the permeability of the backfill to gases that will be generated to prevent gas blockage.

4-3.3 Anode/Structure Lead Wires and Header Cables.

For ICCP systems, select connecting cables and wires based upon consideration of the following factors:

- Current carrying capacity
- Voltage attenuation (IR drop)
- Mechanical strength
- Economics (first cost versus power costs)
- Dielectric strength of insulation
- Durability (abrasion & cut resistance) of insulation

4-3.3.1 ICCP Power Supply to Structure Cables.

Specify HMWPE insulated stranded copper cable, with the wire appropriately sized for current carrying capacity, mechanical strength, and total CP circuit resistance. Wire size must conform to the requirements in the NEC. For submerged applications or chemical environments, specify the appropriate insulation that bests resists deterioration in that environment.

4-3.3.2 ICCP Power Supply to Anode Cables.

Wire size must conform to the requirements in the NEC. The insulation in these cables is critical. The connection between the CP power source and the anodes for ICCP systems, are typically buried or submerged, and are extremely susceptible to failure as they are operated at highly positive potentials. Any contact between the metallic conductors and the environment will result in rapid deterioration of the conductor and loss of continuity of the protective circuit. Specify HMWPE insulation, 0.110 inches thick, as a minimum, for these cables in most buried applications. Where exposure to chlorine will be encountered, such as in seawater or in deep well applications, specify chlorine resistant composite insulation consisting of an HMWPE outer jacket for abrasion resistance combined with an ethylene-chlorotrifluroethylene copolymer inner jacket.

4-3.4 Deep Anode Bed Design.

A deep anode bed consists of one or more anodes installed vertically at a nominal depth of 15m (50 feet) or more below the earth’s surface in a drilled hole for the purpose of supplying CP for an underground or submerged metallic structure. Refer to Figure 4-1. The deep anode bed design must consider several important factors essential to ensuring the proper installation and operation of the well. Refer to the best practices and lessons learned in Appendix B-10.1.

4-3.4.1 Location of Anode Well.

Consider the following when selecting a location for a deep well anode bed:

4-3.4.1.1 Geological Considerations.

Consider subsurface stratigraphy, hydrology, and lithology. Avoid rock, as it is a generally high resistivity environment that could hamper installation and proper operation. In sand environments specify methods to keep hole open during drilling and anode installation. Select a location with consistent subsurface resistivity as much as practicable to help ensure a uniform current discharge from the anodes.

4-3.4.1.2 Ground Water Aquifers.

Consider the location of ground water aquifers. From a geological standpoint, indicate in the design documents if artesian well conditions will be encountered. Such conditions will hamper drilling and anode installation operations, and installation procedures must be specified to account for these conditions. From an environmental standpoint, consider installation methods that will prevent contamination of a water aquifer during installation and operation of the anode well. Refer also to paragraph 4-3.4.5.

4-3.4.1.3 Communication with the Community.

Communicate with both on base and off base community where applicable. Where the CP system is located off base, communicate with the local community in order to identify easement issues, coordinate with local planning for future developments that could result in future easement issues, and coordinate with owners of buried utility pipelines and other buried structures in the area.

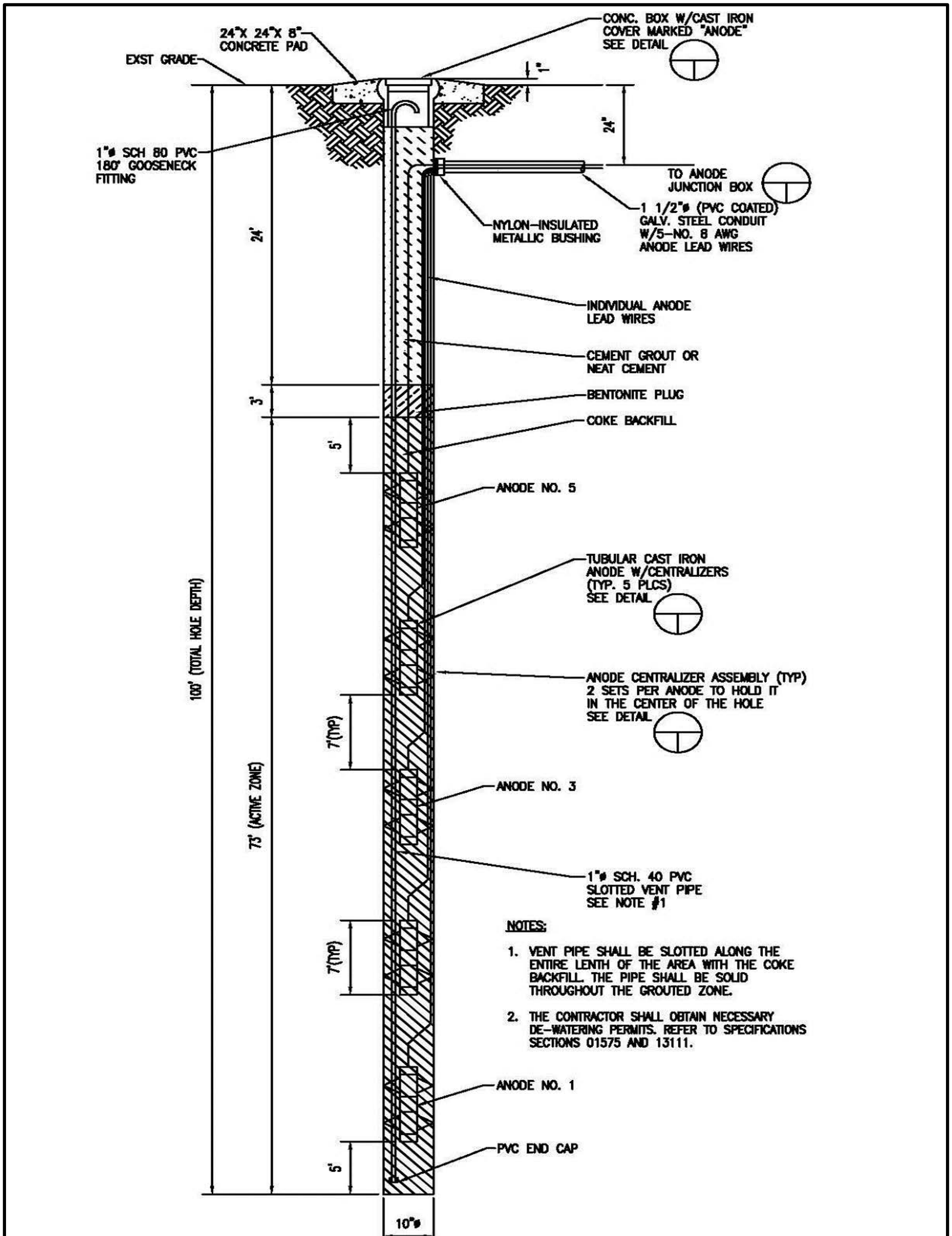
4-3.4.2 Anode Column.

Some anode column design requirements and considerations are as follows:

4-3.4.2.1 Anode Selection.

Select anode type for optimum performance and reduced difficulty of installation. Local subsurface conditions influence the selection of anode type, and anode selection affects the design for the column, i.e. quantity of anodes, depth and diameter of the column, and installation procedures.

Figure 4-1 Schematic of a typical deep well anode bed



4-3.4.2.2 Anode Centralizers.

Provide anode centralizers to help ensure the anodes are completely surrounded by backfill to lessen the chance of premature failure. Design/specify centralizers that do not significantly reduce total anode discharge area. Avoid the attachment of centralizers directly to anode surfaces that are subject to crevice corrosion such as mixed metal oxide or platinum coated titanium or niobium.

4-3.4.2.3 Anode Column Venting.

Provide vent pipes in the anode well to vent gases generated around the anode out of well to avoid gas blockage. Gas blockage can result in increased anode resistance and uneven current discharge from the anode surface resulting in premature failure. Specify vent pipes with holes or slots small enough to prevent the backfill from entering and clogging the vent pipe. Do not terminate the vent pipe inside of the anode junction box. The chlorine gas will cause corrosion of junction box hardware and detrimentally affect operation of the CP system. Also, do not terminate the vent in the anode well head box. The concentration of chlorine gas can result in corrosion of the well head box cover if it is made of steel or cast iron, and can degrade the insulation around the anode lead wires, and result in loss of the anode.

4-3.4.2.4 Anode Installation Procedure.

Follow the anode installation procedures as indicated in UFGS 26 42 17.00 10 and UFGS 26 42 19.00 20. In most cases specify that the contractor must not use the anode lead wire to lift, transport or install the anode. Handling the anode by using the lead wire can compromise integrity of wire and anode connection. Where the situation requires the use of the anode lead wire for anode installation, specify the appropriate pull out strength of the wire-to-anode connection and provide destructive test procedures to verify conformance with the specifications. Refer to UFGS 26 42 17.00 10 and UFGS 26 42 19.00 20.

4-3.4.3 Anode Column Backfill.

Provide a special carbon coke breeze backfill in the anode hole or column for all underground deep anode bed installations, except for open hole, replaceable anode deep wells. Consider open hole deep anode beds only where there is sufficient low resistivity groundwater to keep the anode well filled with water and provide the uniform environment for uniform distribution of current. Environmental concerns must be addressed. Anodes in open holes are more easily replaced in the event of failure. Specific backfill requirements are as follows:

4-3.4.3.1 Backfill Specific Gravity.

Since deep anodes are typically installed in the ground water table, specify backfill with high specific gravity so that the particles will settle and compact themselves since they cannot be tamped. Specify calcined petroleum coke backfill for its spherical shaped particles that can better settle into the deep column and compact itself without tamping.

4-3.4.3.2 Backfill Particle Size.

Specify backfill with small particles for optimum contact between the anode and backfill. Also consider the permeability of the backfill to prevent blockage of gases generated in the well.

4-3.4.3.3 Backfill Installation.

Backfill must be installed by pumping a slurry of the backfill into the hole from the bottom up to preclude voids or “bridging”. Do not use the vent pipe to install the backfill, as it will clog the vent pipe. Large particles specified to prevent gas blockage will be difficult to pump.

4-3.4.4 Anode Lead Wires.

Anode lead wires are a very important component of the anode installations, and many deep anode installations have failed because of improperly specified lead wires. Some considerations for anode lead wires for deep anode beds include:

4-3.4.4.1 Wire Insulation.

Specify HMWPE insulation. For chlorine ion environments, specify a dual insulation consisting of an inner ethylene-chlorotrifluoroethylene layer with an HMWPE outer layer for abrasion resistance.

4-3.4.4.2 Splices Not Allowed.

Provide individual anode lead wires to the anode junction box instead of splicing them to a single header cable from the rectifier. Specify that splices <u>are not allowed</u> in the anode lead wires. Splices are a point of premature failure of anode lead wires.

4-3.4.4.3 Damage Insulation Not Acceptable.

Specify that nicks or other damaged to the wire insulation <u>are not acceptable</u>. As with splices, and even more so with damaged wire insulation, nicks and damaged insulation are points of premature failure of anode lead wires.

4-3.4.5 Environmental Concerns.

Installation of a deep anode bed can impact the environment. Environmental concerns must be considered during the early design stages. Consult with base environmental personnel and ensure that they are afforded the opportunity to review the design. Failure to consider environmental concerns can result in:

- Delays in completing the final design if an environmental issue is identified too late in the design
- Delays in obtaining construction permits

- Work stoppage and costly construction delays if environmental issues must be settled after construction is awarded, with the potential for disapproval of work and cancellation of the installation
- Pollution of the environment and the resulting costly cleanups
- Fines for violating environmental regulations
- Other legal ramifications

4-3.5 Rectifiers and Other DC Power Supplies.

Any source of direct current of appropriate voltage and current can be used as a source of power for ICCP systems. Select the power supply based upon local conditions at the site and evaluation of economics, availability of AC power or fuel, and the availability of maintenance capability. Design drawings must identify the specific source of power and any necessary additional electrical equipment components required to provide power to the rectifiers.

4-3.5.1 Transformer-Rectifier.

Unless AC power is unavailable, specify a transformer-rectifier, or more simply, a rectifier. They are by far the most commonly used power supply type for ICCP systems, as they are readily available in a wide variety of types and capacities that are specifically designed and constructed for use in ICCP systems. The most commonly used type of rectifier has an adjustable step down transformer, rectifying units (stacks), meters, circuit breakers, lightning arresters, current measuring shunts, and transformer adjusting points (taps), all in one enclosure. Ensure rectifiers and associated wiring and conduit are installed according to applicable electrical and safety codes and guidance.

4-3.5.2 Solar Power-Rectifier.

Consider the use of storage batteries and solar panels (Figure 4-2) for ICCP power supplies at remote sites where electrical power is not available. Security must be considered with solar power systems to avoid theft and vandalism especially in off-base locations. Environmental and safety considerations must address procurement, maintenance and disposal of battery electrolytes.

Specify high efficiency (96-98%) controls that have flexibility to match the anode ground bed and its fluctuating conditions. In order to maintain constant CP levels, specify a control unit that has either constant potential (with reference to a permanent reference electrode) control or constant current output capability. Select the controller unit that minimizes the mismatch loss between the PV array and the storage batteries. Finally, consider providing a controller that has built–in current interruption capability so that IR free (more accurate) structure potentials of the pipelines can be measured. NAVFAC Engineering Service Center (ESC) Technical Report TR-2312-SHR *CPC Program Final Report Solar Powered Cathodic Protection System,* documents some of the key considerations and lessons learned when considering the use of solar power.

Figure 4-2 Small Solar Powered CP System. Solar Panels Shown in Picture on Left. Battery Bank and Control Center Shown on Right.

4-3.5.3 Other Power Supplies.

Consider usage of other types of power supplies such as engine or wind driven generators or thermoelectric generators in remote locations where electrical power is not available and solar power is not practicable. They must be justified by life-cycle economic analysis.

4-4 OTHER COMPONENTS.

4-4.1 Electrical Continuity and Isolation.

Electrical continuity or isolation requirements must be determined to design an effective CP system for the structure and ensure it will receive adequate CP as intended. For electrically discontinuous structures, provide continuity bonds (Figure 4-3) or provide independent CP systems for each electrically isolated section of the structure.

Conversely, provide electrical isolation if only a portion of a larger structure will be protected, or other buried metallic structures not intended to be protected are electrically continuous with the structure to be protected.

4-4.1.1 Electrical Bond Wires.

These wires carry more current than test wires, and may require mechanical strength. Specify No. 4 or 8 AWG stranded copper cable with HMWPE insulation for all bond wires unless a larger wire size is required for current carrying capacity.

Figure 4-3 Bond Wire Installed Between Two Electrically Isolated Pipe Sections

4-4.1.2 Electrical Isolation Joints (Insulating Fitting).

Provide dielectric insulation joints (flanges or unions) between sections of a structure to electrically isolate the structure into sections that can be protected by independent CP systems, or to separate sections that require CP from those that do not. Electrical isolation is provided to minimize current requirement for both GCP and ICCP systems by isolating structures that are not intended to be protected by the CP system. Insulating joints are sometimes used to isolate sections of structures so that each section can be protected separately when necessary.

Unless it is not feasible, install electrical isolation devices where the pipe emerges from the ground or in valve pits. Where the isolation joints absolutely must be buried, provide two-wire test stations to allow testing of the electrical isolation joint. Coordinate with the design team/users to ensure mechanical or structural features will not unintentionally bypass the electrical isolation. For example:

- Electrical grounding system connection points that result in the area grounding system (bare copper wire and ground rods) being connected to the CP system
- Tank gauging system or other electrical conduits that unintentionally bypass electrical isolation
- Pipe racks supporting the pipe to be protected as well as pipe not intended to be protected and/or electrical conduits connected to grounding systems

- Small diameter bypass pipelines that bypass the dielectric isolation gasket in the main larger diameter pipeline

Consider the need for surge and fault current protection at isolation devices. If an insulation flange is installed in a hazardous classified area per the NEC, provide a sealed, weatherproof surge arrester across each isolation device. The arrester must be the gapless, self-healing, solid state type (e.g., metal oxide varistor). Cable connections from arresters to isolating devices must be short, direct, and of a size suitable for short-term, high current loading.

4-4.1.2.1 Insulation Joints and Surge Arresters on POL Pipelines.

For POL pipelines, provide surge arrestors across all aboveground insulated flanges connected to below ground cathodically protected piping per UFC 3-460-01. Require surge arrestors to be designed for use with insulated flanges and for use in NEC Class I, Division 1 areas. Provide covers over flanges to preclude dirt from degrading surge arrestors.

4-4.1.2.2 Insulation Flanges and Surge Arresters on Fire Protection Pipelines.

Provide insulation flanges in fire protection risers or in other piping extending from below grade into the building. Install insulation flanges in fire riser piping or other piping, above the floor slab. Additionally, consider installation of AC/DC decoupling devices across the insulation flanges per the NEC. The NEC allows the underground piping extending into the building to be bonded into and used as part of the building grounding system, which can result in premature corrosion failure of the buried piping due to DC component currents discharging to ground via the buried piping.

4-4.2 Connections and Splices.

While connection of wires to the structure can be either by exothermic weld or mechanical connections, utilize exothermic welding (Figure 4-4) as much as practicable. Avoid mechanical connections as much as practicable (Figure 4-5), as corrosion of the mechanical connection tends to result in a high resistance connection over time that could prevent the CP system from properly operating. Insulate underground connections with either epoxy encapsulation or other type of mastic compatible with the pipeline coating. Above grade connections such as wires in test stations are usually mechanical connections. Specify that they be carefully taped in order to prevent corrosion due to the entry of moisture.

Include details on the design drawings showing a typical exothermic welding process and include notes describing the step by step procedure. The UFGS include sections detailing the requirements for exothermic welding. Ensure the project specifications include the applicable requirements including the requirements regarding safety.

Figure 4-4 Exothermic Weld of CP System Wiring to the Structure

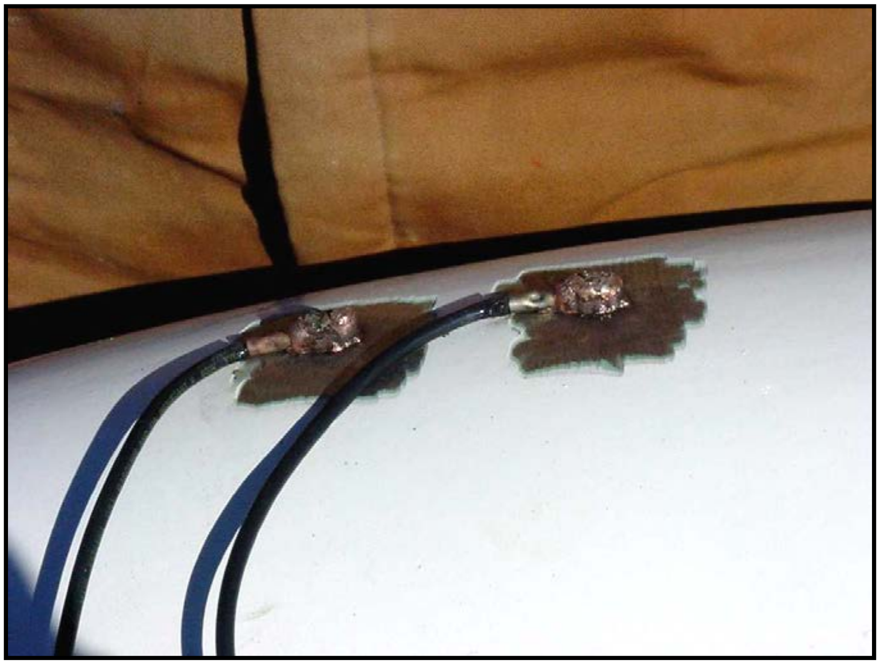


Figure 4-5 Mechanical Connection of Wiring to the Structure

4-4.2.1 GCP Systems.

The following connections are required for GCP anode systems and must be shown on the design drawings:

- Connection between anode(s) and structure through a test station
- Connection between cable and anode (must be factory made with wire connection attached to cast-in core)
- Necessary bonds and test wires

4-4.2.2 ICCP Systems.

The following connections are required for ICCP systems and must be shown on the design drawings:

- Connection between power source and structure
- Connection between anode bed(s) and power source (anode header cable)
- Connection between anode header cable and each anode
- Connection between cable and anode (must be factory made)
- Necessary bonds and test wires

Carefully insulate all connections, particularly in the anode to power supply portion of the circuit where any loss of insulation integrity will result in rapid system failure. All connections in the power source to anode bed portion of the circuit and all cable-to-cable connections must be insulated by encapsulation in epoxy using commercially available kits made expressly for this purpose.

The cable to structure connection is less critical and either epoxy encapsulation or insulation with mastic must be used on this connection.

4-4.3 Test Stations.

Provide a sufficient number of test stations to allow access to the structure for potential surveys to determine if adequate CP has been achieved. They are also necessary to perform recurring maintenance, troubleshooting and repair of the system during its life cycle.

4-4.3.1 Test Station Location and Function.

Accurately identify test station locations on the design and as built drawings. Include details of the schematic wiring of all test stations in the system design. Specify test stations manufactured specifically for the intended purpose. Provide flush mounted test stations in paved areas or other areas where damage by vehicles, etc. is anticipated. Provide above grade test stations where they are not subject to vehicle damage or are located in areas where flush mounted test stations can easily be covered over and lost.

Provide test stations on all foreign structures that cross the protected structure or are in the vicinity of the anode bed. Also provide test stations for all pipeline casings, underground dielectric insulation unions and flanges, and other components such as bonds. Provide test station markers for flush mount test stations on cross country pipelines to facilitate location of these test points.

4-4.3.2 Test Station Wiring.

All test stations must include at least two wires to each structure protected or impacted by the CP system. Provide non-corroding metal or plastic identification tags on all test wires to identify them and indicate the system component to which they are connected.

Since test stations are manufactured in many different types and configurations, ensure that they are adequately sized and configured for the number of test wires and intended purpose of the test station. Some small flush mount test stations are manufactured with five or more terminals on the terminal board, but when installed with thick polyethylene insulated wire, are difficult to open and close, often resulting in damage to the wiring terminals and measuring shunts. Provide test stations large enough to appropriately accommodate the wire quantity, size and insulation type and facilitate maintenance and testing.

4-4.4 Permanent Monitoring Electrodes and Probes.

For structures that will have limited access to the electrolyte after construction, provide permanent electrodes, probes or other means to allow structure-to-electrolyte testing and other means to demonstrate CP system effectiveness. Following are some examples:

- Exterior bottoms of on-grade fuel storage tanks with a secondary containment liner
- Water storage tank interior
- Rebar in a concrete structure
- Submerged waterfront structure

4-4.4.1 Permanent Reference Electrodes.

Provide the type of permanent reference electrode suitable for the electrolyte and specific environment conditions.

4-4.4.1.1 Seawater and Brackish Water.

Specify silver-silver chloride reference electrodes (SCE) for most sea water and brackish water environments. Do not specify copper-copper sulfate reference electrodes (CSE) in these environments.

4-4.4.1.2 Soil and Fresh Water.

Specify CSE or zinc reference electrodes (ZRE) for most soil and fresh water environments. Ensure that reference electrodes for use inside of potable water storage tanks are approved in accordance with NSF/ANSI Standard 61. For soil applications, specify reference electrodes that are prepackaged in backfill SCE by the manufacturer.

4-4.4.1.3 Concrete.

For reinforced concrete, specify SCE manufactured for use embedded in concrete.

4-4.4.1.4 Aboveground Storage Tanks.

Specify dual element CSE/ZRE for the exterior bottom of aboveground (on-grade) storage tanks.

4-4.4.1.5 Industrial Hot Water Tanks.

For industrial hot water tanks, refer to paragraph 4-5.6.2

4-4.4.2 Reference Electrodes with Coupons.

Provide reference electrodes with coupons where voltage drop (IR) free structure-to-electrolyte measurements are necessary and interruption of the CP current is not practicable. NAVFAC ESC Technical Report TR-3559-SHR *Corrosion Protection Utilizing IR Drop Free Sensors and Data Acquisition for Cross Country Pipelines,* includes lessons learned regarding the application of reference electrodes with coupons to monitor CP effectiveness on a buried pipeline.

4-4.4.3 Electrical Resistance Probes.

Provide electrical resistance (ER) probes where it is necessary to demonstrate a reduction of corrosion rate in addition to structure-to-electrolyte measurement to demonstrate CP system effectiveness. Ensure the design includes provisions for protecting the connection point of the lead wires to the probe body. Any corrosion in the connection will render the probes useless. Technical Report TR-NAVFAC EXWC CI-1301 *CPC Program Final Report Electrical Resistance Probe Corrosion Sensors for In Situ Assessment for Waterfront Structures,* documents some of the technical considerations and lessons learned when considering the use of ER probes in submerged waterfront structure applications.

4-5 SPECIAL TECHNOLOGICAL CONSIDERATIONS.

Refer to Appendix B-10 for best practices and lessons learned regarding the special considerations in this section.

4-5.1 Remote Monitoring.

For critical or remote locations, consider the use of remote monitoring equipment to monitor the CP system and the protected structure. Required periodic monitoring of ICCP rectifiers requires a crew to travel to the location to perform testing and can result in up to 60 days between inspections. Remote monitoring systems help reduce testing costs and aid in collection and management of data for historical records.

Remote monitoring units commonly communicate by cell phone technology or satellite transmission technology. Technical Report TR-NAVFAC EXWC CI-1405 *CPC Program Final Report Satellite Based Remote Monitoring Systems for Cathodic Protection Systems in Remote Locations,* documents some of the key considerations and lessons learned when considering the use of satellite remote monitoring. Technical Report ERDC/CERL TR-07-25 *Remote Monitoring of Cathodic Protection and Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson,* documents the use of and lessons learned regarding "drive-by" remote monitoring systems. Refer to paragraph 1.6 for cybersecurity requirements.

4-5.2 Pre-engineered CP for Underground Storage Tanks.

USTs and oil water separators that conform to the Steel Tank Institute STI-P3-90 include a pre-engineered sacrificial anode CP system that is one part of the overall pre-engineered external corrosion control system for the underground steel storage tank (Figure 4-6). The STI-P3® system combines three basic methods of underground corrosion control, all installed on the tanks during manufacture:

- Cathodic Protection
- Protective Coating
- Electrical Isolation of the tank from other underground metallic structures

Figure 4-6 STI-P3® Tank

***** CAUTION - RISK OF INADEQUATE CP *****

The CP system for an STI-P3® tank is intended only to protect the tank. Pipelines associated with the tank will not be protected. A separate CP system must be provided for the associated pipelines to comply with UST regulations. Also note that the integrity of the isolating bushings for an STI-P3® tank must be maintained. Loss of this electrical isolation can result in inadequate protection of the tank because of electrical shorts to other buried metallic structures in the vicinity.

Do not specify these types of pre-engineered CP systems where field survey conditions indicate they are not feasible. For new STI-P3® tanks specify provision of manufacturer provided PP4 CP testing equipment or provide separate appropriate test stations and wiring, to allow proper testing of the CP system.

4-5.3 Aboveground (on-grade) Storage Tanks.

Provide ICCP systems for the exterior bottoms of aboveground (on-grade) storage tanks with a secondary containment liner. Anodes must be installed in the backfill between the tank bottom and the containment liner. Do not specify GCP systems unless mission requirements preclude the use of ICCP systems. Provide a combination of permanent reference electrodes, corrosion probes, and reference electrode tubes to allow sufficient long-term testing and monitoring of the CP system effectiveness. Provide a separate CP system for buried distribution pipelines associated with the tank.

Provide a properly designed ICCP system for aboveground storage tank bottoms without secondary containment liners. With the many other systems incorporated into these storage facilities (e.g. tank gauging systems, fire protection systems, etc.), complete electrical isolation can be difficult to achieve. The tank may also be connected to a grounding system for safety, precluding the possibility of complete tank isolation. Provide CP for buried distribution pipelines associated with the tank. Consider electrical isolation issues, stray current interference issues, and life cycle costs to determine the need for a single integrated CP system for the tank and pipelines or separate CP systems for the tank and pipelines.

4-5.4 CP Systems for Reinforcing Steel in Concrete.

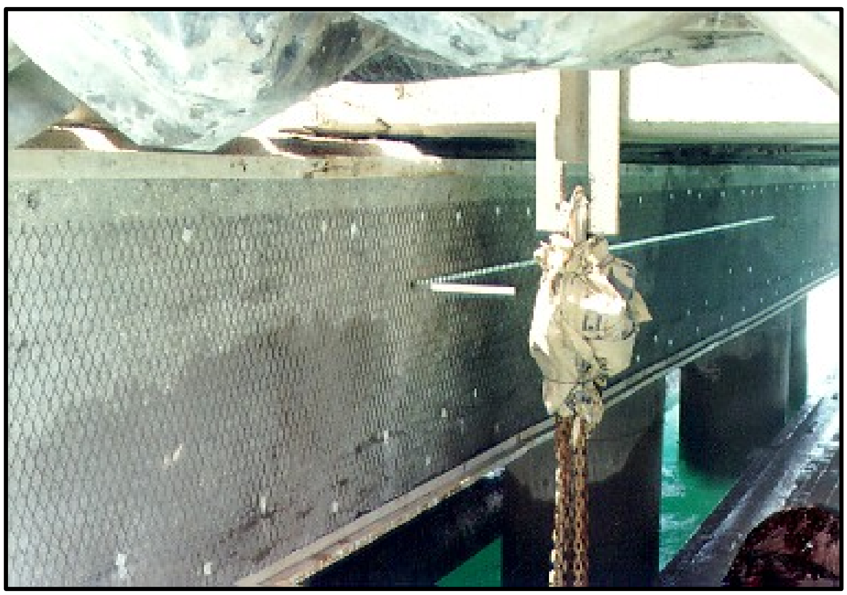
CP systems are not required for reinforcing steel (rebar) for new reinforced concrete structures. Instead, comply with the requirements of the appropriate UFC and UFGS documents that include concrete design considerations that enhance corrosion prevention and control of the rebar. However, for major concrete structure repair projects, provide CP for the rebar in concrete where economical over the life cycle of the structure. CP systems for rebar in concrete must be designed by a qualified person experienced in the design of CP systems for rebar in concrete. Provide permanent reference electrodes or corrosion probes to allow testing and monitoring of the CP system effectiveness.

4-5.4.1 ICCP Systems.

For corrosion protection of reinforced concrete structures requiring significant structural concrete repairs, consider one or a combination of the three different types of ICCP anode systems that is most appropriate for the type of concrete structure and repairs being accomplished.

- Titanium mesh system consisting of mixed metal oxide coatings on an expanded titanium mesh fastened to the concrete surface (Figure 4-7) and overlaid with a cementitious material, usually a Portland cement concrete mix. This type of system is commonly used on deck surfaces, piles or columns
- Titanium ribbon (mesh) slotted system consisting of mixed metal oxide coatings on either solid titanium ribbon strips or on expanded titanium mesh strips (ribbons). The ribbons are installed between the rebar and concrete substrate or in slots cut in the concrete surface and backfilled with a cementitious mix. This type of system is commonly used on deck surfaces

Figure 4-7 Titanium Mesh Anodes Fastened to a Concrete Beam



- Discrete anode system that typically consist of short strips of mixed metal oxide coated expanded titanium mesh, ceramic anodes, or platinized titanium wire typically installed in drilled holes and backfilled with cementitious grout. The length and spacing of the discrete anodes depends on the density of rebar and protection current requirements. These systems are most economical for beams, piles and columns

4-5.4.2 GCP Discrete Anode System.

When cracked and spalled concrete structures containing high chloride contamination are repaired by patching, consider installation of GCP discrete anode systems (DAS) in the vicinity of the patched area. The GCP discrete anodes are sacrificial zinc anodes in a special backfill (Figures 4-8 and 4-9). Unless a large area of concrete is removed during spall repairs, provide discrete anodes areas near the outer edges of the patch before applying the concrete patch. The type, length and spacing of the discrete anodes depend on the density of rebar and patch dimensions.

The intent of the DAS anodes installed along with patches is not to provide adequate CP to the entire structure, but to minimize the galvanic corrosion effects between the rebar surrounding the patched area and the rebar within the patched area. Technical Report TR-NAVFAC EXWC CI-1412 *CPC Program Final Report Alkali Activated Zinc Grouted Anode System for Concrete Reinforcing Steel,* includes details on design considerations for the application of DAS anodes in a waterfront structure.

Figure 4-8 Discrete Zinc Anode (Wrapped in Green Mesh) in Concrete Deck Repair. Device with Yellow Lead Wire is a Permanent Reference Electrode.

4-5.4.3 Pre-engineered CP for Pier Pilings.

Integrated concrete pile repair and corrosion protection systems (Figure 4-9 and 4-10) contain pre-engineered CP systems for the pile reinforcing steel. Consider these type of systems as a viable alternative for long-term repairs of waterfront structures with reinforced concrete piles containing high chloride contamination, and significant spalling/delamination of concrete due to corrosion of reinforcing steel. These systems can increase the service life of a pier patch repair up to 20 years in contrast to only six to seven years if pier pilings containing high chloride levels are only patched. For piles with only minimal damage, prepare a life cycle cost analysis to help determine the economic viability of this technology. NAVFAC ESC Technical Report TR-2292-SHR

CPC Program Final Report Integrated Concrete Pier Piling Repair and Corrosion Protection System, documents an innovative repair technique known as “Lifejacket” which integrates both concrete pile repair and a zinc mesh GCP system.

Figure 4-9 Discrete Zinc Anodes in Fiberglass Jacket for Pile Installation.

Figure 4-10 Photos Showing “Before” and “After” Installation of Integrated Pile Repair Systems

4-5.5 Water Storage Tanks.

Water storage tank CP systems must be designed by a qualified person experienced in the design of CP systems for water storage tanks to ensure its proper operation. Refer also to the best practices and lessons learned in Appendix B-10.4.

4-5.5.1 Interior of Potable Water Tanks.

Ensure that CP system materials are approved for use inside of potable water storage tanks in accordance with NSF/ANSI Standard 61. Coordinate CP system requirements with the interior protective coatings designer to eliminate conflicting requirements. Include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with the ICCP system. For bolted panel storage tanks, require the contractor to ensure all panels of a bolted panel storage tank are electrically continuous.

4-5.5.2 CP for Interior of Water Tanks Subject to Icing Conditions.

There is a persistent problem at DoD installations with CP systems for water storage tanks located in areas with cold winters. Water tank interior CP system anodes are typically suspended from the roof of the tank with wires and cables such that they are submerged in the water. Such systems are often prematurely damaged or destroyed when surface ice forms in the tank in very cold environments. ICCP systems to protect the interior surfaces of water storage tanks in cold climates must be designed to prevent damage from ice. Specify a CP system consisting of mixed metal oxide wire anodes along with a flotation and support system that keeps the anodes submerged in water underneath surface ice, regardless of the water level, where they will no longer be subject to ice damage. Technical Report ERDC/CERL TR-07-22 *Demonstration of Ice-Free Cathodic Protection Systems for Water Storage Tanks at Fort Drum*, documents considerations for designing ICCP systems for water tanks subject to icing conditions. Refer to the material and installation requirements in UFGS 26 42 15.00 10.

4-5.5.3 Bolted or Riveted Water Storage Tanks with Interior Glass Lining.

Where a CP system is planned for a bolted or riveted steel water storage tank with an interior glass lining, include provisions to ensure electrical continuity between the riveted steel plates. The interior glass lining may electrically isolate adjacent plates. For other types of protective coatings, include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with the CP system.

4-5.5.4 Monitoring Water Tank CP Effectiveness.

Provide a CP monitoring system that will allow monitoring of system effectiveness without having to physically climb the tank. Design the monitoring system such that test lead terminals are conveniently located in, or nearby the rectifier at ground level. Consider the use of remote monitoring systems.

4-5.6 Hot Water Storage Tanks.

Steel hot water storage tanks need protection against internal corrosion to prevent chronic leaking and premature failure. Corrosion caused leaks could cause extensive water damage to structures and mission critical electrical and mechanical equipment that may be co-located in rooms where the water storage tanks are located. Furthermore, the resulting leaks will eventually cause an accumulation of moisture that will promote mold and bacteria growth. Technical Report ERDC/CERL TR-07-26 *Cathodic Protection of Hot Water Tanks at Fort Sill*, documents the economics of the application of CP systems for hot water storage tanks. Refer also to Appendix B-10.5.

4-5.6.1 Domestic Hot Water Heaters/Tanks.

Provide factory-equipped glass linings and sacrificial anodes for domestic and smaller hot water heaters/tanks (75 – 1000 GA capacity). The glass linings and sacrificial magnesium anodes are economical for corrosion protection due to the reduced maintenance and monitoring for these systems.

4-5.6.2 Industrial Hot Water Heaters/Tanks.

Provide ICCP systems that use mixed metal oxide titanium rod anodes for larger industrial hot water heaters/tanks where corrosion of the interior has historically been a problem. Provide a capillary pore tube measurement port or bridge that facilitates CP system testing with a reference electrode located outside the hot water tank with the tip held against the ionically conductive capillary tube (see Appendix B-10.5.2.1).

4-5.6.3 ICCP for Water Boxes in Power Plants.

Water boxes can contain a mixture of many different metallic materials. Some of the materials such as titanium, austenitic stainless steels, and super alloy stainless steels are more noble than the rest of the water box components. As a result, without CP, water box components can experience substantial galvanic corrosion. However, improperly designed ICCP systems for water boxes can result in metallurgical problems such as:

- Hydride formation in titanium tubes under excessive CP results in reduced ductility as the hydride forms.
- Generation of chlorine gas at the anodes under excessive CP resulting in pitting corrosion in the upper tubes of austenitic stainless steel tube bundles.
- Hydrogen embrittlement of stainless steel under excessive CP.

Cathodic protection systems must be carefully designed to operate within selected operating potentials, and be properly maintained within these potentials to prevent any metallurgical problems from occurring. Designs must be accomplished by personnel qualified and experienced in these types of systems.

APPENDIX A REFERENCES

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM G57-95a (latest edition): *Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method*

CODE OF FEDERAL REGULATIONS

CFR Title 40 Chapter 1, Part 112, *Oil Pollution Prevention*, Washington DC

CFR Title 40 Part 280, *Technical Standards and Corrective Action for Owners and Operators of Underground Storage Tanks*

CFR Title 49, Chapter 1, Part 192, *Transportation of Natural and Other Gas by Pipeline*

CFR Title 49, Chapter 1, Part 195, *Transportation of Liquids by Pipeline*

DEPARTMENT OF DEFENSE REGULATIONS

Department of Defense, *Overseas Environmental Baseline Guidance Document*

Department of Defense Instruction 5000.67 *Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure*

DEPARTMENT OF THE AIR FORCE REGULATIONS

Department of the Air Force Instruction 32-1054, *Corrosion Control*

NATIONAL ASSOCIATION OF CORROSION ENGINEERS INTERNATIONAL

NACE International Standard Practice SP0100, *Cathodic Protection to Control of Concrete Pressure Pipelines and Mortar Coated Steel Pipelines for Water or Wastewater Service*

NACE International Standard Practice SP0169 (latest edition): *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*

NACE International Recommended Practice RP0193 (latest edition): *External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms*

NACE International Standard Practice SP0196 (latest edition): *Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks*

NACE International Standard Practice SP0285 (latest edition): *Corrosion Control of Underground Storage Tank Systems by Cathodic Protection*

NACE International Standard Practice SP0286 (latest edition): *Electrical Isolation of Cathodically Protected Pipelines*

NACE International Standard Practice SP0290 (latest edition): *Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures*

NACE International Standard Practice SP0388 (latest edition): *Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks*

NACE International Test Method TM101 (latest edition): *Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Tank Systems*

NACE International Test Method TM0497 (latest edition): *Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems*

NACE International Standard Practice SP0572 (latest edition): *Design, Installation, Operation, and Maintenance of Impressed Current Deep Anode Beds*

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 70, *National Electrical Code*

NATIONAL SANITATION FOUNDATION

NSF/ANSI Standard 61, *Drinking Water System Components - Health Effects*

NAVAL FACILITIES ENGINEERING AND EXPEDITIONARY WARFARE CENTER,

NAVFAC ESC TR-2312-SHR, *CPC Program Final Report Solar Powered Cathodic Protection System*

NAVFAC ESC TR-3559-SHR, *Corrosion Protection Utilizing IR Drop Free Sensors and Data Acquisition for Cross Country Pipelines*

TR-NAVFAC EXWC CI-1301, *CPC Program Final Report Electrical Resistance Probe Corrosion Sensors for In Situ Assessment for Waterfront Structures*

TR-NAVFAC EXWC CI-1405, *CPC Program Final Report Satellite Based Remote Monitoring Systems for Cathodic Protection Systems in Remote Locations*

TR-NAVFAC EXWC CI-1412, *CPC Program Final Report Alkali Activated Zinc Grouted Anode System for Concrete Reinforcing Steel*

TR-2292-SHR, *CPC Program Final Report Integrated Concrete Pier Piling Repair and Corrosion Protection System*

TR-NAVFAC EXWC CI-1425, *Environmentally Friendly Cathodic Protection Anode Beds*

STEEL TANK INSTITUTE

Steel Tank Institute STI-P3-90, *Specification and Manual for External Corrosion Protection Underground Steel Storage Tanks*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *General Building Requirements*

UFC 3-460-01, *Design: Petroleum Fuel Facilities*

UFC 3-570-06, *Maintenance and Operation: Cathodic Protection Systems*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFGS 26 42 13.00 20 *Cathodic Protection by Galvanic Anodes*

UFGS 26 42 14.00 10 *Cathodic Protection System (Sacrificial Anode)*

UFGS 26 42 15.00 10 *Cathodic Protection System (Steel Water Tanks)*

UFGS 26 42 17.00 10 *Cathodic Protection System (Impressed Current)*

UFGS 26 42 19.00 20 *Cathodic Protection by Impressed Current*

UFGS 26 42 22.00 20 *Cathodic Protection System for Steel Water Tanks*

US ARMY CORPS OF ENGINEERS ENGINEERING RESEARCH AND DEVELOPMENT CENTER CONSTRUCTION ENGINEERING RESEARCH LABORATORY

ERDC/CERL TR-07-25 *Remote Monitoring of Cathodic Protection and Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson*

ERDC/CERL TR-07-22 *Demonstration of Ice-Free Cathodic Protection Systems for Water Storage Tanks at Fort Drum*

ERDC/CERL TR-07-26 *Cathodic Protection of Hot Water Tanks at Fort Sill*

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APPENDIX B BEST PRACTICES

B-1 CATHODIC PROTECTION PLANNING.

Cathodic protection systems are often not included in a project design because they are not appropriately identified in the project planning documents. CP systems reduce corrosion of buried or submerged metallic structures, thus reducing the probability of failure and concomitant environmental, operational, safety, and economic repercussions. However, in many cases, CP requirements are not considered during the early planning or design of such systems. Also, repairs to existing structures without CP can easily result in accelerated corrosion of the repaired section. Finally, while CP does add additional costs initially, they will generally be the best economic alternative over the life cycle of the structure.

Identifying the CP requirements early on in the process enhances the chances of a successful design. CP requirements added to the scope during the later stages of the process are less likely to be adequately designed or implemented because of limited budgets (often resulting in mediocre design efforts and greater likelihood that the CP requirement will be eliminated), limited time schedules, and resistance from project design teams to further complicate and delay their design process at later stages.

B-1.1 Project Documentation.

The project documents indicate general intent and the final product may change based upon the designers analysis. Even if the designer later determines that a CP system is not required, or a type of CP system different from that identified in the project documents is required, as a minimum, the requirement has been considered. It is usually easier to modify or delete a requirement than it is to add the “new” requirement, particularly in the later design stages.

B-1.1.1 Cost Estimates.

Provide CP system cost estimate information as part of the project documentation. Detailed cost information sheets are most helpful, but if such information is not available, estimate CP system costs based on a percentage of the cost of the structure being repaired, replaced or constructed. Table B-1 provides general guidelines:

Table B-1. General CP System Cost Guidelines

PROJECT COST OR STRUCTURE REPAIR, REPLACEMENT, OR CONSTRUCTION COST	CP SYSTEM COST PERCENTAGE (%)
< $500,000	15 – 20
$500,000 - $5,000,000	10 – 15
> $5,000,000	5 - 10

B-1.1.2 Sketches and Drawings.

Provide proposed CP system sketches and drawings as part of the project documentation when such information is available. Such information may be available from base corrosion/CP surveys, early stage design drawings, previous CP system installation drawings, or facility condition assessment reports.

B-1.2 Corrosion Control/CP System Assistance.

Bases/Installations/Activities should seek assistance from the service CP subject matter experts, MAJCOM Corrosion Engineers, or service execution agents.

B-2 CP SYSTEM DESIGN CONTRACT PROCESS.

B-2.1 Project Documentation.

When properly planned, infrastructure project documentation should already identify general corrosion prevention/CP system requirements. If not, discuss these requirements with the user to ensure that they are included in the process from the onset of design. This will allow the user ample time to arrange for funding for the CP system design and construction if not already included. Addition of these requirements later in the process often results in funding problems and other delays.

B-2.2 Developing A-E Scope of Work.

Spend a conscientious effort in preparing the A-E scope of work. The scope of work describes the nature of the project and the results expected from the designer. In the design contracting world DoD will not get what is desired unless specified in the design.

B-2.2.1 References.

Reference the policy and requirements in Chapter 2. Reference any applicable codes, regulations, and other applicable UFC documents.

B-2.2.2 Designer Field Survey.

Include costs and effort for the A-E to conduct a field survey to determine site conditions required to adequately design a CP system. The A-E designer must conduct specific field tests at the proposed installation site(s) to evaluate as a minimum, the electrolyte corrosiveness (resistivity, pH, etc.) and CP system current requirements.

B-2.2.3 Typical Field Survey Time.

Typically, allot about two days on site for the designer to inspect the project site conditions, conduct field measurements, research as built drawings of existing structures and associated or nearby CP systems, meet with the installation user and engineering personnel, and determine CP system equipment locations. Additional field time may be necessary, for extensive or complex structures.

B-2.2.4 Electrolyte Environment Data Provided by the Government.

It is generally not recommended that the A-E be asked to design a CP system based on electrolyte information provided by the government. The designer must obtain such information during his own field survey. In isolated cases where a field survey cannot be conducted and an adequate amount of reliable historical information is available, it may be beneficial to ask the designer to base his design on the information provided by the government, however, this may release the A-E from liability if the system is inadequate.

B-2.3 What Information to Provide A-E.

A-E firms must be qualified to design the technical aspects of a project, and an integral part of a good design is the incorporation of user requirements. To aid with the preparation of good CP system designs, provide the designer with user preferences and operational requirements that will affect the design. These requirements can either be written into the design scope of work or discussed during a pre-design meeting.

B-2.3.1 Documents with Pertinent Structure Information.

Documents commonly provided by the government include:

- A copy of a published Base Corrosion Control Plan
- General layout of project site showing location of nearby CP systems
- Drawings of existing CP systems on the existing structure or nearby CP systems if the structure is or will be newly constructed. Also provide the latest Base CP System Assessment Survey and available CP system data if appropriate and requested
- Drawings of the facility for which CP is being designed
- Past historical work effort and manpower maintenance requirements for existing systems (if available)

B-2.3.2 Project Limitations and Constraints.

Information regarding user/Base operational requirements and restrictions should be made known to the designer that may impact the design and/or construction of the CP system.

- Access/Security policies and requirements
- Any special limitations on working hours
- Budget limitations for the project
- Anticipated timeframe for construction

- User Operations limitations that may affect construction schedule (e.g. operational schedules that may prohibit shutdown of the facility, access limitations on airfields or waterfront areas, restricted areas, etc.).
- Safety requirements (e.g. hot work permits)
- Environmental and historical preservation limitations

B-2.4 Deliverables – What to Expect from the A-E.

Assuming proper scope of work has been prepared, design submittals must include, as a minimum:

- Design Basis
- Drawings
- Specifications
- Cost Estimate

B-2.5 Common Problems/Lessons Learned with A-E Designs.

B-2.5.1 Ensure That the CP Design Engineer is Qualified.

CP systems must only be designed by a National Association of Corrosion Engineers (NACE) International Certified Cathodic Protection or Corrosion Specialist. In addition to the certification requirements, the CP design engineer should also have a minimum of five years of experience in the design and successful installation of the type of CP being proposed. Include these requirements in the contract statement of work. Refer to paragraph 3-3.2.

B-2.5.2 Vague Statement of Work (SOW).

Disagreement on design results sometimes occur because of a vague statement of work. Ensure that the scope of work explains the expected results. Ensure that all of the structures intended to be protected are identified. Identify specific system features that are desired. For example, if an ICCP system is desired, then clearly state this in the SOW. Consult with service CP subject matter experts for assistance.

B-2.5.3 Appropriate Level of Effort.

Ensure all levels of effort are identified when negotiating with the contractor. Appropriate design survey field time is a common level of effort causing disagreement. In most cases, CP systems cannot be accurately designed without allowing the designer field survey efforts.

B-2.5.4 Maintain Lines of Communication.

Maintain lines of communication between all interested parties. Operational requirements often change during the design and installation process, and the CP engineer, often a sub-contractor, is sometimes not notified of the change that can result in inadequate CP design (e.g. structure size increased, or additional buried structures added). Miscommunication between disciplines as to which drawings will show certain details sometimes results in neither one doing it, or conflicts between different drawings or between drawings and specs which can lead to installation problems.

B-3 CP SYSTEM DESIGN DOCUMENTATION.

B-3.1 DESIGN BASIS.

The design basis must include a narrative description of the proposed CP system, field test data, design calculations, catalog cuts of proposed CP equipment, responses to review comments. The basis must address any environmental and historic preservation requirements and considerations that may impact project execution. Significant amounts of time are often required to comply with environmental and historical preservation requirements. Although the base or installation is typically responsible for processing the environmental requirements, the basis of design must identify these requirements to help ensure that they are addressed early on in the process and prevent delays in construction. Where the protected structure is located outside of the base, the contractor should identify potential easement issues and appropriate contacts for resolving these issues, as well as local Cathodic Protection Coordinating Committee contacts.

B-3.1.1 Narrative Description.

The narrative will help determine that the A-E designer understands the scope of work, the nature of the project, and the expected results. The narrative description must discuss the rationale for selecting the type of system, including the impact of seasonal variations on the CP system design, and include discussion of special requirements and limitations that may impact construction, operation and maintenance.

B-3.1.2 Field Test Data.

The basis of design must include all field test data taken preferably in tabular form including, but not limited to:

- All electrolyte (soil, water, etc.) corrosivity data as necessary (resistivity, pH, chloride content, sulfide/sulfate content, soil classification, and reviews of available soil borings)
- CP system current requirement test data (existing structures as applicable)
- Operational test data for existing or nearby CP systems
- Results of interference tests
- Historical information deemed important to the new CP system design

B-3.1.3 Design Calculations.

The basis for design must include all design calculations including, but not limited to:

- Calculation of surface area of the structure to be protected
- Determination of the CP current requirement. For existing structures, this should almost always be determined by on-site field current requirement tests
- Determination of type of system to be used based on existing variables and cost
- Determination of anode size and quantity
- Determination of CP system circuit resistance
- Determination of rectifier size
- A/C power calculations including short circuit analysis (ICCP systems only)
- Calculation of appropriate wire and conduit size
- Other related electrical calculations as necessary
- Attenuation calculations where appropriate

Section B-6 provides additional details regarding these calculations. Technical Papers 16, *Impressed Current Anode Material Selection and Design Considerations*, and 17, *Galvanic (Sacrificial) Anode Material Selection, Design Considerations*, provide examples of typical design considerations, process and calculations for the project engineer as a guide to follow when reviewing A-E designs. Do not direct A-E designers to follow these examples, and do not cite these examples as standard DoD design procedures. Qualified designers should be able to design a CP system without having to reference these examples.

B-3.2 DESIGN DRAWINGS.

The CP system design drawings must include sufficient detail and clarity to ensure the system is properly constructed. The design drawings should include, but not be limited to:

- Plan view(s) indicating locations of all CP equipment (anodes, rectifiers, test stations, foreign pipeline crossings, stray current test points, dielectric insulating fittings, electrical continuity bond connections, etc.)
- Details of anodes indicating size and weight
- Installation details of the anodes. Where applicable provide notes indicating allowances, if any, for relocating anodes
- Details of the rectifier showing type (air, oil, explosion proof, automatic, multiple circuit, etc.), size and capacity
- Installation details of the rectifiers (pad, wall, pole, grounding, etc.)

- Details of test stations (type, size, terminal boards, quantity and type of shunts and other wire terminals, quantity and size of wires and conduits terminating in the test station)
- Details of anode junction boxes
- Locations and details of dielectric insulating fittings
- Locations and details of electrical continuity bond connections
- Exothermic weld details
- CP system electrical one line diagram(s)
- Electrical installation details such as cable/wire identification schemes and appropriate legends

Refer to Appendix D for examples of typical details.

B-3.2.1 Quantity and Size of Details.

The number of details shown on one sheet and the size of the details must be appropriately sized so that the details are clearly legible when reproduced at half size. Half size drawings with clearly legible details will also facilitate testing and maintenance by base personnel.

B-3.2.2 Notes.

Provide notes on the drawings to further describe and clarify important/critical items in the details, particularly for critical items. Even if critical items are already described in the specifications, it is still useful to have these also included as notes on the drawings. Contractor personnel usually have the drawings at the work site, while the specifications are usually in the office. It is easy to miss some critical installation items if the notes are not included on the drawings. The notes on the drawings will help preclude unnecessary rework and consternation from both the contractor and construction management personnel. Installation notes also help facilitate testing and maintenance by base personnel.

B-3.3 Specifications.

Boiler plate sections include general specifications. Technical sections include descriptions of all CP system equipment and installation procedures; acceptance testing procedures including static (native) potentials, initial and final system potentials, and interference tests; special contractor qualifications; and applicable reference standards. The UFGS include common, standard recommended clauses for:

- Appropriate references to standards and other governing documents
- Contactor qualifications – do not delete this section without approval
- Required submittals
- Specifications of all CP system equipment and materials

- Specifications describing installation procedures
- Specifications describing commissioning and testing procedures
- Maintenance instructions

Open brackets indicate choices where appropriate. The standard and non-optional clauses should generally not be edited without government review and approval. However, since many CP systems are somewhat unique and the UFGS cannot include accurate clauses for every situation encountered, the designer should add missing or delete non-applicable requirements as necessary. Pay attention to user notes in the guide specifications that provide background information on some of the options for standard phrases. When using SPECSINTACT, turn on the “display notes” before deciding to use or delete certain paragraphs.

B-3.3.1 Protective Coatings Specified in Conjunction with Cathodic Protection.

Protective coatings to be applied to a new metallic structure in conjunction with CP must have the minimum characteristics as described in NACE International SP0169 and the appropriate UFGS. Coordinate the coating type and requirements with the CP system being specified. Many of the coatings specified in recently revised UFGS are compatible with CP systems. Utilize the appropriate protective coating UFGS and supplement the UFGS requirements, as necessary, with the minimum coating characteristics indicated in NACE International SP0169. Do not delete the CP requirements simply because it is not compatible with a particular coating.

B-3.4 Common Problems/Lessons Learned with Design Documents.

B-3.4.1 Computer Aided Design.

The use of computers has greatly aided in the design of CP systems (e.g. drawing programs, word processors, and spreadsheets). Many designers use previously completed designs as templates for new designs, and in their haste, forget to change some of the parameters from the previous design. Review all design documents to ensure that the information is accurate.

B-3.4.2 Notes on Drawings for Important/Critical Items.

For important/critical installation process, provide notes on the drawings even if the process is already included the specifications. Contractor personnel in the field often work off of the drawings and important processes can be missed. The notes on the drawings will help preclude unnecessary rework and consternation from both the contractor and construction management personnel.

B-3.4.3 Size of Details on the Drawings.

Avoid details on the drawings that are too small in size. Ensure details are sufficiently legible at half size drawing reduction. In order to minimize the number of sheets, smaller sized details are sometimes crammed in on a sheet. While they may appear sufficiently legible on full size prints or enlarged on a computer screen, the half size drawings may not be as legible. Contractor personnel in the field often have the half size drawings. Good contractor personnel will ask if something is illegible, while others will not and will interpret the drawings to their advantage.

B-3.4.4 Insufficient Environmental Considerations.

Ensure environmental personnel review the design during its early stages. They may identify unknown requirements that may increase the cost estimate significantly (archaeological, environmental controls, water management during drilling, hazardous waste disposal, and work in/adjacent to wetlands). It is better to delay the design completion date and identify additional funding early on, than to delay construction (change orders) and attempt to obtain additional funding which may not be available forcing reduction in scope or cancellation.

B-3.4.5 Electrical Review of CP Designs.

Review CP designs for conformance to the National Electrical Code (NEC). Many CP design engineers are unfamiliar with the NEC particularly with wire size and conduit. Also, the commonly specified electrical wire and cable for CP systems is the HMWPE type insulation. This insulation is thicker than normal and harder to pull through long conduit runs and bends even though the design conforms to code. It is sometimes necessary to specify a larger size conduit to improve constructability.

B-3.4.6 Design Build CP Designs.

Design build contracts are generally based upon performance specifications. Successful application of CP for the system life will be significantly dependent upon the requirements detailed in the request for proposal (RFP). The contractor selected is responsible to design a CP system that will meet the RFP requirements. The government will have to provide or assume certain conditions to make the project awardable such as soil resistivity, detailed description of structure to be protected and if possible the preferred type of CP system. Requirements that are too general and are not explicit in performance will result in the installation of a minimum system that will not perform over the anticipated system life. Typically, the contractor’s warranty is usually one-year, while the system design life is typically 15 - 25 years. There are instances where a contractor has proposed/installed minimal systems “to save the government money”, but those systems have not performed over the anticipated life. Evaluate Contractors technical proposal with the CP system requirements in mind. Discuss CP system requirements at the design/construction kick-off meeting and ensure the contractor implements them on the plans at each submittal stage.

B-3.4.7 As Built Drawings.

Require the contractor to maintain as-built drawings of the CP system and provide them to the Contracting Officer upon completion of the construction contract. Indicate on the drawings the location of all CP components, especially if installed differently from that indicated on the original design.

B-4 TYPES OF CP SYSTEMS.

There are two main types of CP systems, GCP or ICCP, and they can be applied many different ways to cathodically protect many types of structures. The anodes in either type of system can be either distributed or remote, and in an ICCP system the remote anodes can be shallow or deep. There are many different types and sizes of anodes for either type of CP system that can be installed either horizontally or vertically. Since CP is applied to the prevention of corrosion of a wide variety of structures in a variety of environments, each situation will require special consideration. There are fundamental procedures that should be followed in each case, and the method of application of CP to a particular structure depends upon unique design considerations. These considerations help determine alternatives and methods of protection to use in each specific case.

Two main design factors, which considered together can generally indicate the type of protection recommended; the resistivity of the earth and structure coating quality. For buried structures, poor or lack of protective coating and/or high earth resistivity can virtually eliminate the practical application of GCP systems in many specific applications.

B-4.1 GALVANIC CP SYSTEMS.

A GCP system, sometimes called sacrificial anode or “passive” system, is essentially a corrosion cell being utilized in a beneficial way. The structure to be protected is coupled with a more active metal when both are immersed in an electrolyte and connected with an external path as shown in Figure 3-1. In this case the entire surface of the metal being protected becomes the cathode, and the more active anode metal corrodes during the process and is sacrificed. The anode must be periodically replaced, but it is often much more economical to replace the anode than the protected structure.

B-4.1.1 Advantages and Limitations of Galvanic Systems.

Galvanic systems have several advantages over ICCP systems, but unfortunately also have several limitations. Table B-2 summarizes these advantages and limitations.

B-4.1.1.1 Main Advantages.

The main advantages include generally lower installation cost, less maintenance requirements, and unlikelihood of interference to other structures.

B-4.1.1.1 Limitations.

The main limitations stem from their set voltage. The low driving potential between the GCP anode and the structure (less than a volt) often cannot overcome high soil resistivity (ohms law) and/or provide sufficient current to protect a bare or poorly coated structure. Also, GCP systems require isolation, which sometimes is impractical or impossible to accomplish.

Table B-2. Advantages/Limitations of GCP Systems

ADVANTAGES	LIMITATIONS AND DISADVANTAGES
• No external power required • No regulation required • Easy to install • No or minimum of cathodic interference • Anodes can be readily added • Minimum of maintenance • Uniform current distribution • Installation can be inexpensive for new construction • Minimum right of way/easement costs • Efficient use of protective current	• Limited driving potential • Lower/limited current output • Retrofit installation can be expensive • Poorly coated/bare structures require many anodes • Can be ineffective in high resistivity soils. • Inability to meet desired system life for certain anode types for structures immersed in seawater or brackish water.

The use of certain GCP anodes is also limited for use on some structures immersed in seawater or brackish water. Operational requirements may limit the size of anodes, and hence, the CP system life. Ensure that the proper type and size of GCP anodes are specified to meet the desired CP system life for structures immersed in seawater or brackish water.

B-4.1.2 Where Galvanic Systems Not Recommended.

Generally, GCP systems are not economical for structures in electrolytes with resistivity over 30,000 ohm-cm or on bare or poorly coated structures. They are also impractical on systems that cannot be isolated from all other structures.

Specify the proper type and size of GCP anodes (or ICCP system if appropriate) to meet the desired CP system life for structures immersed in seawater or brackish water. Do not specify magnesium anodes as the primary CP system for structures immersed in salt water.

B-4.1.3 Distributed Galvanic System Applications.

Most GCP systems are distributed anode systems. This means the anodes are distributed geometrically along or around the structure to be protected. Individual anodes are spaced with each anode protecting only a portion of the structure. Continuous “ribbon” anodes are also available and installed along the structure or installed with the structure in the same trench. The quantity, size, and spacing of the anodes as well as the distance of the anodes from the structure are determined by the anode output current and the structure current requirement.

B-4.1.3.1 When Distributed Anode System Cost Effective.

A distributed anode system is most cost effective when it is installed during construction of the structure. Generally, a distributed anode system requires a very good coating and isolation of the structure being protected.

B-4.1.3.2 Common Uses.

Common uses of distributed GCP anode systems include well coated, isolated pipelines or underground storage tanks in low soil resistivity when installed for new construction, for application on existing underground storage tanks under the same conditions, and on submerged waterfront structures.

B-4.1.3.3 Common Misapplications.

Common misapplications of distributed GCP anode systems include bare or poorly coated pipelines, tank bottoms or tanks; non-isolated structures; structures in high soil resistivity; or for application on existing distribution systems.

B-4.1.4 Galvanic (Sacrificial) Remote System Applications.

In limited circumstances, GCP systems can be installed in one or more remote locations to provide protection to an entire structure. Individual anodes would be located in the remote locations with the number, size, and spacing determined by the current requirement, individual current output and total current requirement.

B-4.1.4.1 When Remote Anode System Cost Effective.

Remote GCP systems can be very cost effective for new or existing structures that are small in size (surface area), are coated with an extremely good coating (99.7% efficiency), are electrical isolated from other buried metallic structures, and installed in very low resistivity soils, (typically under 3,000 ohm-cm).

B-4.1.4.2 Common Uses.

Common uses include extremely well coated, short isolated sections of pipelines or underground storage tanks in very low soil resistivity.

B-4.1.4.3 Common Misapplications.

Common misapplications include bare or poorly coated pipelines, tank bottoms or underground storage tanks; non-isolated structures; and structures in medium or high soil resistivity.

B-4.2 IMPRESSED CURRENT SYSTEMS.

An ICCP system, sometimes called a “rectifier” or “active” system, like a GCP system, is also essentially a corrosion cell with one main difference. Instead of relying on the natural “driving” potential between two metals, an external power source, usually a transformer-rectifier, provides the driving force. Figure 3-2 illustrates a simple ICCP system.

B-4.2.1 Advantages and Limitations of ICCP systems.

B-4.2.1.1 Main Advantages.

The driving potential of an ICCP system is only limited by the size of the rectifier and the circuit resistance. Most systems are designed to a maximum of 50 amps and can range to over 200 volts, although typical systems are usually under 100 volts and 30 amps. Nearly all ICCP systems have adjustable outputs, an advantage over GCP systems whose outputs are normally not adjustable. ICCP systems can overcome all the limitations of a GCP system; however they do have some limitations and disadvantages as well. Table B-3 summarizes these advantages and limitations.

Table B-3. Advantages/Limitations of ICCP Systems

ADVANTAGES	LIMITATIONS AND DISADVANTAGES
• Can be designed for wide range of voltage and current and structures with high current requirements • Variable voltage and current output • Applicable in high-resistivity environments and applications in water having low resistivity. • High ampere year output available from a single ground bed • Large areas can be protected by a single installation • Effective in protecting uncoated and poorly coated structures, although good coatings would significantly reduce costs. • Effective in protecting structures that cannot be economically electrically isolated from other buried metal structures • Can be easier to retrofit on existing large structures	• Requires external power - monthly power costs • Subject to power failure and vandalism • Higher maintenance and operating cost than GCP systems. Requires more frequent periodic inspection and maintenance • Can cause cathodic interference problems • Overprotection can cause coating damage

B-4.2.1.1 Main Disadvantages.

With this increased voltage and current there is more concern over current distribution and interference to other structures. More care and testing are required for the design and installation. There is a recurring power cost and a much higher maintenance cost. This higher maintenance cost includes more rigorous testing and higher repair and troubleshooting requirements.

B-4.2.2 ICCP Anode Installation Methods for Buried Structures.

There are several common methods of installing ICCP anodes for buried structures.

B-4.2.2.1 Shallow Vertical Anode Placement.

This is the most common method of installing shallow anodes for both remote and distributed anodes. This generally results in lower anode to earth resistance than horizontally installed anodes, and results in more CP current for a given voltage. The top of the anode is normally buried as deep as or deeper than the structure.

B-4.2.2.2 Horizontal Anode Placement.

This method of installing shallow anodes for both remote and distributed anodes is sometimes required due to rock strata, other special ground conditions or space limitations which preclude the use of vertical anode placement. It is important for these anodes to be deeper than the structure. This method results in a higher anode to earth resistance than vertical anodes, and generally requires more anodes (shorter spacing).

B-4.2.2.2 Deep Anode Placement.

Deep anode beds are generally installed in single vertical columns much deeper than shallow vertical anodes. The top anode is normally installed more than 50 feet deep from the ground surface. In effect the anode bed is installed remotely from the structure by being installed deep in the ground.

B-4.2.3 ICCP Anode Installation Methods for Submerged Structures.

There are also several common methods of installing anodes for submerged structures.

B-4.2.3.1 Distributed Anodes.

The most common method of installing anodes for submerged structures is a distributed anode ICCP system in which the anodes are distributed geometrically over the entire structure submerged in the same electrolyte as the structure.

B-4.2.3.2 Land Based Anodes for Waterfront Structures.

Generally, CP system anodes must be installed in the same electrolyte as the protected structure in order for the CP system to properly operate and adequately protect the structure. For waterfront structures such as steel sheet pile bulkheads and steel pilings for piers running parallel to the shoreline, land based deep well anode systems may be installed to protect the submerged portions of the structure.

B-4.2.4 Distributed Anode ICCP System Applications.

Distributed anode ICCP systems are systems for which the anodes are distributed geometrically over the entire structure. They are most cost effective when they are installed along with the installation of the structure. They do not require a good coating or isolation of the structure being protected, although either would reduce costs.

B-4.2.4.1 Advantages.

In addition to those listed in Table B-3, the advantages of distributed anode ICCP systems include:

- Low installation cost when installed with the structure
- Lesser probability of causing interference than remote anode bed ICCP systems.

B-4.2.4.2 Disadvantages.

In addition to those listed in Table B-3, the disadvantages of distributed anode ICCP systems include:

- Greater chance of premature failure
- Is not cost effective to install (exorbitant trenching, boring and excavation costs) on an extensive existing structure, such as a distribution system; and
- damage to anode cables by future excavations is a big problem with this type of system. Protection and maintainability of the extensive anode leads should be addressed by the design and the installation.

B-4.2.4.3 Common Uses.

Common uses of distributed anode ICCP systems include:

- Pipelines with limited easement or land space to install anodes,
- On-grade storage tank bottoms,
- Newly constructed underground storage tanks, and application of CP to existing underground storage tanks or aboveground storage tank bottoms.

This is the only type of ICCP system used for water tank interiors.

B-4.2.4.4 Common Misapplications.

Common misapplications of distributed anode systems include the failure to distribute the anodes over the entire structure, or distribution of the anodes at excessive intervals.

Either case will result in poor current distribution and lack of protection between or at a distance from the nearest anodes while overprotecting the structure near the anodes.

B-4.2.5 Remote Anode Bed ICCP System Applications.

Remote anode bed ICCP systems can be used regardless of structure coating quality, soil resistivity or current requirements. They do not require any coating on the structure, and may not require isolation of the structure being protected (although either would reduce costs). Therefore, this method can be used on many types of existing structures. Multiple remote systems are commonly used to protect very large or extensive structures, such as cross country pipelines and large distribution systems. Multiple remote systems are several remote systems, distributed and geometrically placed, to provide current to different areas of extensive structures.

B-4.2.5.1 Advantages.

In addition to those listed in Table B-3, the advantages of remote anode ICCP systems include:

- Longer runs of pipelines can be protected with a single system
- Improved chances in finding a good anode bed location

B-4.2.5.2 Disadvantages.

In addition to those listed in Table B-3, the disadvantages of remote anode ICCP systems include:

- Interference to other structures is of high concern and the mitigation of interference should be part of the design and installation
- Easement issues when located off base
- Damage to anode cables by future excavations

B-4.2.5.3 Common Uses.

Common uses of remote ICCP anode systems include:

- Long pipeline runs or extensive pipeline distribution systems (e.g. fuel and natural gas distribution systems)
- On-grade storage tank bottoms
- Fuel storage tank farms with multiple on-grade storage tanks
- Situations where distributed anodes or shallow anodes in closer proximity to the structure(s) is not possible (e.g. pipelines running under an airfield or waterway)

A deep anode bed installation, described in paragraph B-4.2.6, is considered a remote system.

B-4.2.5.4 Common Misapplication.

A common misapplication of remote anode systems is installation of the anodes too close to parts of the structures where they are not truly remote from the entire structure. Poor or uneven current distribution results from not being truly remote from the structure and can result in inadequate protection of remote areas of the structure, while overprotecting parts of the structure nearby the anodes.

B-4.2.6 Deep Anode Bed ICCP System Applications.

A deep anode bed system is considered a remote anode bed system; its remoteness from the structure attained by installing the anodes deep in the ground below the structure. The top-most anode of a deep anode bed is normally installed at least 50 feet deep. Multiple deep anode systems, geometrically located, are commonly designed to protect very large or extensive structures, such as cross country pipelines, large storage tank farms, large distribution systems, and sheet pile bulkheads. Each individual system is commonly limited to approximately 60 amps. By installing the anode deep in the ground, remote from a structure, high current levels can be evenly distributed over very large or extensive areas of a structure or distribution system.

B-4.2.6.1 Advantages of Deep Anode Bed Systems.

In addition to those listed in Table B-3, the advantages of deep anode bed systems include:

- Longer runs of pipelines or multiple structures electrically bonded together can be protected with a single system. Improved current distribution, since the deep well is generally remote from the structure(s)
- High current output, but with less chance of causing stray current interference on nearby foreign structures
- Improved chances in finding a good anode bed location
- Installation of the deep well anode system may be easier
- Minimized excavations, particularly in congested areas
- Less likelihood of damage to anode leads, especially when the rectifier is located adjacent to the top of the anode bed installation
- Fewer problems with easement issues for systems located off base. The system can often be installed within the structure easement
- Land and waterside of waterfront structures can be protected with landside installations
- Less affected by seasonal moisture variations

B-4.2.6.2 Disadvantages of Deep Anode Bed Systems.

In addition to those listed in Table B-3, the disadvantages of deep anode bed systems include

- Generally higher cost and greater difficulty for well drilling and environmental considerations (e.g. implementing measures during design and construction to satisfy local water authority concerns about water aquifer contamination)
- Designer must be familiar with the geological factors that will impact the installation
- Prediction of deep anode performance is more difficult and less exact than for shallow beds
- Higher chance of premature failure if not properly designed, installed, and maintained
- Compaction of anode backfill may be difficult to achieve
- Must vent chlorine and other gas generated in the anode well to ensure proper operation (usually accomplished by installation of a vent pipe in the anode well)
- Environmental considerations for preventing contamination of groundwater may complicate installation

B-4.2.6.3 Common Uses.

Common uses of ICCP deep anode systems include:

- Multiple underground structures with high current requirements
- Installation of a single landside ICCP system to protect both land and seaside of steel sheet pile bulkheads
- Long or extensive pipeline distribution systems, particularly where space availability and easement issues limit the installation of anode beds (e.g. fuel and utility distribution systems)
- Long or extensive pipeline distribution systems or other structures in congested areas where stray current interference on foreign structures must be minimized (e.g. fuel and utility distribution systems)
- Existing large on-grade storage tank bottoms
- Existing fuel storage tank farms with multiple on-grade storage tanks
- Structures buried deep in the earth such as missile silos and well casings
- Situations where distributed anodes or shallow anodes in closer proximity to the structure(s) are not possible (e.g. pipelines running under an airfield or waterway)

B-4.2.6.4 Common Misapplications.

Common misapplications of deep anode systems include:

- Installation of deep anodes without considering all of the geological and environmental factors that affect the installation and operation
- Installation of anodes too shallow in the ground where they are not truly remote from the entire structure. The top anode is normally installed at a minimum of 50 feet deep. Installing the anodes too shallow will result in poor current distribution and the lack of adequate protection to remote areas of the structure, while overprotecting nearby parts of the structure

B-5 GENERAL DESIGN PRINCIPLES.

B-5.1 DESIGN APPROACH.

There are several different approaches to designing a CP system. Each approach must consider the set of design parameters affecting the structure to be protected to help determine the type of system best suited for the specific case. These design parameters include (but are not limited to):

- Type and geometry of structure to be protected
- Electrolyte conditions (mainly resistivity, but also pH, chloride content, moisture content, and sulfide content)
- Cathodic protection current requirement
- Type and quality of the structure coating
- Presence of other structures in the area
- Presence of other CP systems in the area

The first consideration in the decision process is to establish if the structure to be protected is existing, new, or a new structure that will be connected to existing structures with existing CP systems. The next decision is to determine if a GCP or ICCP system should be specified based on the design parameters and economics. If a GCP system cannot be ruled out, a design for both GCP and ICCP must be accomplished, and a determination made by evaluating the installation and maintenance life cycle cost.

B-5.1.1 CP System Operation Dependent Upon Local Environment.

The actual functioning of any CP system is dependent upon the local environment at each point on the surface of the structure to be protected, condition of the structure, and the actual level of protective current supplied to each point of the structure. It is impractical to determine the exact environmental conditions at each point on the structure, and as the environmental conditions change due to changes in soil moisture and aeration. It is also difficult to predict the actual distribution of protective current on the structure in many cases due to differing environment; the presence of other metallic structures in the vicinity of the structure to be protected, both known and unknown; and limitations on the ability to place anodes at ideal locations due to property boundaries or other limitations. Thus, while a good approximation of the system requirements can be obtained through field surveys, and a good approximation of current distribution can be made when allowances are made for differing environments and interfering structures, the installed system will, at a minimum, require initial adjustments to balance the system and periodic adjustments to maintain that balance. In some cases, particularly in the case of previously unknown interfering metallic structures in the vicinity of the structure being protected, modifications to the initially designed system may be required in order to achieve adequate protection. The design and operation of CP systems may be an iterative procedure.

B-5.2 DESIGN PARAMETERS AND CONSIDERATIONS.

B-5.2.1 Electrolyte Resistivity.

Electrolyte (soil, water, etc.) resistivity is one of the major parameters that affect CP system designs. The electrolyte resistivity must be measured during a field survey, and this parameter is used to determine anode to electrolyte resistance. The anode to electrolyte resistance is a major factor in selecting the type of CP system, the type of anodes, and the size and quantity of anodes, since the anode resistance often accounts for most of the CP system circuit resistance. High resistivity environments preclude the use of GCP systems, and the higher the resistivity, the greater the likelihood that an ICCP system will be required. Also, the higher the resistivity, the longer the anode must be, and the greater the quantity of anodes that will be required to reduce circuit resistance.

Seasonal variations at a particular location can result in significant fluctuations in soil resistivity due to changing moisture content and temperature. The designer must discuss the impact of the seasonal variations with local knowledgeable personnel as such resistivity variations will affect the CP systems design calculations, and in extreme situations, may dictate the type of CP system specified.

B-5.2.2 Cathodic Protection Current Requirement.

The current requirement is the amount of current that is required for adequate protection of the structure, and is used to help determine the type of system and the size and quantity of anodes. High current requirements increase the likelihood that ICCP systems will be required. For existing structures, the current requirement should be determined by field measurement, while for new structures, the current can be estimated using current densities appropriate for the environment.

B-5.2.3 New Construction or Existing Structure.

For existing structures, ICCP is usually more cost effective, unless the structure surface area is small and well coated. The electrolyte resistivity around existing structures and the current requirement for the structure must be measured during the design field survey. Without this resistivity and current requirement information, a CP system for the existing structure cannot be accurately designed.

-5.2.3.1 New Construction.

For new construction, the type of coating on the structure can be specified and the electrolyte resistivity measured, but accurately designing CP can be challenging due to unknown conditions that can occur during installation. Current requirements cannot be accurately calculated for new construction which is not electrically isolated.

Also for new construction other factors such as other existing CP systems and locations of other structures become very important. If the design is for new construction which connects to existing utilities, the type of system should be the same. In some cases the existing utilities CP system can protect the new construction with no further CP design or installation.

B-5.2.3.2 Structures with Existing CP Systems.

This parameter can often help easily determine the type and design of the CP system. Replacing the existing system in kind is all that is needed if the existing system functioned properly. However, GCP systems at the end of their design life are sometimes more economically replaced by ICCP systems. Also, if the previous system did not function properly, the new system should be designed to overcome the problems encountered with the existing CP system.

B-5.3 GENERAL CATHODIC PROTECTION DESIGN PROCESS.

B-5.3.1 Field/Site Surveys.

The first and foremost step of a CP system design is the field/site survey. In most cases, conduct a field/site survey in order to establish the actual environmental conditions that will be encountered, determine user requirements, and identify constructability parameters. There are only a very few instances in which a CP system can be properly designed without a field survey; therefore, always allow the designer field survey efforts when planning a CP design effort. The level of effort will be dependent upon the size and complexity of the structure(s) to be protected and whether the structure is new or existing. For submerged systems, all that is generally required is a water analysis, current requirement test (if the structure is existing), identification of interfering structures, determination of AC power sources, or other special circumstances. For buried systems, more extensive information may be required.

B-5.3.2 Electrolyte Characteristics.

Electrolyte resistivity is the single most important characteristic used in the design of CP systems for buried structures. Protective current requirements, sacrificial anode outputs, and ICCP anode bed resistance are all dependent upon electrolyte resistivity.

Other electrolyte characteristics may have a significant impact on electrolyte corrosivity and CP current requirements. Sulfide, sulfate, chloride, pH, and other chemical constituents may affect the current requirements necessary for CP as well as the protection criteria for some materials. Unless experience in the area has shown otherwise, analysis for sulfate, sulfide, and chloride content should be performed on electrolyte samples from the site.

B-5.3.2.1 Determining Electrolyte Resistivity of Soils In-Situ.

Most designers will measure soil resistivity in situ using the Wenner 4-electrode method as shown in Figures B-3 and B-4. In this method, a current is passed through two electrodes and a drop in potential through the soil due to the passage of the current is measured with a second pair of intermediary electrodes. All four electrodes are setup equidistant, and in a straight line. A specialized instrument is used to supply the current and measure the potential drop. In order to reduce the influence of any stray currents in the area and polarization at the electrodes, alternating current is used in the instrument. The soil resistivity is calculated from the indicated reading by using the following formula:

$$\rho = 191.5 \times a \times R$$

where

ρ	=	Soil resistivity (ohm-cm)
a	=	electrode spacing (feet)
R	=	meter resistance reading (ohms)

In the Wenner 4-electrode method, the average resistivity of the soil between the two center electrodes to a depth equal to the electrode spacing is measured. If the electrode spacing is increased then the average soil resistivity to a greater depth is measured. If the average resistivity increases as the electrode spacing increases, there is a region of higher soil resistivity in the deeper soil layers. If the average soil resistivity decreases with depth, there is a region of lower soil resistivity in the deeper soil layers.

B-5.3.2.2 Determining Electrolyte Resistivity Using a Soil Box.

When it is impractical to make field measurements of soil resistivity, soil samples can be taken from an appropriate depth and the resistivity of the sample can be determined by the use of a soil box. The measurement made using the soil box is essentially an application of the 4-electrode method (Figure B-5). Metal contacts in each end of the box represent the two outer electrodes in the 4-pin method, and are used to pass current through the sample. Potential drop is measured across probes on the soil box inserted into the soil. The resistivity is calculated using constants furnished with the particular size of soil box being used. Due to the disturbance of the soil during sampling and possible drying out of the soil during shipment, this method of soil resistivity measurement is less accurate than actual field tests by the preferred Wenner 4-electrode method. To minimize drying out of samples they should be placed in soil sample jars and sealed prior to shipment.

Figure B-3 Wenner Four Electrode Method Schematic

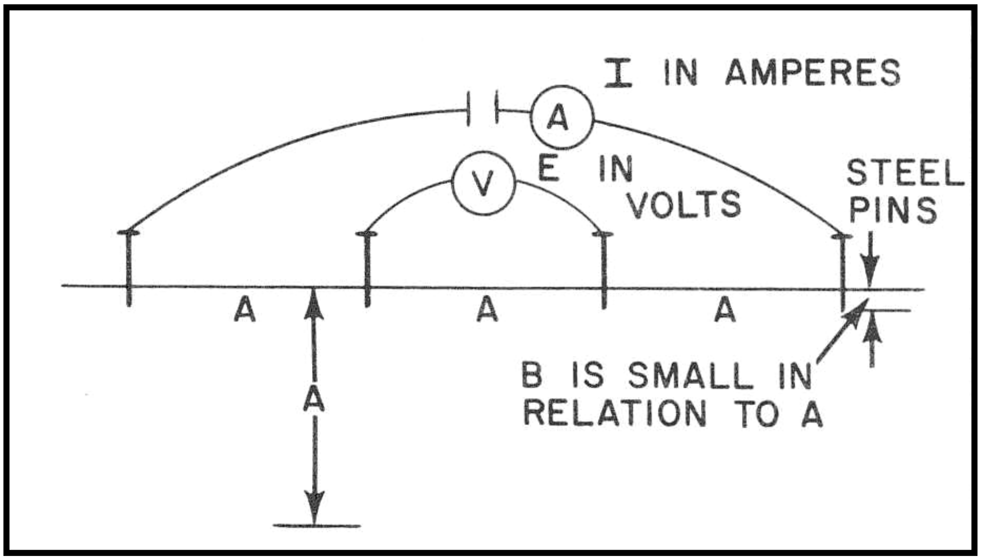


Figure B-4 Wenner Four Electrode Method for Measuring Soil Resistivity

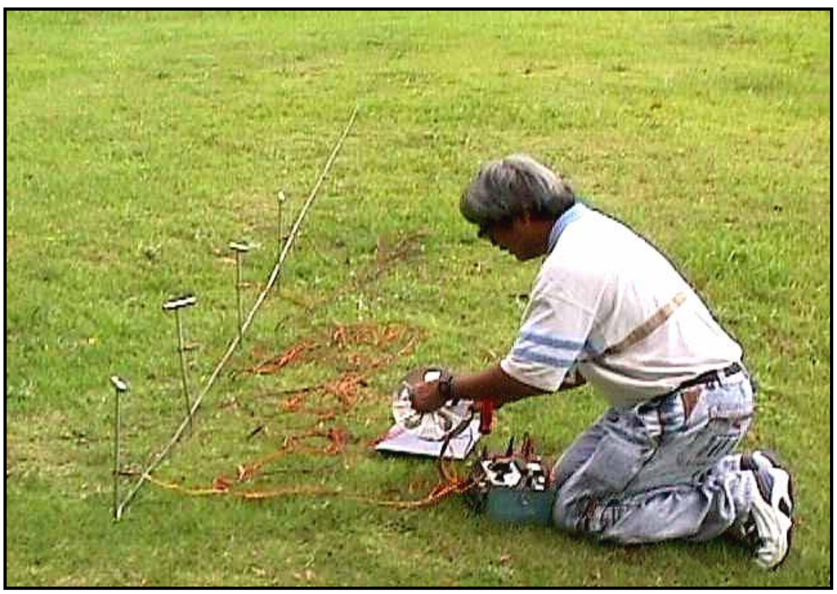
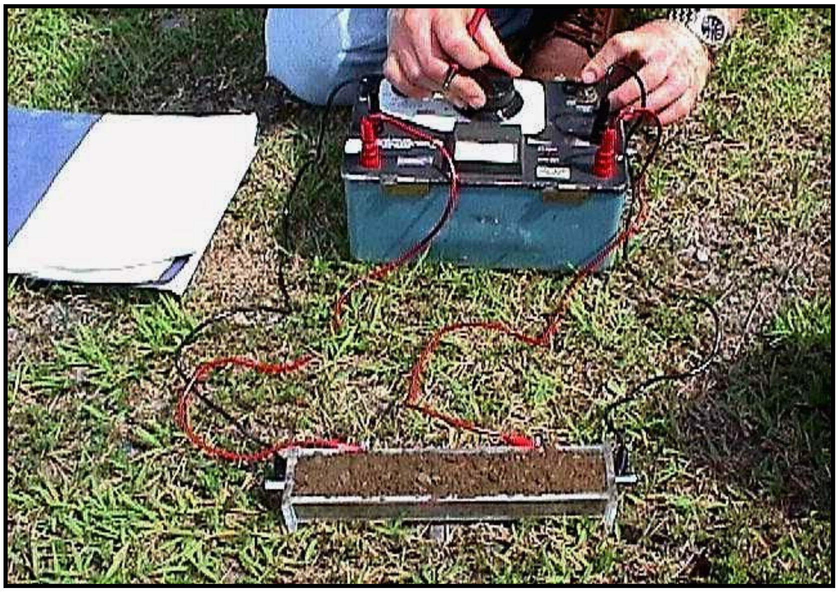


Figure B-5 Measuring Soil Resistivity in a Soil Box



B-5.3.2.3 Water Analysis.

If the CP system is being installed inside of a water tank or other submerged structure, samples of water should be analyzed for pH, chloride, sulfate, and resistivity at a minimum. Other factors such as hardness may be pertinent to the specific circumstance. The resistivity of liquids can be measured using the Wenner 4-electrode method and a soil box or by using a conductivity meter which is specifically designed for the measurement of the conductivity of solutions. Conductivity is the inverse of resistivity.

$$\rho_w = \frac{1}{C}$$

where

ρ_w = water resistivity (ohm-cm)

C = water conductivity (mhos or siemens)

B-5.3.3 Determine CP System Current Requirement.

B-5.3.3.1 Current Requirement Testing on Existing Structures.

The most desirable means of determining the amount of current required for protection of an existing structure is to measure the actual amount of current required to achieve protection through installation and operation of a temporary CP system. Perform measurements of the temporary CP currents supplied and the structure-to-electrolyte potentials achieved on the structure to establish the current required to protect the structure.

If the temporary system cannot provide sufficient current to protect the entire structure, one method to determine the total amount of current required would be to protect a section of the structure, then multiply the result to estimate the amount of current to protect the entire structure. For example if 5 amps will protect one mile of pipeline, then 10 amps should protect 2 miles. A second method is extrapolation of the current and protection levels. For example, if 5 amps provide half the required current (half the required potential shift for protection) then linear extrapolation of the current versus potential line on a graph to the desired potential shift will yield the estimated required current to protect the structure.

Verify that the current requirement test results are reasonable by comparing them to a theoretical current requirement calculation as described in paragraph B-6.2. A large variation between the results of the field tests and theoretical calculations could be a result of:

- Incorrect assumptions about the existing protective coating condition.
- Electrical continuity with other structures in the vicinity (electrical isolation may be required).
- Unknown electrical isolation of portions of segments of the structure (electrical continuity bonding may be required).
- Specific electrolyte characteristics affecting the current requirement.

B-5.3.3.2 Current Requirement Calculations for New Structures.

For the design of CP systems to be installed in conjunction with the installation of a new structure, the estimated current requirements can be calculated as described in paragraph B-6.2.

B-5.3.4 Determine Coating Conductance.

In the design of CP systems the condition of protective coatings is an important factor. Protective coatings can both reduce corrosion of structures and reduce CP current requirements. For this reason, both coatings and CP should be applied synergistically on buried or submerged structures. For existing buried structures the condition of the coating can be determined by electrical field tests of the effective electrical resistance of the coating. The resistance measurements are then usually converted to conductivity per unit area, or conductance. Procedures for determining coating conductance are beyond the scope of this UFC.

B-5.3.5 Determine Electrical Continuity and Isolation.

B-5.3.5.1 Electrical Continuity Testing.

Continuity testing is important to determine if the structure being protected is electrically continuous. It is also used to determine which foreign structures are continuous to the structure being protected. For purposes of a current requirement test, it is very important to know what structures are connected to the structure being tested for proper evaluation of the current requirement.

B-5.3.5.2 Electrical Isolation Joints (Insulating Fitting).

Determine locations where electrical isolation is necessary. Electrical isolation is necessary to minimize current requirement for both GCP and ICCP systems by isolating structures that are not intended to be protected by the CP system. Insulating joints are sometimes used to isolate sections of structures so that each section can be protected separately when necessary.

B-5.3.6 Locate Other Structures in the Area.

Buried or submerged structures other than the intended structure to be protected may impact or be impacted by the planned CP system, and the site survey should include the location of any such structures. Buried structures such as pipelines which have risers, valves, etc., in the area can be traced using electronic tracers. The presence of buried structures in the area that do not have any surface indications are difficult to locate, and the maintenance of accurate records showing all buried structures and utilities is extremely important.

B-5.3.7 Selection of GCP or ICCP Systems.

The decision between using sacrificial anode or ICCP systems is based upon two major factors, feasibility and cost. Often, a CP system using both methods is designed for a given structure and the systems are directly compared in order to select the most appropriate type of system. Economic analysis may be necessary to determine the least cost system. In general, systems with small stable current requirements (0.5 Amp or less per 100 lineal feet of structure) are more likely to be protected using sacrificial anode type systems and those structures with larger (1 Amp or more per 100 lineal feet of structure) or where the current requirements vary considerably with time are more likely to be protected using ICCP systems. ICCP systems are generally used where larger amounts of current than can be supplied by a sacrificial anode system are required.

B-5.3.8 Determine Availability of AC Power.

During the site survey, determine the availability of AC power at the site as the cost of installing new AC power service may be an important factor in determining whether a GCP or ICCP system is the more practical solution for the specific application.

B-6 TYPICAL DESIGN CALCULATIONS.

This section provides general information and practices about the CP system design calculation process. Technical Papers 16 and 17 provide additional considerations during the design process as well as simplified examples of CP system designs that the project engineer can use as guides for reviewing actual CP system designs.

B-6.1 Calculate Structure Surface Area to be Protected.

For new structures which will be protected by CP systems, field current requirement tests in most cases cannot be conducted and the current requirements will need to be calculated. The total bare surface area of the buried or submerged structure to be protected (e.g. the uncoated submerged areas of a water tank interior or the uncoated areas of a buried pipeline) must be calculated in order to calculate the current requirements. If the structure has/will have a protective coating, then the bare surface area of the structure to be cathodically protected can be significantly reduced dependent upon the protective coating efficiency. The current required to protect a well coated structure can be several orders of magnitude less than the current required to protect the same structure if it is uncoated. The reduced amount of current required for the protection of well coated structures reduces the cost of protection as well as reducing other problems such as interference with other structures.

B-6.2 Calculate Cathodic Protection Current Requirements.

For existing structures, current requirement tests should already have been conducted during the field survey. The designer should verify that the current requirement test results are reasonable by comparing them to theoretical current requirement calculations. For the design of CP systems to be installed in conjunction with the installation of a new structure, the estimated current requirements can be calculated by multiplying the required current density by the area of the structure to be protected using the equation.

$$I = A \times CD$$

where

A	=	Area of structure to be cathodically protected (ft^2)
I	=	Current required for cathodic protection (amperes)
CD	=	Current density (milliamperes/ft^2)

Table B-4 provides current density ranges for typical environments.

B-6.3 Determine CP System Circuit Resistance.

After the current requirement is determined, next determine the circuit resistance of the system. This requires calculation of the anode-to-electrolyte resistance, resistance of lead wires and the structure-to-electrolyte resistance.

Table B-4. Current Density Requirements for Cathodic Protection of Bare Steel

ENVIRONMENT	MILLIAMPERES (mA) PER SQUARE FOOT (mA/ft²)
Soil with resistivity <1,000 ohm-cm	6.0 - 25.0
Soil with resistivity 1,000 - 10,000 ohm-cm	3.0 - 6.0
Soil with resistivity 10,000 - 30,000 ohm-cm	2.0 - 3.0
Soil with resistivity >30,000 ohm-cm	1.0 - 2.0
Highly aggressive soil with anaerobic bacteria	15.0 - 40.0
Still fresh water	2.0 - 4.0
Moving fresh water	4.0 - 6.0
Turbulent fresh water	5.0 - 15.0
Hot fresh water	5.0 - 15.0
Still seawater	1.0 - 3.0
Moving seawater	3.0 - 25.0
Concrete	0.5 - 1.5

B-6.3.1 Structure to Electrolyte Resistance.

For some GCP systems, the structure-to-electrolyte resistance may be a factor, if the structure is very small or small with a good dielectric coating. In most ICCP systems, the major factor in the determination of the total circuit resistance is the anode-to-electrolyte resistance. If ICCP systems are used to protect very small or small well coated structures, the structure-to-electrolyte resistance could be a factor. Anode and structure leads are normally sized so that lead wire resistance is often negligible. Lead wire resistance may be significant if long runs of wire are required, or anode-to-electrolyte resistance is very low.

B-6.3.2 Calculate Anode to Electrolyte Resistance.

Also known as "ground bed resistance" or “anode bed resistance,” this is often the parameter that most impacts the CP system circuit resistance. Anode-to-electrolyte resistance is dependent upon the electrolyte resistivity, but can be varied within limits by the use of different sizes or quantities of anodes.

Calculate anode-to-electrolyte resistance calculations from data on soil resistivity, anode type, size, shape, and configuration of multiple anode arrays. First, arbitrarily choose the type, size, and shape of the anode to be used. Next, calculate the resistance of a single anode. Then determine the effect of the use of multiple anodes. The process is iterative and several attempts may be necessary to determine the optimum anode system and corresponding anode-to-electrolyte resistance.

During actual operation, the environmental resistivity may not be uniform, or may undergo seasonal variations, and the calculation of anode-to-electrolyte resistivity is only an approximation of the actual resistance to be encountered. Therefore, the actual CP system operation results may be somewhat different than that calculated. Thus, after installation, the system may need to be adjusted periodically to provide the required protective current output.

B-6.3.2.1 Effect on System Design and Performance.

For ICCP systems the anode-to-electrolyte resistance is an important factor in the determination of the driving potential required to provide the current required for effective CP in ICCP systems. The lowest anode-to-electrolyte resistance commensurate with total system cost is desirable since it will reduce the power costs by lowering the output potential of the power supply. This lower power supply output potential also results in higher reliability for other system components, particularly the insulation on cables, splices, and connections. In general, anode bed resistances below 2 ohms are desirable and are rarely designed over 4 ohms.

B-6.3.2.2 Basic Equations.

The formulas developed by H. B. Dwight for a single cylindrical anode are commonly used as part of an iterative calculation process to determine the anode-to-electrolyte resistance. The formulae shown below are only some of several formulae used for CP design calculations and are provided for information only. Do not reference these formulae as DOD policy. Misapplication of these formulae by unqualified personnel can result in improperly operating CP systems. The formula for a vertically oriented anode is:

$$R_v = 0.0052\ \rho/L \times [\ln(8L/d) - 1]$$

The formula for a horizontally oriented anode is:

$$R = 0.0052\ \rho/L \times \ln\{[4L^2 + 4L(s^2 + L^2)^{1/2}]/ds\} + s/L - (s^2 + L^2)^{1/2} - 1$$

where

R_v	=	electrolyte-to-anode resistance for a single vertical anode to a remote reference (ohms)
R_h	=	electrolyte-to-anode resistance for a single horizontal anode to a remote reference (ohms)
ρ	=	electrolyte resistivity (ohm-cm) at the location and depth of the anode
L	=	anode length or backfill column length if backfill is used (feet)
d	=	effective diameter of anode or backfill column (feet)
s	=	twice depth of anode (feet)

B-6.3.2.3 Special Formulae for Water Tanks.

For water tanks where circular arrays of anodes are commonly used and where the structure surrounds the anodes and electrolyte, special formulae have been developed to calculate the anode-to-electrolyte resistance. For a single cylindrical anode, the formula developed by E. R. Shepard is commonly used:

$$R = 0.012\ \rho_w \log (D/d)/L$$

where

R	=	anode-to-electrolyte resistance (ohms)
ρ_w	=	water resistivity (ohm-cm)
L	=	length of a single anode (feet) (backfill is not used)
D/d	=	ratio of anode diameter (d) to tank diameter (D) (same units for each)

The anodes are usually arranged in a circular array in the tank bowl. Determine the optimum diameter of this array by the following formula:

$$r = DN/[2(\pi + N)]$$

where

r	=	radius of anode array (feet)
D	=	tank diameter (feet)
N	=	number of anodes

B-6.3.3 Effect of Backfill.

Backfill is very important and is usually used to surround the anodes with a material of uniform resistivity to allow the anode to emit current evenly from its entire surface and reduce localized or uneven dissolution of the anode. In the case of ICCP anodes, backfill also reduces anode-to-electrolyte resistance; increases porosity around the anodes to insure that any gasses formed during operation will be properly vented; and reduces polarization effects. Under favorable circumstances, the anode-to-electrolyte resistance can be reduced to one-half through the use of backfill. In extremely low resistance environments most anodes can be used without backfill; however, except for anodes submerged in water, the use of backfill is highly recommended.

B-6.3.3.1 Backfill for GCP anodes.

For use in soil, the backfill must be used with GCP anodes in most cases and is highly desirable in most instances. The backfill typically consists of mixture of hydrated gypsum, bentonite, and sodium sulfate. Besides providing a uniform resistivity environment which reduces the self-corrosion rate, the backfill is hygroscopic and will absorb moisture from the surrounding soil to lower the resistivity and improve the anode current output.

B-6.3.3.2 Backfill for ICCP anodes.

For nearly all underground ICCP installations, provide a special carbon backfill, referred to in the industry as coke breeze, in the anode hole or column. Some of the reasons for using this special backfill include the following:

- Lower anode ground bed resistance, hence, resulting in lower rectifier design voltages and reduced probability of stray current interference.
- Improved current distribution along the anode since the backfill will provide a generally uniform environment. Helps avoid premature anode failure.Prolonged anode life since the carbon backfill is also consumed instead of anode.Stability of the anode hole or well.Permeable medium for migration of gases, thereby avoiding premature increase in anode bed resistance.When backfill is used with ICCP anodes, the effective diameter of the anode installation is the diameter of the backfill column rather than the diameter of the anode itself. This often results in a significant reduction in anode-to-electrolyte resistance which can be useful in reducing the number of anodes required, the required rectifier driving voltage, or both. Ensure that the appropriate type of backfill is specified and provided.

Backfill for ICCP anodes is carbonaceous material from several sources. It can be coke breeze (crushed coke), flake graphite, or round particle calcined petroleum coke. Specify calcined petroleum coke, or coke that has been heated to remove high resistivity petroleum by-products. The calcined petroleum coke has a lower total bulk resistivity and its more spherical particles aid in the compaction of the backfill. Experience has shown that round particle calcined petroleum coke has many advantages over coke breeze made from coal. Also, specify backfill that has a carbon content greater than 92%, preferably greater than 99%, for greater anode system life. Specify small diameter calcined petroleum coke for deep well anode installations. Because the material can be pumped and has good porosity and particle-to-particle contact, round particle petroleum coke backfill is the most desirable material and its higher cost will be justified for deep anode installations.

B-6.3.3.3 Anodes Prepackaged with Backfill.

In areas where the soil is extremely wet or loose, such as in a swampy area, it may not be possible to properly install or tamp the backfill material. Packaged anodes with the backfill contained in metal cylinders (cans) or cloth sacks surrounding the anodes may be useful in these circumstances. The package anodes will have a higher cost, but are generally easier to install than separate installation of anode and backfill. Besides the higher costs, packaged anodes also have the following additional disadvantages:

- High unit weight reduces ease of handling
- Possibility of voids developing in backfill during transportation and handling
- The critical anode cable and connection between the anode and cable are hidden and difficult to inspect

B-6.3.4 Calculate Operating Considerations.

For GCP systems, determine the circuit resistance which is the sum of the anode to electrolyte resistance, the structure to electrolyte resistance and the lead wires. The driving potential is set by the natural potential difference between the GCP anode and the polarized structure. The current can only be adjusted by adding additional anodes to increase current, or installing fewer anodes or a resistor with each anode to decrease current.

For ICCP systems, the driving potential is not set by the natural potential difference. System current is dependent upon the circuit resistance and the voltage of the power source. System current can be adjusted by changing the voltage applied to the system or by changing the circuit resistance. Circuit resistance is determined by selection of the anode size, number of anodes and anode spacing.

B-6.3.5 Determine the Number of Anodes Required.

The quantity of anodes required for the CP system is dependent upon the system current requirement and the maximum individual anode current output. The system current requirement is a function of the structure size, coating, and environment in which it is installed. The maximum individual anode current output is dependent upon anode type, anode size, and environment resistivity. For GCP anodes, anode life is determined by anode current, anode type, and anode efficiency. For ICCP anodes, anode life is a direct result of current and time. Each anode has a specific weight loss per ampere-year calculated from Faraday’s Law or from manufacturer charts in anode life versus current discharge.

For GCP anodes such as zinc, magnesium and high purity magnesium, calculate the anode life based on anode type, anode efficiency, effective useful life factor and anode current. The anode efficiency is a percent of the anode discharge for CP compared to the anodes self-corrosion rate. Zinc is normally 90 percent, while magnesium and high potential magnesium is 50 percent. The effective useful life factor is the percentage of weight loss before anode failure. For most anodes, failure will occur after 80 percent of the weight is lost.

$$\text{Anode Life} = \frac{W * u * e}{I * S}$$

where

W	=	Total Anode Weight
u	=	Anode Effective Useful Life Factor

e = Anode Efficiency

I = Anode Current Output in Amperes

S = Anode Consumption Rate

In the case of ICCP bulk anodes such as High Silicon Chromium Bearing Cast Iron (HSCBCI), the manufacturer or distributor for the anode will provide the anode consumption rate. HSCBCI is usually 1 pound per amp year. The effective useful life factor is usually 80 percent. In systems with multiple anodes, use the maximum anode output to calculate life of the anode system (not the average anode output).

$$\text{Anode Life} = \frac{W * u}{I * S}$$

where

W = Total Anode Weight

u = Anode Effective Useful Life Factor

I = Anode Current Output in Amperes

S = Anode Consumption Rate

In the case of dimensionally stable ICCP anodes such as mixed metal oxide and platinized niobium, charts are available from the manufacturer or distributor for the specific anode, usually in years at specific current outputs.

B-6.3.6 Power Supply Requirements (ICCP Systems).

B-6.3.6.1 Determine Power Supply Requirements.

Calculate the power supply requirements, namely current and voltage, using Ohm’s law and the required current for protection of the structure and the calculated or measured total circuit resistance. Include factors for anode back voltage and current losses due to unknown electrical shorts to other structures as necessary.

B-6.3.6.2 Select Power Supply Type.

Any source of direct current of appropriate voltage and current can be used as a source of power for ICCP systems. The selection of power supply depends upon local conditions at the site and should be evaluated based upon economics, availability of AC power or fuel, and the availability of maintenance.

B-6.3.6.3 Transformer-Rectifiers.

Transformer-rectifiers, or more simply, rectifiers, are by far the most commonly used power supply type for ICCP systems. They are available in a wide variety of types and capacities specifically designed and constructed for use in ICCP systems. The most commonly used type of rectifier has an adjustable step down transformer, rectifying units (stacks), meters, circuit breakers, lightning arresters, current measuring shunts, and transformer adjusting points (taps), all in one case.

The rectifier selected for a specific ICCP application must be matched to both the electrical requirements and the environmental conditions at the site. Rectifiers are available in many electrical types and specifically designed for use in ICCP systems in many environments. Technical Paper 16 provides additional details about rectifier selection as well as simplified examples of CP system designs that the project engineer can use as guides for reviewing actual CP system designs.

B-6.3.6.4 Solar Power.

For solar powered systems, solar cells convert sunlight directly into direct current electricity. Consider using solar panels for CP power supplies at remote sites where neither electrical power nor fuel is available. In order to supply current continuously, solar cells are used in a system that both supplies power to the CP system and also recharges a set of batteries when sunlight is received (Figure 4-2). When sunlight is not being received, the batteries supply the required current.

Solar powered CP systems should use high efficiency (96-98%) controls that have flexibility to match the anode ground bed and its fluctuating conditions. The controller unit should also be selected to minimize the mismatch loss between the PV array and the storage batteries. Finally, consider providing a controller that has built–in current interruption capability so that IR free (more accurate) structure potentials of the pipelines can be measured.

B-6.3.6.5 Batteries.

When current requirements are low, storage batteries can be used to supply power for ICCP systems at remote sites. They must be periodically recharged and maintained. Again, environmental and safety considerations must include procurement, maintenance and disposal of battery electrolytes, usually acids.

B-6.3.6.6 Generators.

Engine or wind driven generators can also be used to supply direct current power for ICCP systems at sites where AC power is not available.

B-7 OTHER CP SYSTEM COMPONENT DESIGN CONSIDERATIONS.

In addition to calculation and selection of the anodes used and the source of power for cathodic protection, CP systems contain other important components. The entire system must be reliable in order to provide effective protection.

B-7.1 Connecting Wires.

The connecting cables used between the various components of CP systems are vital to the proper performance of the system. Any break in the primary circuit will result in failure of the system and will require repair to restore the flow of protective current. Breaks in the auxiliary connections such as those used to test the system will also result in difficulties in proper adjustment and inspection of the system. Proper selection of cable size, type of insulation and routing is necessary for proper and reliable system operation.

Use only copper cables in any CP installation. High connection resistances and difficulty in making welded connections associated with the use of aluminum wires precludes their use in cathodic protection.

B-7.1.1 Determination of Connecting Wire Size and Type.

For sacrificial anode CP systems, the electrical currents are usually low, and the size of the conductors is normally more a function of mechanical strength than of ampacity or resistance. In systems where sacrificial anodes are used in groups such as remote anode beds, the currents can be larger and the resistive drop in the cable must be considered. Calculate the most economic wire size, but do not use wire sizes smaller than No. 12 AWG or foreign equivalent.

For ICCP systems, connecting cables should be selected based upon consideration of the following factors:

- Current carrying capacity
- Voltage attenuation (IR drop)
- Mechanical strength
- Economics (first cost versus power costs)
- Dielectric strength of insulation
- Durability (abrasion & cut resistance) of insulation

B-7.1.2 Wire Insulation.

B-7.1.2.1 GCP Systems.

For GCP systems, the connecting wires are, themselves, cathodically protected, and insulation is not as critical as in portions of ICCP systems. Specify Type TW, Type RHW-USE or HMWPE insulation. Specify HMWPE, a heavier insulation, where mechanical strength is desired. For submerged applications or chemical environments, specify the appropriate insulation that bests resists deterioration in that environment.

B-7.1.2.2 ICCP Systems.

For ICCP systems, the connection between the CP power source and the anodes are usually submerged or buried at least over part of their length. These cables are extremely susceptible to failure as they are operated at highly positive potentials. Refer to paragraph B-7.1.3.4

B-7.1.3 Recommended Cables for Specific Applications.

Because of similarities in required characteristics of the various connecting cables in many CP systems, the following paragraphs detail the established general specifications for cable sizes and types for many CP system requirements.

B-7.1.3.1 Test Wires.

Test station wires carry only very small currents and, as they are themselves cathodically protected, insulation requirements are not critical, but should be selected to match the environment. Specify solid copper wires, No. 12 gauge AWG, minimum, with type TW, RHW-USE or polyethylene insulation for this application unless otherwise dictated by economics or site conditions.

B-7.1.3.2 Bond Wires.

These wires carry more current than test wires, and may have a positive potential with respect to surrounding structures. Specify No. 4 or 8 AWG stranded copper cable with HMWPE insulation for all bond wires unless a larger wire size is required for current carrying capacity.

B-7.1.3.3 Power Supply to Structure Cables.

Specify HMWPE insulated stranded copper cable, with the wire appropriately sized for current carrying capacity, mechanical strength, and total CP circuit resistance. Wire size must conform to the requirements in the National Electrical Code. For submerged applications or chemical environments, specify the appropriate insulation that bests resists deterioration in that environment.

B-7.1.3.4 Power Supply to Anode Cable.

The insulation in these cables is critical. The connections between the CP power source and the anodes for ICCP systems, are typically buried or submerged, and are extremely susceptible to failure as they are operated at highly positive potentials. Any contact between the metallic conductors and the environment will result in rapid deterioration of the conductor and loss of continuity of the protective circuit. Specify HMWPE insulation, 0.110 inches thick, as a minimum, on these cables for most buried applications. Where exposure to chlorine will be encountered, such as in seawater or in deep well applications, specify chlorine resistant composite insulation consisting of an HMWPE outer jacket for abrasion resistance combined with an ethylene-chlorotrifluroethylene copolymer (ECTFE) inner jacket. For less critical applications such as test wires, and above ground wiring, specify thermoplastic insulation (Type TW), synthetic rubber (RHW USE), or HMWPE.

The minimum anode connection wire size is No. 8 AWG. The wire used to interconnect the anodes to the junction box or header cable, and to connect the anode bed with the power supply is commonly in the range of No. 2 AWG or larger. The actual wire size must conform to the requirements in the National Electrical Code (NEC).

B-7.1.4 Economic Wire Size.

For GCP systems, determine the most economic wire size when currents larger than one ampere flow in any portion of a sacrificial anode circuit. Compare the cost of additional anodes to overcome the resistive losses to the annual fixed costs for the cable size being analyzed.

For ICCP systems, select the size of the connection between the structure, anode bed and the power supply in ICCP systems to minimize overall cost. This can be determined by calculating the annual fixed cost of the selected wire and comparing them with the cost of power losses for the system. When the annual fixed cost and the cost associated with power losses are equal, their sum is minimal and the most economical selection of wire size is confirmed. If the power losses exceed the annual costs, a larger wire size is required. If the annual fixed costs exceed the power loss, then a selection of a smaller wire size would be appropriate. The formula for determining power loss costs is:

$$V = MK_m$$

where:

$$M = 0.0876\ I^2R$$

$$K_m = \frac{LP}{E}$$

and:

V	=	Annual cost of power losses ($)
I	=	Current Flow (Amperes)
R	=	Resistance of 100 feet of cable
P	=	Power Cost (cents/KWH)
E	=	Power Source (Rectifier) Efficiency (%)
L	=	Length of Cable (feet)

The formula for determining the annual cost of fixed charges is:

$$F = E \times S \times L$$

where:

F	=	Annual Fixed Charges ($/yr)
E	=	Estimated annual charges *
S	=	Initial Cable Cost ($/ft)
L	=	Cable Length (ft)

* The estimated annual charges used will vary. They are the sum of depreciation, interest, taxes, insurance, operation and maintenance.

B-7.2 Connections and Splices.

Wire splices and connections are a source of undesirable circuit resistance and are a weak point in the reliability of the system as they often fail due to either corrosion or mechanical damage. Buried wire splices are not permitted in many situations. Refer to the appropriate UFGS. Keep wire splices and connections to an absolute minimum, and the type of connection used must have low resistance, high reliability, and good resistance to corrosion. While connection of wires to the structure can be either by exothermic weld or mechanical connections, specify exothermic welding (Figure 4-4) as much as practicable. Avoid mechanical connections as much as practicable (Figure 4-5), as corrosion of the mechanical connection tends to result in a high resistance connection over time that could prevent the CP system from properly operating. Insulate underground connections with either epoxy encapsulation or other type of mastic compatible with the pipeline coating. Above grade connections such as wiring in test stations are typically mechanical connections and must be carefully taped in order to prevent corrosion due to the entry of moisture.

Carefully evaluate the need for additional connections and splices. Specifically show the location of all necessary splices and connections on the design drawings. The designer of the system must determine the need for additional splices and connections. Do not leave this determination to the discretion of the installer.

B-7.2.1 GCP Systems.

The following connections are required for GCP anode systems and must be shown on the design drawings:

- Connection between anode(s) and structure through a test station.
- Connection between cable and anode (Must be factory made or connection is attached to cast-in core)
- Necessary bonds and test wires

B-7.2.2 ICCP Systems.

The following connections are required for ICCP systems:

- Connection between power source and structure
- Connection between anode bed(s) and power source (anode header cable)
- Connection between anode header cable and each anode
- Connection between cable and anode (must be factory made)
- Necessary bonds and test wires

Carefully insulate all connections, particularly in the anode to power supply portion of the circuit where any loss of insulation integrity will result in rapid system failure. All connections in the power source-to-anode bed portion of the circuit and all cable-to-cable connections must be insulated by encapsulation in epoxy using commercially available kits made expressly for this purpose.

The cable to structure connection is less critical and either epoxy encapsulation or insulation with mastic must be used on this connection.

B-7.3 Bonds and Insulating Joints.

CP designs must include provision of electrical continuity bonds where necessary to ensure electrical continuity of all of the structures to be protected. Portions of metallic utility distribution pipeline systems are often replaced with non-metallic pipe sections, introducing electrical discontinuities into the pipeline system. Base utility distribution system plans are not always updated to reflect these replacements, and the designer should be allowed to conduct field current requirement and continuity tests to verify continuity if any doubt. If electrical discontinuities cause the pipeline system to be too fragmented, consider providing multiple smaller CP systems. Some isolated sections of pipelines may be small enough to use GCP anodes.

Use HMWPE insulated seven-strand copper cable, No. 8 AWG or larger cable for bonds between sections of the protected structure or between the protected structure and a foreign structure (Figure 4-3). Run all resistive bonds into a test station to allow for adjustment. Also run direct bonds into test stations if future adjustments or connections may be required. Make all bond-to-structure connections using exothermic weld connections, insulated by epoxy or mastic encapsulation.

B-7.4 Test Stations - Location and Function.

Include the location and wiring of all test stations in the system design. Color code all test wires, or identify them with non-corroding metal or plastic identification tags indicating the system component to which they are connected. Locate test stations either flush with the pavement or soil surface as shown in Figure B-6, or above grade as shown in Figure B-7. In either case, use test stations manufactured specifically for the intended purpose. Flush mounted test stations are preferred in paved areas or other areas where damage by vehicles, operational equipment, etc. is anticipated. Above grade test stations are preferable in unpaved areas and areas where flush mounted test stations can easily be covered over and lost. Provide test stations for all foreign structures that cross the protected structure or are in the vicinity of the anode bed. Provide test stations for all pipeline casings, underground dielectric insulation unions and flanges, at all foreign line crossings, and other components such as bonds to facilitate testing.

Balancing resistors are sometimes required when multiple anode beds are used with a single rectifier. Install these resistors in an above grade terminal box as shown in Figure B-8.

Figure B-6 Typical Ground Flush Mount Test Station

Figure B-7 Above Grade Test Stations. PVC Pipe Mount on the Left, Pole Mount in the Center, and Wall Mount on the Right.

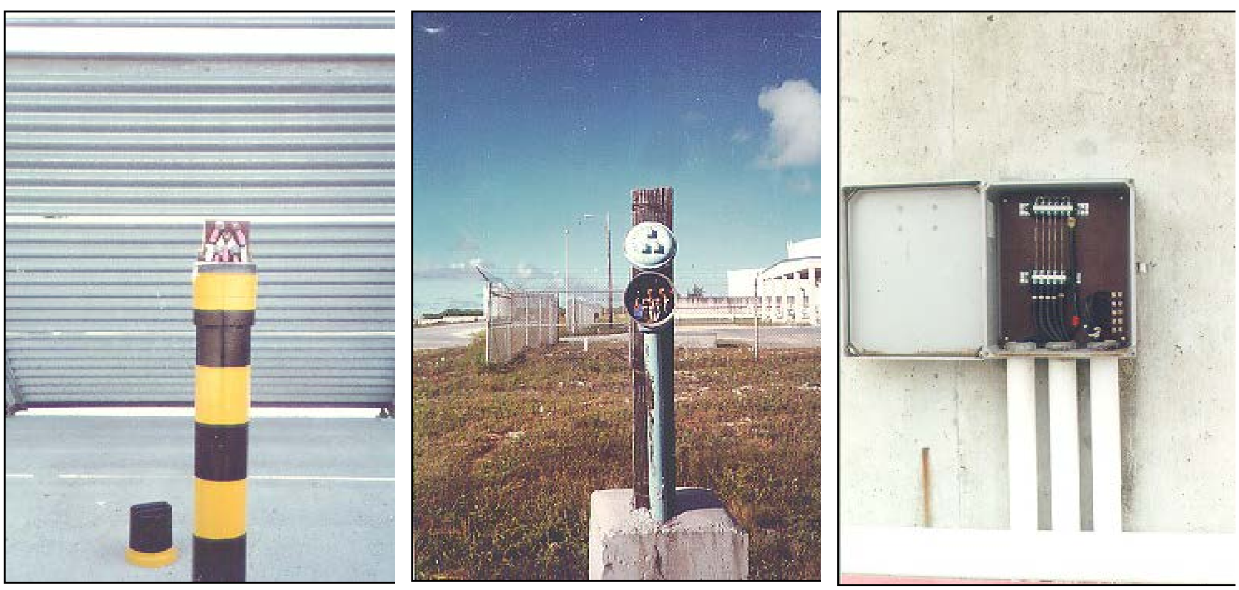


Figure B-8 Resistors in an Above Grade Terminal Box

B-7.4.1 GCP systems.

The most common type of test station used in GCP systems is the current-potential test station shown in Figures B-13 through B-11. In this test station, the anode lead wire is connected to the structure lead using a 0.01 ohm resistor (shunt) which is used to measure the current output by measuring the voltage drop across the shunt. The second structure lead is used to measure the structure potential using a non-current carrying connection thus eliminating any potential drop along the conductor. The second structure connection can also be used as a spare if the primary structure connection is damaged. Test stations for GCP systems can either be of the flush mounted or above grade type.

If flush mounted test stations are used, the soil exposed in the bottom of the test station can be used to measure the structure to electrolyte potential. Location of such test stations directly over the structure is advantageous as IR drops due to current flowing through the soil are minimized. Other test stations which are used in GCP systems are the potential test station, the soil contact test station, the line current (IR Drop) test station, the insulating joint test station, the casing insulation test station, and the bond test station.

Figure B-9 Flush Mounted Current-Potential Test Station

Figure B-10 Pipe Mounted Test Station. Figure on Right is a Close-Up of the Test Station "Head" or Terminal Board.

Figure B-11 Wall/Pole Mount Type Test Station.

B-7.4.2 ICCP systems.

There are five basic types of test stations used in ICCP systems:

- The potential test station (see Appendix D)
- The soil access test station (see Appendix D)
- The line current (IR Drop) test station
- The casing insulation test station
- The bond test station (see Appendix D)

Specify solid copper wires, No. 12 AWG, either TW or RHW-USE insulated. If future bonding across flanges or between structures may be required, connect HMWPE insulated stranded copper cables, No. 8 AWG or larger if required, to the structure(s) and run them into a test station for future use.

B-8 DESIGN PRACTICES THAT FACILITATE OPERATION AND MAINTENANCE.

Design of the system must include required items needed to conduct operations and maintenance on the system. Over the life cycle of the system, these items will save time by making it easier for personnel to perform the required testing, troubleshooting and repair of the system. Without sufficient test stations and test access, it may be impossible to accurately evaluate a CP system for adequacy of protection.

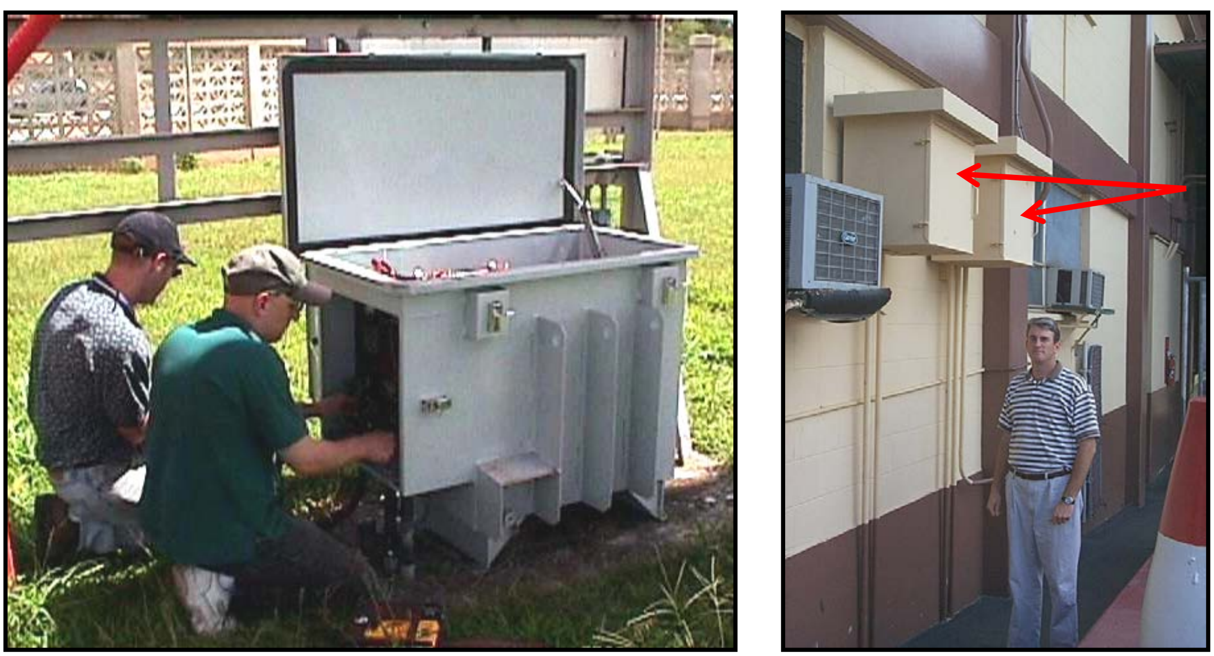
B-8.1 As Built Drawings.

Require accurate and detailed drawings of the installed system and the structure be provided upon project completion to allow base personnel to perform comprehensive evaluation, testing, troubleshooting or repair. The accurate location of all CP components, especially anodes and anode cables, can save days of effort by repair crews attempting to repair breaks in these cables. Structure leads, although less likely to fail, can be extremely difficult to locate and repair. Proper evaluation of CP systems requires accessing all test points on the structure and all CP components. As built drawings save a great deal of time when locating the test stations, finding the permanent reference cell locations, and other testing requirements, such as foreign line crossings, bonds, isolations and casings.

B-8.2 Locate Equipment Where Readily Maintainable.

Locate CP equipment where they would be readily maintainable. Locate rectifiers where they may be easily inspected and repaired. Rectifiers that are inaccessible are not likely to be properly maintained (Figure B-12). The rectifier in the picture on the left of Figure B-12 is easily accessed. The two rectifiers in the picture on the right are mounted over six feet high and will likely not be properly maintained Provide test stations that are appropriate for the environment in which they are located. For example, do not specify flush mount test stations where there is a high probability that they will be covered by soil or vegetation. If flush mount test stations must be used in such areas, provide test station markers (Figure B-13). Provide insulating joints where they can be readily tested.

Figure B-12 Rectifiers Located for Ease of Maintenance. .



B-8.3 Test Stations.

Provide test stations to allow access to the structure for potential surveys to determine if adequate CP has been achieved. They are also necessary to perform recurring maintenance, troubleshooting and repair of the system during its life cycle. Installing a sufficient number of test stations to allow access to and testing of the structure at all locations is essential to maintaining the system. All test stations must include two wires to each structure protected or impacted by the CP system. This allows the maintenance crew to test the connection to the structure and allows for possible bonding or interference bonding. It is also important to have access to foreign lines to provide for interference testing and possible mitigation.

Provide test stations on all foreign lines that cross the protected structure or are in the vicinity of the anode bed. These test stations must be accurately shown on the as built drawings, especially if they are not located over the protected structure. Provide test stations for all pipeline casings, at all foreign line crossings, and for other components such as bonds. Provide test station markers (Figure B-13) for flush mount test stations on cross country pipelines to facilitate location of these test points.

Figure B-13 Test Station Marker for Flush Mount Test Station.

Since test stations are manufactured in many different types and configurations, ensure that they are adequately sized and configured for the number of test wires and intended purpose of the test station. Some small flush mount test stations are manufactured with five or more terminals on the terminal board, but when installed with thick HMWPE insulated wire, are difficult to open and close often resulting in damage to the wiring terminals and measuring shunts (Figure B-14). Provide test stations large enough to appropriately accommodate the wire quantity, size and insulation type and facilitate maintenance and testing.

Figure B-14 Small Flush Mounted Test Station with Too Many Large Sized Wires.

B-8.4 Markers and Labeling.

Clearly mark and label wires in all test stations and rectifiers. Wire colors, markings and test station labeling must be uniform and systematic. Rectifiers and test stations must be numbered and accurately included in the as built drawings. Rectifier anode and structure leads must be permanently marked; and very importantly, anode leads and structure leads must never be mixed up, as catastrophic results would ensue. Refer to paragraph B-9.1.4.

B-8.5 Test Access.

Provide soil access test stations to allow the reference electrode to contact the same electrolyte that is in contact with the protected structure (e.g. where a pipeline runs under an extensive paved area such as an airfield parking apron). Reference electrodes cannot “read” through non-electrolytes such as plastic, rubber, oil or asphalt. Reference electrodes also cannot accurately “read” through concrete, especially if it is reinforced concrete. Possible shorts of the reinforcing steel to the protected structure would cause the reference cell to “see” the rebar, instead of the protected structure. Therefore, provide sufficient soil access test stations to allow for accurate monitoring, evaluation, and troubleshooting of the CP system.

B-8.6 Permanent Reference Electrodes (PRCs).

Provide PRCs in locations to facilitate testing of the CP potentials on a structure where portable reference electrodes cannot access the electrolyte, or access would be difficult or dangerous. Provide PRCs at locations such as under storage tanks, between pipeline crossings, under pavement or concrete, inside of water tanks and elevated water towers, and along waterfront structures. PRCs also allow for reliable and repeatable data and are often installed at specific points along the structure. Also install PRCs at critical points to allow them to be monitored remotely. When practical, install multiple PRCs in hard to reach areas, such as under the bottoms of on-grade storage tanks and inside elevated water tanks, to allow remote testing of the structure using the PRC. One PRC can be used to test the accuracy of another PRC. PRCs used to control automatic rectifiers are especially prone to failure and should have multiple back up PRCs installed to allow for testing of the PRCs and swapping of the control PRC if required.

B-8.7 Electrical Resistance Probes.

Where it is beneficial to also know actual cumulative corrosion rates in addition to CP system effectiveness, provide electrical resistance (ER) probe(s) in addition to PRCs. An ER probe monitoring system consists of an electrical resistance meter, usually with data logging functions, connected to a probe. This technique operates by measuring the change in electrical resistance of a metallic element immersed in a product media relative to a reference element sealed within the probe body. If the corrosion occurring in the vessel or structure under study is roughly uniform, a change in resistance is proportional to an increment of corrosion. Although universally applicable, the ER method is uniquely suited to corrosive environments having either poor or non-continuous electrolytes such as vapors, gases, soils, hydrocarbons, and non-aqueous liquids. ER probes are manufactured in various configurations, and Figure B-15 illustrates is an example of one type of ER probe.

Figure B-15 Example of an ER Probe

Metal loss from and ER probe is cumulative over time. The electrical resistance meter measures the resistance and an algorithm calculates the cumulative corrosion rate over the period of time since the initial measurement. After a probe is connected to a CP system, declining corrosion rates suggest that the CP system has mitigated corrosion of the probes. The cumulative corrosion rates on a structure with an effective CP system would be expected to continue to decrease to negligible rates with time.

When used to monitor a structure under CP, the ER probe should be allowed to freely corrode for a short period of time before electrically connecting it to the cathodically protected structure. Over time, it will be necessary to temporarily disconnect the ER probe to make a measurement after which, the probe must be reconnected back to the cathodically protected structure. Since the system is measuring very small resistances, take the following measures to prevent premature failure of the ER probe system:

B-8.7.1 Probe Location.

Select and install probes in locations to preclude physical damage. On waterfront applications, avoid locations where floating debris and day to day operations can result in damage to the probes or connecting wires.

B-8.7.2 Prevent Water Intrusion.

For submerged applications, it is imperative to take every effort to prevent water intrusion into, and the subsequent corrosion of the connector between the probe and its lead wire. Encapsulate the probe connection to the lead wire (Figure B-16). For submerged applications, pre-assemble sections of conduits to be submerged before installation. This is also necessary to prevent water infiltration into probe-lead wire connection (Figure B-17).

B-8.7.3 Connection to CP System.

After allowing the probe to freely corrode for a short period of time, connect the probe to the cathodically protected structure as soon as practical after the CP system is energized. For probes to be installed in the vicinity of CP systems, particularly those operating at high CP system current levels, the potential for stray current effects and resulting pre-mature failure of the probe is high. Design a good connection means between the probe and the cathodically protected structure that will easily enable temporary disconnection to take measurements with the ER meter.

B-8.7.4 Backup PRC.

If a monitoring location is critical, provide a backup PRC adjacent to the probe in the event the probe fails and cannot be immediately replaced.

Figure B-16 Probe with Encapsulated Connector.

Figure B-17 Pre-Assembled Conduit System, Probe, and PRC for Submerged Use.

B-8.8 Coupon Test Station System.

Coupon test stations include a small sample of metal (coupon) made of similar material as the protected structure usually packaged with a PRC. The packaged coupon/PRC is typically installed adjacent to a buried or submerged structure with test wires running to a convenient measuring point (test station). Such devices allow for error free reading when the CP current to the structure cannot be easily interrupted.

Potential measurements of underground structures made with a PRC placed on the electrolyte surface or buried PRCs often contain an error known as voltage (IR) Drop error. IR Drop error results from the interaction of the CP current with the soil resistance. One way of accounting for this error is to momentarily interrupt the CP current and measure the potential immediately after interruption. This so-called "instant-off" potential can be substantially free of IR Drop error. Even in cases where current interruption is possible, there may be other sources of current at that location such as those from nearby CP systems, stray currents or telluric currents. Cathodic protection coupons, sometimes called instant off sensors, provide a means to make instant off potential measurements under those conditions.

Coupons are sometimes installed for structures protected by a GCP system with numerous distributed sacrificial anodes. It is nearly impossible to feasibly interrupt CP current on such systems and coupons provide a means to measure IR free potentials.

B-8.9 Anode Current Output.

Design systems with capability to monitor anode output currents. Provide readily accessible test stations with individual current measuring shunts to simplify measuring of individual anode current outputs to ensure that anodes are properly operating and are not being overdriven. Ensure terminals are prominently identified and wires are tagged. Figure B-18 illustrates an example anode junction box.

B-8.10 Electrical Isolation Testing.

Locate dielectric isolating flanges or unions where they may be readily inspected and tested. Preferably, locate these joints in valve pits, or located above grade.

Figure B-18 Anode Junction Box

B-8.11 Remote Monitoring.

For critical or remote locations, consider the use of remote monitoring equipment to monitor the CP system and the protected structure. A remote monitoring unit (RMU) can include components to monitor rectifier output, potential reference cells, interference test bonds, critical bonds, or foreign structure potentials. Remote monitoring can give an instant alarm if the system goes above or below set points. Monthly monitoring can result in up to 60 days between checks, and requires a crew to travel to the location and perform testing. Most RMUs are paid for by savings in these testing costs over a short period of time, when there are sufficient quantities of systems or distance between CP equipment locations. Remote monitoring systems also aid in collection and management of data for historical records.

B-8.11.1 Remote Monitoring Communication Methods.

Remote monitoring units commonly communicate by cell phone technology; telephone land lines; Supervisory, Control and Data Acquisition (SCADA) systems; or satellite transmission technology. Remote monitoring units, and automated data collection units must be planned, designed, acquired, executed and maintained in accordance with DoD Instruction 8500.01 and DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

B-8.11.2 Remote Monitoring Selection Considerations

The following are some important considerations for selecting and installing a remote monitoring unit.

B-8.11.2.1 Rectifier Information.

Prior to selecting the RMU unit, collect adequate information about the rectifier and the location of the installation in order to obtain properly sized/configured RMU components.

- Rectifier maximum DC output voltage and current
- Availability of A/C power, including the operating A/C voltage, and means of running AC power cables to the unit
- RMU mounting location and method of mounting
- Need for one way or two-way communication
- Characteristics of the local operating environment

B-8.11.2.2 RMU Unit Type and Suitability.

Research the various units to determine which units would be most suitable for their intended application. Prior to selecting a satellite communication unit, ensure satellite coverage/location of satellites will allow sufficient communication signal strength where the RMUs will be installed. Install the antennas in a location that allows good communication.

B-8.11.2.3 RMU Power Source.

Ensure that the units selected have a reliable power source. Select units utilizing A/C power or solar power as the primary source and batteries serving as a back-up/secondary power source in the event the primary power source fails.

B-8.11.2.4 Surge Protection.

Provide units with proper surge protection and isolation if the locations of these units are subject to frequent AC power surges or lightning strikes during inclement weather.

B-8.12 GPS Synchronizable Interruption.

For long pipelines that may require close interval, instant off surveys, the installation of GPS synchronizable interrupters in all rectifiers can reduce costs of all future surveys. These are normally used for gas and fuel lines that are monitored in house. The interruption cycle start and stop times are set by computer, then the survey is completed during that time. All rectifiers are turned on and off at specific intervals for a specific time, synchronized together using GPS signals.

B-9 LESSONS LEARNED AND OTHER PRECAUTIONS FOR CP SYSTEM DESIGN.

B-9.1 Common Problems and Design Deficiencies.

B-9.1.1 Qualified Personnel.

Ensure new projects are designed, reviewed, monitored and inspected by qualified personnel. New systems that are not designed, installed, or tested properly result in inadequate corrosion control or even corrosion damage and significant loss in life cycle costs of government infrastructure and assets. Work accomplished by qualified personnel provides greater reliability of critical assets such as fuel systems, fire protection, gas and other infrastructure required for mission accomplishment, safety and environmental protection.

B-9.1.2 Improper Application of GCP Systems.

Table B-5 provides some commonly found problems with CP designs of GCP systems, particularly when unqualified personnel accomplish the design, that result in inadequate CP of the structure or other problems associated with cathodic protection.

B-9.1.3 Improper Structure Bonding/Electrical Discontinuities.

Application of ICCP to a pipeline distribution system with electrical discontinuities will result in unprotected areas and possible interference to the electrically discontinuous section(s) of the structure intended to be protected. All electrically discontinuous section(s) of the structure(s) to be protected must be properly bonded into the system to ensure adequate protection. Common causes of electrical discontinuities include

- Dresser couplings
- Mechanical pipe section connections such as found in ductile iron pipe
- Plastic valves and fittings
- Non-metallic sections of pipeline (new, existing or future installation)
- Improper bonding (or lack of bonding) on joints, flanges or previously installed dielectric isolation unions or flanges

Provide electrical continuity bonds where necessary to ensure electrical continuity of all of the structures to be protected.

Table B-5. Common Problems with GCP System Designs

PROBLEM	SOLUTION
Use of GCP system for bare or poorly coated structures, for example aboveground storage tank bottoms or pipeline distribution systems. In most cases, GCP system cannot economically protect bare or poorly coated structures.	• Use ICCP system. • Where applicable, isolate the structure into smaller sections for which GCP systems are feasible.
Use of GCP system in high soil resistivity, for example underground pipelines, underground storage tanks.	• Use ICCP system. • Where feasible, consider non-metallic materials for the structure.
Use of GCP system for isolated laterals to a main with ICCP system results in interference problems on the lateral.	• Consider using deep well anodes for the ICCP system. • Include provisions for proper bonding. • Consider ICCP system for entire structure.
Use of GCP system for improperly electrically isolated structures. Failure of existing dielectric unions or flanges and other shorts result in loss of protection to the entire structure. One electrical short can result in loss of protection to the entire structure.	• Properly electrically isolate the protected structure. • Install electrical isolation in readily maintainable location. • Consider if ICCP system feasible.
Excessive spacing of sacrificial anodes resulting in inadequate protection of the structure between successive anodes. This is often caused by improper design, over estimating the coating efficiency, or under estimating the soil resistivity or anode output (resistance to earth).	• Ensure qualified designer. • Do not guess the coating efficiency. Conduct field test. • Do not guess the soil resistivity. Conduct field test. • Do not guess on current requirement. Conduct field test. • Use correct parameters in calculations.

Portions of metallic utility distribution pipeline systems are often replaced with non-metallic pipe sections, introducing electrical discontinuities into the pipeline system. Base utility distribution system plans are not always updated to reflect these replacements; therefore, allow the designer to conduct field current requirement and continuity tests to verify continuity if any doubt. Where feasible, during installation of new non-metallic pipe, provide adequately sized tracer wire for the non-metallic pipe sections that can double as a bond wire. As this may not always be technically feasible; alternatively, install tracer wires/tapes/devices directly above the plastic pipe at a depth that will be detectible by current detection equipment and technologies. If electrical discontinuities cause the pipeline system to be too fragmented, consider providing multiple smaller CP systems. Some isolated sections of pipelines may be small enough to use GCP anodes, but the designer must consider possible interference problems on these sections.

B-9.1.4 Improper structure connection.

Improper connection of the structure to an ICCP system is another common problem. Examples of improper connection include:

B-9.1.4.1 Improper Connection to Conduit Pipe.

An ICCP system is improperly applied to a high temperature hot water distribution system with structure connections to the inner carrier pipelines instead of the outer conduit that results in interference and corrosion of the conduit. In this case, the CP was intended for the outer conduit, not the interior carrier pipe.

B-9.1.4.2 Improper Connection of Rectifier Lead Wires.

ICCP rectifier positive and negative lead wires (rectifier positive lead is improperly connected to the structure to be protected and the negative lead to the anode bed) that results in serious corrosion of the structure. This results in the structure protecting the anodes, and the structure suffering severe corrosion damage in a relatively short time. For proper CP system operation, ensure connection of the rectifier negative lead to the structure and the positive lead to the anode bed.

B-9.1.5 Improper Consideration of Permanent Reference Electrodes (PRCs).

PRCs do not last forever. PRCs used in water tanks and water towers, especially when used in conjunction with an automatic rectifier, often fail with time, resulting in excessive current (automatic rectifier increases its output in attempt to attain proper potential readings with the PRCs) that can cause cathodic disbondment of the coating.

PRCs used under on-grade storage tank bottoms fail because of one or more of the following causes:

- High resistivity of, plus a lack of moisture in the tank bedding material that causes excessive contact resistance and inability to obtain accurate potential readings
- Fuel contamination of the PRC again affecting the accuracy of the PRC or causing deterioration of the insulation of the connecting wires and eventual failure

The difficulty in replacing these PRCs often result in the PRCs not being replaced, leaving base personnel with little or no means to determine if the structure is adequately protected. In extreme cases, the anodes may also fail for the same reasons and with the loss of the PRCs it becomes impossible to determine if adequate protection is present. Alternative solutions for consideration include:

- Providing dual element (copper-copper sulfate/zinc) PRCs
- Providing a secondary means of measurement consisting of several perforated/slotted plastic pipes in the tank bedding installed radially to allow insertion of a portable reference electrode in the tube at any distance between the tank outer edge and the center

B-9.1.6 High Temperature Hot Water (HTHW) Systems.

HTHW distribution systems have many problems associated with electrical isolation reliability and failure of GCP systems; therefore, provide an ICCP system instead, capable of protecting the structure without requiring electrical isolation at numerous locations. Inadvertent failure to install a single insulator, thermal failure of a single installed insulator, or inadvertent removal of a single insulator during routine maintenance can render a GCP system to be ineffective. An ICCP system will generally have some spare capacity to adjust the output current in case of such an event. However, an ICCP system design may result in large current requirements, and to preclude interference, may require bonding or interference mitigation on other buried metal structures in the vicinity. Such an ICCP system should only be designed by a certified CP Specialist. Base the design on data taken during a design field survey that is representative of the entire system. Do not base the design of a CP system for a HTHW piping system upon a single soil resistivity measurement.

B-9.1.7 Aboveground (On-grade) Fuel Storage Tanks.

Provide ICCP systems for the exterior bottoms of aboveground storage tanks with a secondary containment liner. Anodes must be installed in the backfill between the tank bottom and the containment liner. Do not specify GCP systems unless mission requirements preclude the use of ICCP systems. Provide a combination of permanent reference electrodes, corrosion probes, and reference electrode tubes to allow sufficient long-term testing and monitoring of the CP system effectiveness. Provide a separate CP system for buried distribution pipelines associated with the tank.

Provide a properly designed ICCP system for aboveground storage tank bottoms without secondary containment liners. With the many other systems incorporated into these storage facilities, complete electrical isolation can be difficult to achieve. Automated tank gauging systems, product recovery systems, leak detection systems, electrical grounding systems, fire protection systems, bonding systems and other miscellaneous conduits and controls include components that will inadvertently bypass installed electrical isolation devices. The tank may also be connected to a grounding system for safety, precluding the possibility of complete tank isolation. Provide CP for buried distribution pipelines associated with the tank. Consider electrical isolation issues, stray current interference issues, and life cycle costs to determine the need for a single integrated CP system for the tank and pipelines or separate systems for the tank and pipelines.

B-9.1.8 Excessive Cathodic Protection (Overprotection) Concerns.

Excessive CP (overprotection) is caused by application of excessive amounts of CP current and voltage. In addition to being wasteful of anode material or electrical power, excess potentials can cause disbondment of protective coatings; hydrogen embrittlement of certain types of steels, especially high strength steels; and corrosion damage of amphoteric metal structures made of aluminum and lead. Excessive CP current can also cause stray current (or interference) corrosion damage other metal structures in the vicinity.

B-9.1.8.1 Coating Disbondment.

Excess CP current results in protective potentials above established limits, and can result in the generation of hydrogen gas. Cathodic protection levels at potentials exceeding a polarized potential of -1.1 V with respect to a copper/copper sulfate reference electrode, result in the generation of excessive amounts of hydrogen gas on the surface of a protected metallic structure. When more gas is generated than can permeate the coating, bubbling or blistering of the protective coating occurs, causing disbonding of the coating from the structure surface. Electrolyte (water) can subsequently fill the space left between the coating and the metal, and as the coating is an electrical insulator, sufficient current for effective CP cannot flow to the affected area between the coating and the structure surface. Without CP, corrosion of the structure under the disbonded coating will occur.

Coating disbondment is a particular problem in water tanks in which the type of coating provided is especially prone to hydrogen disbondment and protective potentials exceed polarized potentials of -1.1 Volts DC. In soil environments where high quality coatings were provided, disbondment seldom occurs at potentials less negative than -1.1 Volts DC polarized potential (instant off).

B-9.1.8.1 Hydrogen Embrittlement.

The hydrogen produced when CP currents are excessive can also result in the reduction of the ductility of steel. This is particularly true for high strength steels (in excess of 130,000 pounds per square inch yield strength). This could lead to cracking from stress and loss of yield strength.

B-9.1.9 Stray Currents or Interference Concerns.

Stray currents, also called interference, result from external electromotive forces and can greatly accelerate corrosion. Stray current corrosion can be caused by voltage gradients (current flow) resulting from DC transit systems, HVDC Transmission systems, DC welding, telluric earth currents, and CP systems. The amount of corrosion caused is directly proportional to the amount of DC current flowing in the electrolyte. Steel corrodes at a dissolution rate of about 20 pounds per ampere-year. CP systems can impress large amounts of current from their anodes, through the electrolyte, to the cathode.

When a metallic structure not connected to or intended to be protected by the CP system (referred to as the “foreign” structure) is immersed in the same electrolyte in the vicinity of the protected structure, it is subjected to stray current corrosion because of the electromotive force being applied through that electrolyte and can undergo extremely severe corrosion without proper mitigation.

B-9.1.9.1 Mechanism of Stray Current by CP Systems.

A CP system is a large corrosion cell, a result of an electro-chemical reaction that involves electrical current flow and chemical ion migration. The current flowing from the anodes of a CP system flows through an infinite number of paths in the electrolyte toward all parts of the intended protected structure. Since the CP system is an electrical circuit, all of the electrical current provided by the rectifier through the anodes and the electrolyte must eventually return to the rectifier. In doing so, the basic laws of electrical current flow prevail, and most of the current will flow through the path of least resistance. A “foreign” metallic structure in the vicinity of the protected structure may provide such a low resistance path back to the rectifier. Figure B-19 illustrates an example of interference on a pipeline in the vicinity of DC rail systems. Figure B-20 illustrates an example of interference on “foreign” pipelines in the vicinity of a CP system.

Where the current flows from the electrolyte onto the “foreign” structure, the current will collect and flow along the foreign structure until a low resistance path, commonly where the “foreign” and protected structures physically cross or are in close proximity, will allow the current to flow off of the foreign structure into the electrolyte towards and onto the protected structure to eventually return to the rectifier. At these points where the current flows off of the “foreign” structure (discharges) into the electrolyte, oxidation reactions (corrosion) occur. At metal dissolution rates of 20 pounds per ampere-year, significant interference concentrated at discharge points such as a coating holiday on the foreign structure could cause significant amounts of corrosion in a very short amount of time, in some cases, as quickly as several days.

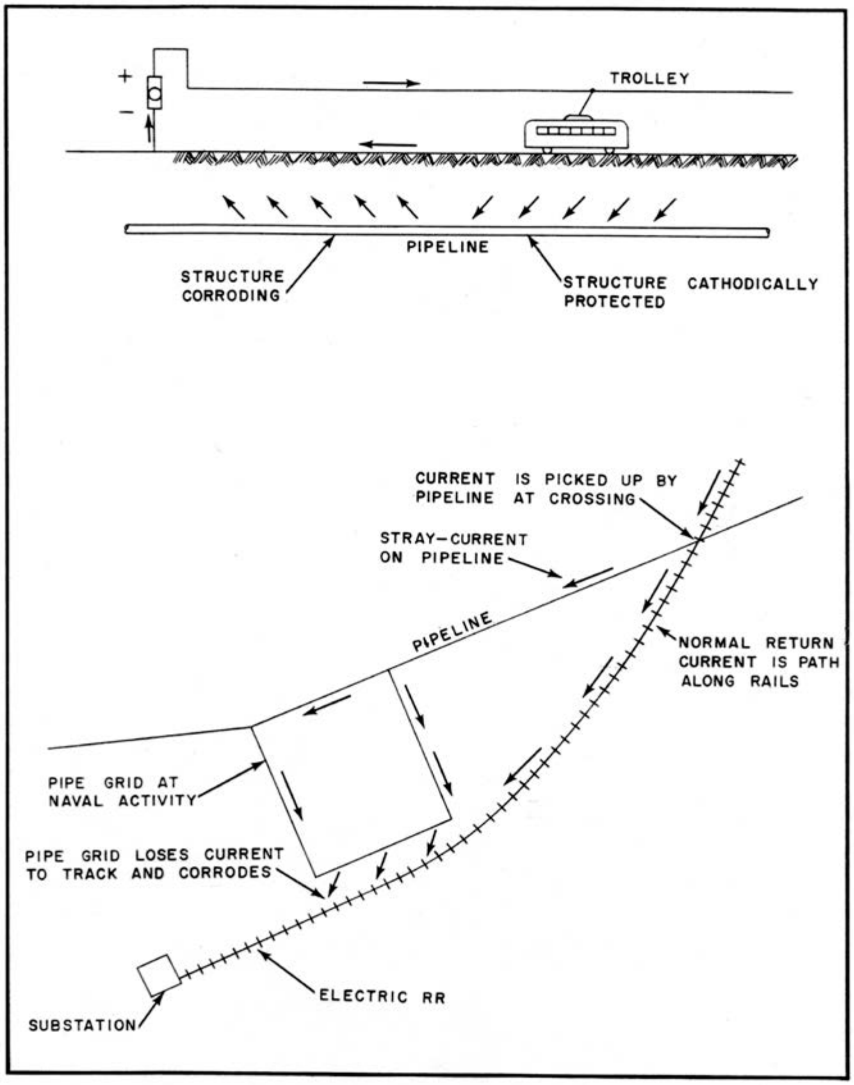
B-9.1.9.2 Impact of Stray Currents on the Protected Structure.

Although corrosion is not usually accelerated on the protected structure, cathodic interference can disturb the desired current distribution on the protected structure, and can reduce the amount of CP in some areas of the protected structure to inadequate levels.

B-9.1.9.3 Detecting Interference.

Cathodic protection interference problems are most commonly detected through the measurement of structure-to-electrolyte potentials. Where necessary, conduct stray current interference testing as part of the design field survey.

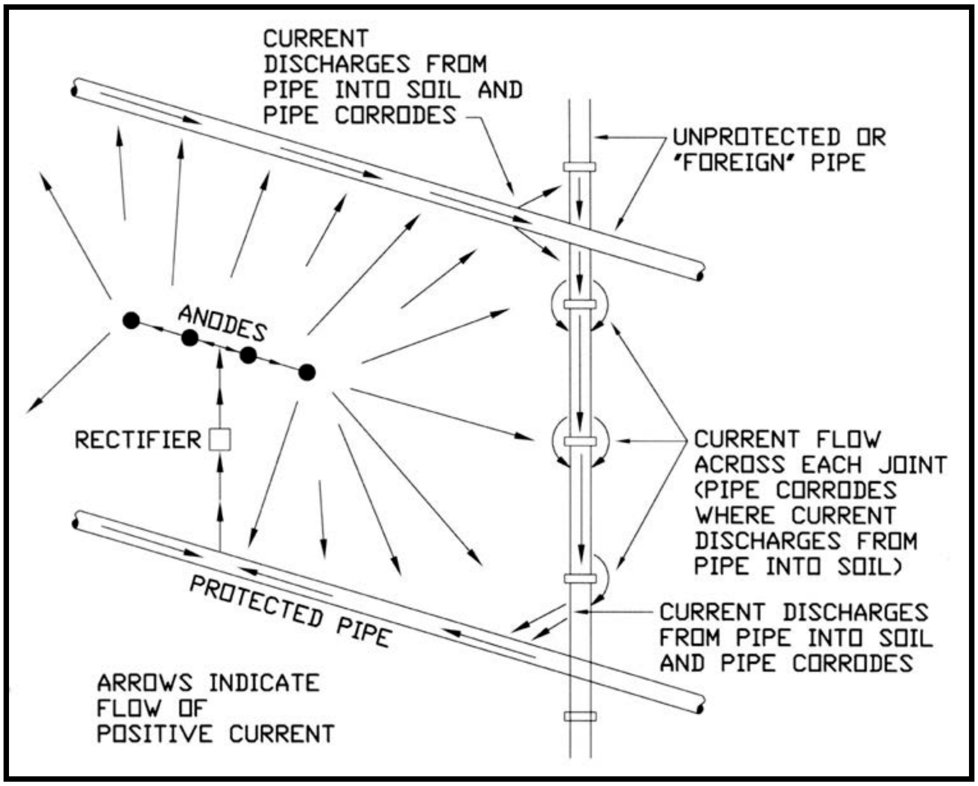
Figure B-19 Interference on Pipeline in Vicinity of a DC Powered Rail System.



B-9.1.9.4 Mitigating Interference.

Include mitigation methods for interference detected during the design field survey tests or anticipated based on structure layout in the drawings and specifications. In other cases interference may not be detected until after the CP installation, during system commissioning, and the interference mitigation methods will need to be determined immediately after the commissioning. Interference can be mitigated by several methods, depending on the ownership of the foreign structure, the protective coatings on each structure, and the surrounding soil conditions. If the foreign structure is owned by the same party, consider interference mitigation on the foreign structure as part of the CP system design.

Figure B-20 Interference on Foreign Pipelines in the Vicinity of a CP System.

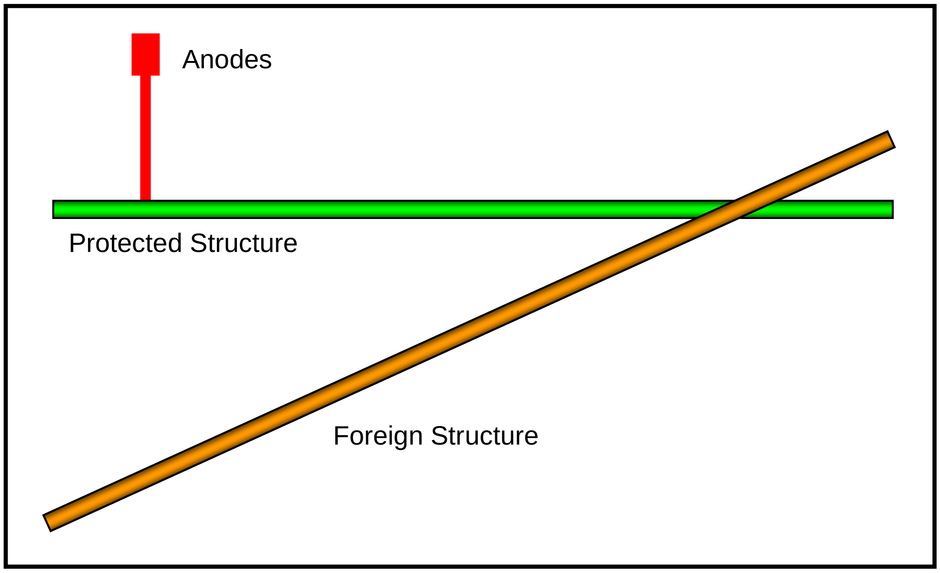


B-9.1.9.4.1 Anode Bed Location.

A significant factor in controlling interference is proper location of the anode bed. In general, the remote anode beds commonly used in ICCP systems cause more problems with interference than do sacrificial anode systems where the anode-to-structure distances are usually in the order of 10 feet or less and the driving potential is small (less than one volt). The influence on foreign structures is a primary consideration in the location of remote anode beds. Figure B-21 shows an example of an anode bed located to minimize interference on a foreign structure. Placing the anodes in between the two pipelines, nearby the crossing point or on the opposite side of the foreign pipeline would likely result in significant interference.

Deep anode beds generally have a significantly lower possibility of causing interference to foreign structures, as the foreign structures, in this case, usually do not provide lower resistant paths for the current from the anodes.

Figure B-21 Placing Anodes to Minimize Interference.



B-9.1.9.4.2 Direct Bonding.

Another technique for mitigating interference is to bond the foreign structure to the protected structure. The bonding can either be a direct low-resistance connection or a resistive bond. Bonding both structures together essentially provides CP to both structures. This can be accomplished to mitigate interference even if complete protection cannot be provided to the foreign structure. Direct bonding of a foreign structure to a protected structure will often require designing a larger capacity CP system than would be required just for the protected structure since the foreign structure can drain away substantial amounts of CP current intended for the protected structure.

Typically, provide the bond in a location where the structures physically cross or are in close proximity. Provide a test station at the direct bond location in order to verify the continuity of the bond, and to measure the current flowing through the bond. Specify insulated copper wire of appropriate size to properly carry the anticipated electrical bond current, and with a minimum wire size of No. 8 AWG for mechanical strength. Do not specify bare copper wire (e.g. grounding wires). Bare copper wire can drain away substantial amounts of CP current intended for the protected structure, and the insulated wire is necessary to minimize the amount of bare metal introduced to the CP system. Where interference testing cannot be conducted during the design survey, provide a bond station wherever pipelines cross and at other locations where interference is possible to allow for future bonding and testing. A bond test station must have two wires to each structure and room for possible installation of a resistor required in the future.

B-9.1.9.4.3 Resistance Bonding.

Direct bonding may not be desirable when the existing CP system cannot supply enough current to protect both the protected structure and bonded foreign structure (usually because of current distribution problems), or the foreign structure is not owned by the same installation as the protected structure. In the latter case, the structure owner supplying the CP current may desire to reduce the current provided to the foreign structure to just the minimum levels required to mitigate the interference. In either case, provide a resistive bond between the structures that can be adjusted to supply only the minimum amount of current to the foreign structure to bring its potential to its normal level prior to provision of the CP system for the protected structure.

Provide bond test stations where resistive bonds are used in order to facilitate testing of the corrective action and adjustment of the resistor, if required in the future. The resistor may either be a commercially supplied wire wound adjustable resistor of the proper resistance and current rating or may be fabricated from nickel-chromium alloy (nichrome) resistance wire cut to appropriate length in the field and wound into a coil. Adjustment of the resistor to correct the interference is determined by installing a temporary resistive bond and measuring the current through the resistor and the changes in potential achieved by the temporary bonding.

B-9.1.9.4.4 Use of Galvanic (Sacrificial) Anodes to Mitigate Interference.

Where the interference is localized, and the magnitude of the interference current is small, typically less than one ampere, sacrificial anode(s) on the foreign structure at the point of discharge may be an acceptable method to mitigate the interference. In order to determine the feasibility of using the sacrificial anode mitigation method, first measure the amount of bond current required to negate the interference. Next, calculate the ability of the GCP anodes to provide sufficient current based on the soil resistivity in the interference area. Size the GCP anode(s) to provide current in excess of the required bond current to control the interference. Provide test stations to monitor the potentials of both structures and GCP anode current outputs.

B-10 SPECIALIZED CP TECHNOLOGY AND CONSIDERATIONS.

B-10.1 Deep Anode Beds.

A deep anode bed according to the NACE International, is one or more anodes installed vertically at a nominal depth of 15m (50 ft) or more below the earth’s surface in a drilled hole for the purpose of supplying CP for an underground or submerged metallic structure. Refer to Figure 4-1.

B-10.1.1 Advantages/Disadvantages of Deep Anode Bed Systems.

Paragraphs B.4.2.6.1 and B.4.2.6.2 describe the advantages and disadvantages of deep anode bed systems.

B-10.1.2 Deep Anode Bed Design.

Deep anode bed calculations are fairly simple and follow the process for calculating a shallow vertical anode bed, except that the anode well resistance would be calculated using the Dwight equation for a single anode, whose length is that of the entire active zone. However, equally important and more difficult to determine factors must be considered when designing a deep well anode system.

B-10.1.2.1 Location.

Determining a good location for the deep anode column is essential to help ensure the proper design, installation, and operation of the column. Paragraph 4.3.4.1 describes requirements to consider in locating a deep anode bed.

B-10.1.2.2 Anode Column.

Some anode column design requirements and considerations are as follows:

B-10.1.2.2.1 Anode Type.

Select anode type for optimum performance and reduced difficulty of installation. Local subsurface conditions influence the selection of anode type, and anode selection affects the design for the column, i.e. quantity of anodes, depth and diameter of the column, and installation procedures. Technical Paper 16 provides information on the operational characteristics of different anodes in different environments.

B-10.1.2.2.2 Anode Centralizers.

Provide anode centralizers (Figure B-22) to help ensure the anodes are completely surrounded by backfill to lessen the chance of premature failure. Design/specify centralizers that do not significantly reduce total anode discharge area. Avoid the attachment of centralizers directly to anode surfaces that are subject to crevice corrosion such as mixed metal oxide or platinum coated titanium or niobium.

B-10.1.2.2.3 Anode Column Venting.

Provide vent pipes in the anode column to vent gases generated around the anode out of well to avoid gas blockage. Gas blockage can result in increased anode resistance and uneven current discharge from the anode surface resulting in premature failure. Specify vent pipes with holes or slots small enough to prevent the backfill from entering and clogging the vent pipe. Do not terminate the vent pipe inside of the anode junction box. Any chlorine gas generated will cause corrosion of the junction box hardware and detrimentally affect operation of the CP system. Terminate the vent pipes outside of the junction box as shown in Figure B-23 and seal the conduit to prevent gas from entering the junction box. Also, where practicable, do not terminate the vent in the anode well head box. The concentration of chlorine gas can result in corrosion of the well head box cover if it is made of steel or cast iron as shown in Figure B-24, and can degrade the insulation around the anode lead wires, and result in loss of the anode.

Figure B-22 Centralizers Installed on High Silicon Cast Iron Anodes

B-10.1.2.2.4 Anode Installation Procedure.

Follow the anode installation procedures as indicated in UFGS 26 42 17.00 10 and UFGS 26 42 19.00 20. In most cases specify that the contractor must not use the anode lead wire to lift, transport or install the anode. Handling the anode by using the lead wire can compromise integrity of wire and anode connection. Where the situation requires the use of the anode lead wire for anode installation, specify the appropriate pull out strength of the wire-to-anode connection to prevent damage to the connection, and provide destructive test procedures to verify conformance with the specifications. Refer to UFGS UFGS 26 42 17.00 10 and UFGS 26 42 19.00 20.

B-10.1.2.3 Anode Column Backfill.

Provide a special carbon backfill, referred to in the industry as coke breeze, in the anode hole or column for nearly all underground deep anode bed installations. Paragraph 4.3.4.3 describes requirements to consider for anode column backfill. Technical Report TR-NAVFAC EXWC CI-1425 *Environmentally Friendly Cathodic Protection Anode Beds*, describes a conductive concrete anode system that includes an impermeable backfill that can be considered as an option in deep anode bed CP systems where cross contamination of ground water aquifers is a concern or where artesian well conditions may complicate installation of the deep anode bed. Backfill is not required for open-hole, replaceable deep anode columns. Open-hole deep anode columns are considered where there is sufficient low resistivity groundwater to keep the anode well filled with water. In this case, the water provides the uniform environment for uniform distribution of current, with the advantage of more easily replaced anodes in the event of failure.

Figure B-23 Anode Column Vent Pipes Run Outside of Anode Junction Box.

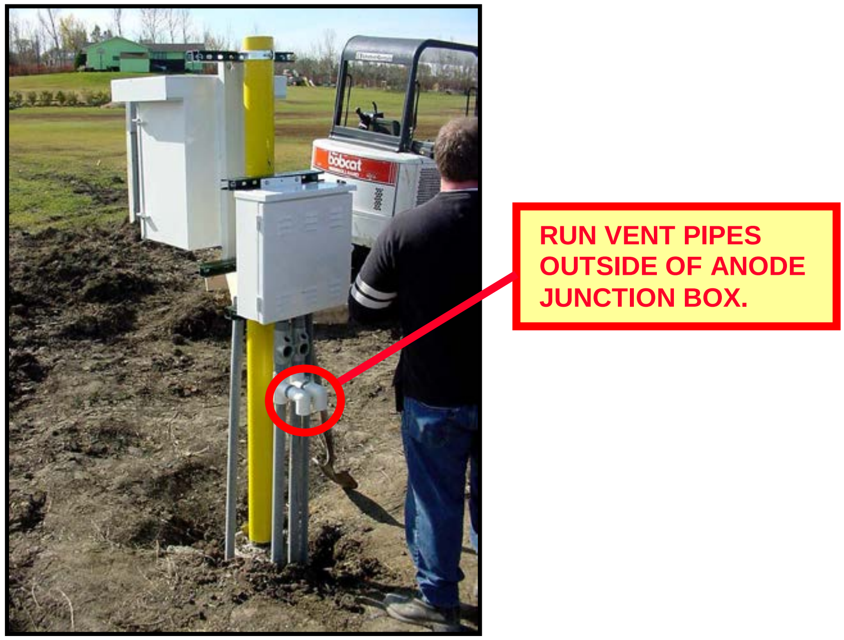


Figure B-24 Severe Corrosion of Cast Iron Cover on the Anode Well Head Box Caused By Chlorine Gas Vented into the Box.

B-10.1.2.4 Anode Lead Wires.

Anode lead wires are very important components of the anode installations, and many deep anode installations have failed because of improperly specified lead wires. Some considerations for anode lead wires for deep anode beds include:

B-10.1.2.4.1 Wire Insulation.

Specify HMWPE insulation. For chlorine ion environments, specify a dual insulation consisting of an inner ethylene-chlorotrifluoroethylene layer with an HMWPE outer layer for abrasion resistance.

B-10.1.2.4.2 Splices Not Allowed.

Provide individual anode lead wires to the anode junction box instead of splicing them to a single header cable from the rectifier. Anode columns that traverse differing soil strata can result in uneven current distribution from the anodes (i.e. higher current output of individual anodes located in low resistivity strata) that can lead to premature failure of that anode. Loss of anodes can then result in overload of the remaining anodes that may then prematurely fail. This domino effect will eventually result in premature failure of the anode column. Specify that splices are not allowed in the anode lead wires. Splices are a point of premature failure of anode lead wires.

B-10.1.2.4.1 Damaged Wire Insulation Not Acceptable.

Specify that nicks or other damaged to the wire insulation are not acceptable. As with splices, and even more so with damaged wire insulation, nicks and damaged insulation are points of premature failure of anode lead wires.

B-10.1.2.5 Environmental Concerns.

Installation of a deep anode bed can impact the environment. Environmental concerns must be considered during the early design stages. Consult with base environmental personnel and ensure that they are afforded the opportunity to review the design. Failure to consider environmental concerns can result in:

- Delays in completing the final design if an environmental issue is identified too late in the design
- Delays in obtaining construction permits
- Work stoppage and costly construction delays if environmental issues must be settled after construction is awarded with the potential for disapproval of work and cancellation of the installation
- Pollution of the environment and the resulting costly cleanups
- Fines for violating environmental regulations
- Other legal ramifications

B-10.2 Pre-engineered Cathodic Protection for Underground Storage Tanks.

USTs and oil water separators that conform to the Steel Tank Institute STI-P3-90 standard include a pre-engineered sacrificial anode CP system that is one part of the overall pre-engineered external corrosion control system for the underground steel storage tank (Figure B-25). The STI-P3® system combines three basic methods of underground corrosion control, all installed on the tanks during manufacture:

- Cathodic protection
- Protective coating
- Electrical Isolation of the tank from other underground metallic structures

Do not specify these types of pre-engineered CP systems where field survey conditions indicate they are not feasible. For new STI-P3® tanks specify provision of manufacturer provided PP4 CP testing equipment or provide separate appropriate test stations and wiring, to allow proper testing of the CP system.

***** CAUTION - RISK OF INADEQUATE CP *****

The CP system for an STI-P3® tank is intended only to protect the tank. Pipelines associated with the tank will not be protected. A separate CP system must be provided for the associated pipelines to comply with UST regulations. Also note that the integrity of the isolating bushings for an STI-P3® tank must be maintained. Loss of this electrical isolation can result in inadequate protection of the tank because of electrical shorts to other buried metallic structures in the vicinity.

Figure B-25 STI-P3® Tank

B-10.2.1 Dielectric Coating.

Every STI-P3® underground storage tank is protected with one of the three generic types of coating that have been tested to STI requirements and then approved for adoption into the STI-P3® specification: coal tar epoxy, urethane, or isophthalic polyester resin. This first line of defense against corrosion completely covers the external surface of the tank. A coating is applied to a blast-cleaned, prepared surface. If this coating is flawless, external corrosion cannot occur. Also, even if not perfect, the protective coating serves to reduce the amount of protective current needed for CP.

B-10.2.2 Cathodic Protection.

The only practical approach to a pre-engineered CP system for this application is using GCP anodes attached to the tank. GCP anodes develop their own protective current because of the natural potential difference between the anode metal and the metal being protected. This means that the anode system is self-activated after the tank is buried and will continue to provide corrosion control until the anode is consumed by corrosion.

Sacrificial GCP anodes made of either high-purity zinc or magnesium prevent corrosion of any exposed metallic surfaces, such as nicks or scratches in the coating that may occur during transportation or installation of the tank. Welded to the tank, these anodes control the direction of electrical current flow and will deteriorate in place of the steel. Based on the estimate of the average current produced by the anodes in a given soil, the estimated useful life of the anode system can be calculated. If the coating remains undamaged, the anodes will serve merely as back-up protection. Zinc anodes are provided where the soil resistivity is less than 2,000 ohm-cm. Otherwise magnesium anodes are provided.

B-10.2.3 Electrical Isolation.

All STI-P3® tanks must be electrically isolated from all other metallic underground structures that will be exposed to the backfill. This includes hold down straps installed to prevent the tank from floating out of the excavation during a high water table. Tank openings are electrically isolated by use of dielectric nylon bushings or flange isolators that will be compatible with stored product. By preventing contact between the tank and other nearby metal structures through the piping system, the chance of stray current corrosion is minimized, and the current demand that such contact would add is eliminated. This isolation, which defines the area to be protected by anodes, is intact when shipped from the factory.

B-10.2.4 Test Stations.

The STI-P3® design uniquely enables the testing of the tank's corrosion protection system. Varying federal and state regulations require that periodic CP tests be performed on single-wall STI-P3® tanks. For new STI-P3® tanks, specify provision of PP4 CP testing equipment or provide appropriate test stations and wiring, to allow proper testing of the CP system.

B-10.3 CP Systems for Reinforcing Steel in Concrete.

The chemical and alkaline nature of reinforced concrete normally results in the rebar developing a passive surface film that mitigates the effects of corrosion. Corrosion normally occurs around the tidal and splash zones due to the intrusion of oxygen, moisture, and chloride ions that will destroy the passive film. Most of the spalling and crack damage is a result of corrosion of the steel reinforcing bar (rebar) due to the presence of chlorides in the concrete. The reinforcing steel corrosion products (rust) occupy a larger volume of space than the original bar, and will exert enough force on the concrete to cause structural cracks, delaminations, and spalling of the concrete structure. Structural engineers contracted to design the structural repairs frequently specify the industry state-of-the-practice repairs for damaged piles, typically, patching of spalled concrete and epoxy injection to repair cracks. Such repairs are expected to last for 20 – 25 years; however, repairs by patching do not stop the existing rebar corrosion process due to the continued presence of chlorides, and will often cause increased corrosion of the rebar just adjacent to the patched areas, resulting in larger spalled and cracked areas after only six to seven years.

CP systems are generally not required for rebar for new reinforced concrete structures. Instead, comply with the requirements of the appropriate UFC and UFGS documents that include concrete design considerations that enhance corrosion prevention and control of the rebar. However, for major concrete structure repair projects, provide CP for the rebar in concrete where economical over the life cycle of the structure. CP systems for rebar in concrete must be designed by a qualified person experienced in the design of CP systems for rebar in concrete. Provide permanent reference electrodes or corrosion probes to allow testing and monitoring of the CP system effectiveness.

B-10.3.1 ICCP Systems.

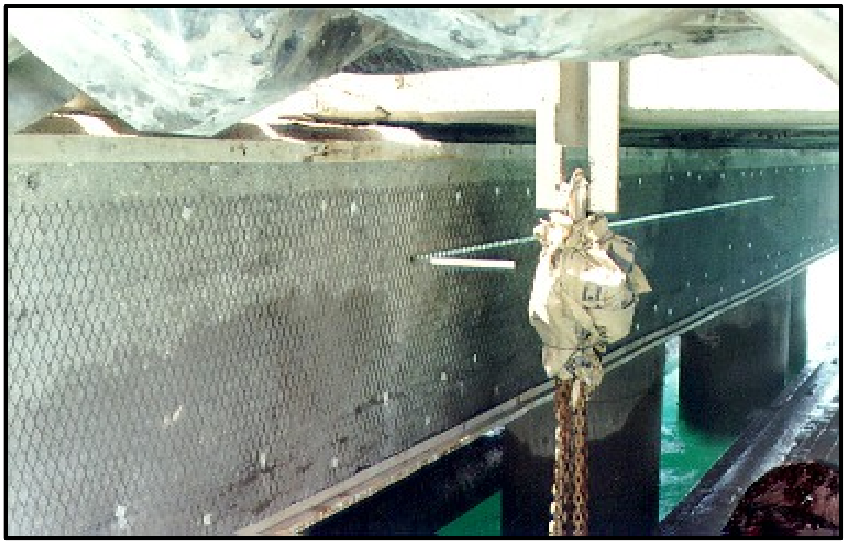
For corrosion protection of reinforced concrete structures requiring significant structural concrete repairs, CP can be applied to protect the reinforcing steel from corrosion where economical. While several different types of ICCP anode systems are manufactured, consider one or a combination of the three different types of ICCP anode systems that is most appropriate for the type of concrete structure and repairs being accomplished.

- Titanium mesh system consisting of mixed metal oxide coatings on an expanded titanium mesh fastened to the concrete surface (Figure B-26), and overlaid with a cementitious material, usually a Portland cement concrete mix. This type of system is commonly used on deck surfaces, piles or columns

- Titanium ribbon (mesh) slotted system consisting of mixed metal oxide coatings on either solid titanium ribbon strips or on expanded titanium mesh ribbon strips. The ribbons are installed between the rebar and concrete substrate or in slots cut in the concrete surface, and backfilled with a cementitious mix. This type of system is commonly used on deck surfaces

- Discrete anode system that typically consist of short strips of mixed metal oxide coated expanded titanium mesh, ceramic anodes, or platinized titanium wire typically installed in drilled holes and backfilled with cementitious grout. The length and spacing of the discrete anodes depends on the density of rebar and protection current requirements. These systems are most economical for beams, piles and columns

Figure B-26 Titanium Mesh Anodes Fastened to a Concrete Beam



B-10.3.1 GCP Discrete Anode System (DAS).

When cracked and spalled concrete structures containing high chloride contamination are repaired by patching because of funding limitations, consider installation of GCP discrete anodes in the vicinity of the patched area. The GCP discrete anodes are sacrificial zinc anodes in a special backfill (Figure B-27 and B-28). Unless a large area of concrete is removed during spall repairs, provide discrete anodes areas near the outer edges of the patch before applying the concrete patch. The type, length and spacing of the discrete anodes depends on the density of rebar and patch dimensions. The intent of the DAS anodes installed along with patches is not to provide adequate CP to the entire structure, but to minimize the galvanic corrosion effects between the rebar surrounding the patched area and the rebar within the patched area.

B-10.3.2 Pre-engineered CP for Pier Pilings.

While GCP DAS can be provided for corrosion protection during the repair of reinforced concrete piles (Figure B-29), another alternative is an integrated concrete pile repair and corrosion protection system (Figure B-30) containing pre-engineered CP systems for the pile reinforcing steel. Refer to paragraph 4-5.4.3. Consider this type of system as a viable alternative for long-term repairs of waterfront structures with reinforced concrete piles containing high chloride contamination, and significant spalling/delamination of concrete due to corrosion of reinforcing steel. This system can increase the service life of a pier patch repair up to 20 years in contrast to only six to seven years if pier pilings containing high chloride levels are only patched. For piles with only minimal damage, prepare a life cycle cost analysis to help determine the economic viability of this technology.

Figure B-27 Discrete Zinc Anode (Wrapped in Green Mesh) in Concrete Deck Repair. Device with the Yellow Lead Wire is a Permanent Reference Electrode.

Figure B-28 Discrete Zinc Anodes in Fiberglass Jacket for Pile Installation.

Figure B-29 Photos Showing "Before" and "After" Installation of Integrated Pile Repair and CP Systems

B-10.3.2.1 System Description.

The integrated pile repair corrosion protection system is comprised of high purity expanded zinc mesh CP anode mounted into a durable, stay in place fiberglass form that positions the anode material the appropriate distance relative to the steel rebar in the piling. In addition, the form creates an essential annular space for filling with concrete material to complete/improve the structural repairs to the piling. A supplemental bulk anode is added to protect the submerged portion of the pile and minimize current demand on the lower portion of the anode mesh (see figure B-30).

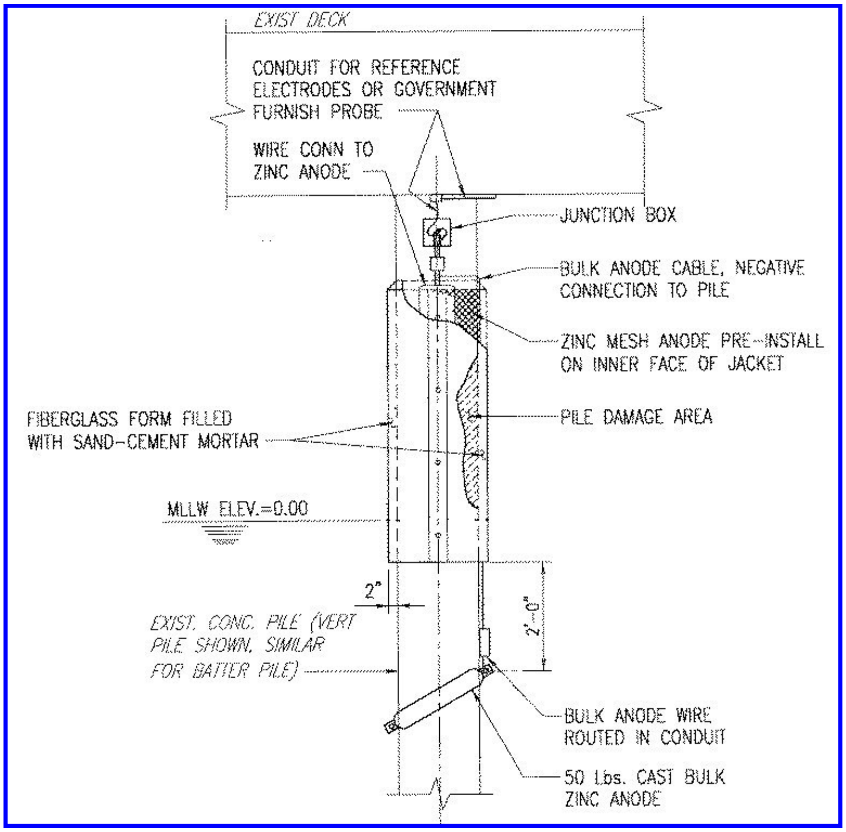
The system comes complete and ready to install with all components pre-positioned and fixed in place. The external jacket material is a durable fiberglass shell that is equipped with unique interlocking seams that literally snap together. Manufacturer's literature indicates that non-specialty contractors and supervised general laborers can do the job. Once installed, the system requires very little maintenance or monitoring, an expense that is often neglected with other ICCP systems that becomes a burden during the ICCP system life cycle. Based on results from a DOD demonstration project of this technology, the estimated average service life of the zinc CP system mesh is in excess of 25 years.

The system can be designed for a wide variety of pier piling structure configurations and can easily be integrated with the other pier piling repairs already being designed (removal of spalled concrete, replacement of badly corroded rebar sections, patching of spalled concrete areas, and repairs to small cracks in the concrete).

B-10.3.2.2 System Design.

Most Architect-Engineering (A-E) firms and even CP firms do not have experience with this technology. Close coordination between the design agent, the A-E designer, the product manufacturer, and service CP technical experts is necessary to ensure the system is properly designed, and adequate testing facilities are incorporated to permit monitoring of these systems.

Figure B-30 Typical Lifejacket Installation



B-10.3.2.2.1 Anticipated Concrete Repair Scope Creep.

From past experience in concrete waterfront repair projects, the scope of concrete repairs tends to increase over the design requirements as demolition of spalled concrete uncovers unseen damaged areas. Ideally, demolition of all spalled and cracked concrete should be completed prior to ordering jacket system materials to ensure proper jacket lengths and no negative impacts to the system installations. However, as the pile jacket systems may be a long lead time item, this plan would delay their installation and would also complicate installation as specific jackets would need to be matched to specific piles. It may be more reasonable and prudent to specify a jacket of length from two feet below the low water level to three or four feet above the high water level. Unforeseen additional damage found during demolition beyond the jacket length would be repaired in accordance with the appropriate typically prescribed repairs designed for concrete damage on piles without this system.

B-10.3.2.2.2 Pile Rebar Electrical Continuity.

Electrical continuity among all of the reinforcing steel in the pile is necessary for proper operation and effectiveness of the CP system. The normal manufacturer's recommended procedure is for the contractor to drill several small holes in the concrete piles to locate rebars and permit testing to determine electrical continuity between the rebars. Where not found electrically continuous, the contractor is required to install bond wires between such rebars to ensure electrical continuity. Since this process is essentially a trial and error process, it would require the contractor's corrosion technician to be on site for long amounts of time during this process, and the process may slow down the installation. If during a repair project, a large quantity of piles require repair, it may be more cost and time efficient for the contractor to demolish a band of concrete around the entire perimeter of the piles to expose all of the rebars in the piles (Figure B-31), and weld a continuous metal bar to each of the rebars in the pile to ensure their continuity. This will reduce the time needed for the contractor's corrosion engineer to conduct continuity testing, reduce the time for installation, and also ensure that the piles would not have to be reworked because of electrical discontinuities found during system commissioning.

B-10.3.2.2.3 System Installation.

Most contractors also do not have experience with this technology; therefore, specify requirements for project execution procedures for close coordination between the user, designer, contractor, and the product supplier/ manufacturer. Prior to commencement of construction, meet with the contractor to resolve issues that he may not understand or are not technically feasible in the design. Closely coordinate with the contractor to develop a system installation procedure as part of their quality control plan.

Figure B-31 Concrete Demolished Around Entire Pile to Permit Installation of a Bar Welded to Each Rebar to Establish Electrical Continuity.

B-10.3.2.2.5 Monitoring Test Stations.

A typical integrated concrete pile repair and corrosion protection system installation will come with a small test box mounted just above or on one of the jacket faces. Also consider the installation of several special monitoring test boxes along the pier or wharf deck in various random areas throughout the structure to facilitate testing of these systems. The additional cost for these special test boxes will be offset by

- Eliminating the cost and time need to obtain and launch a boat to navigate to the piles during each round of testing. By having test boxes mounted on the deck of the pier, a significant amount of time is saved while conducting the tests. For example, a full round of tests for an averaged sized pier can be conducted on the pier deck in one to two hours versus the several hours to almost a day that would have been required using a boat
- Providing a stable surface on which to conduct the tests. Due to the constantly moving boat in the water, two people would be required during testing; one to hold the boat as steady as possible against the piles while the other conducts the test measurements. Only one person is required to conduct the tests at the deck mounted test boxes. Tide levels also impact testing procedures

B-10.4 Interior of Potable Water Tanks.

Water storage tank CP systems must be designed by a qualified person experienced in the design of CP systems for water storage tanks to ensure its proper operation. Ensure that CP system materials are approved for use inside of potable water storage tanks in accordance with NSF/ANSI Standard 61. Coordinate CP systems requirements with the interior protective coatings designer to eliminate conflicting requirements.

B-10.4.1 CP for Interior of Water Tanks Subject to Icing Conditions.

There is a persistent problem at DoD installations with CP systems for water storage tanks located in areas with cold winters. Water tank interior CP system anodes are typically suspended from the roof of the tank with wires and cables such that they are submerged in the water. Such systems are often prematurely damaged or destroyed when surface ice forms in the tank in very cold environments.

Older water tank CP systems used heavy silicon-iron or graphite anodes. Such systems were vulnerable to failure not only due to ice, but also due to the weight of the suspended anodes pulling on the wire and electrical connections. Ceramic-coated anodes have been used as a lightweight alternative to the silicon-iron and graphite anodes in recent years. These anodes are typically made by depositing mixed metal oxides (MMO) onto titanium substrates including rods, wire, and discs. The MMO-coated anode eliminates the problems caused by anode weight, but when they are suspended from the roof of the tank, the anodes, cables, and wiring are still susceptible to ice damage. ICCP systems to protect the interior surfaces of water storage tanks in cold climates must be designed to prevent damage from ice. Specify a CP system consisting of MMO wire anodes along with a flotation and support system that keeps the anodes submerged in water underneath surface ice, regardless of the water level, where they will no longer be subject to ice damage. Refer to material and installation details in UFGS 26 42 15.00 10.

B-10.4.1.2 System Design.

The design to prevent ice damage uses MMO-coated wire anodes along with a flotation and support system that keeps the anodes submerged in water underneath surface ice, regardless of the water level. Because the anodes and their supports are kept away from the ice, they will not be subject to ice damage. There are several design considerations for anode support systems developed by industry. One design example utilizes an octagonal-shaped buoy constructed on-site inside the tank from 4-inch diameter Schedule 40 PVC pressure pipe sections (Figure B-32). The sections cannot be pre-assembled because the finished buoy would be too large to insert through a tank hatch. The buoy is tethered with polyester ropes to the bottom of the riser in the center of the tank. This installation may not be practical during cold weather, as the PVC cement for joining pipes would not set properly in the cold weather conditions.

An alternative design for installation in cold weather, successfully demonstrated by the U.S. Army, consists of 4-inch diameter Schedule 40 PVC pressure pipes installed in a pattern of the “spokes” of an octagonal umbrella-like support structure (Figure B-33). These anode support arms are attached to the riser via hinged connectors. Polyester marine rope forms the outer hoop of the support structure, and the anode wire is wrapped around the rope. PVC legs at each corner of the octagon oriented downward from the plane of the hoop prevent contact between the anode and the tank walls. Four commercial fishing net floats are attached at the far end of each anode support arm to prevent the hoop from sinking. The positive lead wires (attached to the anode wire on two diametrically opposite sides and connections water-proofed) are also spirally wound around the buoy and terminated outside the tank through a tank-entrance pressure fitting. A lead wire from a copper/copper-sulfate reference electrode permanently mounted on the hoop leg is also terminated outside via this fitting. The negative lead wire is exothermically welded to the steel tank access tube ladder strut, coated with epoxy, and also terminated outside the tank through the pressure fitting. This system design does not require on-site assembly of PVC pipe sections, thus it is possible to install it during cold weather.

B-10.4.2 Bolted or Riveted Water Storage Tanks with Interior Glass Lining.

Where a CP system is planned for a bolted or riveted steel water storage tank with an interior glass lining, include provisions to ensure electrical continuity between the riveted steel plates. The interior glass lining may electrically isolate adjacent plates. For other types of protective coatings, include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with the CP system.

Figure B-32 Octagonal Shaped Buoy Design.

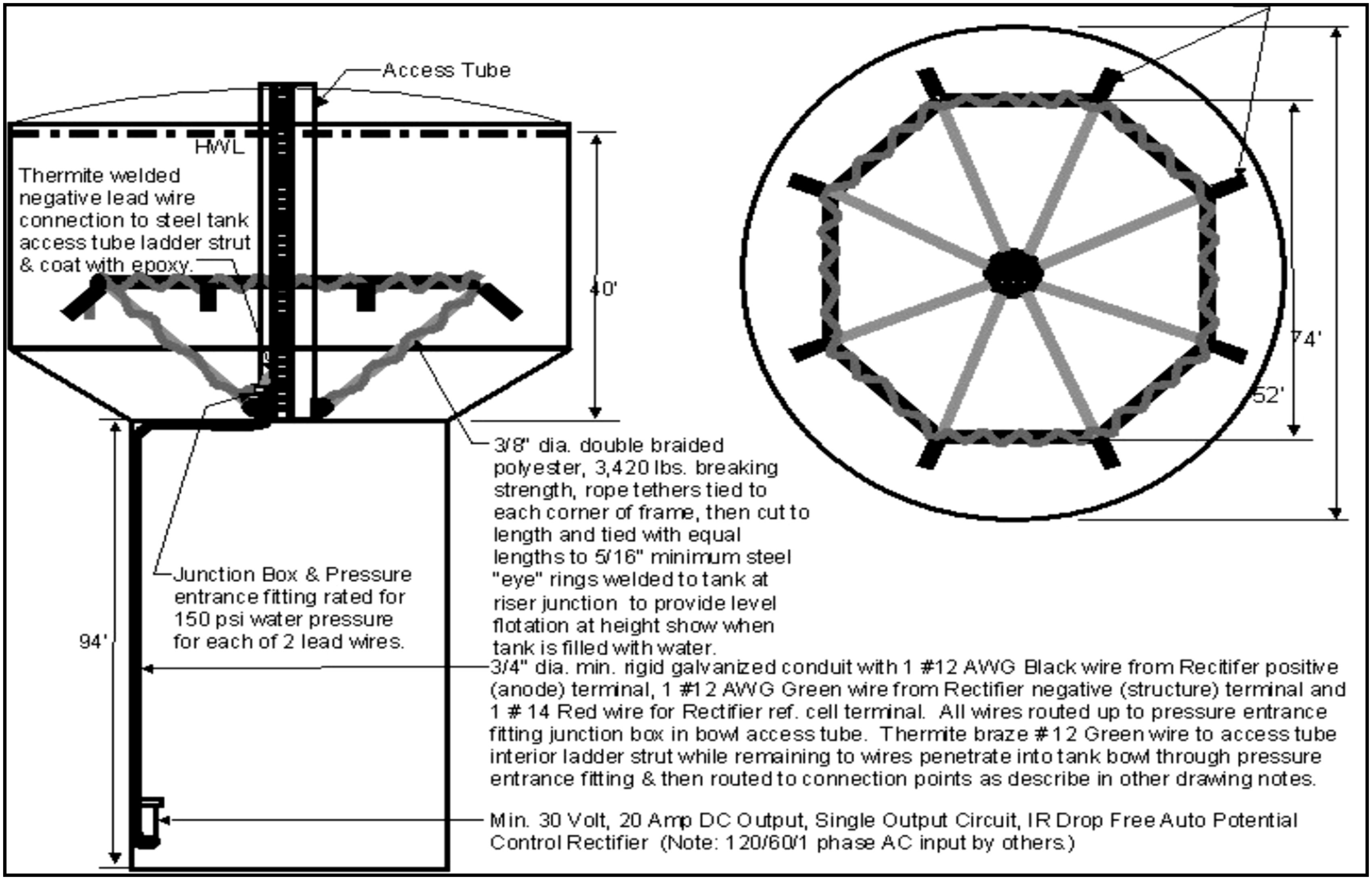
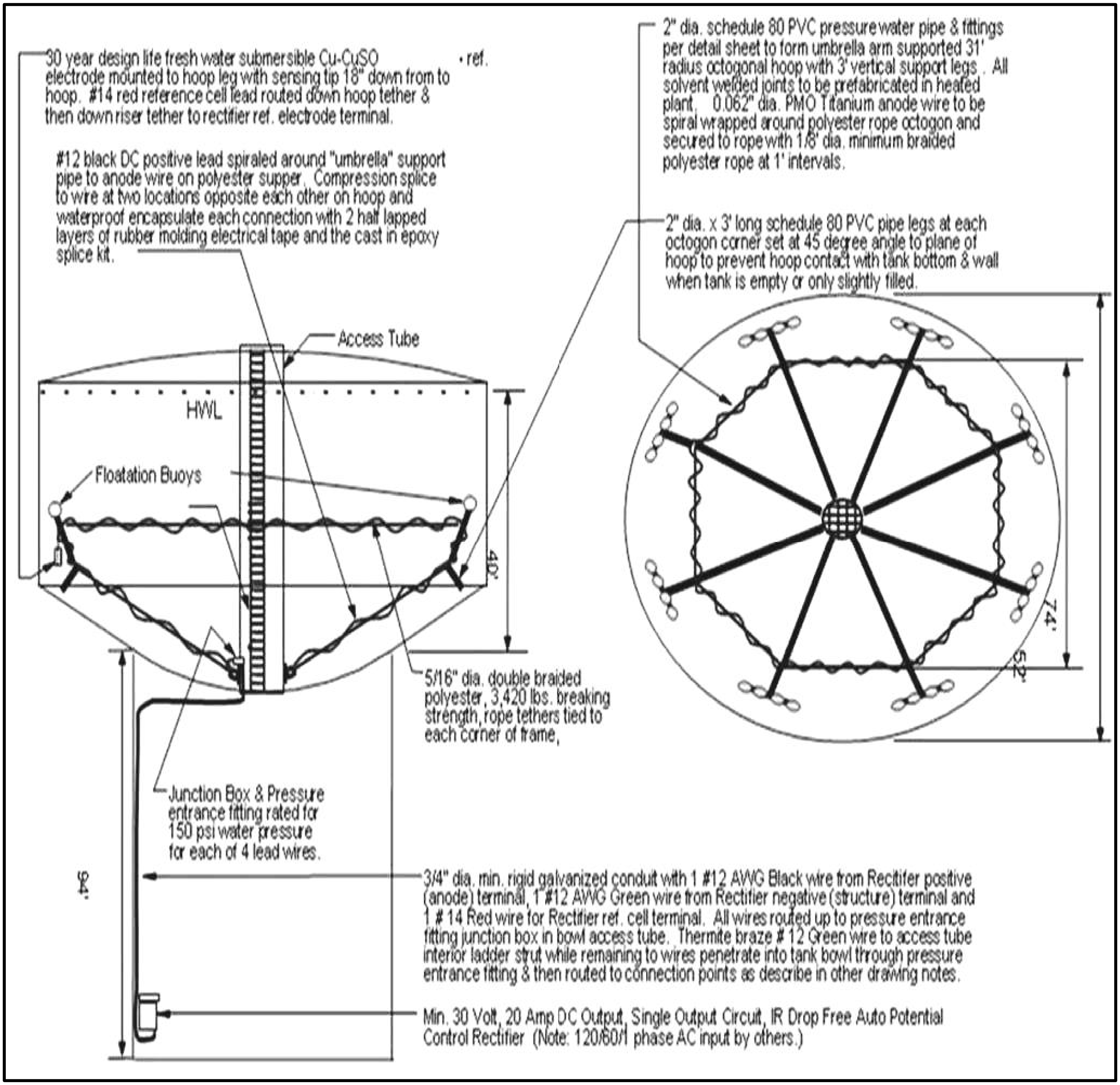


Figure B-33 Umbrella-like Anode Support Structure Design.



B-10.4.3 Monitoring Water Tank CP Effectiveness.

Provide a CP monitoring system that will allow monitoring of system effectiveness without having to physically climb the tank. Design the monitoring system such that test lead terminals are conveniently located in, or nearby the rectifier at ground level. Consider the use of remote monitoring systems.

B-10.5 Hot Water Storage Tanks.

Steel hot water storage tanks need protection against internal corrosion to prevent chronic leaking and premature failure. Corrosion caused leaks could cause extensive water damage to structures and mission critical electrical and mechanical equipment that may be co-located in the same rooms with the water storage tanks. Furthermore, the resulting leaks will eventually cause an accumulation of moisture that will promote mold and bacteria growth.

B-10.5.1 Domestic Hot Water Heaters/Tanks.

Provide factory-equipped glass linings and sacrificial anodes for domestic and smaller hot water heaters/tanks (75 – 1000 GA capacity). The glass linings and sacrificial magnesium anodes are economical for corrosion protection due to the reduced maintenance and monitoring for these systems.

B-10.5.2 Industrial Hot Water Heaters/Tanks.

Provide ICCP systems that use mixed metal oxide titanium rod anodes for larger industrial hot water heaters/tanks. Such systems have been successfully installed in Navy and Army installations. Figure B-34 illustrates a system installed in a vertical tank with a man-way access opening. In this example, a separate sacrificial anode is also installed to protect the man-way access cover since the sealing gasket prevented electrical continuity to the rest of the tank.

If an existing tank does not have a man-way access opening to permit work from the inside of each tank, utilize flexible and joinable mixed metal oxide coated anode rods, which can be bent and inserted into the tanks in 4-ft-long segments. This avoids having to break out any walls to provide clearance for their installation. Subsequent segments could be screw coupled to the first and subsequent segments as the assembly is pushed into the tank until the far end of the tank is reached (may require four or five segments). Insertion and penetration of the anode rod at each end of the tank can be made through a 1-in.-diameter “weld-o-let” fitting that is welded in place from the exterior on opposite ends of the tank (Figures B-35 and B-36). These provide threaded holes for high pressure stainless steel compression sealing elements minimizing the impact on the pressure vessel tank wall. The wire with black insulation in Figure B-36 is the positive lead wire from ICCP rectifier unit attached to the anode. The white insulation wire is rectifier system negative wire.

Figure B-34 CP System for a Vertical Hot Water Tank with a Man-Way Access Opening.

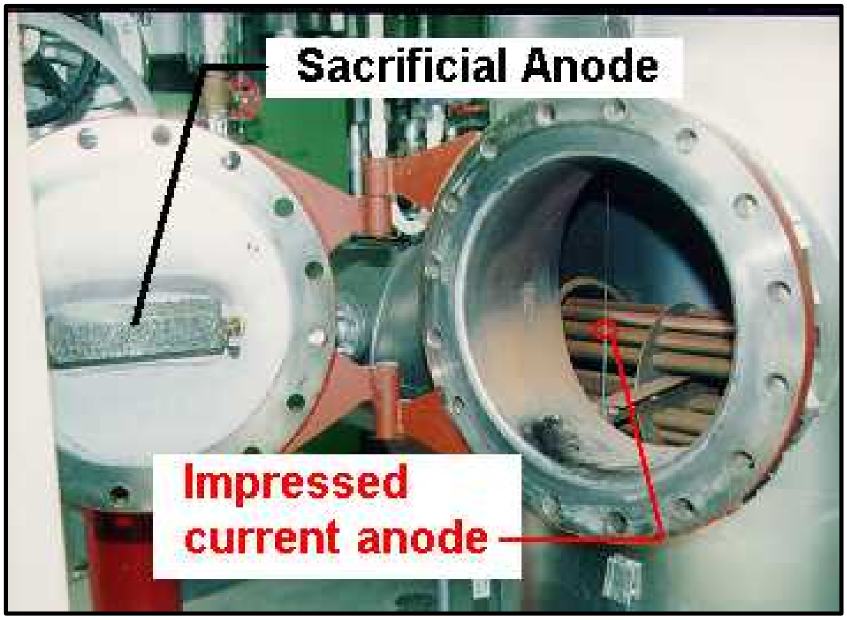


Figure B-35 CP System Rectifier and Anode Condulet Fitting on Side of Water Tank.

Figure B-36 Close up of Condulet Fitting Showing Anode Rod Extending Out of the Storage Tank.

B-10.5.2.1 Monitoring Water Tank CP Effectiveness.

Manufacturers of commonly used reference electrodes for CP system testing may not guarantee the accuracy of a permanently installed reference electrode in the high temperatures of a hot water storage tank. Instead, provide a capillary pore tube measurement port or bridge that facilitates taking these measurements with a reference electrode located outside the hot water tank with the tip held against the ionically conductive capillary tube (Figure B-37).

Figure B-37 Reference Electrode Placed in Contact with Moist Wadding Temporarily Placed Inside of the Capillary Tube Monitoring Port.

B-10.5.3 ICCP for Water Boxes in Power Plants.

Water boxes can contain a mixture of many different metallic materials. Some of the materials such as titanium, austenitic stainless steels, and super alloy stainless steels are more noble than the rest of the water box components. As a result, without CP, water box components can experience substantial galvanic corrosion. However, improperly designed ICCP systems for water boxes can result in metallurgical problems such as:

- Hydride formation in titanium tubes under excessive CP results in reduced ductility as the hydride forms
- Generation of chlorine gas at the anodes under excessive CP resulting in pitting corrosion in the upper tubes of austenitic stainless steel tube bundles
- Hydrogen embrittlement of stainless steel under excessive cathodic protection

Cathodic protection systems must be carefully designed to operate within selected operating potentials, and be properly maintained within these potentials to prevent any metallurgical problems from occurring. Designs must be accomplished by personnel qualified and experienced in these types of systems.

B-11 CP SYSTEM COMMISISONING.

B-11.1 System Commissioning Procedures.

Proper commissioning of the new CP system plays an important role in the operation and maintenance of the CP system. Proper commissioning by qualified personnel helps ensure the system is properly operating from the onset and helps identify system deficiencies, both design and construction, that should be corrected before the system is accepted. A properly commissioned system will help simplify maintenance and operation, and commissioning test data can be used as a baseline for future operation and troubleshooting. Specify adequate commissioning procedures so that the system is energized and fully tested to ensure its proper operation before being accepted from the contractor. General commissioning procedures are detailed in the UFGS listed in paragraph 3-4.3, and the following are examples of requirements from these specifications that should be tailored towards the specific CP system being designed.

B-11.1.1 General.

Specify that the systems shall be tested and inspected by the Contractor's corrosion engineer in the presence of the Contracting Officer's corrosion protection engineer or an approved representative. Include requirements to record test data, including date, time, and locations of testing and submit required reports to the Contracting Officer. Require that the contractor shall correct, at his expense, all deficiencies in the materials and installation observed by these tests and inspections, and must pay for retests made necessary by the corrections.

B-11.1.2 Base Potential Tests.

Prior to energizing the CP system, require the contractor to measure the base (native) structure-to-electrolyte potentials of the structure. Require that the measurements be made at anode junction boxes, test stations and other locations suitable for test purposes (such as service risers or valves) at intervals along the structure with measurements at each end point and the midpoint as a minimum. Indicate that the locations of these measurements shall be identical to the locations specified for measuring energized structure-to-electrolyte potentials. For USTs, take a minimum of three measurements with the reference electrode located as follows:

- Directly over the longitudinal and transverse centerlines of the tank at intervals not exceeding the diameter of the tank and to a distance from the tank of two times the tank diameter.
- At points directly around the circumference of the tank.]

B-11.1.3 Permanent Reference Electrode (PRC) Calibration.

Specify that the contractor must verify calibration of the PRC by measuring the potential difference between the PRC and an independent (portable) calibrated reference electrode placed in the soil or water adjacent to or as close as practicable to the PRC. Potential differences between the two electrodes of the same generic type should not exceed 15 millivolts. Zinc PRCs should be within the range of -1000 to -1150 millivolts when calibrated with a CSE. Require that permanent reference electrodes not within these potential differences shall be removed from the construction site by the end of the day and replaced at the contractor's expense. The testing provision shall also apply to replacement reference electrodes as well.

B-11.1.4 Insulation Joint Testing.

Require the contractor to perform insulation integrity testing at each dielectric insulating joint or fitting before and after the CP system is energized. Before energizing, test using an insulation checker. After energizing, test the insulation by measuring the potential shift on both sides of the insulating joint. Indicate that this testing shall demonstrate that no metallic contact or short circuit exists between the two insulated sections of the pipe or structure. Require the contractor to report and repair defective insulating fittings at their expense.

B-11.1.5 Electrical Continuity Testing.

Require the contractor to conduct electrical continuity testing of the structures intended to be cathodically protected prior to backfilling of the structure.

B-11.1.6 Rectifier System Testing.

Upon completion of the installation, "Baseline Potential Tests", "Insulation Joint Tests", and "Electrical Continuity Tests", indicate that the contractor can energize and adjust each rectifier and conduct the following inspections and tests:

- Verify the correct AC power supply to the rectifier
- Inspect and record the rectifier DC output panel meters
- Verify the panel meter readings using portable, calibrated meters and shunts
- Adjust the rectifier output as required to attain effective cathodic protection levels
- Correct noted deficiencies

This testing shall demonstrate that the rectifier system is capable of functioning properly as required to provide effective cathodic protection.

B-11.1.7 Pipe Casing Testing.

Before final acceptance of the CP installation, require the contractor to test the electrical insulation of the carrier pipe from casings and correct any short circuits.

B-11.1.8 Energized Potential Tests.

With the entire CP system put into operation require the contractor to measure structure-to-electrolyte potentials along the structure using a portable reference electrode(s) appropriate for the electrolyte and a voltmeter having an input impedance of not less than 10 megohms. The locations of these measurements must be identical to the locations used for the base potential measurements.

B-11.1.9 Interference Testing.

Perform interference testing with respect to any crossing and nearby foreign pipelines in cooperation with the owner of the foreign pipelines. The testing shall verify that the subject CP system does not have a deleterious effect on the foreign pipelines, and vice versa. Prepare a full report of the tests, giving all details including remedial actions taken or recommendations to correct noted interference problems.

B-11.2 System Commissioning FAQs.

Refer to Technical Paper 18, *Frequently Asked Questions About Cathodic Protection System Equipment Commissioning and Testing*, for additional information and FAQs regarding CP system commissioning.

APPENDIX C GLOSSARY

ACRONYMS

AC	Alternating Current
A-E or A/E	Architect-Engineer
AFCEC	Air Force Civil Engineer Center
ANSI	American National Standards Institute
AST	Aboveground (on-grade) storage tank
ASTM	American Society for Testing and Materials
AWG	American Wire Gage
CFR	Code of Federal Regulations
CP	Cathodic Protection
CPC	Corrosion Prevention and Control
CSE	Copper-copper sulfate (reference) electrode
DC	Direct Current
DoD	Department of Defense
EPA	Environmental Protection Agency
ER (probes)	Electrical Resistance (probes)
ERDC/CERL	Engineering Research and Development Center/Construction Engineering Research Laboratory
FGS	Final Governing Standards
GCP	Galvanic (Sacrificial) cathodic protection
HMWPE	High molecular weight polyethylene
HQUSACE	Headquarters, U.S. Army Corps of Engineers
ICCP	Impressed current cathodic protection
IR (Drop)	Voltage (drop)
OEBGD	Overseas Environmental Baseline Guidance Document

pH	A measure of hydrogen ion activity
POL	Petroleum, Oil and Lubricants
PRC	Permanent reference electrode
NACE International	National Association Corrosion Engineers International
NAVFAC	Naval Facilities Engineering Command (NAVFACENGCOM)
NAVFAC ESC	NAVFAC Engineering Service Center (now NAVFAC EXWC)
NAVFAC EXWC	NAVFAC Engineering and Expeditionary Warfare Center
NEC	National Electrical Code
NSF	National Sanitation Foundation
O&M	Operation and Maintenance
RFP	Request for Proposal
SCE	Silver-silver chloride (reference) electrode
S/E	Structure-to Electrolyte
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guides Specifications.
U.S.	United States
USACE	United States Army Corps of Engineers
UST	Underground Storage Tank
ZRE	Zinc reference electrode

DEFINITION OF TERMS

Amphoteric material: Material subject to attack by both acid and alkaline environments; include aluminum, zinc, and lead.

Anode: The electrode of an electrochemical cell at which oxidation occurs. (The anode is usually the electrode where corrosion occurs and metal ions enter the solution).

Bimetallic corrosion: (See galvanic corrosion).

Bond: See continuity bond.

Cathode: The electrode of an electrochemical cell at which reduction occurs.

Cathodic protection: A technique to prevent the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.

Coating: A dielectric material applied to a structure to separate it from its environment.[1]

Conductivity: The measurement of a material's ability to conduct electrical current.

Continuity bond: Metallic connection that provides electrical continuity.

Corrosion: The deterioration of a material or its properties due to a reaction of that material with its chemical environment.

Corrosion potential: The potential of a corroding metal surface relative to a reference electrode under specific conditions in an electrolyte.

Corrosion rate: The rate at which corrosion proceeds.[1]

Crevice Corrosion: Localized corrosion resulting from a concentration cell formed between two metal surfaces or between a metal and non-metallic surface.

Current density: The current per unit area.

Electrical isolation: Condition of being electrically separated from other metallic structures or the environment. [1]

Electrode: A conductor used to establish electrical contact with an electrolyte and through which current is transferred to or from an electrolyte.[1]

Electrolyte: A chemical substance or mixture containing ions that migrate in an electric field. Examples are soil and seawater.

Fiber Reinforced Plastics (FRP): A broad group of composite materials composed of fibers embedded in a plastic resin matrix.

Foreign structure: Any structure that is not intended as a part of the system of interest.

Galvanic anode. A metal that, because of its relative position in the galvanic series, provides sacrificial protection to metal or metals that are more noble in the series, when coupled in an electrolyte. These anodes are the current source in one type of cathodic protection.[1]

Galvanic cell: A corrosion cell in which anode and cathode are dissimilar conductors, producing corrosion because of their innate difference in potential.

Galvanic corrosion: Corrosion resulting from the coupling of dissimilar metals in an electrolyte.

Holiday: A discontinuity in a coating that exposes the metal surface to the environment.

Hydrogen embrittlement: The severe loss of ductility of a metal when hydrogen has been introduced into the metal structure.

Hydrogen overvoltage: Voltage characteristic for each metal-environmental combination above which hydrogen gas is liberated.

Impressed current: Direct current supplied by a power source external to the electrode system. For the purposes of this manual, direct current for cathodic protection.

Interference: Any electrical disturbance on a metallic structure as a result of stray current.

Interference bond: A metallic connection designed to control electrical current interchange between metallic systems.

IR drop: Voltage across a resistance according to Ohm's Law. [1]

pH: A measure of hydrogen ion activity defined by: $pH = \log_{10} (1/aH^+)$ where aH^+ = hydrogen ion activity = molal concentration of hydrogen ions multiplied by the mean ion activity coefficient (= 1 for simplified calculations).

Pipe-to-soil potential: The potential difference between the pipe metallic surface and electrolyte that is measured with reference to an electrode in contact with the electrolyte. See also structure-to-electrolyte potential.[1]

Polarization: The deviation from the open circuit potential of an electrode resulting from the flow of current.

Reference electrode: A reversible electrode with a potential that may be considered constant under similar conditions of measurement.

Resistivity: The measurement of a material's ability to oppose the flow of electric current.

Rust: A reddish-brown corrosion product of iron that is primarily hydrated iron oxide.

Sacrificial anode: See galvanic anode.

Stray current: Current flowing through paths other than the intended circuit.

Stray current corrosion: Corrosion resulting from stray current flow through paths other than the intended circuit.

Structure-to-electrolyte potential (also structure-to-soil potential): The potential difference between a buried metallic structure surface and electrolyte that is measured with reference to an electrode in contact with the electrolyte. See also pipe-to-soil potential.

Structure-to-structure voltage (also structure-to-structure potential): Difference in voltage between metallic structures in a common electrolyte.

Surge arrestors: A protective device for limiting surge voltages by discharging or bypassing surge current, and it also prevents continued flow of follow current while remaining capable of repeating these functions. Designed primarily for connection between a conductor of an electrical system and ground to limit the magnitude of transient (surge) overvoltages on equipment. Also known as arrestor or arrester, surge arrester, lightning arrestor or arrester.

Uniform corrosion: Corrosion attack of a metal that is essentially the same at all exposed areas of its surface.

Voltage: An electromotive force, or a difference in electrode potentials expressed in volts.

APPENDIX D EXAMPLE CATHODIC PROTECTION DESIGN DETAILS

Figure D-1 Example GCP Anode Installation Detail

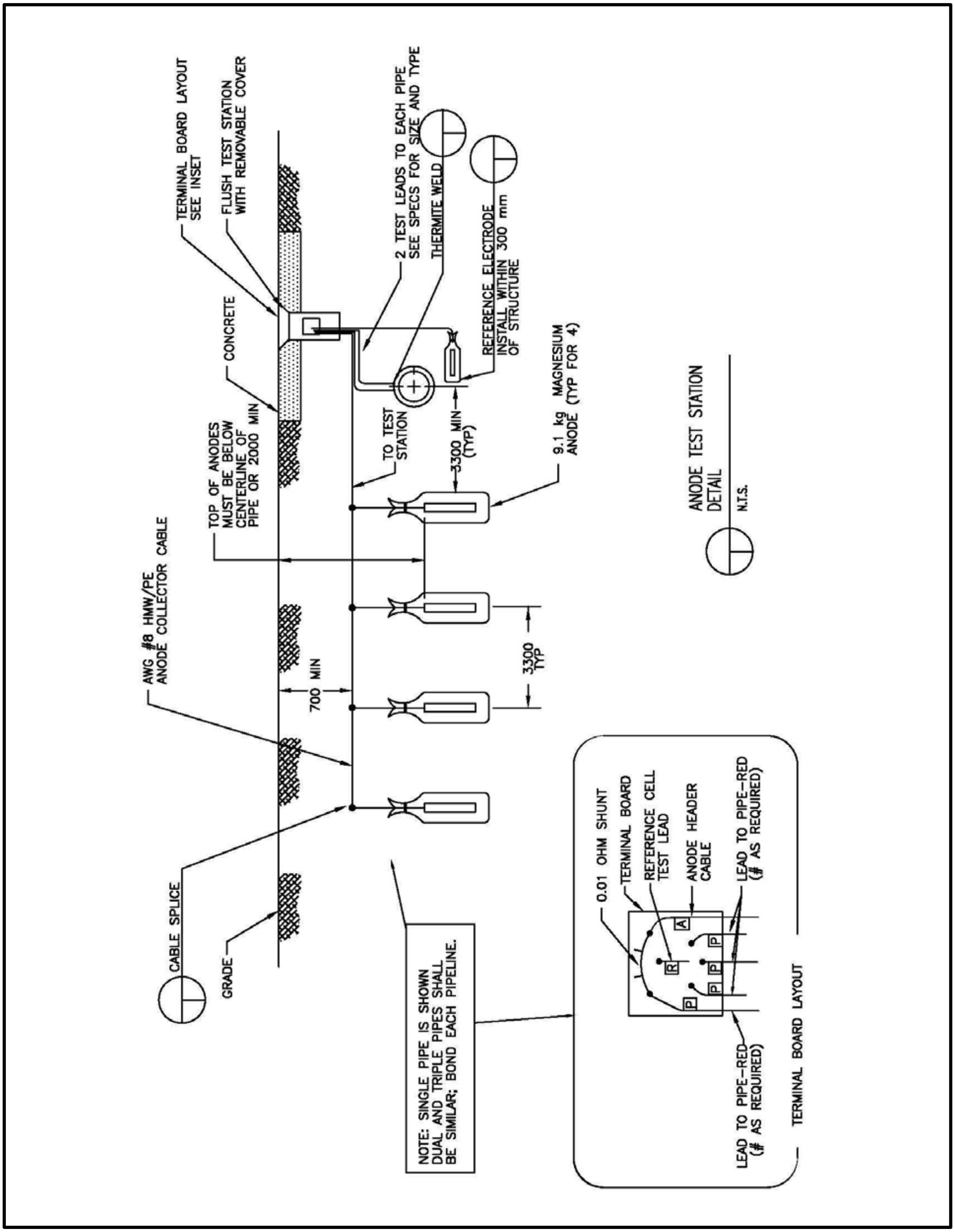


Figure D-2 Example ICCP Anode Installation Detail

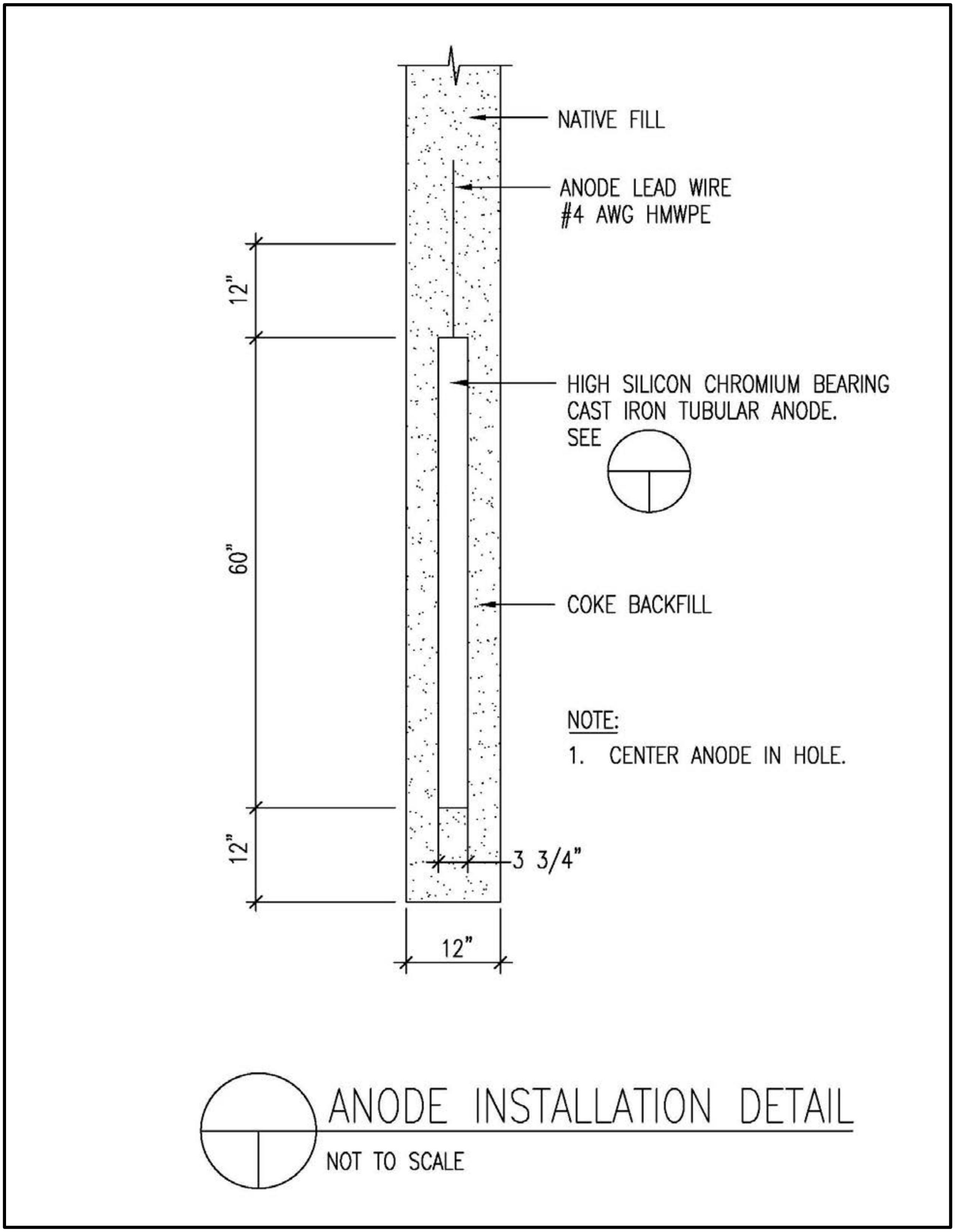


Figure D-3 Example Deep Anode Installation Detail

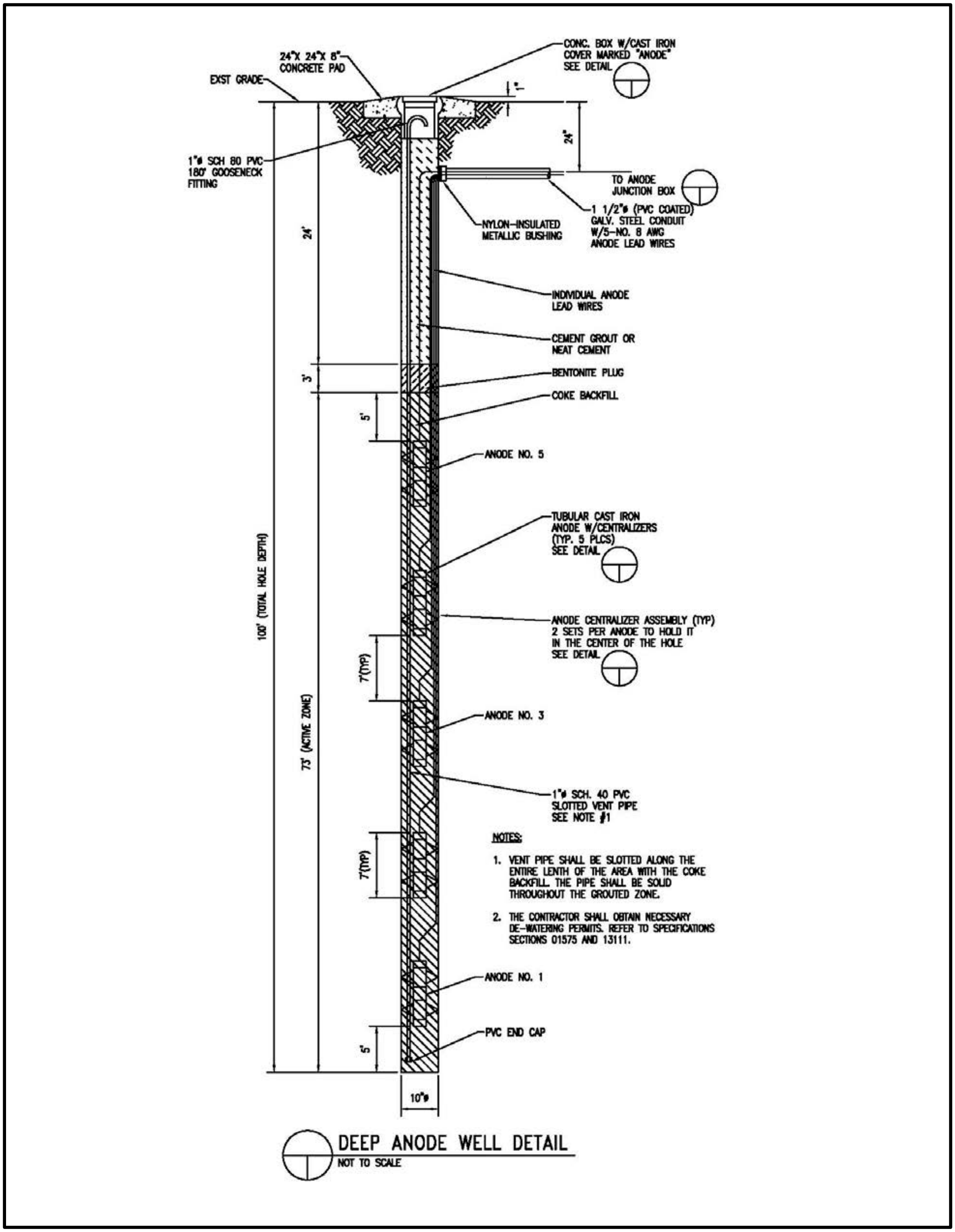


Figure D-4 Example GCP Anode Detail

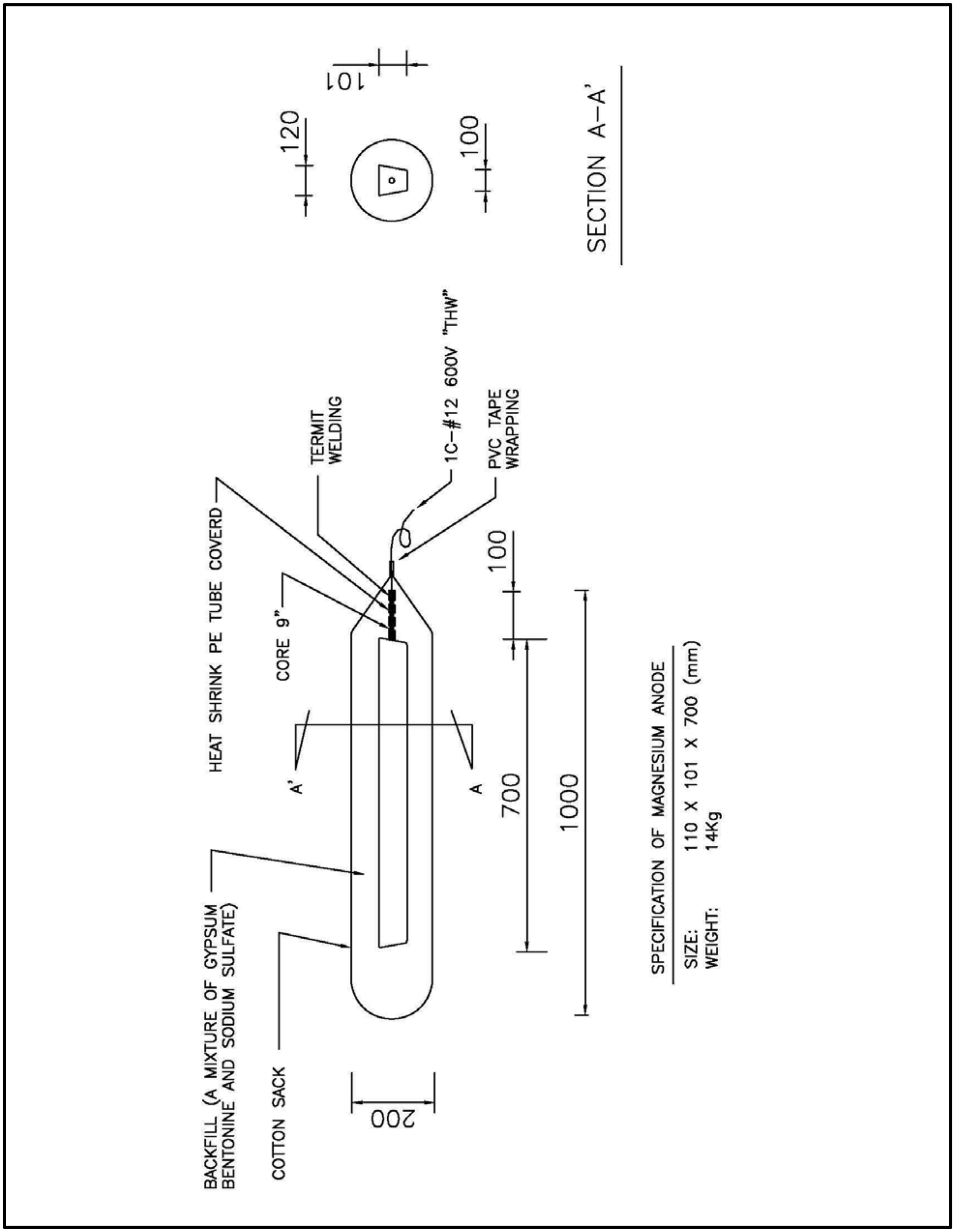


Figure D-5 Example Seawater GCP Anode Detail

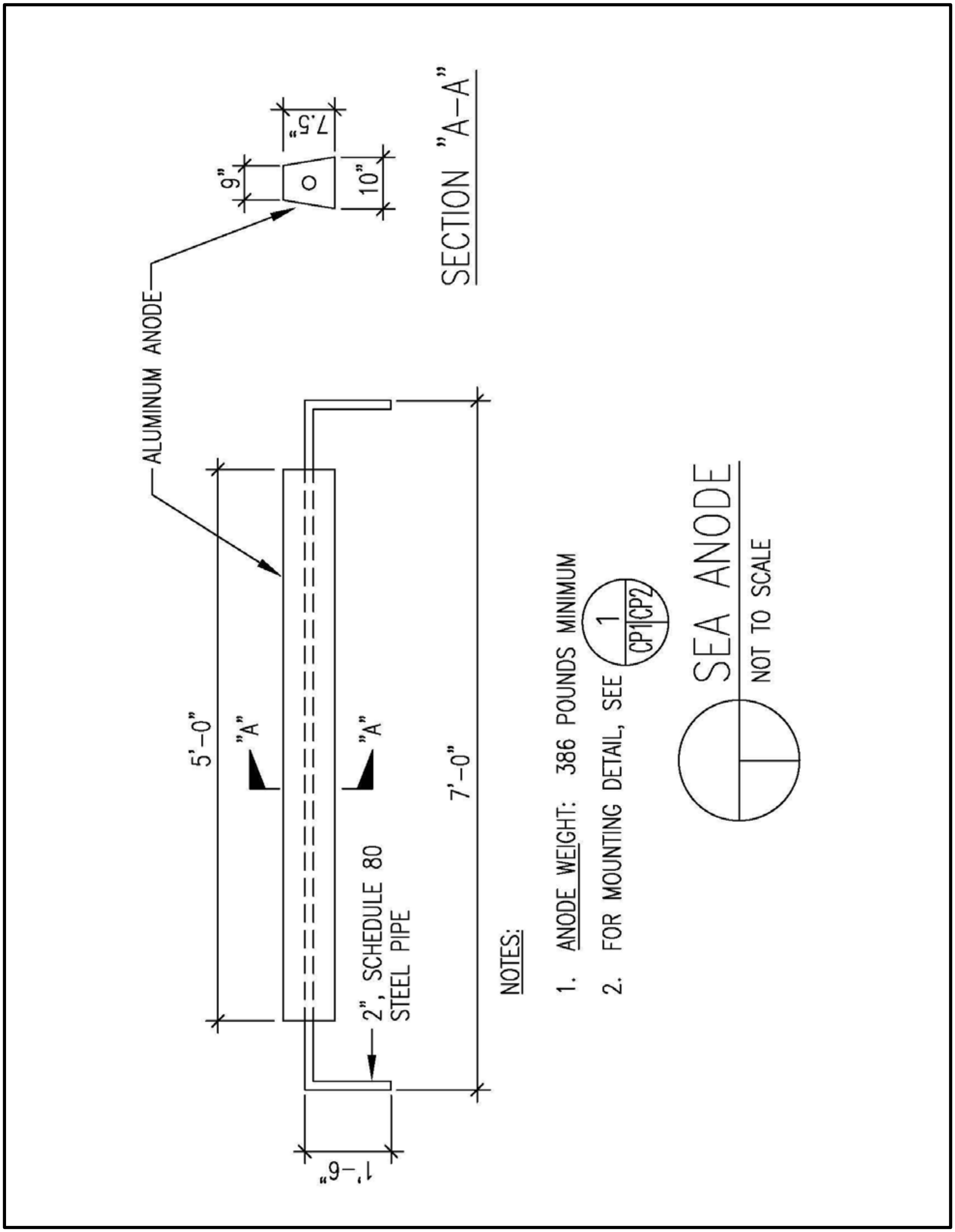


Figure D-6 Example ICCP Oil Cooled Rectifier Detail

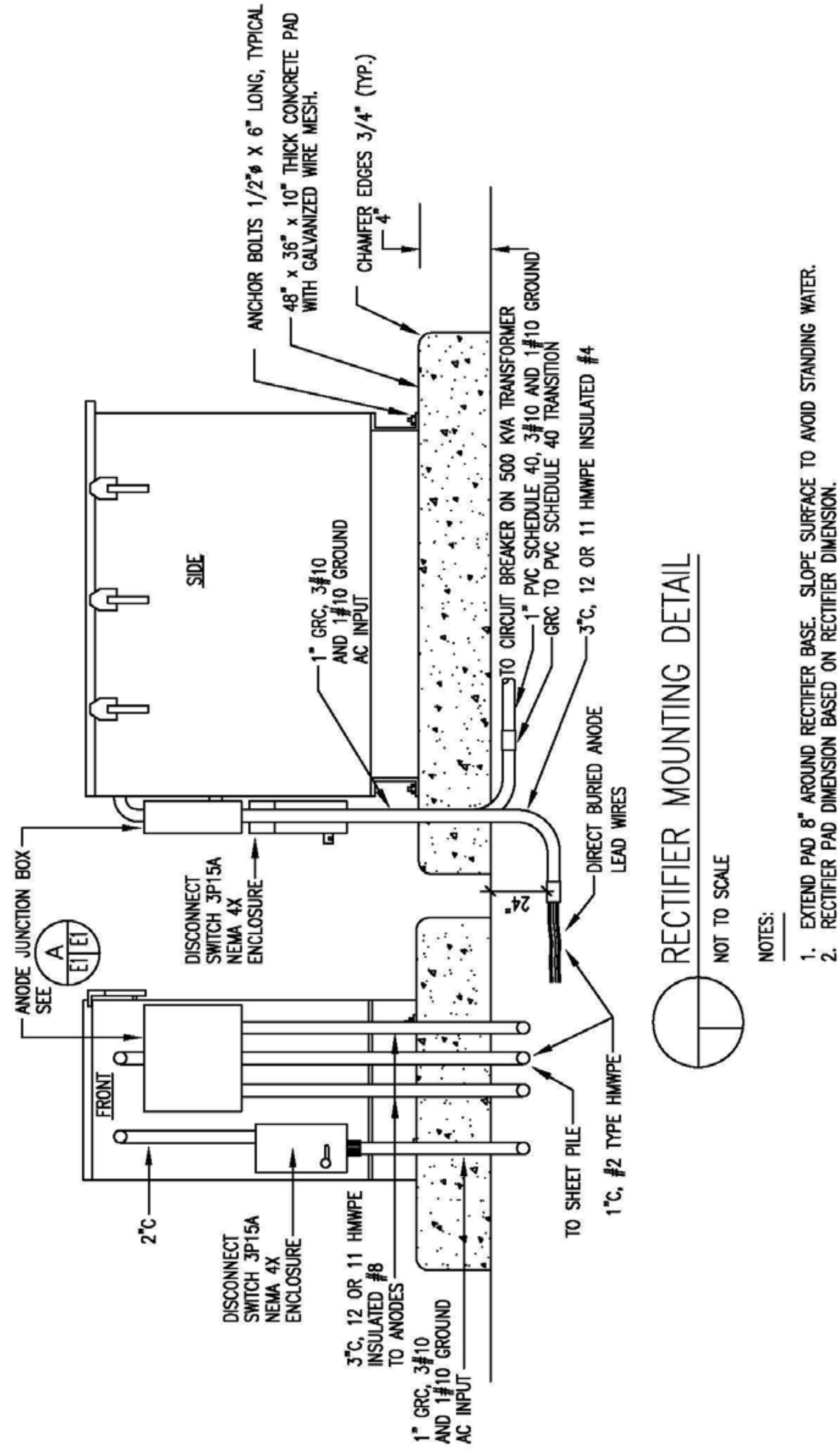


Figure D-7 Example Anode Junction Box Detail

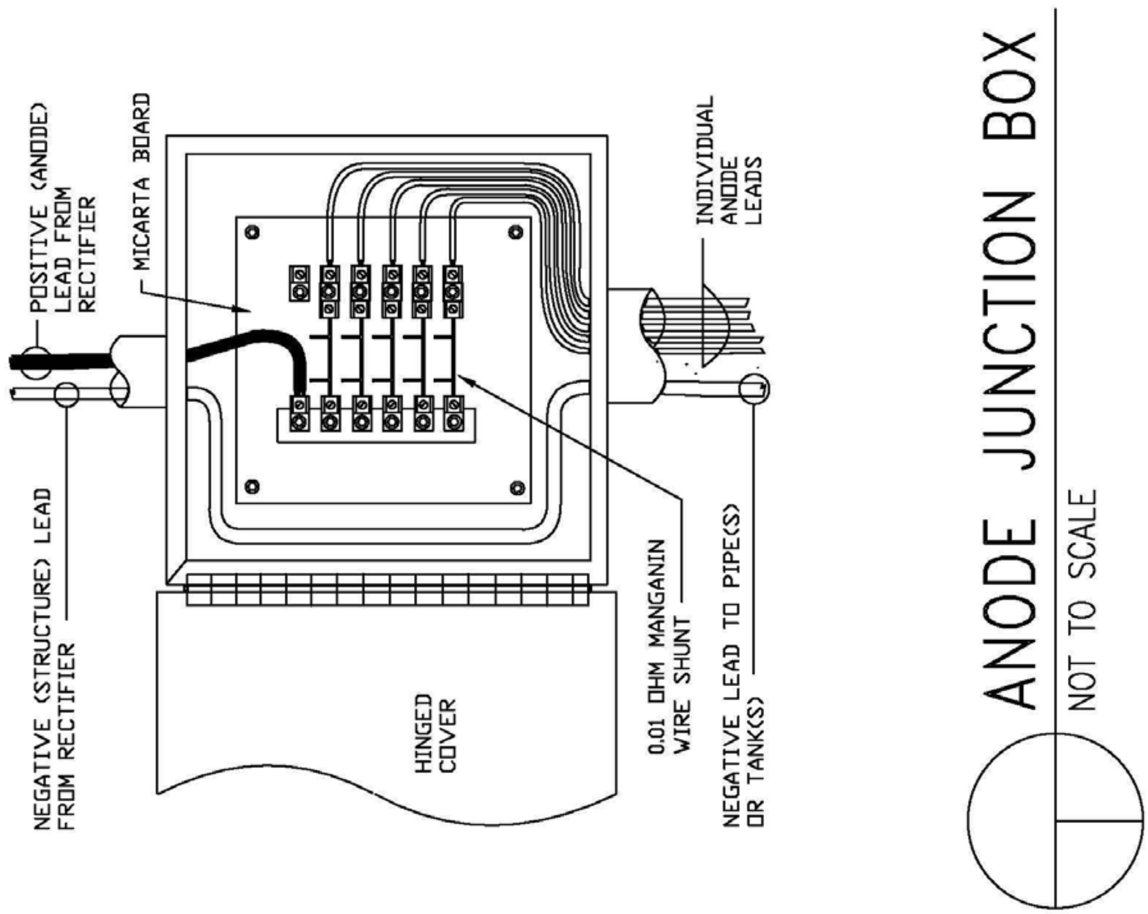


Figure D-8 Example Flush Mount Test Station Detail

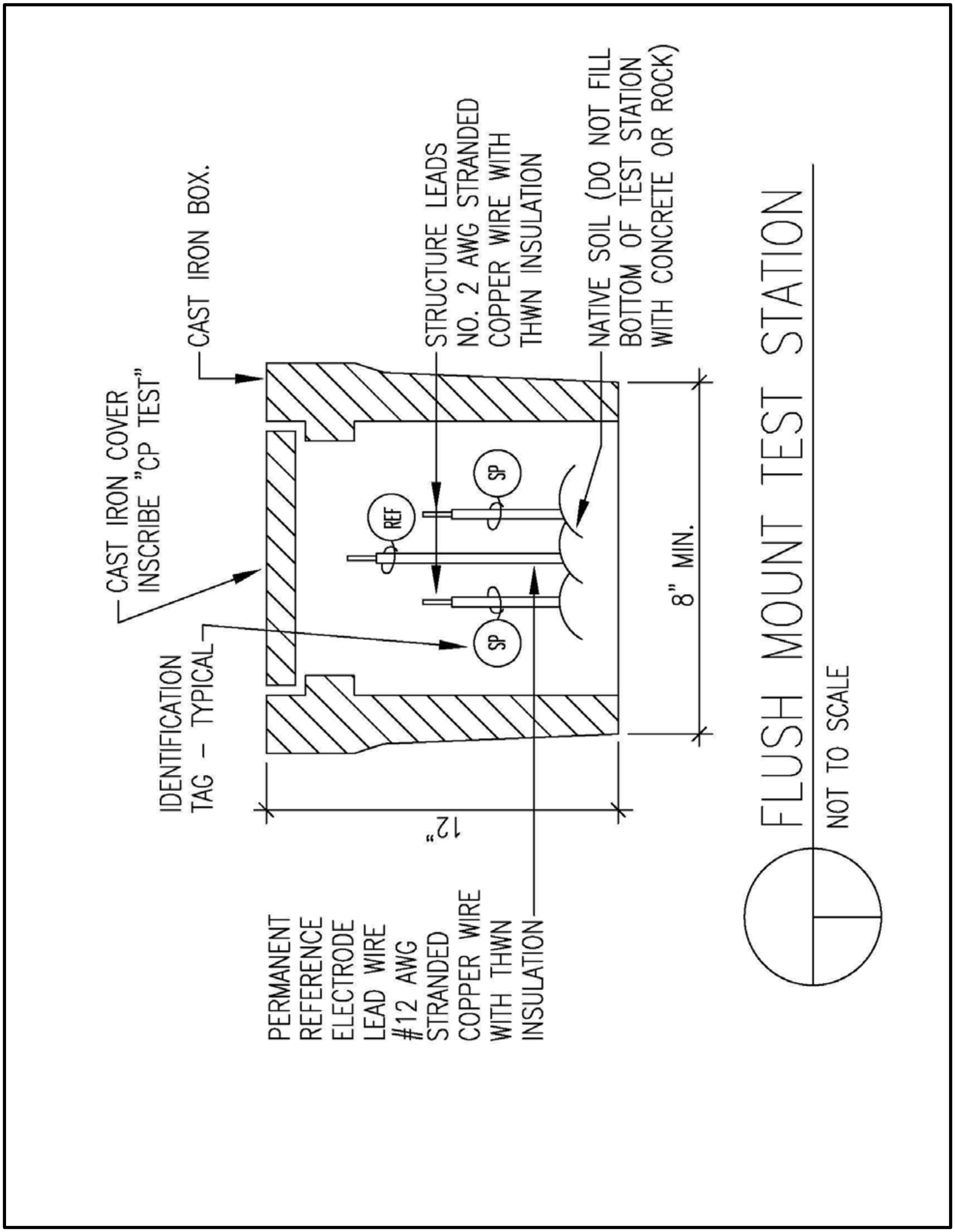


Figure D-9 Example Flush Mount Bond Test Station Detail

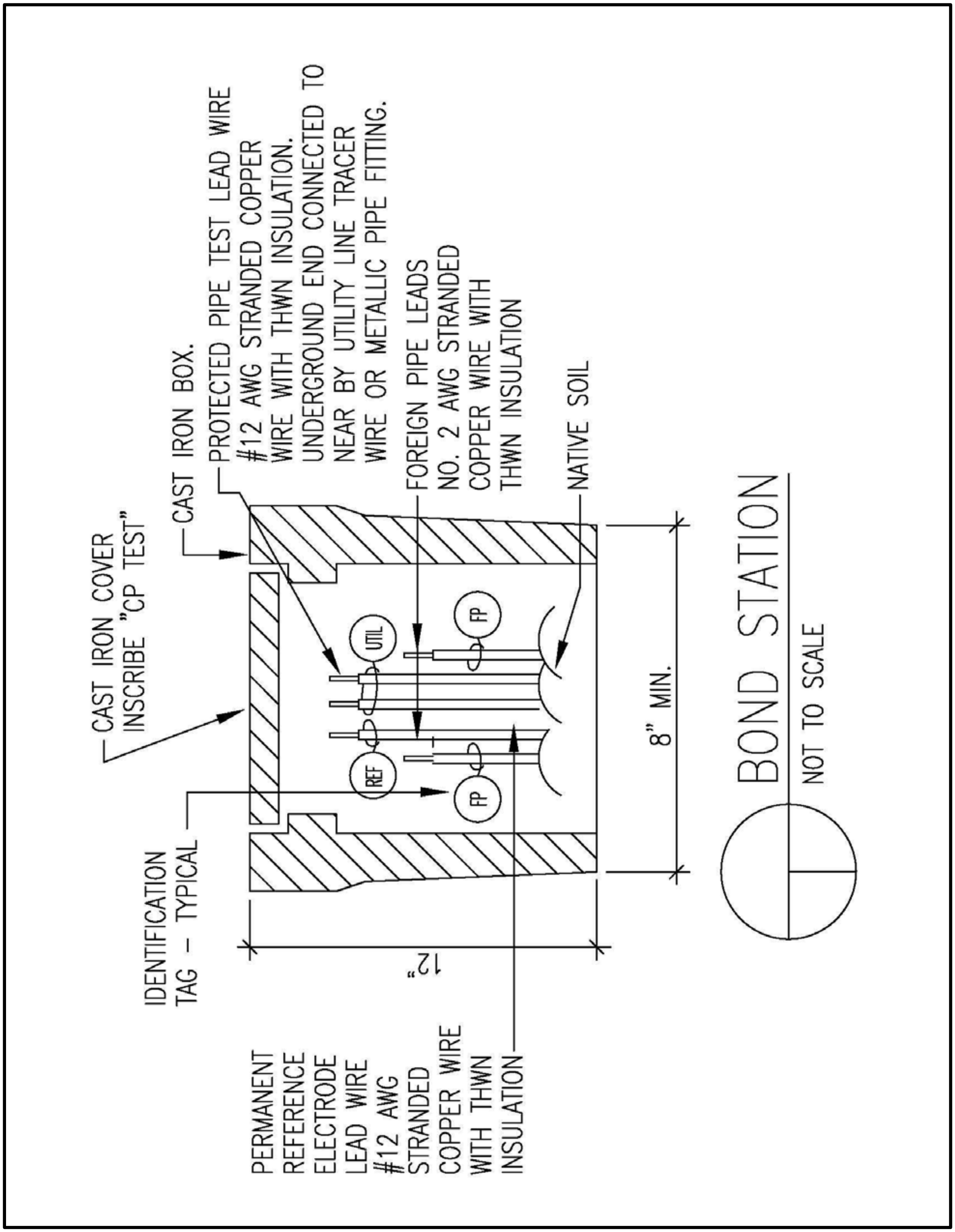


Figure D-10 Example Soil Access Test Station Detail

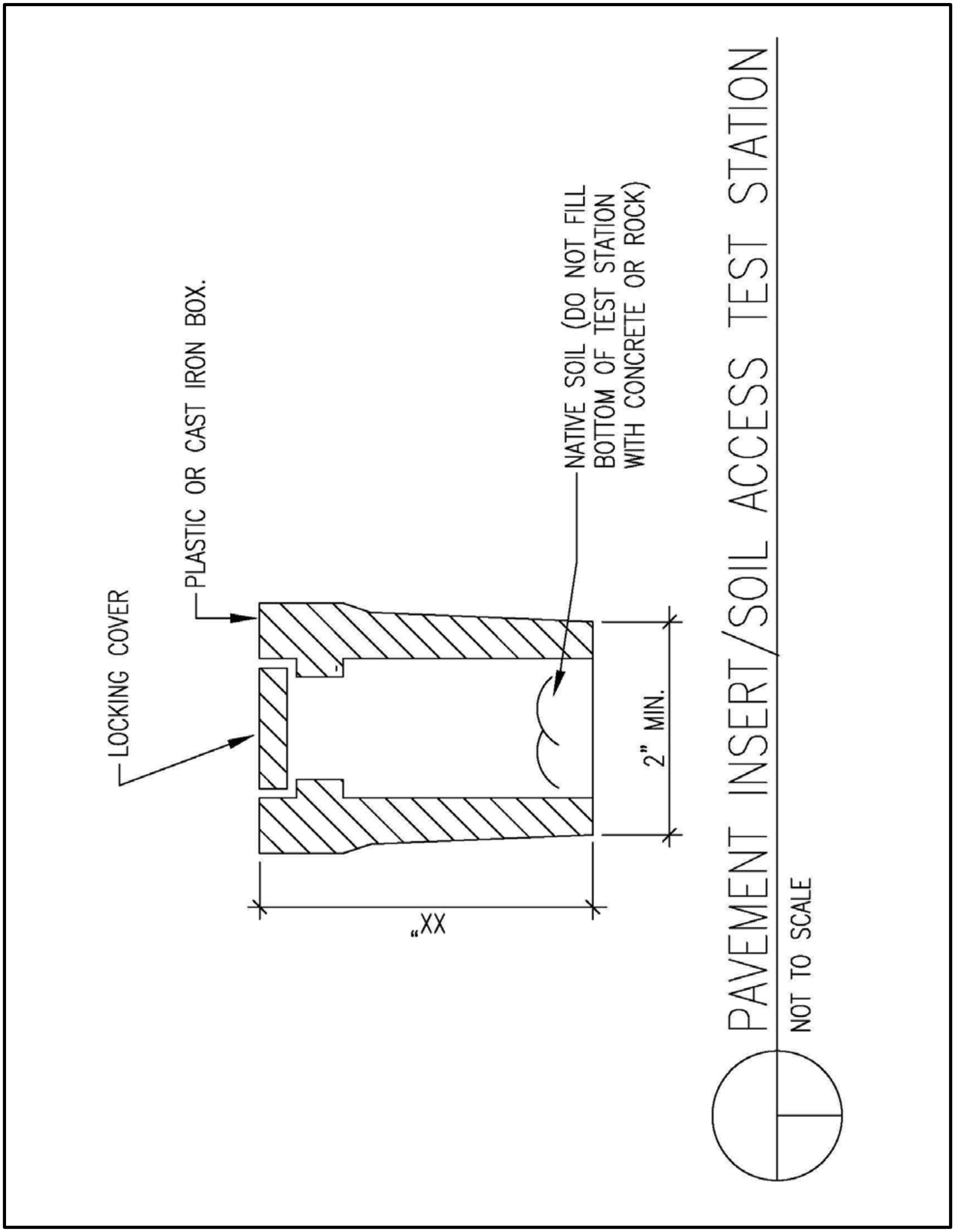
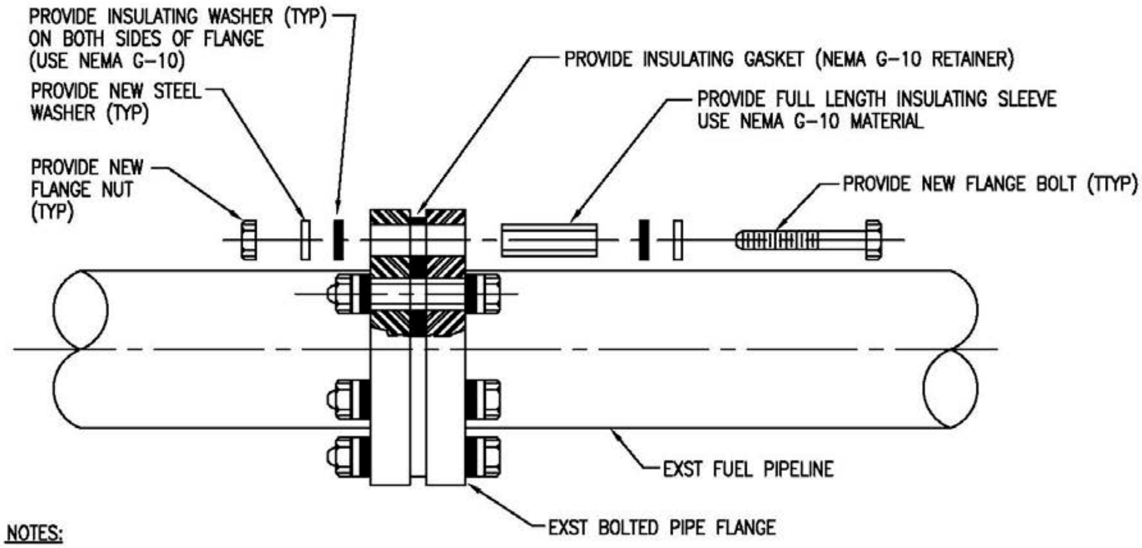


Figure D-11 Example Dielectric Insulation Flange Detail



NOTES:

1. DRAIN RESIDUAL FUEL FROM FUEL LINE IN ACCORDANCE WITH SPECIFICATION SECTION 01140. REMOVE EXISTING GASKETS. THE EXISTING GASKETS MAY CONTAIN ASBESTOS. REFER TO SPECIFICATIONS SECTION 13281 FOR APPLICABLE REQUIREMENTS
2. POLYETHYLENE, MYLAR, AND PHENOLIC INSULATING SLEEVES AND WASHERS ARE NOT ACCEPTABLE AND WILL BE REJECTED. PROVIDE NEMA G–10 TYPE INSULATING SLEEVES AND WASHERS.
3. DOUBLE INSULATING WASHERS ARE REQUIRED (ONE FOR EACH SIDE OF EACH FLANGE BOLT)
4. FULL FACE GASKETS REQUIRED. GASKET RETAINER MUST BE HIGH COMPRESSIVE STRENGTH ASTM G–10 MATERIAL.
5. NEW GRADE 8 BOLT AND NUTS REQUIRED FOR EACH FLANGE.
6. HARDWARE QUANTITIES IN INSULATING FLANGE KIT WILL VARY BASED ON GASKET PATTERN AND PIPE SIZE.
7. DO NOT COAT OR SPRAY INSULATING COMPONENTS WITH GREASE.
8. AFTER INSULATING FLANGE KIT IS COMPLETELY INSTALLED, WRAP FLANGE WITH MIN. 3 LAYERS OF PIPE JOINT TAPE WRAP.

DIELECTRIC INSULATING FLANGE
NOT TO SCALE

Figure D-12 Example Exothermic Weld Detail

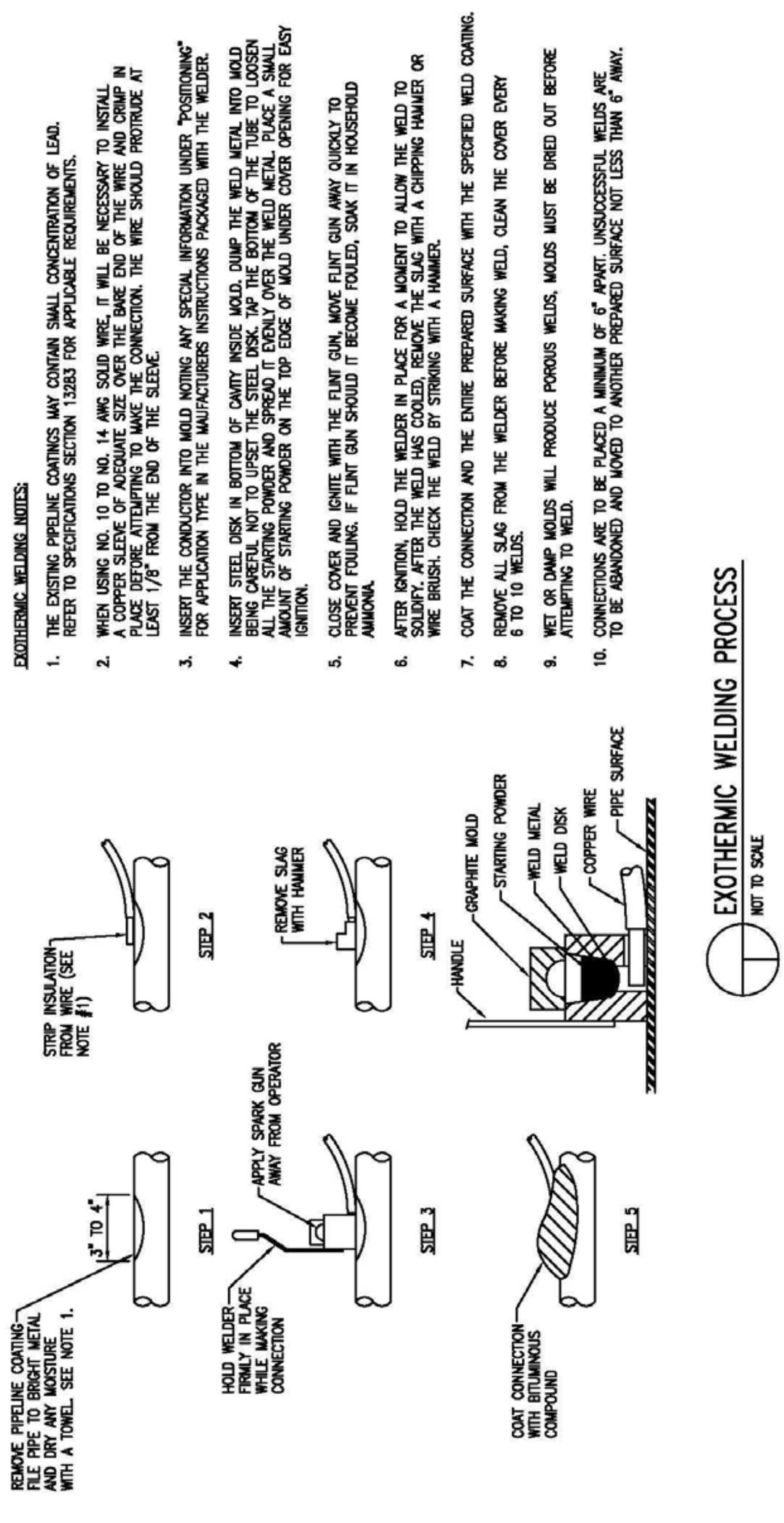
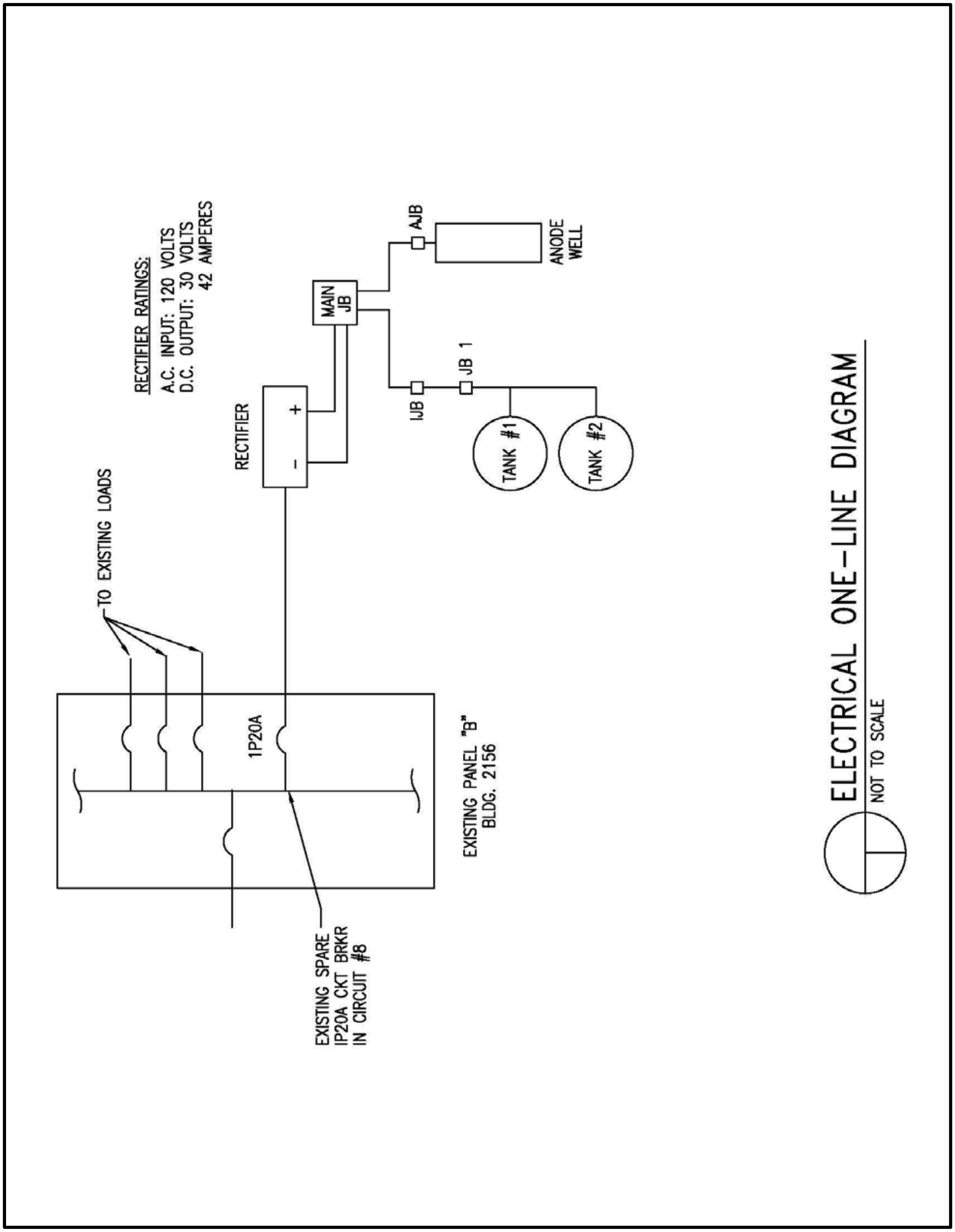


Figure D-13 Example Electrical One-Line Schematic Diagram



UFC 3-570-06
15 July 2019

UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE: CATHODIC PROTECTION SYSTEMS

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OPERATION AND MAINTENANCE: CATHODIC PROTECTION SYSTEMS

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AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

U.S. ARMY CORPS OF ENGINEERS

Record of Changes (changes are indicated by \1\.../1/)

Change No.	Date	Location

This UFC supersedes UFC 3-570-06, dated January 2003.

FOREWORD

The UFC system is prescribed by MIL-STD 3007; provides planning, design, construction, sustainment, restoration, and modernization criteria; and applies to the Military Departments, the Defense Agencies, and the Department of Defense (DoD) Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFAs), Host Nation Funded Construction Agreements (HNFAs), and, in some instances, Bilateral Infrastructure Agreements (BIAs). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-570-06, *Operation and Maintenance: Cathodic Protection Systems*

Superseding:

- UFC 3-570-06, Operation and Maintenance: Cathodic Protection Systems, 31 January 2003
- Public Works Bulletin 420-49-29, *Operation and Maintenance of Cathodic Protection Systems,* 2 December 1999

Description: This document provides technical personnel guidance for inspection and maintenance of cathodic protection (CP) systems.

Reasons for Document:

- Updated to reflect industry standards.
- Recommended changes from Air Force, Army, and Navy personnel to ensure this document applies to all branches.
- New industry technology and guidance.
- Chapter 2, “Principles of Operation,” and Chapter 7, “Test Procedures“ converted into technical papers with appropriate updates.
- Troubleshooting techniques placed in an appendix.
- Appendixes labeled properly to include service-specific guidance, training and certification, and additional references.
- Contents adjusted to account for new formatting per UFC 1-300-01.

Impact:

- Cost impact is negligible.

Unification Issues:

- None.

TABLE OF CONTENTS

FIGURES

TABLES

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides guidance for operation and maintenance of CP systems. It should be used by field personnel to perform scheduled inspections and preventive maintenance and to troubleshoot and repair CP systems. Information on non-routine field measurements is also included to enable technical assistance personnel to troubleshoot problems beyond the normal capability of field personnel to isolate or correct.

1-2 APPLICABILITY.

CP is an electrochemical (half electrical and half chemical) method used to control corrosion of buried or submerged metallic structures. It prevents corrosion by making the protected structure a cathode by installing a more anodic metal (sacrificial or galvanic) anode or a metallic (impressed current) anode connected to a direct current (DC) power source. When the proper amount of current is applied, all of the anodic areas on the structure are changed to the same potential, thereby removing all of the anodic locations and allowing the entire structure to become a cathode. Since all corrosion occurs at the anode, the structure no longer corrodes. The electrons move in the metallic path, reduction (chemical) reactions occur at the surface of the cathode, and oxidation (chemical) reactions occur at the surface of the anode. Reduction reactions at the cathode result in a hydrogen coating and a more alkaline environment, and the oxidation reaction at the anode results in corrosion and a more acidic environment. After a CP system is installed and adjusted to provide adequate protection, currents and potentials should remain relatively stable; typically, a plus or minus ten percent change in currents or potentials indicates a problem.

Employ CP within the following equipment/systems:

- Underground fuel storage tanks and ground-level tank bottoms.
- Fuel distribution and storage systems.
- Elevated and ground-level water storage tank interiors and ground-level tank bottoms.
- Potable water distribution systems.
- Natural gas or propane distribution systems.
- Compressed gas distribution systems, such as air, oxygen, and nitrogen.
- Fire protection water storage tanks, piping, or water lines.
- Sewage tanks, lift stations, and effluent pipelines.
- Steel sheet pile seawalls, pier support/fender piles, and other submerged steel structures.
- Concrete reinforcing steel.
- Industrial waste pipelines.

- Dams and lock systems.
- Cooling towers.
- Recirculating water systems (hot or cold).

1-3 OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA).

Comply with all OSHA requirements, as applicable.

1-4 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies. Comply with all applicable provisions of the current issues of these consensus standards as follows and as noted elsewhere in this document. Appendix G contains additional useful references.

1-5 GLOSSARY.

Appendix E contains acronyms, abbreviations, and terms.

1-6 BENEFITS.

For utilities, there are two choices: (1) install and maintain CP; or (2) periodically replace the utility when the leak failure rate becomes an operational (or financial) burden. Properly installed and maintained CP systems dramatically reduce life cycle costs by indefinitely extending a utility's lifetime. CP systems also reduce the government's potential liability from premature failure of utilities, such as gas line explosions and jet fuel leaks. Environmental cleanup, transportation, and disposing of contaminated soil, monitoring requirements, and other costs connected to a “reportable” leak can cost the government over $1 million. Notices of Violations (NOVs) can carry stiff fines and penalties. CP is essential to maintaining any metallic structure in a corrosive environment at the lowest life cycle cost.

1-7 CP SYSTEM MAINTENANCE.

System performance can be monitored by measuring the supplied current, by measuring the potential of the structure to the electrolyte with proper reference cell, or (preferably) by a combination of the two methods. Scheduled maintenance and preventive maintenance may include inspection and adjustment of equipment items, such as current rectifiers or anodes; unscheduled maintenance may include troubleshooting and repair of items identified as defective during scheduled inspections, such as anode beds or electrical conductors and connections.

1-8 CP PROGRAM ELEMENTS.

A CP program includes:

- Corrosion control by CP design.
- Corrosion control during in-house and contracted job orders, work orders, and projects.
- Use of CP to eliminate electrochemical reactions (corrosion).
- Use of protective coatings to reduce CP current requirements.
- Location of CP components for excavation permits.
- Scheduled inspections and preventive maintenance.
- Troubleshooting and repair.
- Failure analysis and initiation of corrective actions on corrosion failures caused by materials, design, construction, or the environment.
- Historical records and documentation required for demonstration of compliance and efficient operations and maintenance of CP systems.

Note: Guidance in this UFC applies to both galvanic anode cathodic protection (GACP) and impressed current cathodic protection (ICCP) systems.

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CHAPTER 2 CRITERIA

2-1 POTENTIAL MEASUREMENT.

To comply with environmental regulations, public law, and industry standards, adequate CP is required to stop corrosion on all protected structures. Adequate CP is a level of CP that meets one, or all, of the criteria detailed in this chapter. This chapter includes criteria and inspection actions that, when used either separately or in combination, indicate whether adequate CP of protected structures (infrastructure) has been achieved. The effectiveness of CP or other corrosion control measures can be affirmed by visual observation, measurements of pipe wall thickness, or by use of internal inspection devices. Because such methods sometimes are not practical, meeting any criterion or combination of criteria in this chapter is evidence that adequate CP has been achieved. When access to or excavations of the structure are made for any purpose, the protected structure should be inspected for evidence of corrosion and/or coating condition. See Chapter 4, or apply sound engineering practices as defined in Appendix B, to determine the methods and frequency of testing required to satisfy these criteria.

Potential measurement, based on the theory of measuring an unknown potential by relating it to a known reference electrode, is the principal test procedure used to determine the efficiency and adequacy of CP systems. In evaluating the potential measurement results against existing criteria, sources of error and the limitations of criteria must be considered.

The most commonly protected structures are buried or submerged metallic pipeline systems. The criteria herein are taken from National Association of Corrosion Engineers (NACE®) International SP0169, with minor revisions. The current revision of this standard should be consulted. Other types of infrastructure may use other NACE International Standards. References to other standards are contained in Appendix G-2.1.

2-1.1 Sources of Potential Error.

Before taking a potential measurement of a structure to determine if adequate CP has been achieved, there are five sources of error that must be addressed to ensure accurate measurements.

2-1.1.1 Accuracy of Equipment.

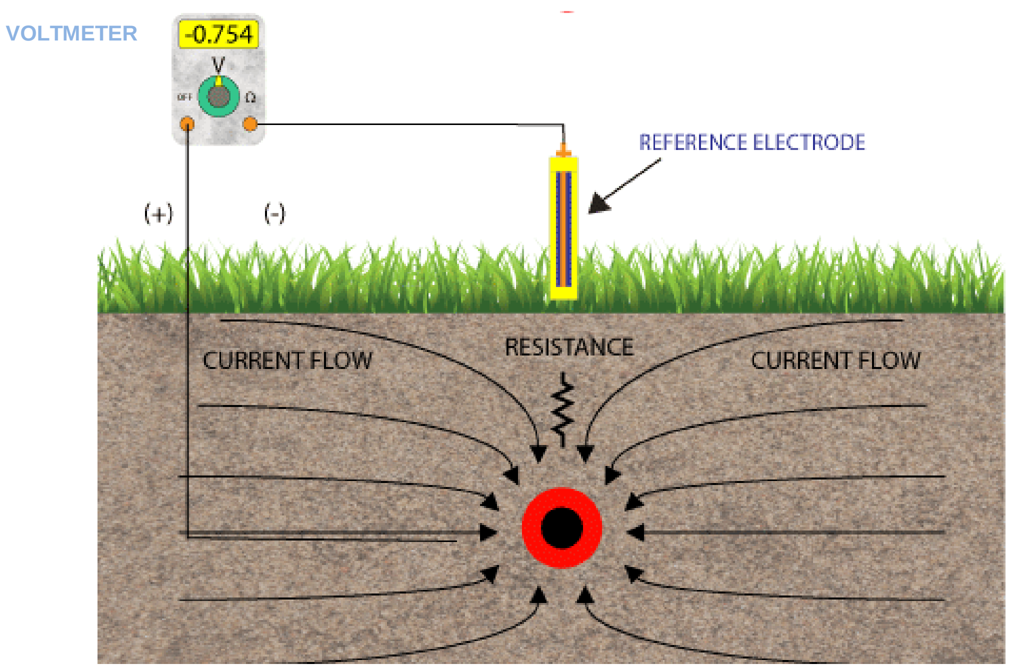
The accuracy of the reference electrode and meter being used must be verified or certified. Voltmeters must be calibrated annually. The reference electrode must be maintained according to manufacturer's specifications annually and must be verified before use.

WARNING
Metered leads should be fully insulated and undamaged to ensure electrical safety and accuracy of measurement. Employ applicable electrical safety practices to avoid damage to equipment or electrical shock to personnel.

2-1.1.2 Voltage Drop.

A voltage drop is caused by current flowing through resistance. See Figure 2-1. When CP is enabled, the current flowing through the electrolyte causes a voltage drop between the reference electrode and the protected structure, adding a more negative component to the displayed voltage on the meter (i.e., −0.85 volts DC versus −0.75 volts DC). This error increases with higher currents or resistivities and with greater distances from the reference electrode to the structure or nearest holiday.

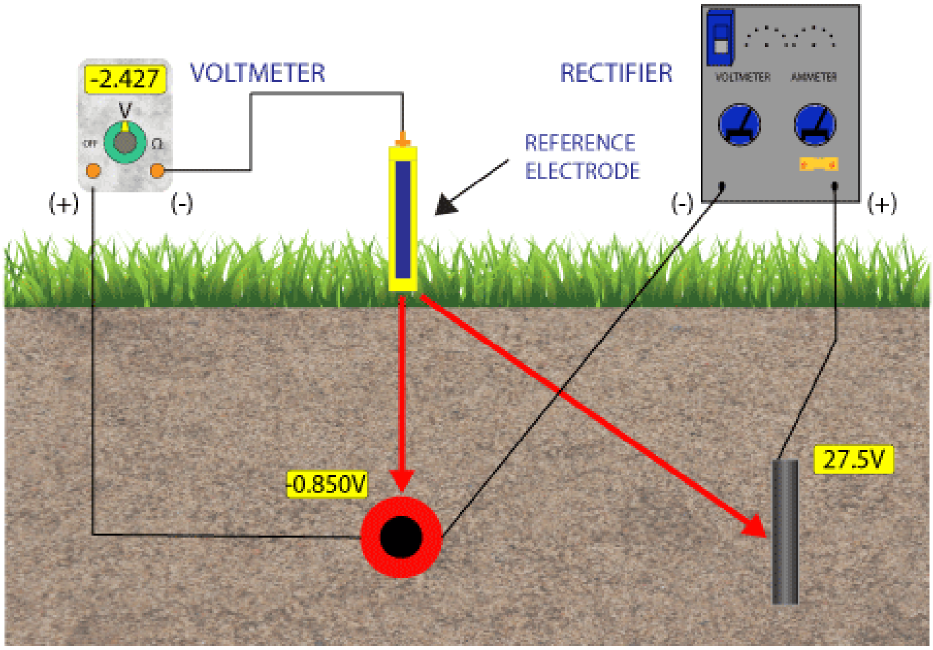
Figure 2-1 Voltage Drop



2-1.1.3 Anode Gradient Field.

The voltage gradient of the anode causes an error when the anode is connected in the circuit during testing (current is on). See Figure 2-2. For galvanic anodes, the potential must be taken as remote as possible from the anodes and as close as possible and directly over the structure being tested. For ICCP systems, when current is applied, the rectifier voltage at the anode is a component of the potential measurement throughout the system. All rectifiers must be synchronized and interrupted to remove this error. Well coated structures and CP systems with high rectifier voltages or distributed anode systems must be interrupted to provide accurate potential measurements.

Figure 2-2 Anode Gradient Field



2-1.1.4 Contact Resistance.

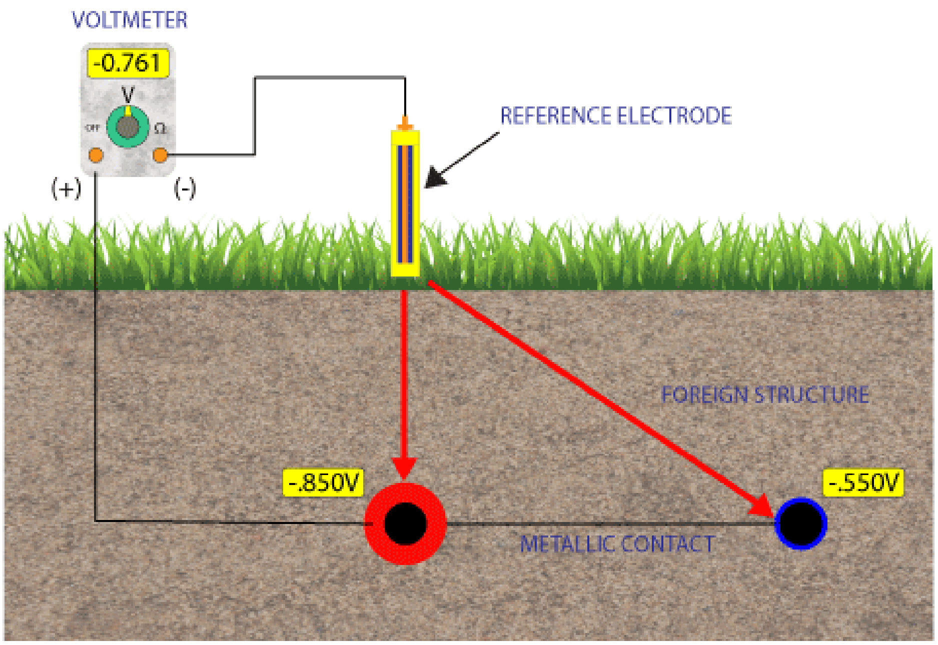
Contact resistance error is present when the reference electrode is not in good contact with the electrolyte. This resistance provides a positive error in the measurement. A high input impedance voltmeter also reduces this error. A selectable input resistance voltmeter can be used to determine if this error is present. By increasing the input resistance, the measurement becomes more negative when this error is present.

The application of water to the electrolyte at the reference electrode contact point reduces this error. In dry or high resistivity areas, water or an extremely high input impedance meter or both must be used to obtain accurate measurements.

2-1.1.5 Mixed Metal Potential.

This error results when a potential measurement being taken on the structure is mixed with the potential of other structures also connected to the circuit being tested. See Figure 2-3. If the structure being tested is not isolated from other structures or has bimetallic components (composed of different metals), the potential measurement is a weighted average of the different metals and must be considered to determine adequate protection. For all bimetallic or non-isolated structures, the 100 mV drop criteria must meet the criteria for the most negative metal and, in the case of steel, must meet the 850 instant off criteria as described in 2-1.2. In the case of connection to a more active metal, such as zinc ribbon or magnesium anodes in ICCP systems, there are negative errors that must be considered.

Figure 2-3 Mixed Metal Potential



2-1.2 Criteria for CP.

The criteria in this section have been developed through laboratory experiments and/or have been verified by evaluating data obtained from successfully operated CP systems. Situations may exist where a single criterion for evaluating the effectiveness of CP may not be satisfactory for all conditions. Often, a combination of criteria is needed for a single structure.

2-1.2.1 Corrosion Leak History.

Corrosion leak history is valuable in assessing the effectiveness of CP. However, corrosion leak history by itself must not be used to determine whether adequate levels of CP have been achieved unless it is impractical to make electrical surveys.

2-1.2.2 Applicability.

Special conditions in which CP is ineffective or only partially effective sometimes exist. Such conditions may include elevated temperatures, disbonded coatings, thermal insulating coatings, shielding, bacterial attack, and unusual contaminants in the electrolyte. Deviation from the recommended practice may be warranted in specific situations, provided corrosion control personnel in responsible charge are able to demonstrate that the objectives expressed in the recommended practice have been achieved.

Criteria are intended to serve as a guide for establishing minimum requirements for control of corrosion on the following systems.

2-1.2.2.1 New Piping Systems.

Corrosion control by coating supplemented with CP, or by some other proven method, should be provided in the initial design and maintained during the service life of the piping system, unless investigations indicate that corrosion control is not required. Consideration should be given to the construction of pipelines in a manner that facilitates the use of in-line inspection tools.

2-1.2.2.2 Existing Coated Piping Systems.

CP should be provided and maintained unless investigations indicate that CP is not required.

2-1.2.2.3 Existing Uncoated Piping Systems.

Studies should be conducted to determine the extent and rate of corrosion on existing uncoated piping systems. When these studies indicate that corrosion will affect the safe or economic operation of the system, adequate corrosion control measures should be taken.

2-1.2.3 References.

Personnel responsible for corrosion control are not limited to criteria in this chapter. Criteria that have been successfully applied on existing piping systems can continue to be used on those piping systems. Any other criteria used must achieve corrosion control comparable to that attained with the criteria within this chapter.

All criteria described in this chapter are in accordance with NACE standards. See Appendix A.

2-1.2.4 Steel and Cast Iron Piping.

Corrosion control can be achieved at various levels of cathodic polarization depending on the environmental conditions. However, in the absence of specific data that demonstrate that adequate CP has been achieved, one or more of the following conditions shall apply:

2-1.2.4.1 Cathodic Potential of at Least −850 mV.

A cathodic potential of at least −850 mV with the CP applied must exist. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte. Voltage drops other than those across the structure-to-electrolyte (S/E) boundary must be considered for valid interpretation of this voltage measurement.

Note: Consideration is understood to mean the application of sound engineering practices in determining the significance of voltage drops by methods such as:

- Measuring or calculating the voltage drop(s).
- Reviewing the historical performance of the CP system.
- Evaluating the physical and electrical characteristics of the pipe and its environment.
- Determining whether or not there is physical evidence of corrosion.

2-1.2.4.2 Polarized Potential of at Least −850 mV.

A polarized potential (the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization) of at least −850 mV relative to a saturated copper/copper sulfate reference electrode must exist.

2-1.2.4.3 Minimum of 100 mV of Cathodic Polarization.

A minimum of 100 mV of cathodic polarization must exist between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion. This criterion may not be valid when bimetallic corrosion; such as when connected to copper grounding, is present.

2-1.2.4.4 Special Conditions.

- On bare or ineffectively coated pipelines where long line corrosion activity is a primary concern, the measurement of a net protective current at predetermined current discharge points from the electrolyte to the pipe surface, as measured by an earth current technique, may be sufficient.
- In some situations, such as the presence of sulfides, bacteria, elevated temperatures, acid environments, and dissimilar metals, the criteria in paragraph 2-1.2.4 may not be sufficient.
- When a pipeline is encased in concrete or buried in dry or aerated high resistivity soil, values less negative than the criteria listed in paragraph 2-1.2.4 may be sufficient.

Note: Using polarized potentials less negative than −850 mV is not recommended for CP of pipelines when operating pressures and conditions are conducive to stress corrosion cracking.

Note: Use of excessive polarized potentials (greater than −1200 V) on coated pipelines should be avoided to minimize cathodic disbondment of the coating. Further investigation is required to determine if other current sources, such as interference pickup or previously installed galvanic anodes, are affecting the structure.

Note: Polarized potentials that result in excessive generation of hydrogen should be avoided on all metals, particularly higher strength steel, certain grades of stainless steel, titanium, aluminum alloys, and pre-stressed concrete pipe.

Note: The earth current technique is often meaningless in multiple pipe rights-of-way, in high resistivity surface soil, for deeply buried pipe, in stray current areas, or where local corrosion cell action predominates.

2-1.2.5 Aluminum Piping.

A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte must exist. The formation or decay of this polarization can be used in this criterion.

2-1.2.5.1 Excessive Voltages

If aluminum is cathodically protected at voltages more negative than −1200 mV (measured between the pipe surface and a saturated copper/copper sulfate reference electrode contacting the electrolyte) and compensation is made for the voltage drops other than those across the pipe–electrolyte boundary, it may suffer corrosion as the result of the buildup of alkali on the metal surface. A polarized potential more negative than −1200 mV must not be used unless previous test results indicate that no appreciable corrosion will occur in the particular environment.

Note: Aluminum may suffer from corrosion under high pH conditions, and application of CP tends to increase the pH at the metal surface. Therefore, careful investigation or testing must be conducted before applying CP to stop pitting attack on aluminum in environments with a natural pH in excess of 8.0.

2-1.2.6 Copper Piping.

A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte must exist. The formation or decay of this polarization can be used in this criterion.

2-1.2.7 Dissimilar Metal Piping.

A negative voltage between all pipe surfaces and a stable reference electrode contacting the electrolyte equal to that required for the protection of the most anodic metal should be maintained.

Note: Amphoteric materials that could be damaged by high alkalinity created by CP should be electrically isolated and separately protected.

2-1.2.8 Other Considerations.

2-1.2.8.1 Determining Voltage Drops.

Methods for determining voltage drop(s) must be selected and applied using sound engineering practices. Once determined, the voltage drop(s) may be used for correcting future measurements at the same location, provided that conditions (such as pipe and CP system operating conditions, soil characteristics, and coating quality) remain similar.

Note: Placing the reference electrode next to the pipe surface may not be at the pipe–electrolyte interface. A reference electrode placed at a coated pipe surface may not significantly reduce soil voltage drop in the measurement if the nearest coating holiday is remote from the reference electrode location.

2-1.2.8.2 Sound Engineering Practices.

When it is impractical or considered unnecessary to disconnect all current sources to correct for voltage drop(s) in the pipe–electrolyte potential measurements, sound engineering practices should be used to ensure that adequate CP has been achieved.

2-1.2.8.3 In-Line Inspection of Pipes.

In-line inspection of pipelines may be helpful to determine the presence or absence of pitting corrosion damage. Absence of corrosion damage or the halting of its growth may indicate adequate corrosion control. The in-line inspection technique, however, may not be capable of detecting all types of corrosion damage. The technique also has limitations in its accuracy and may report items that are not corrosion as anomalies. For example, longitudinal seam corrosion and general corrosion may not be readily detected by in-line inspection. Also, possible thickness variations, dents, gouges, and external ferrous objects may be detected as corrosion. The appropriate use of in-line inspection must be carefully considered.

2-1.2.8.4 Stray Currents and Stray Electrical Gradients.

Situations involving stray currents and stray electrical gradients that require special analysis may exist. If needed, interference testing may need to be performed (see Appendix B for more information).

2-1.2.9 Alternative Reference Electrodes.

2-1.2.9.1 Alternative to Saturated Copper/Copper Sulfate.

Other standard reference electrodes may be substituted for the saturated copper/copper sulfate reference electrode. Table 2-1 lists commonly used reference electrodes as listed in SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*.

Table 2-1 Common Reference Electrodes

Reference Electrodes	Electrolyte Solution	Potential at 25ºC (V/SHE)*	Potential at 25ºC (V/CSE)**	Temperature Coefficient (mV/ºC)	Typical Usage
$Cu/CuSO_4$	Sat. $Cu/CuSO_4$	+0.316	0	0.9 (0.5)	Soils, fresh water
Ag/AgCl	0.6 M NaCl (3.5%)	+0.256	−0.06	−0.33 (0.18)	Seawater, brackish
Ag/AgCl	Sat KCl	+0.222	−0.094	−0.70 (0.39)	
Ag/AgCl	0.1 N KCl	+0.288	−0.028	−0.43	
Zn	Saline solution	−0.79 ± 0.1	−1.1 ± 0.1		Seawater
Zn	Soil	−0.80 ± 0.1	−1.1 ± 0.1		Underground

**SHE – standard hydrogen electrode, **CSE – copper sulfate electrode*

2-1.2.9.2 Alternative Metallic Material or Structure.

An alternative metallic material or structure may be used in place of the saturated copper/copper sulfate reference electrode if the stability of its electrode potential is ensured and if its voltage equivalent referred to a saturated copper/copper sulfate reference electrode is established.

2-1.3 Criteria Limitations.

2-1.3.1 Mixed Metal Potentials.

The 100 mV criteria should not be used on bimetallic systems due to errors from mixed potentials. Adequate CP must be 100 mV from instant off to the most active potential of the most active metal. In the case of steel, instant off must be −850 mV.

2-1.3.2 Structure-to-Earth Resistance.

For small, well coated structures in high resistivity electrolytes and using galvanic anodes, it may be physically impossible to meet either −850 mV instant off or 100 mV shift. The structure may have a resistance to earth of over 200 ohms, and one galvanic anode may have a resistance to earth of over 50 ohms. After two anodes, additional anodes do not noticeably lower the resistance or provide additional current. It is generally accepted that if the on potential (mixed potential) is over 850 mV, what little corrosion exists is occurring at the anode. This is common in nonmetallic water systems with metallic elbows, tees, risers, or valves.

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CHAPTER 3 SCHEDULED INSPECTIONS AND SURVEYS

3-1 GALVANIC.

To comply with environmental regulations, public law, and industry standards, preventive maintenance is required for all installed CP systems. Minimum maintenance actions for both GACP and ICCP systems are detailed in this chapter to ensure all protected structures comply with the criteria outlined in Chapter 2.

3-1.1 Galvanic Corrosion Survey.

The galvanic corrosion survey is conducted to determine if adequate CP exists on the protected structure. A close-interval potential survey (CIS) should be conducted after installation and polarization using the procedures in paragraph 3-2.5 for impressed current systems.

3-1.1.1 Survey Interval.

Conduct a galvanic corrosion survey at the following intervals:

- Within 30 days after major modification to the CP system or the protected structure.
- After any corrosion failure or leak of the protected structure.
- After any inspection or survey that indicates potential measurements are out of compliance.
- 1 year from last corrosion survey.

3-1.1.2 Minimum Requirements.

- Using data from the most recent CIS, or using sound engineering practices, choose a sufficient number of locations for potential testing to ensure the entire structure has adequate CP.
- Test CP system components in accordance with Table 3-1. Table 3-2 presents requirements for potential testing of the protected structure.

Table 3-1 Corrosion Survey Component Testing

CP System	Test Measurement(s)
GACP (at each test station)	• One S/E potential measurement with the reference electrode placed directly over/adjacent to the protected structure at the location(s) nearest the anode(s) • One S/E potential measurement with the reference electrode placed directly over/adjacent to the protected structure midway between anode(s) • One anode-to-electrolyte potential measurement with the reference electrode placed directly over/adjacent to the anode with the anode lead disconnected • Anode-to-structure current using (in order of preference): 1) a clamp-on milliammeter, 2) a multimeter measuring millivolts across a calibrated shunt, or 3) a multimeter connected in series measuring milliamperes
ICCP	Rectifier operational inspection (paragraph 3-2.1)

Table 3-2 Corrosion Survey Potential Measurements

Structure Type	Potential Measurement Locations
Pipelines	Locate the reference electrode: • Over the pipeline at all test stations and at all points where the structure can be contacted (where it enters/exits the ground, passes through a pit, or is exposed). • Over the pipeline at least every 1,000 feet (305 meters) for pipelines off the installation. • Over the pipeline at least every 500 feet (152 meters) for pipelines on the installation.
On grade storage tanks	Locate the reference electrode: • Next to the tank at four equally spaced locations around the tank circumference at compass points or as specified on a drawing. • At a distance one tank radius away from the tank at eight equally spaced locations around the tank circumference.
Underground storage tanks	Locate the reference electrode: • Over the center and over each end of the tank. • Over each end of the feed/return piping. • Over the manhole, fill pipe, and vent pipe. • Over all metallic structures in the area if readings indicate an isolated system is shorted to a foreign structure.

Structure Type	Potential Measurement Locations
Isolated structures	Take one S/E potential measurement on each side of all dielectric fittings/couplings without moving the reference electrode. **Note:** If the potential difference between measurements on each side of a dielectric coupling is less than 10 mV, verify its integrity using an isolation flange tester.
All structures with foreign line crossings	Locate the reference electrode: • Over the foreign line at all points where it crosses the protected structure. • Over the foreign line where it passes nearby the anode bed.
All structures with cased crossings	Locate the reference electrode: • Over the protected structure on each side of all casings. • Over each end of the casing on all casings. **Note:** If the casing is shorted or partially shorted to the pipeline and the potentials over the pipeline are depressed below the criteria described in Chapter 2, take immediate action to clear the short.
Waterfront structures	Take measurements at all permanent reference electrodes. Locate portable reference electrodes: • Adjacent to the structure at all test stations. • Every 150 feet (46 meters) along a continuous length of sheet pile wall at both the surface and at the bottom. • At other test points identified in maintenance manuals or past surveys.
Other structures	Locate the reference electrode at test points identified in the maintenance manual or other past surveys.
All structures	Annotate the soil condition (or tide level for waterfront structures) for comparison to past and future measurements.

3-1.2 Galvanic Anode System Check.

Conduct the galvanic anode system check to monitor the system between corrosion surveys.

3-1.2.1 Inspection Interval.

The check must include 10 percent of the test stations, including the three lowest and the three highest potential measurements from previous surveys. Conduct a galvanic corrosion survey as defined in the NACE standards and Department of Transportation (DOT) regulations.

3-1.2.2 Minimum Requirements.

a. Review all potential readings.

b. For all structures, compare the potential measurements to those previously taken at the same locations to identify changes. Low potentials can indicate a short or other problem. High potentials can indicate interference.

c. If the potential measurements reveal current output that does not satisfy criteria in Chapter 2, adjust or supplement the system as necessary. After 30 days, perform the survey again.

3-1.3 Galvanic Anode Check.

Conduct the galvanic anode system check to determine its operational condition.

3-1.3.1 Maintenance Interval.

Perform the galvanic anode system check as required to locate problems indicated by other surveys.

3-1.3.2 Minimum Requirements.

a. Measure the potential of the structure with the reference electrode located directly over the structure, adjacent to an anode (structure-to-earth, volts DC).

b. Measure the potential of the structure with the reference electrode located directly over the structure, midway between anodes (remote structure-to-earth, volts DC). In this case, remote is as far as possible from the anodes, directly over the protected structure.

c. Disconnect the anode lead from the structure and measure potential of the anode with the reference electrode located directly over the anode (anode-to-earth, volts DC).

d. Measure structure-to-anode current (anode output current, mA) using (in order of preference): 1) a clamp-on milliammeter, 2) a multimeter measuring millivolts across a calibrated shunt, or 3) a multimeter connected in series measuring milliamperes.

e. Compare measurements to those previously taken at the same location.

f. Inspect junction and test boxes, tighten any loose wire connections, and test insulating joints.

Note: Loss of anode-to-earth potential indicates a failed (consumed) anode or failed anode lead.

Note: Loss of anode output current with stable anode-to-earth potential indicates consumption of the anode and pending failure.

Note: Loss of structure-to-earth potential with stable anode-to-earth potential and anode output current indicates loss of isolation or other problems that require further troubleshooting.

3-2 IMPRESSED CURRENT.

3-2.1 Rectifier Operational Inspection.

The purpose of the rectifier operational inspection is to determine the serviceability of all components required to apply current to the anodes of the impressed current system. A thorough inspection ensures dependable current until the next inspection.

3-2.1.1 Inspection Interval.

Perform this inspection together with the CIS, the corrosion survey, and the water tank calibration, or when any inspection or survey indicates that problems with the rectifier may exist.

3-2.1.2 Minimum Requirements.

a. Visually check all rectifier components, shunt box components, safety switches, circuit breakers, and other system power components.

b. Tighten all accessible connections and check temperature of all components and connections.

c. Use vacuum or blower to clean inside of rectifier cabinet or more detailed cleaning as required.

d. Using a calibrated meter, measure the output voltage and current, and calibrate the rectifier meters, if present.

e. For rectifiers with more than one circuit, measure the output voltage and current for each circuit using a calibrated meter, and calibrate the rectifier meters, if present.

f. For rectifiers with potential voltmeters, using a calibrated meter, measure the potentials for each voltmeter, and calibrate that rectifier meter.

g. Using a maintained reference electrode, measure the potential difference to the installed permanent reference electrode by placing both electrodes together in the electrolyte with CP current off. If the difference is more than 10 mV, replace the permanent reference electrode.

h. Calculate the CP system circuit resistance of each circuit by dividing the rectifier DC voltage output of each circuit by the rectifier DC ampere output for that circuit.

i. Calculate the rectifier efficiency by dividing the calculated output DC power by the factored input alternating current (AC) power. (This also includes timing the revolutions of the kilowatt hours (kWh) meter and annotating the meter factor from the face of the kWh meter.)

3-2.2 ICCP System Check.

The ICCP system check ensures that the system is operating at the same level as the last CIS or corrosion survey. This is a non-interrupted check, and the potential measurements must be compared to previous ON cycle potential measurements.

The locations for the potential measurements must be taken from the last CIS or corrosion survey, whichever is most recent, to reasonably ensure that the current output of the system is still being applied and is still adequate.

3-2.2.1 Maintenance Interval.

Conduct the ICCP system check within 60 days of the last CIS, corrosion survey, or ICCP system check. More frequent checks may be required by public law or local regulations.

Note: Underground storage tank CP rectifiers must be inspected at a frequency not exceeding 60 days to ensure compliance with regulations. Check with state Environmental Protection Agency (EPA) authorities, as state regulations may be more stringent or may impose additional requirements.

3-2.2.2 Minimum Requirements.

a. Measure rectifier DC voltage and DC ampere outputs.

b. Verify the DC ampere output of the rectifier meets the current (ampere) requirement found on the last CIS or corrosion survey. If necessary, adjust the rectifier output, and measure outputs again. Repeat procedure as necessary.

c. Calculate the rectifier system circuit resistance by dividing the rectifier DC output voltage by the rectifier DC output current. If the rectifier has more than one circuit, calculate the resistance of each circuit.

d. Take S/E potential measurements at the locations of the three lowest and three highest potential measurements identified in the most recent CIS or corrosion survey.

e. Compare the potential measurements to previous measurements at the same locations and determine if changes have occurred. If potential measurements do not satisfy criteria in Chapter 2 and the rectifier current output meets the current requirement from the last survey, adjust or supplement the CP system as necessary. See Appendix B.

f. Conduct a corrosion survey 30 days after adjustment or modification to the CP system.

3-2.3 Corrosion Survey.

The corrosion survey is conducted to ensure adequate CP still exists as proven on the last CIS. The procedures are the same as the CIS, with different minimum requirements for the potential measurements. The CIS data should be used to determine where potential measurements must be taken to reasonably ensure that the criteria of CP are being met for the entire structure being protected and no interference problems exist on any foreign structures.

3-2.3.1 Survey Interval.

Conduct a corrosion survey at the following intervals:

- 30 days after major modification to the CP system or the protected structure.
- After any corrosion leak on the protected structure.
- After any inspection or survey that indicates that the current requirement of the last corrosion survey is not valid (low or high potential measurements at the proper current output level).
- 1 year from last CIS or corrosion survey.

3-2.3.2 Minimum Requirements.

a. Perform the rectifier operational inspection (paragraph 3-2.1).

b. Using data from the most recent CIS, or using sound engineering practices, choose a sufficient number of locations for potential testing to ensure the entire structure has adequate CP.

c. Test CP system components in accordance with Table 3-1. Table 3-2 presents requirements for potential testing of the protected structure.

3-2.4 Anode Bed Survey.

The impressed current anode bed survey is a non-interrupted survey of the anode bed to determine the condition of the anodes. It identifies any possible problem with the impressed current anodes. It may also be used to predict failure and to program replacement.

3-2.4.1 Survey Interval.

This survey would normally be done together with the CIS. It can also be done during troubleshooting.

3-2.4.2 Minimum Requirements.

At a minimum, an impressed current anode bed survey should include ON potential over the anodes at intervals described in Table 3-3, unless the system has incorporated other means for monitoring the anodes (e.g., individual anode leads in an anode junction box).

Table 3-3 Recommended Over-the-Anode Intervals for the Impressed Current Anode Bed Survey

CP System Type	Test Measurement
All ICCP	Perform rectifier operational inspection.
Remote shallow anode beds	• Measure anode-to-soil potentials at 2-foot (0.6-meter) intervals along the length of the anode bed, beginning 10 feet (3 meters) before the first anode and ending 10 feet (3 meters) past the last anode in the anode bed. • Plot test results on graph paper to give a visual indication of the anode bed condition.
Distributed shallow anode beds	Measure one anode-to-soil potential with the reference electrode located directly over each anode.
Deep anode beds	• In lieu of anode potential measurements, measure anode circuit current using (in order of preference): 1) a clamp-on milliammeter, 2) a multimeter measuring millivolts across a calibrated shunt, or 3) a multimeter connected in series measuring milliamperes. • Measure the anode current for each anode if separate leads are available.

3-2.5 Close-Interval Potential Survey.

The CIS is an interrupted potential survey on impressed current systems and a non-interrupted potential survey on GACP systems; it can be labor intensive. The purpose of this survey is to ensure that adequate CP is maintained over the entire protected structure. It identifies problems within the protected structure or any interference problem on all foreign structures.

The interruption cycle must have an ON cycle of minimum duration four times longer than the OFF cycle, and the OFF cycle should not exceed 1 second. For surveys on GACP systems, measurement errors must be considered, typically through application of sound engineering practices that address the location of the reference electrode, the protected structure, the anodes, the condition of the coating, the soil resistivity, and the depth of the protected structure (refer to Chapter 2). If test stations are installed at each anode, this also can be an interrupted potential survey.

3-2.5.1 Survey Interval.

Conduct CIS at the following intervals:

- 30 days after CP system is installed, energized, and properly adjusted.
- 5 years from the last CIS.

Note: Typically, DoD fuel pipelines are maintained by the Defense Logistics Agency (DLA)-Energy command via two Centrally Managed Programs (CMPs): Integrity Management Program (IMP) and CP. An IMP survey is typically executed every 5 years on a rotating schedule and is normally inclusive of a coating assessment, a CIS, a direct current voltage gradient (DCVG) or alternating current voltage gradient (ACVG) study, and an internal pipe/smart pig survey. Therefore, CP surveys typically do not include a CIS of fuel pipelines.

3-2.5.2 Minimum Requirements.

a. Test CP system components in accordance with Table 3-4 and perform potential measurements of the protected structure in accordance with Table 3-5.

b. Review all potential readings.

c. Annotate the low potential measurements, the high potential measurements, and other significant potential measurements to re-evaluate those locations when performing the corrosion survey.

d. If the data taken show that the current output is not sufficient to satisfy the criteria in Chapter 2, adjust or supplement the system as necessary. See Appendix B.

e. After 30 days, perform a corrosion survey for those locations identified in the paragraph above.

Table 3-4 Test Measurements for Close-Interval Potential Survey

CP System Type	Test Measurement
GACP (at each test station)	• One anode-to-soil potential measurement with the reference electrode placed over the anode and the anode lead disconnected. • Anode-to-structure current using (in order of preference): 1) a clamp-on milliammeter, 2) a multimeter measuring millivolts across a calibrated shunt, or 3) a multimeter connected in series measuring milliamperes. • S/E potential measurement with the reference electrode placed over the structure adjacent to the anode. • S/E potential measurement with the reference electrode placed over the structure remote from the anode.
ICCP	• Rectifier operational inspection (paragraph 3-2.1). • Impressed current anode bed survey (paragraph 3-2.4).

Table 3-5 Close-Interval Potential Survey Potential Measurement Locations

Structure Type	Potential Measurement Locations
Pipelines	Locate the reference electrode over the pipeline at intervals not to exceed the depth of the pipeline, normally every 3 to 5 feet (1 to 1.5 meters).
On grade storage tanks	Measure at permanent reference electrodes, if installed. Locate the reference electrode: • Next to the tank every 6 feet (1.8 meters) around the tank circumference. • At a distance one tank radius away from the tank at eight equally spaced locations around the tank circumference. • In pull tubes at intervals of 3 to 5 feet (1 to 1.5 meters), if installed.
Underground storage tanks	Locate the reference electrode: • Every 3 feet (1 meter) over the tank. • At least every 3 feet (1 meter) over feed and return piping. • Over the manhole, fill pipe, and vent pipe. • Over all metallic structures in the area if readings indicate that an isolated system is shorted to a foreign structure.

Structure Type	Potential Measurement Locations
Isolated structures	Take one S/E potential measurement on each side of all dielectric fittings/couplings without moving the reference electrode. **Note:** If the potential difference between measurements on each side of a dielectric fitting/coupling is <10 mV, verify its integrity using an isolation flange tester.
All structures with foreign line crossings	Locate the reference electrode: • Over the foreign line at all points where it crosses the protected structure. • Over the foreign line where it passes near the anode bed.
All structures with cased crossings	Locate the reference electrode: • Over each end of the casing on all casings. **Note:** If the casing is shorted or partially shorted to the pipeline and the potentials over the pipeline are depressed below criteria described in Chapter 2, high priority must be given to clear the short.
All structures in soil	Record the soil condition for comparison of past/future potential and current measurements.

3-2.6 Water Tank Calibration.

The water tank calibration is to ensure that CP is maintained over the entire surface of the tank interior, as well as to ensure there are no excessive voltages on any part of the tank interior that could damage the coating.

Water tank calibration comprises an interrupted potential survey on ICCP systems or a non-interrupted potential survey on GACP systems. The interruption cycle must have an ON cycle that is a minimum of four times longer than the OFF cycle where the OFF cycle is normally 1 second.

On a GACP system, measurement errors must be accounted for using sound engineering practices, including reference electrode placement, anode positions, and coating condition. If the system design permits, this may also include an interrupted potential survey.

3-2.6.1 Survey Interval.

Conduct water tank calibrations according to the following intervals:

- 30 days after the CP system is installed, modified, or adjusted.
- 1 year from the last water tank calibration.

3-2.6.2 Minimum Requirements.

Inspect water tanks in accordance with Tables 3-6 and 3-7. For all tanks, compare potential measurements to measurements previously taken at the same locations to determine if changes have occurred.

If potential measurements do not satisfy Chapter 2 criteria and the current output meets the current requirement from the last survey, adjust or supplement the system as necessary. See Appendix B. After 30 days, perform a water tank calibration.

WARNING
AC voltage (over 100 V) is still present inside the rectifier with the rectifier panel circuit breaker or power switch OFF. Employ applicable electrical safety practices to avoid damage to equipment or electrical shock to personnel.

Table 3-6 Water Tank Calibration CP System Component Test

CP System Type	Test Measurement
GACP	Measure anode-to-structure current using (in order of preference): 1) a clamp-on milliammeter, 2) a multimeter measuring millivolts across a calibrated shunt, or 3) a multimeter connected in series measuring milliamperes.
ICCP	• Perform the rectifier operational inspection (paragraph 3-2.5). • Calculate the rectifier efficiency by dividing the calculated output DC power by the factored input AC power.

Table 3-7 Water Tank Calibration Potential Measurements

Structure Type	Potential Measurement Locations
Tank walls	Position the reference electrode near the water surface, at mid-depth, and at the bottom in the following locations: • Next to the tank wall directly adjacent to each anode string. • Next to the tank wall midway between two adjacent anode strings.
Tank bottom	Locate the reference electrode: • 2 inches (5 centimeters) above the tank bottom directly beneath each anode string. • 2 inches (5 centimeters) above the tank bottom and as far away from the anode strings as possible.
Metallic riser (elevated water tanks)	Locate the reference electrode adjacent to the riser wall at intervals of 5 feet (1.5 meters) from the top to the bottom of the riser.

Structure Type	Potential Measurement Locations
Permanent reference electrodes	Measure and compare the potential of each permanent reference electrode to a portable reference electrode to determine its accuracy.
All tanks	Annotate the water level for comparison to past and future measurements.

3-2.7 Leak Survey.

The leak survey identifies the cause of all leaks and the action required to prevent future leaks from occurring or to reduce the leak rate.

3-2.7.1 Survey Interval.

Conduct leak surveys after excavation and before backfilling of any leak on any pipeline or tank.

3-2.7.2 Minimum Requirements.

a. Measure the pH of the soil where it contacts the pipeline or tank.

b. Measure the “as found” S/E potential of the pipe or tank where it contacts the soil. “As found” means before any adjustments of existing CP systems, addition of any form of CP, or installation of isolation or bonding components.

c. Determine the cause of the leak.

d. Evaluate the condition and determine appropriate repairs to the pipe or tank coating system.

e. Measure the “as left” S/E potential of the pipe or tank where it contacts the soil. “As left” means after all actions are taken to prevent future leaks.

Note: If these actions are taken after backfill operations, surface potentials are acceptable as described in Chapter 2.

Note: If the leak survey determines the cause to be corrosion, determine the type of corrosion. Table 3-8 lists recommended corrective actions to prevent future leaks.

Table 3-8 Recommended Corrective Actions for Preventing Leaks

CP System Type	Recommended Action
Structure not cathodically protected	Take appropriate action to reduce the possibility of future leaks according to the type of corrosion found.
Structure cathodically protected	• Determine the presence of interference, and, if found, take action to mitigate interference corrosion. • Install isolation couplings, electrical continuity bonds, or CP as appropriate.

3-2.8 Resistance Bond Check.

The resistance bond check is an operational inspection of two metallic structures connected with some type of semiconductor or resistor. This survey ensures that the structures affected by the bond are maintained at adequate levels and interference is mitigated. The bond may include reverse current switches, diodes, resistors, or other protective devices whose failures would jeopardize structure protection. These bonds may be between different sections of a protected structure or may be between a protected structure and any other metallic structure (unprotected or protected with a different CP system).

This is a non-interrupted check and the potential measurements must be compared to previous ON cycle potential measurements taken at the same locations. The locations for the potential measurements and meter connections must be the same and the operational status of any CP systems must be known.

3-2.8.1 Survey Intervals.

- Every 60 days for critical bonds. (Critical bonds are bonds that, when failed, result in loss of adequate protection to the facility.)
- After each corrosion survey and CIS for non-critical bonds.
- Immediately after CP system failure on either or both sides of the bond (unless immediate repair is possible).

More frequent checks may be required by public law or local regulations.

3-2.8.2 Minimum Requirements.

- Potential measurement of protected structure at bond location.
- Potential measurement of structure bonded to protected structure.
- Measurement of structure-to-structure current direction and current magnitude (amps or milliamps, depending on current magnitude), using (in order of preference) 1) a clamp-on milliammeter, 2) a multimeter

measuring millivolts across a calibrated shunt, or 3) a multimeter connected in series measuring milliamperes.

- Measurement of rectifier DC voltage and ampere output of the CP system on either (or both) side(s) of the resistance bond. For troubleshooting bonds with rectifiers on either (or both) structure(s), interrupting rectifier(s) may be required to troubleshoot or adjust bond.
- Evidence of proper functioning, which may include current output, normal power consumption, a signal indicating normal operation, or satisfactory CP levels on the structures, according to the function or design of the bond.
- Comparison of all measurements to previous surveys.
- If the potential measurements, current flow, current direction, or other measurement has changed from the last check, investigation to determine if bond is operating as intended or if troubleshooting or adjustments are required.
- Adjustment or repair of the component as necessary, and repeat of bond test.

3-2.9 Direct Current Voltage Gradient (DCVG) Survey.

A DCVG survey is an accurate method used to size and locate pipe coating defects (holidays). The technique is based on measuring the voltage gradients in the soil above a cathodically protected pipeline. In a DCVG, a DC signal is applied to the pipeline and the voltage (potential) gradient in the soil above the pipeline is measured. Voltage gradients, as measured between two calibrated reference electrodes spaced apart, arise as a result of the current pickup or discharge at pipeline coating holiday locations. This potential gradient can be detected between two electrodes placed on the soil surface with a sensitive analog mV meter; therefore, the location of the coating defect can be determined with precision of 4 to 8 inches (10 to 20 centimeters).

The size or severity of the coating defect is characterized by a relative number, the Indication Severity %IR calculation.

Once the survey technician has recorded the DCVG measurements and GPS locations, the %IR values are calculated. The calculations involve using the signal magnitude at a contact point and remote earth, creating a pipe-to-remote earth voltage gradient value. Over-the-line-remote earth value is then measured and the %IR value is calculated. See Equation 3-1.

Equation 3-1. %IR Calculation

$$\%\boldsymbol{IR} = \frac{\boldsymbol{Over - the - Line - Remote - Earth - Value}}{\boldsymbol{Calculated\ Pipe - to - Remote\ Earth\ Value}} \boldsymbol{X100}$$

Depending on the magnitude of the %IR, a determination can be made where physical examination of the pipe and coating repair are necessary. The DCVG survey uses the pipeline's ICCP system. If no ICCP system is installed, a temporary ICCP system can be used.

3-2.9.1 Survey Intervals.

Conduct a DCVG survey at the following intervals:

- 30 days after new pipeline installation.
- After a CIS has been performed.
- On demand when a coating evaluation is needed, such as when a pipeline excavation and recoat has been performed, when a third-party excavation has been performed and coating damage is suspected, when a new pipeline segment has been installed, when determined due to coating age and condition that a DCVG survey is required, and at the discretion of operations.
- Every 7 years when evaluating high consequence area (HCA).

3-2.9.2 Minimum Requirements.

- Perform DCVG survey at locations where potentials do not achieve criteria of CIS.
- Review all survey data.
- Annotate the locations indicating coating holidays and prioritize using the %IR.

CHAPTER 4 PRIORITIES FOR TESTING, TROUBLESHOOTING, AND REPAIR

4-1 INTRODUCTION.

To properly operate and maintain a CP system, it is essential to apply continuous protection to the protected structure. Interruptions in protection result in irreversible corrosion damage to the structure. Along with the importance or cost of the structure, the factors that affect the rate of corrosion also relate directly to priority considerations. The long-term strategy to prevent corrosion of infrastructure is outlined in USC Title 10-2228*, Office of Corrosion Policy and Oversight* and in DoD Instruction 5000.36, *Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure*.

While scheduled inspections and surveys are performed to ensure continued satisfactory performance of CP systems, problems that require troubleshooting and maintenance outside scheduled times can occur. These problems may require unscheduled maintenance actions. For instance, if potentials that do not meet the criteria for CP are found (see Chapter 2), troubleshooting and repair must be performed (see Appendix B). Addressing these issues ensures the consistent operation of the system and greatly reduces the life cycle cost of the infrastructure being protected. In addressing unscheduled maintenance issues, the priority of restoration of the system affected, as well as the budget and equipment available to correct the problem, must also be considered. A priority, either emergency or routine, must be assigned to restore adequate CP to affected structures. The following priority considerations are detailed to allow a knowledge-based priority determination.

4-2 EMERGENCY PRIORITY CONSIDERATIONS.

GACP systems are inherently maintenance-free. ICCP systems require a higher level of maintenance. Maintaining adequate CP on all protected, buried, or submerged metallic structures is critical to prevent or mitigate corrosion. An assignment of emergency priority means an issue needs to be addressed immediately.

Failure of CP systems that affect public safety and/or those that are federally regulated must be given emergency priority to repair or replace. This would include pipelines, underground storage tanks, aboveground storage tanks, and other structures with CP that contain hazardous chemicals, fuels, or natural gas. High-pressure transmission lines in HCAs should be given emergency priority.

Any metallic structure or utility that would adversely affect the mission capability if a failure occurs must be given high priority. This includes fire protection pipelines, sea walls, locks, flood gates, and other critical metallic structures or utilities required for mission accomplishment. Other examples include underground oxygen pipelines to hospitals and underground air, steam, or other pipelines whose failure would compromise mission requirements.

4-3 ROUTINE PRIORITY CONSIDERATIONS.

The factors affecting the scheduling of routine priority work orders for restoration of adequate CP depend on the type of utility, mission impact of failure, and seriousness of the corrosion probability. All inadequate levels of CP adversely affect the life cycle cost of the infrastructure. Corrosion problems listed below affect the rate of corrosion and should be considered for scheduling purposes to troubleshoot, repair, and restore adequate CP.

4-3.1 Interference.

The presence of interference can be extremely corrosive to structures where current picked up from a foreign source is discharging from a metallic structure or utility, especially if that utility is coated. Corrosion failures can occur in an extremely short amount of time, possibly in days if the interference is extremely serious. This usually occurs where underground pipelines cross other pipelines or electrical grounds where the interference is being applied by another CP system that is not isolated. The seriousness is determined by the potential measured and can easily be a positive potential to a saturated copper/copper sulfate reference electrode.

For every amp-year of current (1 amp for 1 year), 20.7 pounds of steel are lost. When this metal loss is discharging from coating defects, extremely short time to failure occurs. This mode of failure is usually only discovered after failure has occurred, and the highest possible priority must be given to mitigate further failures. If it is found before failure, the same applies—corrosion failure is imminent.

4-3.2 Corrosiveness of the Soil.

For underground or submerged metallic structures, the electrolyte resistivity is the basic measurement for the corrosiveness of the electrolyte—the lower the resistivity, the higher the corrosion rate. See Table 4-1.

Table 4-1 Soil Corrosiveness

Soil Corrosiveness	Soil Resistivity (Ω-cm)
Severely corrosive	0 to 500
Very corrosive	500 to 999
Corrosive	1,000 to 2,999
Moderately corrosive	3,000 to 9999
Slightly corrosive	10,000 to 25,000
Relatively less corrosive	>25,000

4-3.3 Determining Scheduling Priority.

The potential difference between the measured potential and the potential required for adequate protection should be considered and compared with the corrosiveness to determine priority. Other corrosiveness factors, such as high temperature and acidic electrolytes, increase the corrosion rate and elevate the priority.

Table 4-2 can be used as a tool to determine scheduling priority. For each factor, the appropriate measurement is taken. Based on the measurement, a factor value is assigned and a sum is then calculated.

- If sum is over 5, assign emergency priority.
- If sum is 5, schedule before any other action; expedite parts.
- If sum is 4, schedule immediately if possible; rush parts, maximum of 30 days.
- If sum is 3, schedule maximum of 60 days.
- If sum is 2 or below, schedule before next inspection cycle.

Table 4-2 Scheduling Considerations Based on Factor Value Sum

Factor	Factor Value								
	5	**4**	**3**	**2**	**1**	**0**	**-1**	**-2**	**-3**
Electrolyte resistivity (ohm-cm)	<1000	1001 to 2000	2001 to 4000	4001 to 8000	8001 to 16000	16001 to 100000	100001 to 200000	200001 to 400000	>400000
Temperature (ºF)	>210	201 to 210	191 to 200	181 to 190	170 to 180	33 to 169	0 to 32	<0	—
pH	<3.5	3.5 to 4	4.1 to 5	—	—	—	9 to 10	10.1 to 11	>11
Potential (mV)	>+200	0 to +200	0 to −200	−201 to −300	−301 to −400	−401 to −600	−601 to −700	−701 to −800	−801 to −850
Hazardous storage (Yes/No)	—	Yes	—	—	—	—	No	—	—
Mission essential (Yes/No)	—	—	Yes	—	—	—	No	—	—
HCA* (Yes/No)	—	—	—	—	Yes	—	No	—	—
High value or leak repair cost (Yes/No)	—	—	—	Yes	—	—	No	—	—

*For hazardous storage tanks and pipelines only.

4-3.3.1 Scheduling Examples.

4-3.3.1.1 Example 1.

Example 1 concerns an underground water distribution pipeline in 2,500 ohm-cm soil at ambient temperature with pH 9.5. Instant off potential is –710 mV. It is not hazardous, mission essential, or of high value. See Table 4-3.

Table 4-3 Example 1 Values

Factor	Measurement	Factor Value Based on Table 4-2
Electrolyte resistivity (ohm-cm)	2,500	3
Temperature (ºF)	60	0
pH	9.5	–1
Potential (mV)	−710	–2
Hazardous storage (Yes/No)	No	–1
Mission essential (Yes/No)	No	–1
HCA* (Yes/No)	N/A	0
High value or leak repair cost (Yes/No)	No	–1
Sum	—	–3

The factor value sum is −3, so work should be scheduled before the next inspection cycle.

4-3.3.1.2 Example 2.

Example 2 concerns an underground fuel pipeline in 15,000 ohm/cm soil at ambient temperature with pH 7.5. Instant off potential is −612 mV. It is hazardous, not in an HCA, and not mission essential, and it is a high value for leak repair cost. See Table 4-4.

Table 4-4 Example 2 Values

Factor	Measurement	Factor Value Based on Table 4-2
Electrolyte resistivity (ohm-cm)	15,000	1
Temperature (ºF)	60	0
pH	7.5	0
Potential (mV)	–612	–1
Hazardous storage (Yes/No)	Yes	4
Mission essential (Yes/No)	No	–1
HCA* (Yes/No)	No	–1
High value or leak repair cost (Yes/No)	Yes	2
Sum	—	4

The sum of all factor values is 4, so work should be scheduled immediately if possible; rush parts, maximum of 30 days.

4-3.3.1.3 Example 3.

Example 3 concerns an underground fuel pipeline in 1500 ohm-cm soil at ambient temperature with pH 4.5 and instant off potential of –615 mV. It is hazardous, is not in an HCA and is not mission essential, and it is a high value for a leak repair cost. See Table 4-5.

Table 4-5 Example 3 Values

Factor	Measurement	Factor Value Based on Table 4-2
Electrolyte resistivity (ohm-cm)	1500	4
Temperature (ºF)	60	0
pH	4.5	3
Potential (mV)	–615	–1
Hazardous storage (Yes/No)	Yes	4
Mission essential (Yes/No)	No	–1
HCA* (Yes/No)	No	–1
High value or leak repair cost (Yes/No)	Yes	2
Sum		10

The factor value sum is 10, so work should be assigned emergency priority.

4-3.4 Estimated Time to Failure.

For any infrastructure not categorized above, the priority is dependent on the estimated time to failure compared to the resulting loss in life cycle costs or costs of the release, cleanup, and repair of the failure.

4-3.5 Past Leak History.

Past leak history can show a trend and should also elevate the priority to troubleshoot the cause of the previous leaks and apply a mitigation plan to prevent further failures. The leaks may not be caused by corrosion, and other steps may be necessary. If the leaks are caused by corrosion and have had adequate CP, additional actions may still be required. Increasing current density or additional actions, such as locating and repairing damaged or unbonded coatings, may be required.

4-4 INFRASTRUCTURE WITHOUT CATHODIC PROTECTION.

There may be metallic infrastructure without CP. A plan to evaluate all other metallic infrastructure should be in place. Periodic review of buried metallic or submerged metallic structures should be conducted to determine if CP would be economically feasible to lower the life cycle cost of these infrastructure investments.

4-5 CORROSION ISSUES BEYOND CAPABILITY OF EXISTING RESOURCES.

If problems cannot be completed due to economic, personnel, or other limitations, identify the requirement and submit a budgetary plan for required upgrades. Identify additional requirements that add reliability to existing systems. Identify and submit cost-effective initiatives to increase the CP to protected or unprotected structures. If the capability to maintain, troubleshoot, or repair CP systems is not available by government employees, submit requirements for contracted assistance to accomplish all of the goals of the Corrosion Control Program to mitigate corrosion and lower the life cycle cost of the infrastructure.

4-6 UPGRADE EQUIPMENT.

Consider cost-effective measures to make data collection more timely or effective or to make recordkeeping easier or more complete, or consider upgrading equipment to minimize time required for surveys, troubleshooting, or data collection.

4-6.1 Remote Monitoring.

Remote monitoring can be installed to instantly identify readings that are below or above set points. These remote monitoring systems can monitor rectifier AC input voltage, DC output voltage and current, structure potentials, and many other things such as structure bonds, resistance bonds, test station potentials, and galvanic anode currents. Immediate notification of these problems can greatly accelerate the time required to repair the cause of the alarm. These systems can accelerate the data collection and recordkeeping functions, as well as provide much needed data for effective troubleshooting.

4-6.2 Equipment.

New and upgraded equipment that greatly reduces survey time, troubleshooting time, and personnel is available. See TSEWG TP-24, *Cathodic Protection Test Procedures* for available equipment and capabilities.

4-7 COMMON PROBLEMS.

Common problems that can occur in GACP or ICCP systems outside of scheduled maintenance times can be found in Appendix B-1.1 and B-2.1, respectively. Specific references for Army, Air Force, and Navy can be found in Appendix G-3.

APPENDIX A REFERENCES

A-1 AIR FORCE

10 USC Title 2228, *Office of Corrosion Policy and Oversight*
(https://www.law.cornell.edu/)

(https://www.e-publishing.af.mil/Product-Index/#/?view=org&orgID=10141&catID=8&isForm=true&modID=449&tabID=131)

AF Form 1457, *Water Treatment Operating Log for Cooling Tower Systems*

AF 1459, *Water Treatment Operating Log for Steam and Hot Water Boilers*

AF 1686, *Cathodic Protection Operating Log for Sacrificial Anode System (Not Local Reproduction Authorized [LRA])*

AF 1687, *Leak/Failure Data Record Resource Advocacy/Corrosion Control Metric*

AF 1688, *Annual Cathodic Protection Performance Survey (Not LRA)*

AF 1689, *Water Tank Calibration*

A-2 ARMY

Army Regulations (AR) 200-1, *Environmental Protection and Enhancement*
(https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/r200_1.pdf)

A-3 DEPARTMENT OF DEFENSE

DoD Instruction 5000.36, *Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure*
https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500067p.pdf

Public Works Bulletin 420-49-29, *Operation and Maintenance of Cathodic Protection Systems*
(https://www.wbdg.org/FFC/ARMYCOE/PWTB/pwtb_420_49_29.pdf)

TSEWG TP-24, *Cathodic Protection Test Procedures*
(AFCEC/COSC, under development)

UFC 1-200-01, *DoD Building Code (General Building Requirements)*
(http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc)

A-4 NACE INTERNATIONAL®

www.nace.org

SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*

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APPENDIX B BEST PRACTICES

B-1 TROUBLESHOOTING GALVANIC SYSTEMS.

Galvanic CP is inherently maintenance free. The current is a result of the potential difference of the two metals. Recurring maintenance checks are performed to ensure continued satisfactory performance. Galvanic anodes sacrifice themselves to protect the structure. They normally consume themselves at a constant rate, and failure can be predicted by current measurement versus time. The starting point for all troubleshooting for galvanic systems is at the anode (or anode connection). For galvanic systems, there must be an anode test lead for conclusive testing of the anodes.

B-1.1 Common Problems.

The most common problems in sacrificial anode systems are shorts or failure of dielectrics on isolated protected structures. Due to the very limited voltage, sacrificial anodes usually cannot supply sufficient current to protect the structures if isolation is lost. On well-coated structures, the contact resistance to earth is high. Other metals in the earth that are not coated have a very low contact resistance, providing a low-resistance path for anode current. Maintaining the dielectrics in an isolated system is essential to continued satisfactory performance of sacrificial anode systems. One failed dielectric can result in loss of protection for the entire system. See paragraph B-1.5 for detailed procedures to locate failed dielectrics.

B-1.2 Lead Wires.

Failure of the anode lead wires is uncommon, since copper exposed by nicks or insulation defects are cathodically protected by the anodes. However, these wires can be cut by extraneous excavations. Exercising control over digging permits in the areas of the anode ground beds may ensure that if the wires are cut, they can be repaired on site, before backfilling occurs. Troubleshooting to locate the break at a later date is usually not successful, and replacement of a prematurely failed anode is more economical in almost all cases. A sudden zero anode current output reading may indicate failed lead wires.

B-1.3 Anode Consumption.

When sacrificial anode systems reach the end of their useful life, potential, current, and voltage measurements begin to change. When performing recurring maintenance, a significant drop in anode current indicates imminent failure of the anode. Potential measurements over the protected structure begin to show dips or drops in the areas of failed anodes. A significant drop in anode potential indicates a failed anode. Anode current may actually reverse after failure, due to the copper center tap of the anode being cathodic to the protected structure. When drops in the potential of the protected structure begin to occur, a closer inspection should be made to determine the extent of the damage to the anodes.

B-1.4 Improper Use.

Except on small or extremely well coated structures, such as underground storage tanks or short pipelines with butyl rubber/extruded polyethylene coatings, it is normally not economical to replace a distributed galvanic anode system. When galvanic anodes begin to fail on a distributed system, ICCP should be considered.

B-1.5 Dielectric Testing Procedures.

B-1.5.1 Background.

If a CP system is designed to protect an isolated structure, shorted dielectrics normally result in loss of adequate protection to that structure. Shorts may also result in poor current distribution or shielding, resulting in the loss of adequate protection to areas of the structure. Testing an installed dielectric presents several problems. Since typical installations normally include many dielectrics, all of which are in a parallel circuit, failure of one dielectric can effectively short the entire system. There are indications of the shorted condition of one dielectric at many, or all, other dielectrics installed. Usually, the farther the distance between the dielectric being tested and the dielectric that is shorted, the easier it is to test that dielectric.

Most methods of testing a dielectric give a reliable indication of only one condition of the dielectric (either shorted or not shorted condition) and further testing may be required for the other condition. The radio frequency tester (insulated flange tester), because of its wavelength and the strength of the signal, is the only method that gives a totally reliable indication of the condition of that specific dielectric. This method does not read through other parallel paths, even when these paths are in the immediate vicinity. In fact, this method can pinpoint the fault to a particular flange bolt or the flange gasket. Therefore, this method should be used for testing when any other method is not conclusive.

B-1.5.2 Testing Methods.

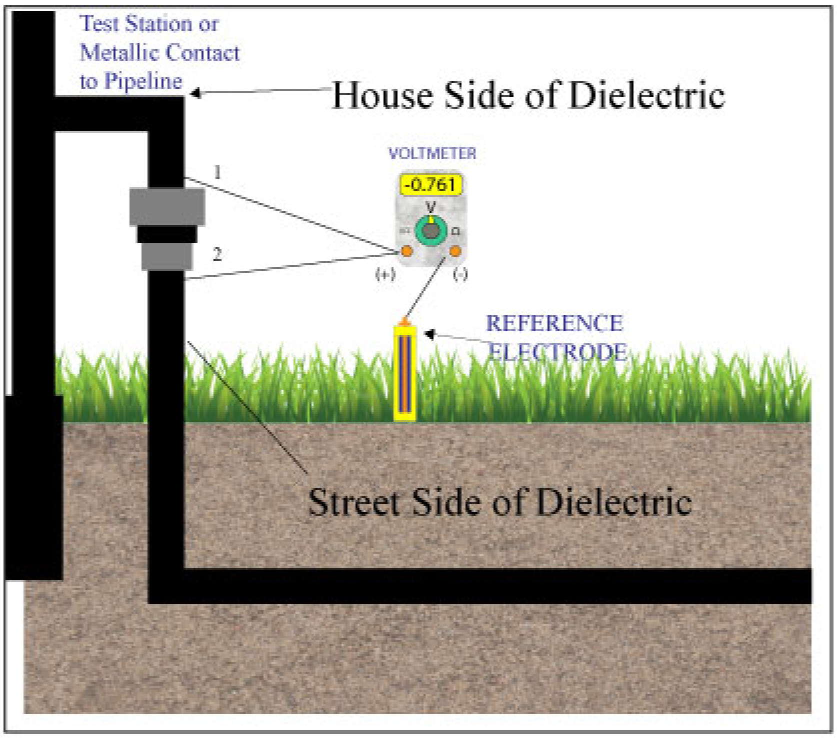
The preferred method to determine if a dielectric may be shorted is by potential testing. This method provides an immediate indication if the dielectric is not shorted and, at the same time, provides valuable potential data. If this method indicates that the dielectric may be shorted, other methods of verification are required. The radio frequency tester (insulated flange tester) should be used when a shorted condition is indicated by potential measurements. The pipe locator and the power supply methods of verification may be used to test installed dielectrics. The pipe locator method (paragraph B-1.5.3) can determine that an installed dielectric is bad but does not give conclusive evidence if the test indicates that the dielectric is good. The power supply method, which can determine that an installed dielectric is good, does not give conclusive evidence if the test indicates that an installed dielectric is bad.

CAUTION
Do not use an ohmmeter to measure resistance of an installed dielectric. If the dielectric is good, current flows through the meter and damage could result. If the current damages the meter, the measurement does not give a valid resistance value.

B-1.5.3 Testing for a Shorted Dielectric.

Take a potential measurement of both sides of the installed dielectric by changing only the structure connection, without moving the saturated copper/copper sulfate reference electrode. See Figure B-1.

Figure B-1 Testing for a Shorted Dielectric



B-1.5.3.1 Significantly Different Potential Measurements.

If the two potential measurements are significantly different (over 10 mV), the dielectric is good. The street side of the dielectric, under normal conditions (with CP), should be at a potential more negative than –0.85 volts DC, and the house side of the dielectric should be between approximately –0.15 and –0.45 volts DC (a difference of between 400 and 700 mV). If the dielectric is good and the house side of the dielectric has a potential more negative than expected, another shorted dielectric in the area should be suspected, and further investigation is required (for example, if the house side potential reading is over –0.65 volts DC, with a street side potential the same or more negative).

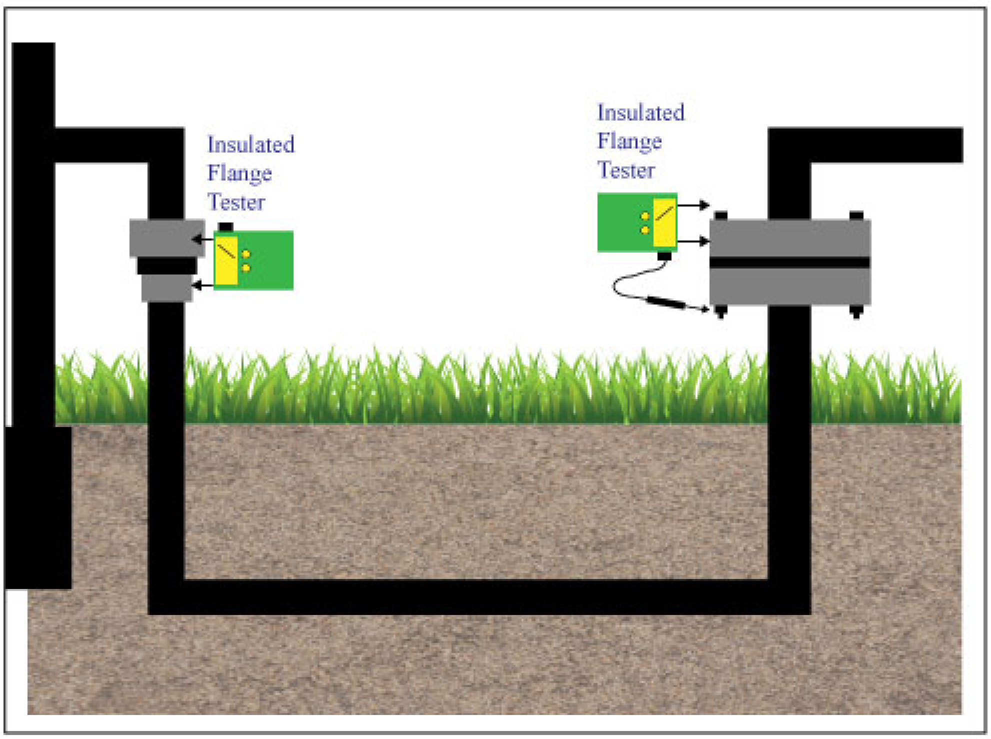
B-1.5.3.2 Not Significantly Different Potential Measurements.

The dielectric may be shorted and additional testing is required if the two potential measurements are not significantly different (under 10 mV). The preferred method is to use a radio frequency tester (insulated flange tester) to test that specific dielectric (paragraph B-1.5.2). Other possible methods that may or may not be conclusive include using the pipe locator method (paragraph B-1.5.3) or the impressed test current method (paragraph B-1.5.4).

B-1.5.4 Using a Radio Frequency Tester.

This method is the most accurate and conclusive method of testing a dielectric. Turn the insulated flange tester test switch to “zero,” turn the control knob on, and zero the needle indicator. Turn the test switch to “test” and, without turning the control knob, test the dielectric. See Figure B-2.

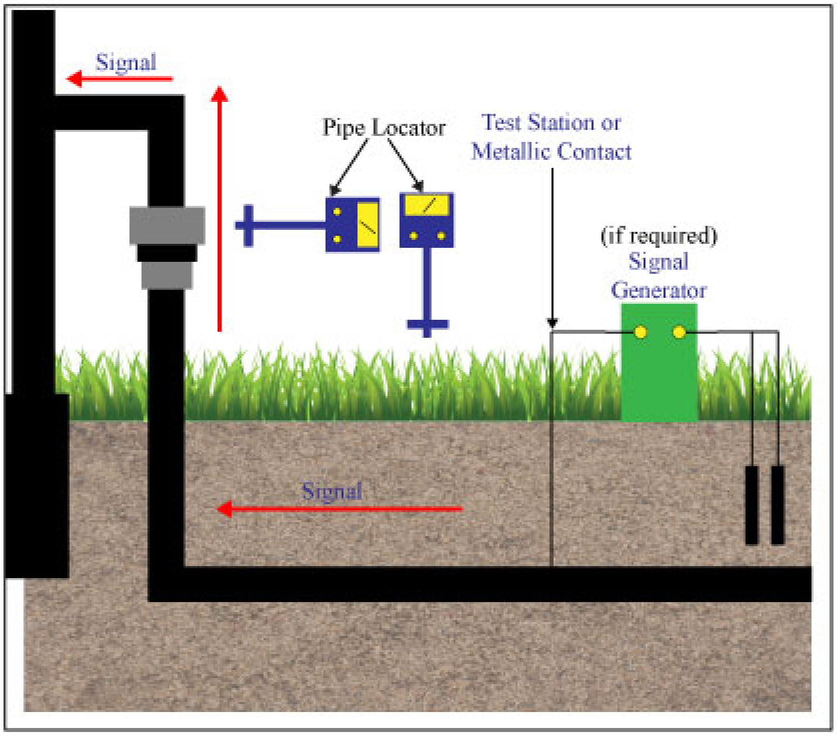
Figure B-2 Testing an Installed Dielectric with Insulated Flange Tester



B-1.5.5 Using a Pipe Locator.

Using two different types of pipe locators may indicate that a dielectric is bad. One uses a short wavelength signal (paragraph B-1.5.3.2), and one uses the signal from an impressed current system (60-cycle “noise”—this method can only be used on impressed current systems with a single-phase rectifier) (paragraph B-1.5.3.1). These methods give a rapid indication if the dielectric is shorted but may not be conclusive. See Figure B-3.

Figure B-3 Testing for Shorted Dielectric with Impressed Test Current



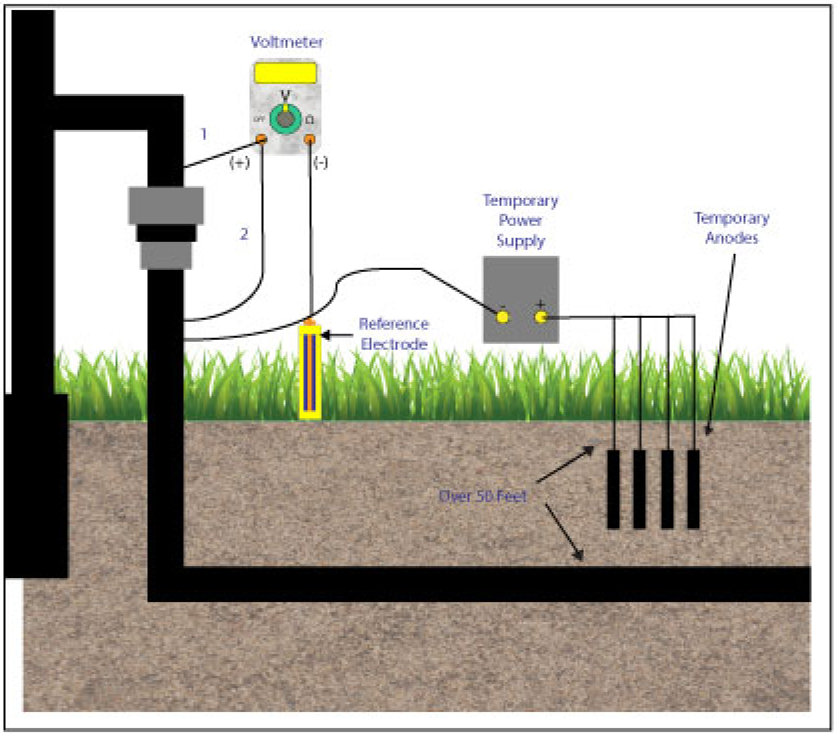
B-1.5.5.1 Pipe Horn, Model FDAC200.

The Pipe Horn, Model FDAC200, detects the signal from a single-phase rectifier. With the impressed current system on, this locator can be used to follow the underground pipeline. If a dielectric is shorted and the current is sufficient, the locator follows the signal across the dielectric. Consequently, if the signal is followed through the dielectric, that dielectric is bad. If no signal can be followed, verify with the insulated flange tester (paragraph B-1.5.2).

B-1.5.5.2 Short Wavelength Pipe Locator.

A short wavelength pipe locator, using a direct connection, detects the signal from a signal generator. To obtain a strong signal, ensure that a good metallic connection is made, a good battery is installed in the signal generator, and, most importantly, that the signal generator has a good, low-resistant ground. This locator can then be used to follow the underground pipeline. If a dielectric is shorted, and the signal is sufficient, the locator follows the signal across the dielectric. Consequently, if the signal is followed through the dielectric, that dielectric is bad. If no signal can be followed, verify with the insulated flange tester (paragraph B-1.5.2). See Figure B-4.

Figure B-4 Testing for Shorted Dielectric with Power Supply



B-1.5.6 Using a Temporary Ground to Impress Test Current.

Use a temporary ground to impress test current to the street side of the dielectric, or, if possible, merely increase the current level of the existing system. Note that the temporary ground should be installed where the current distributes to the location being tested. Repeat the potential measurement of both structures. If the potential of the house side of the dielectric remains approximately the same or changes in a positive direction (less negative) when the potential of the street side of the dielectric changes in a negative direction, they are not shorted. If both potential measurements change in a more negative direction as current is increased, the two structures are shorted together.

B-2 TROUBLESHOOTING IMPRESSED CURRENT SYSTEMS.

B-2.1 Common Problems.

The following section lists how to troubleshoot common problems associated with ICCP systems.

B-2.2 Zero Output Current.

The following lists the possible causes and troubleshooting steps for the condition when there is zero output current and slight increase in output voltage. Historical data indicate that output has remained relatively constant for a long period of time.

B-2.2.1 Troubleshooting Broken Anode Lead (Header Cable).

- With power OFF, disconnect anode lead(s) at P4.
- Connect P4 (positive terminal) to an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods.
- For a short period of time, turn power ON and note AC (paragraph B-2.7). One of two conditions exists: either current is now present (changed) or it is not present (not changed).

Note: If the structure being tested is the inside of a water tank or tower, and the lack of water does not allow current flow (no electrolyte), fill the tank and then retest.

- If current exists, the anode lead is broken or the anodes have failed (proceed to paragraph B-2.13).
- If no current exists, the structure lead may be broken (see next section).

B-2.2.2 Troubleshooting Broken Structure Lead.

- The temporary or alternative anode should be connected to terminal P4 as described in previous section.
- With power OFF, disconnect structure lead at N4.
- Connect N4 (negative terminal) to alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods.
- For a short period of time, turn power ON and note AC. One of two conditions exists: either current is now present (changed) or it is not present (not changed).
- If current still does not exist (not changed), the temporary anode bed is not sufficient. Supplement the temporary anode bed, and then perform steps in paragraph B-2.8.
- If current is present (changed), the structure connection is broken. Use the fault detector and cable locator connected directly to the structure lead at N4 to trace the structure lead from the rectifier toward the structure. This can be extremely difficult in some cases.

- An alternative method is to locate the first structure connection (from drawings, markers, or induction methods). Excavate to the structure and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit.
- Use the fault detector and cable locator connected directly to the structure lead to trace the lead from the structure toward the rectifier. If this is still unsuccessful, replace the structure lead from the rectifier to the structure.

Note: When using the direct connection method, it is essential to have a low-resistance, isolated ground for the fault detector or cable locator to put strong locator signals on the cable under test.

B-2.3 Zero Output Current and Maximum Output Voltage.

The following lists the possible causes and troubleshooting steps for the condition when there is zero output current and maximum output voltage. Historical data show that system voltage increased several times and output current decreased slowly at first, then faster as time progressed.

B-2.3.1 Troubleshooting Failed Anode Bed.

- Determine from records if there is sufficient anode material to attempt locating and repairing the fault.
- Calculate current and time to amp-years.
- Compare that calculation to the weight of the installed anodes and the weight loss of the anode material. This indicates if the anodes are expended or have significant life remaining. Another indicator is that if there is a gradual failure over a period of time, the anodes have failed. See paragraph B-2.13 for further direction.

B-2.4 Zero Output Current and/or Zero or Minimal Output Voltage.

The following lists the possible causes and troubleshooting steps for the condition when there is zero output current and/or zero or minimal output voltage. No historical data are immediately available.

B-2.4.1 Troubleshooting Loss of AC Power.

- Check all fuses and measure AC voltage input to the rectifier.
- With power OFF, remove all fuses at the rectifier and any fusible disconnect.
- Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse. Corrosion on fuse end caps or fuse holders also causes loss of voltage.
- Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found.

- If a disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale.
- Measure the voltage on the rectifier side of the disconnect. If a disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A3 (output of circuit breaker) and ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead.
- If voltage is present, either the transformer or the connections inside the rectifier are faulty (proceed to paragraph B-2.14).
- If voltage is not present, there is a loss of AC power to the rectifier.
- Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and input side of the circuit breaker (A1) on the second power lead.
- If voltage is not present, proceed to paragraph B-2.15.
- If voltage is present, replace circuit breaker or fuse.
- Verify the circuit breaker has not tripped or fuse has not blown.
- If properly operating, measure the AC voltage from the circuit breaker or fuse where power is supplied to the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect meter to the output of circuit breaker or the output side of the fuse and ground or neutral bar.
- For 220/240 V, single-phase systems, use the same procedures, but connect the meter to the output lugs of the circuit breakers or the output side of the fuses.
- If voltage is present, locate the break in the power feed from that point to the rectifier circuit breaker (or rectifier fusible disconnect, whichever was last tested).

- If voltage is not present, measure the AC voltage to the circuit breaker or fuse supplying power to the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect the meter to the main lugs of the circuit breaker panel or the input side of the fuses and ground.
- For 220/240 V, single-phase systems, use the same procedures, but check individual lugs separately.
- If voltage is not present, locate the circuit breaker panel or transformer supplying power to the panel and apply the applicable procedures in paragraph B-2.15.
- If voltage is present, replace the circuit breaker or fuses.

B-2.4.2 Troubleshoot Defective Meters.

- This symptom indicates defective diodes/selenium plates or improper AC input.
- To troubleshoot AC input to the stacks, measure the AC voltage input to the stacks of the rectifier with a handheld multimeter on the AC volts scale.
- Measure voltage from F6 to C6 (tap bars). One of two conditions may exist: voltage may be near zero or near normal.
- If voltage is near zero, there is a loss of AC power to the rectifier, bad fuses or circuit breakers, or a bad transformer (or connections) in the rectifier.
- Check all fuses and measure AC voltage input to the rectifier. With power OFF, remove all fuses at the rectifier and any fusible disconnect.
- Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse.
- Corrosion on fuse end caps or fuse holders also causes loss of voltage.
- Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found.
- If disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale.
- Measure the voltage on the rectifier side of the disconnect.
- If disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A3 (output of circuit breaker) and

ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker.

- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead.
- If voltage is present, either the transformer or the connections inside the rectifier are faulty (proceed to paragraph B-2.14).
- If voltage is not present, there is a loss of AC power to the rectifier. Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and input side of the circuit breaker (A1) on the second power lead.
- If voltage is not present, proceed to paragraph B-2.15; if voltage is present, replace circuit breaker or fuse.
- If voltage is near normal, there are faulty diodes/selenium plates or bad connections inside the rectifier. Check the diodes/selenium plates of the rectifier with a handheld multimeter on the diode check scale.
- With power OFF, remove the tap bars or shorting wires and the anode lead (P4) and/or the structure lead (N4).
- Check the diode/selenium plate sets by connecting one test lead to N4 and the other to F6 (diode 3), then to C6 (diode 4). Both should beep or not beep.
- Reverse test leads and repeat connections. The beep should be opposite (both should not beep or beep). Repeat the test using P4 instead of N4 to test diodes/selenium plate sets (diodes 1 and 2).

Note: An ohms scale may be used. A good diode has very high resistance in one direction and low resistance in the other direction.

- With power OFF, check for loose connections from F6 to F7, C6 to C7, P1 to P2, P2 to P4, and N1 through N4, and continuity of all wires between those points.
- Repair or replace loose connections and replace damaged or broken wires, if possible. If no problems are found, replace the stacks.
- If the rectifier does not have taps, proceed to paragraph B-2.6; if that test is normal, the rectifier must be removed from the cabinet for checkout.

- Refer to specific rectifier manual to troubleshoot the diodes/selenium plates and the transformer.
- For general reference, see paragraph B-2.12 for the stacks and paragraph B-2.14 for the transformer.
- If the current is normal and a rectifier ammeter reading is significantly different, either the shunt, the connections, or the ammeter is/are faulty. Measure DC with a handheld multimeter connected in series and with the meter on the DC amps scale.
- Disconnect anode header cable at P4 and measure current from P4 to anode lead.
- Compare the measured current value to the current value taken in paragraph B-2.7. If values are significantly different, replace the shunt. If values are the same, the current is normal, the rectifier ammeter reads normal, and structure potentials are still significantly changed from normal, there may be a change in the protected structure.
- If the protected structure is isolated, check all dielectrics and repair or replace faulty ones.
- If the protected structure is not isolated, check for additions to the protected structure or new structures in the area that are continuous with the protected structure, increase current to protect larger structure(s), isolate other structure(s), or install additional impressed current system(s) as required.

WARNING

AC voltage is still present inside the rectifier with the rectifier circuit breaker or power switch OFF. To prevent possible injury or death, employ electrical safety practices for working with live circuits when needlepoint leads are used with power ON.

- With power OFF, check for loose connections from N2 through N9, including any press-to-test switches or buttons, and continuity of all wires between those points. This requires disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation.
- Repair or replace loose connections and replace damaged or broken wires or proceed to the next step.
- With power OFF, remove ammeter from rectifier. This requires disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet.
- Disconnect one end of the resistors on reverse side of meter.

- Measure the resistance of the resistors with a handheld multimeter on the ohms scale and compare to the value of the resistor (if no resistors are present, replace meter).
- Replace resistor or meter as required.

B-2.4.3 Troubleshoot Broken Anode or Structure Leads.

- With power OFF, disconnect anode lead(s) at P4.
- Connect P4 (positive terminal) to an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods.
- For a short period of time, turn power ON and note AC (paragraph B-2.7). One of two conditions exists: either current is now present (changed) or it is not present (not changed).

Note: If the structure being tested is the inside of a water tank or tower and the lack of water does not allow current flow (no electrolyte), fill the tank and then retest.

- If current is present, the anode lead is broken or the anodes have failed. Before a great deal of time is expended troubleshooting an anode bed, it should be determined from records if there is sufficient anode material to attempt locating and repairing the fault. Generally, if the current and time is calculated to amp-years, comparing that number to the weight of the installed anodes and the weight loss of the anode material indicates if the anodes are expended or have significant life remaining.
- Another indicator is that if a gradual failure occurred over a period of time, the anodes have failed. If the failure was sudden, a cable break can be expected. If failed anodes are found, replace the anode bed.
- If a broken anode lead is found, repair the cable. The first step to locating the break is to find the location of any excavations that have occurred in the area of the anode cable. There are two methods of troubleshooting anode beds, depending upon whether all anodes have failed (no current) or some (or most) of the anodes have failed.
- If one or more anodes are functioning, the best method is first to locate the functioning anodes, then an anode bed gradient graph to isolate and locate the problem.

Note: If separate anode lead wires in a junction box were installed, use these to measure the anode current and determine the functioning anodes.

- Perform a CIS over the anode bed. For the purpose of troubleshooting, you may adjust the rectifier to the highest voltage setting that would not result in coating damage to the structure to allow easier location of the anodes.

- Measure the potentials over the anodes with a handheld multimeter on the volts DC scale. With power ON, connect the positive lead of the multimeter to the structure lead (N4) of the rectifier.
- Using a saturated copper/copper sulfate reference cell connected to the negative lead of the multimeter, locate the point of highest voltage on the surface of the ground (directly over an anode).
- Repeat by locating all operational anodes.
- Mark each anode found and compare to system drawings.
- Starting in a straight line 10 feet (3 meters) from the first anode, perform a potential test every 2 feet (0.6 meters) over the entire length of the anode bed to a point 10 feet (3 meters) past where the last anode is (or is supposed to be) located.
- Using graph paper and using vertical lines to represent the measured potentials and horizontal lines to represent the 2-foot (0.6-meter) intervals, graph all readings. This shows the condition of all anodes and indicates if a broken header cable (anode lead) or failed anodes exist. It shows a broken cable between functional and non-functional anodes. If anodes are failing, the gradients peak differently or the gradients fall, then rise intermittently.
- If no anodes are operational, use the fault detector and cable locator connected directly to the anode cable P4 to trace the anode lead from the rectifier toward the anode bed. This can be extremely difficult in some cases.
- An alternative method is to locate the first anode (from drawings, markers, or induction methods).
- Excavate to the first anode and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit.
- Use the fault detector and cable locator connected directly to the anode to trace the anode lead from the anode toward the rectifier.
- If this is still unsuccessful, replace the anode lead from the rectifier to the anode.

Note: When using the direct connection method, it is essential to have a low-resistance, isolated ground for the fault detector or cable locator to allow a strong locator signal on the cable under test.

- If no current exists, the structure lead may be broken.
- The temporary or alternative anode should remain connected to terminal P4 as described in paragraph B-2.8.
- With power OFF, disconnect structure lead at N4.

- Connect N4 (negative terminal) to an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods.
- For a short period of time, turn power ON and note AC. One of two conditions exists: either current is now present (changed) or it is not present (not changed).
- If current still does not exist (not changed), the temporary anode bed is not sufficient. Supplement the temporary anode bed, then perform the steps in paragraph B-2.8.
- If current is present, the structure connection is broken. Use the fault detector and cable locator connected directly to the structure lead at N4 to trace the structure lead from the rectifier toward the structure. This can be extremely difficult in some cases.
- An alternative method is to locate the first structure connection (from drawings, markers, or induction methods).
- Excavate to the structure and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit.
- Use the fault detector and cable locator connected directly to the structure lead to trace the lead from the structure toward the rectifier.
- If this is still unsuccessful, replace the structure lead from the rectifier to the structure.

Note: When using the direct connection method, it is essential to have a low-resistance, isolated ground for the fault detector or cable locator to put strong locator signals on the cable under test.

- The temporary or alternative anode should remain connected to terminal P4 as described in paragraph B-2.8.
- With power OFF, disconnect structure lead at N4.
- Connect N4 (negative terminal) to an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods.
- For a short period of time, turn power ON and note AC. One of two conditions exists: either current is now present (changed) or it is not present (not changed).
- If the current is present, the structure connection is broken. Use the fault detector and cable locator connected directly to the structure lead at N4 to trace the structure lead from the rectifier toward the structure. This can be extremely difficult in some cases.

- An alternative method is to locate the first structure connection (from drawings, markers, or induction methods).
- Excavate to the structure and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit.
- Use the fault detector and cable locator connected directly to the structure lead to trace the lead from the structure toward the rectifier.
- If this is still unsuccessful, replace the structure lead from the rectifier to the structure.

Note: When using the direct connection method, it is essential to have a low-resistance, isolated ground for the fault detector or cable locator to put strong locator signals on the cable under test.

- If current still does not exist (not changed), the temporary anode bed is not sufficient. Supplement the temporary anode bed, then repeat paragraph B-2.8.

B-2.4.4 Troubleshoot Blown Fuses or Tripped Circuit Breakers.

- Check all fuses and measure AC voltage input to the rectifier.
- With power OFF, remove all fuses at the rectifier and any fusible disconnect.
- Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse.
- Corrosion on fuse end caps or fuse holders also causes loss of voltage.
- Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found.
- If a disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale. Measure the voltage on the rectifier side of the disconnect.
- If a disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A3 (output of circuit breaker) and ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead.
- If voltage is present, either the transformer or the connections inside the rectifier are faulty (proceed to paragraph B-2.14).

- If voltage is not present, there is a loss of AC power to the rectifier. Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier.
- If voltage is present, locate the break in the power feed from that point to the rectifier circuit breaker (or rectifier fusible disconnect, whichever was last tested).
- If voltage is not present, measure the AC voltage to the circuit breaker or fuse supplying power to the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect the meter to the main lugs of the circuit breaker panel or the input side of the fuses and ground.
- For 220/240 V, single-phase systems, use the same procedures, but check individual lugs separately. If voltage is not present, locate the circuit breaker panel or transformer supplying power to the panel and apply the applicable procedures in paragraph B-2.15; if voltage is present, replace the circuit breaker or fuses.

B-2.4.5 Troubleshoot Loose or Bad Wire Connections.

- Check the diodes/selenium plates of the rectifier with a handheld multimeter on the diode check scale. With power OFF, remove the tap bars or shorting wires and the anode lead (P4) and/or the structure lead (N4).
- Check the diode/selenium plate sets by connecting one test lead to N4 and the other to F6 (diode 3), then to C6 (diode 4). Both should beep or not beep.
- Reverse test leads and repeat connections. The beep should be opposite (both should not beep or beep).
- Repeat the test using P4 instead of N4 to test diodes/selenium plate sets (diodes 1 and 2).

Note: An ohms scale may be used. A good diode has very high resistance in one direction and low resistance in the other direction.

- With power OFF, check for loose connections from F6 to F7, C6 to C7, P1 to P2, P2 to P4, and N1 through N4, and check continuity of all wires between those points. Repair or replace loose connections and replace damaged or broken wires, if possible. If no problems are found, replace the stacks.

- Before a great deal of time is expended troubleshooting an anode bed, it should be determined from records if there is sufficient anode material to attempt locating and repairing the fault. Generally, if the current and time are calculated to amp-years, comparing that number to the weight of the installed anodes and the weight loss of the anode material indicates if the anodes are expended or have significant life remaining. Another indicator is that if a gradual failure occurred over a period of time, the anodes have failed. If the failure was sudden, a cable break can be expected.
- If failed anodes are found, replace the anode bed.
- If a broken anode lead is found, repair the cable. The first step to locating the break is to find the location of any excavations that have occurred in the area of the anode cable.
- There are two methods of troubleshooting anode beds, depending upon whether all anodes have failed (no current), or some (or most) of the anodes have failed. If one or more anodes are functioning, the best method is first to locate the functioning anodes, then an anode bed gradient graph to isolate and locate the problem.

Note: If separate anode lead wires in a junction box were installed, use these to measure the anode current and determine the functioning anodes.

- Perform a CIS over the anode bed. For the purpose of troubleshooting, you may adjust the rectifier to the highest voltage setting that would not result in coating damage to the structure to allow easier location of the anodes.
- Measure the potentials over the anodes with a handheld multimeter on the volts DC scale.
- With power ON, connect the positive lead of the multimeter to the structure lead (N4) of the rectifier.
- Using a saturated copper/copper sulfate reference cell connected to the negative lead of the multimeter, locate the point of highest voltage on the surface of the ground (directly over an anode).
- Repeat by locating all operational anodes.
- Mark each anode found and compare to system drawings. Starting in a straight line 10 feet (3 meters) from the first anode, perform a potential test every 2 feet (0.6 meters) over the entire length of the anode bed to a point 10 feet (3 meters) past where the last anode is (or is supposed to be) located.
- Using graph paper and using vertical lines to represent the measured potentials and horizontal lines to represent the 2-foot (0.6-meter) intervals, graph all readings. This shows the condition of all anodes and indicates if a broken header cable (anode lead) or failed anodes exist. It shows a broken cable between functional and non-functional anodes. If anodes are

failing, the gradients peak differently or the gradients fall, and then rise intermittently.

- If no anodes are operational, use the fault detector and cable locator connected directly to the anode cable P4 to trace the anode lead from the rectifier toward the anode bed. This can be extremely difficult in some cases.
- An alternative method is to locate the first anode (from drawings, markers, or induction methods).
- Excavate to the first anode and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit.
- Use the fault detector and cable locator connected directly to the anode to trace the anode lead from the anode toward the rectifier.
- If this is still unsuccessful, replace the anode lead from the rectifier to the anode.

Note: When using the direct connection method, it is essential to have a low-resistance, isolated ground for the fault detector or cable locator that allows a strong locator signal on the cable under test.

B-2.5 Rectifier Voltage Is Half of Normal.

The following lists possible causes and troubleshooting steps for the condition when the rectifier voltage is about half of normal. Rectifier output is required to be turned up to regain proper amount of current.

B-2.5.1 Troubleshoot Lightning or Other Power Surges.

- Check all fuses and measure AC voltage input to the rectifier. With power OFF, remove all fuses at the rectifier and any fusible disconnect.
- Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse.
- Corrosion on fuse end caps or fuse holders also causes loss of voltage.
- Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found.
- If a disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale. Measure the voltage on the rectifier side of the disconnect.
- If a disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A3 (output of circuit breaker) and ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker.

- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead.
- If voltage is present, then either the transformer or the connections inside the rectifier are faulty (proceed to paragraph B-2.15).
- If voltage is not present, then there may be loss of AC power to the rectifier. Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and input side of the circuit breaker (A1) on the second power lead.
- If voltage is present, replace circuit breaker or fuse.
- If voltage to the rectifier is not present, measure the AC voltage from the circuit breaker or fuse where power is supplied to the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect meter to the output of circuit breaker or the output side of the fuse and ground or neutral bar.
- For 220/240 V, single-phase systems, use the same procedures, but connect the meter to the output lugs of the circuit breakers or the output side of the fuses.
- If voltage is present, locate the break in the power feed from that point to the rectifier circuit breaker (or rectifier fusible disconnect, whichever was last tested).
- If voltage is not present, measure the AC voltage to the circuit breaker or fuse supplying power to the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect the meter to the main lugs of the circuit breaker panel or the input side of the fuses and ground.
- For 220/240 V, single-phase systems, use the same procedures, but check individual lugs separately. If voltage is not present, locate the circuit breaker panel or transformer supplying power to the panel and repeat paragraph B-2.15; if voltage is present, replace the circuit breaker or fuses.

B-2.5.2 Troubleshoot Sudden Decrease in Soil Resistivity Due to Long Period of Heavy Rain.

- Check all fuses and measure AC voltage input to the rectifier. With power OFF, remove all fuses at the rectifier and any fusible disconnect.
- Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse. Corrosion on fuse end caps or fuse holders also causes loss of voltage.
- Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found.
- If disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale.
- Measure the voltage on the rectifier side of the disconnect.
- If disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A3 (output of circuit breaker) and ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead.
- If voltage is present, either the transformer or the connections inside the rectifier are faulty (proceed to paragraph B-2.15).
- If voltage is not present, there is a loss of AC power to the rectifier. Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.
- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and input side of the circuit breaker (A1) on the second power lead. If voltage is not present, proceed to paragraph B-2.15; if voltage is present, replace circuit breaker or fuse.

B-2.6 Rectifier Output Is Decreased.

The following lists the causes and troubleshooting steps for the condition when the rectifier output is decreased but the voltage is near normal.

B-2.6.1 Troubleshoot Rectifier Is Half Waving and One of the Diodes or Selenium Plates Burned Out.

- Measure the DC voltage output of the rectifier with a handheld multimeter. With power ON and scale on volts DC, measure voltage from N4 to P4 (see Figure B-6). One of three conditions may exist: voltage may be near zero (proceed to paragraph B-2.7.1), near half of normal (proceed to paragraph B-2.7.2), or near normal (proceed to paragraph B-2.7.3).
- With power OFF, check for loose connections from P2 to P3, N2 and N5 through N7, including any press-to-test switches or buttons, and continuity of all wires between those points. This requires disconnecting AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation.
- Repair or replace loose connections and replace damaged or broken wires. If problems are not found, proceed with paragraph B-2.7.3.
- With power OFF, remove voltmeter from rectifier. This requires disconnecting AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet.
- Disconnect one end of the resistors on reverse side of meter.
- Measure the resistance of the resistors with a handheld multimeter on the ohms scale and compare to the value of the resistor (if no resistors are present, replace meter).
- Replace resistor or meter as required.

B-2.6.2 Troubleshoot Failure of Some Anodes or Anode Leads When Soil Is Dried Out (Increased Resistivity).

- Measure the DC output of the rectifier with a handheld multimeter on the mV scale. Measure mV from N2 to N3. Multiply the indicated reading by the appropriate multiplication factor (see Figure B-7).
- One of three conditions may exist:

a. The current may be near zero, indicating a break in the anode lead, failed anodes, or a break in the structure lead (proceed to paragraph B-2.8.1).

b. The current may be near half of normal, indicating a defective diode/selenium plate; a break in the header cable between anodes; or, if there are multiple anode leads, loss of one anode lead or anode bed. Measure the DC voltage output of the rectifier with a handheld multimeter on the volts DC scale. Measure the voltage from N4 to P4. If voltage is also half of normal, proceed to paragraph B-2.13 to troubleshoot the diodes/selenium plates. If voltage is normal, proceed to paragraph B-2.14 to troubleshoot the anode bed.

c. The current may be near normal. Proceed to paragraph B-2.8.3 for detailed instructions.

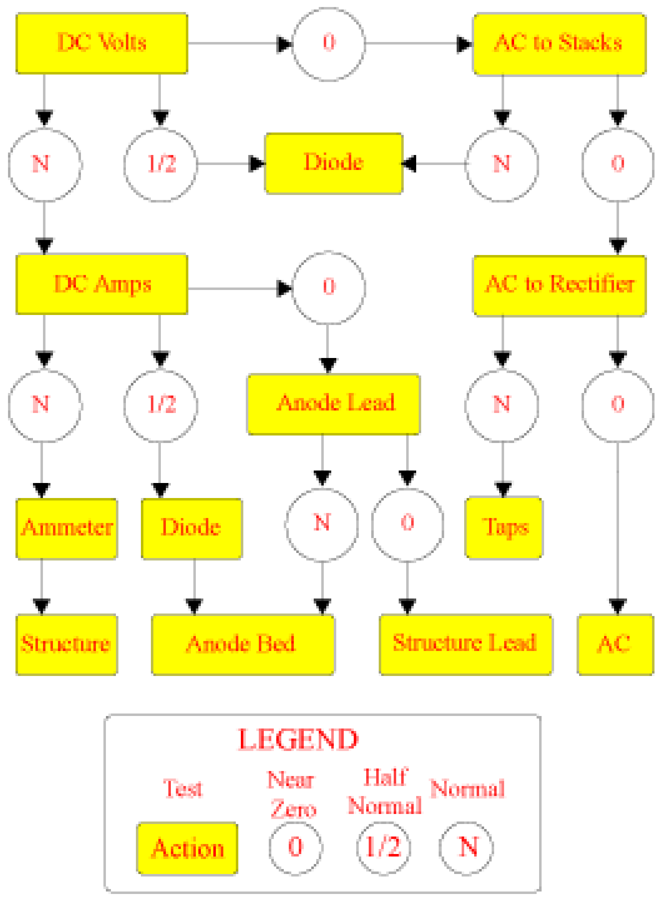
WARNING
All connections should be made with alligator clip leads with the rectifier circuit breaker or power switch OFF. To prevent possible injury or death, employ electrical safety practices for working with live circuits when needlepoint leads are used with power ON.

The starting point for all impressed current systems troubleshooting is at the rectifier. Indications of all problems are present at this location. The greatest aids to troubleshooting are historical data and drawings of the system. Usually, the fault may be isolated and then verified by testing. There are sufficient test points on the face plate of the rectifier to isolate the faulty component. Figure B-5 depicts the troubleshooting block diagram.

WARNING
AC voltage is still present inside the rectifier with the rectifier circuit breaker or power switch OFF. All connections inside the rectifier cabinet should be made with alligator clip leads connected with the power to the rectifier OFF. To prevent possible injury or death, employ electrical safety practices for working with live circuits when needlepoint leads are used with power ON.

WARNING
For Navy projects, when conducting work on or near circuits, energized lines, or parts of equipment operating at or above 50 V, utilize work practices identified in OPNAV P-45-117-6-98.

Figure B-5 Troubleshooting Block Diagram



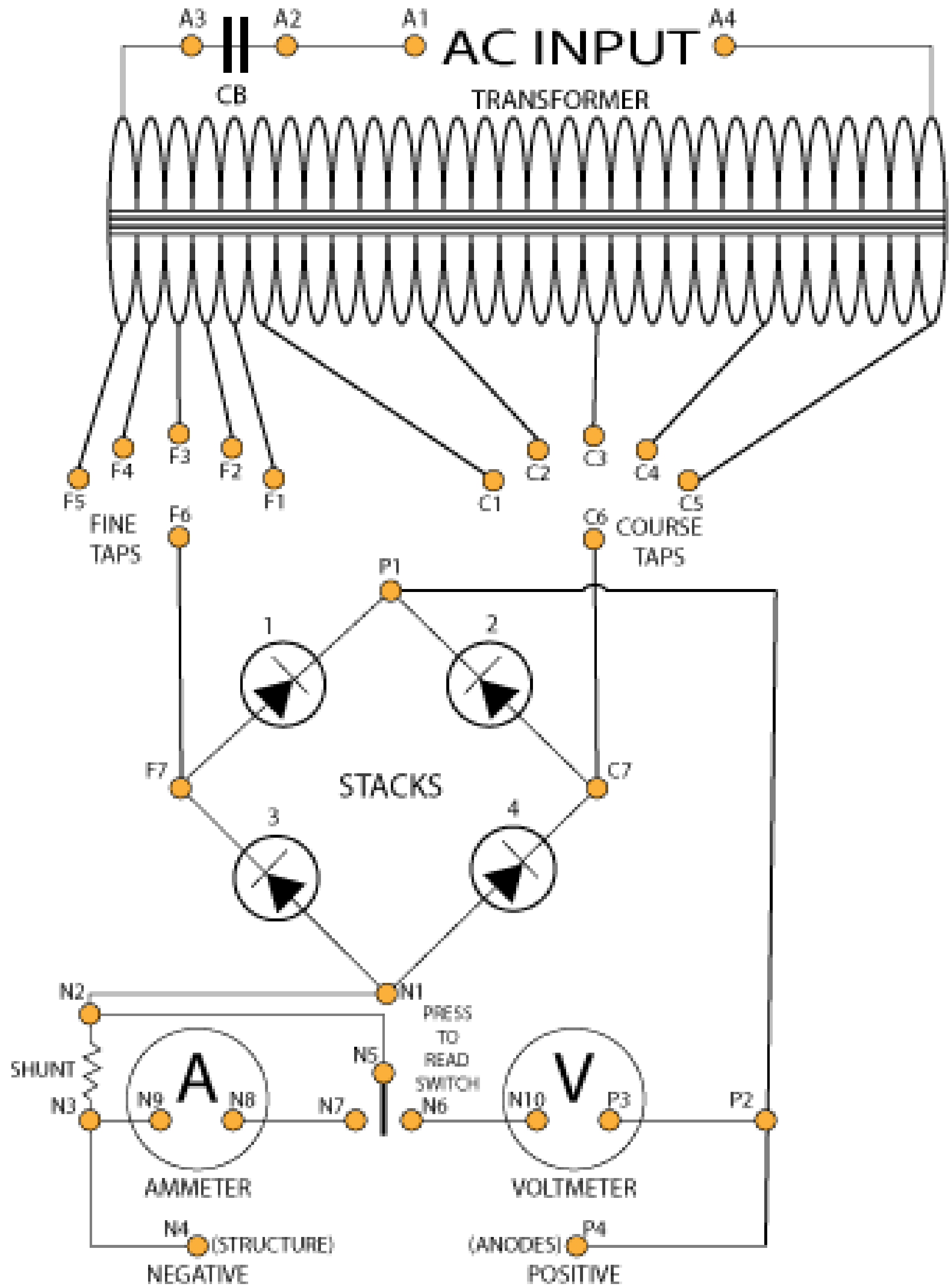
B-2.7 DC Voltage.

Measure the DC voltage output of the rectifier with a handheld multimeter. With the power ON and the scale on volts DC, measure voltage from N4 to P4 (see Figure B-6). One of three conditions may exist: voltage may be near zero (proceed to paragraph B-2.7.1), near half of normal (proceed to paragraph B-2.7.2), or near normal (proceed to paragraph B-2.7.3).

- With power OFF, check for loose connections from P2 to P3, N2 and N5 through N7, including any press-to-test switches or buttons, and continuity of all wires between those points. This requires disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation. Repair or replace loose connections and replace damaged or broken wires. If problems are not found, proceed to paragraph B-2.7.3.
- With power OFF, remove voltmeter from rectifier. This requires disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Disconnect one end of the resistors on

reverse side of meter. Measure the resistance of the resistors with a handheld multimeter on the ohms scale and compare to the value of the resistor (if no resistors are present, replace meter). Replace resistor or meter as required.

Figure B-6 Typical Rectifier Wiring Diagram



B-2.7.1 No DC Voltage.

No DC voltage indicates that one of the components in the rectifier is faulty or there has been a loss of AC power (proceed to paragraph B-2.11).

B-2.7.2 Half the Normal Voltage Output.

This case indicates defective diodes/selenium plates or improper AC input. Proceed to paragraph B-2.11 to check the AC input to the stacks and paragraph B-2.13 to troubleshoot the diodes/selenium plates.

B-2.7.3 Normal DC Voltage.

This case indicates a break in the anode lead, failed anodes, or a break in the structure lead (proceed to paragraph B-2.10). If the voltage is normal and the rectifier voltmeter reads significantly different, the connections or the voltmeter are faulty (proceed to paragraph B-2.10).

B-2.8 DC Current.

Measure the DC current output of the rectifier with a handheld multimeter on the mV scale. Measure the mV from N2 to N3 across the shunt resistor. Multiply the indicated reading by the appropriate multiplication factor. See Figure B-7. One of three conditions may exist: the current may be near zero (proceed to paragraph B-2.8.1), near half of normal (proceed to paragraph B-2.8.2), or near normal (proceed to paragraph B-2.8.3).

Figure B-7 Shunt Multiplication Factors

SHUNT SIZE		MEASURE	X	FACTOR	=	AMPS
50 mV	100A	___mV	X	2	=	___A
50 mV	75A	___mV	X	1.5	=	___A
50 mV	50A	___mV	X	1	=	___A
50 mV	45A	___mV	X	.9	=	___A
50 mV	40A	___mV	X	.8	=	___A
50 mV	35A	___mV	X	.7	=	___A
50 mV	30A	___mV	X	.6	=	___A
50 mV	25A	___mV	X	.5	=	___A
50 mV	20A	___mV	X	.4	=	___A
50 mV	15A	___mV	X	.3	=	___A
50 mV	10A	___mV	X	.2	=	___A
50 mV	5A	___mV	X	.1	=	___A
a mV	b A	___mV	X	$\frac{bA}{amV}$	=	___A

B-2.8.1 Normal DC Voltage with Near Zero Current.

This condition indicates a break in the anode lead, failed anodes, or a break in the structure lead (proceed to paragraphs B-2.9 and B-2.10).

B-2.8.2 Half the Normal Current Output.

This condition indicates either a defective diode/selenium plate; a break in the header cable between anodes; or, if there are multiple anode leads, loss of one anode lead or anode bed. Measure the DC voltage output of the rectifier with a handheld multimeter on the volts DC scale. Measure the voltage from N4 to P4. If voltage is also half of normal, proceed to paragraph B-2.13 to troubleshoot the diodes/selenium plates. If voltage is normal, proceed to paragraph B-2.12 to troubleshoot the anode bed.

B-2.8.3 Current Is Normal and Rectifier Ammeter Reads Differently.

If the current is normal and a rectifier ammeter reading is significantly different, then the shunt, the connections, or the ammeter is faulty (proceed to paragraph B-2.8.3.a)). If the current is normal, the rectifier ammeter reads normal, and structure potentials are still significantly changed from normal, proceed to paragraph B-2.8.3.d).

a. Measure DC with a handheld multimeter connected in series and with the meter on the DC amps scale. Disconnect anode header cable at P4 and measure current from P4 to anode lead. Compare the measured current value to the current value taken in paragraph B-2.7. If values are significantly different, replace the shunt. If values are the same, proceed to paragraph B-2.8.3.d).

WARNING

AC voltage is still present inside the rectifier with the rectifier circuit breaker or power switch OFF. All connections should be made with alligator clip leads with the rectifier circuit breaker or power switch OFF. To prevent possible injury or death, employ electrical safety practices for working with live circuits when needlepoint leads are used with power ON.

WARNING

For Navy projects, when conducting work on or near circuits, energized lines, or parts of equipment operating at or above 50 V, utilize work practices identified in OPNAV P-45-117-6-98.

b. With power OFF, check for loose connections from N2 through N9, including any press-to-test switches or buttons, and continuity of all wires between those points. This requires disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation. Repair or replace loose connections and replace damaged or broken wires. If problems are not found, proceed to paragraph B-2.8.3.c).

c. With power OFF, remove ammeter from rectifier. This requires disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Disconnect one end of the resistors on reverse side of meter. Measure the resistance of the resistors with a handheld multimeter on the ohms scale and compare to the value of the resistor (if no resistors are present, replace meter). Replace resistor or meter as required.

d. Normal current values accompanied by loss of potential shifts indicate a change in the protected structure. If the protected structure is isolated, all dielectrics and repair or replace faulty ones. If the protected structure is not isolated, check for additions to the protected structure or n check ew structures in the area that are continuous with the protected structure, increase current to protect larger structure(s), isolate other structure(s), or install additional impressed current system(s) as required.

B-2.9 Anode Lead Wires.

With power OFF, disconnect anode lead(s) at P4. Connect P4 (positive terminal) to an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods. For a short period of time, turn power ON and note AC. One of two conditions exists: either current is now present (changed) or it is not present (not changed).

Note: If the structure being tested is the inside of a water tank or tower, and the lack of water does not allow current flow (no electrolyte), fill the tank and then retest.

B-2.9.1 Current Is Present.

If current exists, the anode lead is broken or the anodes have failed (proceed to paragraph B-2.14).

B-2.9.2 Current Is Not Present.

If no current exists, the structure lead may be broken (proceed to paragraph B-2.10).

B-2.10 Structure Lead.

For this test, the temporary or alternative anode should remain connected to terminal P4. With power OFF, disconnect structure lead at N4. Connect N4 (negative terminal) to an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods. For a short period of time, turn power ON and note AC. One of two conditions exists: either current is now present (changed) (proceed to paragraph

B-2.9.1) or it is not present (not changed). If current still does not exist (not changed), the temporary anode bed is not sufficient. Supplement the temporary anode bed, then repeat paragraph B-2.8.

B-2.10.1 Structure Connection Broken.

Since current is now present, the structure connection is broken. Use the fault detector and cable locator, connected directly to the structure lead at N4, to trace the structure lead from the rectifier toward the structure. This can be extremely difficult in some cases. An alternative method is to locate the first structure connection (from drawings, markers, or induction methods). Excavate to the structure and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit. Use the fault detector and cable locator, connected directly to the structure lead, to trace the lead from the structure toward the rectifier. If this is still unsuccessful, replace the structure lead from the rectifier to the structure.

Note: When using the direct connection method, it is essential to have a low-resistance isolated ground for the fault detector or cable locator to put strong locator signals on the cable under test.

If current still does not exist (not changed), the temporary anode bed is not sufficient. Supplement the temporary anode bed, then repeat paragraph B-2.8.

B-2.11 AC Voltage to Stacks.

Measure the AC voltage input to the stacks of the rectifier with a handheld multimeter on the AC volts scale. Measure voltage from F6 to C6 (tap bars). One of two conditions may exist: voltage may be near zero (proceed to paragraph B-2.11.1) or near normal (proceed to paragraph B-2.11.2).

B-2.11.1 Voltage Near Zero.

This indicates loss of AC power to the rectifier, bad fuses or circuit breakers, or a bad transformer (or connections) in the rectifier (proceed to paragraph B-2.12).

B-2.11.2 Voltage Near Normal.

This indicates faulty diodes/selenium plates or bad connections inside the rectifier (proceed to paragraph B-2.13). If the rectifier does not have taps, proceed to paragraph B-2.12; if that test is normal, the rectifier must be removed from the cabinet for checkout. Refer to specific rectifier manual to troubleshoot the diodes/selenium plates and the transformer. For general reference, see paragraph B-2.13 for the stacks and paragraph B-2.14 for the transformer.

B-2.12 Fuses.

Check all fuses and measure AC voltage input to the rectifier. With power OFF, remove all fuses at the rectifier and any fusible disconnect. Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse. Corrosion on fuse end caps or fuse holders also causes loss of voltage. Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found. If a disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale. Measure the voltage on the rectifier side of the disconnect. If a disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on AC volts scale. For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A3 (output of circuit breaker) and ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker. For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead (not shown on drawing). If voltage is present, proceed to paragraph B-2.12.1. If voltage is not present, proceed to paragraph B-2.12.2.

B-2.12.1 Voltage Is Present.

This indicates that either the transformer or the connections inside the rectifier are faulty (proceed to paragraph B-2.15).

B-2.12.2 Voltage Is Not Present.

This indicates loss of AC power to the rectifier. Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volts scale.

- For 110/120 V, single-phase rectifiers, turn power to the rectifier OFF, open cabinet, and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier.
- For 220/240 V, single-phase rectifiers, use the same procedures, but connect meter to A4 and input side of the circuit breaker (A1) on the second power lead.

If voltage is not present, proceed to paragraph B-2.16; if voltage is present, replace circuit breaker or fuse.

B-2.13 Diodes.

Check the diodes/selenium plates of the rectifier with a handheld multimeter on the diode check scale. With power OFF, remove the tap bars or shorting wires and the anode lead (P4) and/or the structure lead (N4). Check the diode/selenium plate sets by connecting one test lead to N4 and the other to F6 (diode 3), then to C6 (diode 4). Both should beep or not beep. Reverse test leads and repeat connections. The beep should be opposite (both should either not beep or beep). Repeat the test using P4 instead of N4 to test diodes/selenium plate sets (diodes 1 and 2).

Note: An ohms scale may be used. A good diode has very high resistance in one direction and low resistance in the other direction.

With power OFF, check for loose connections from F6 to F7, C6 to C7, P1 to P2, P2 to P4, and N1 through N4, and continuity of all wires between those points. Repair or replace loose connections and replace damaged or broken wires, if possible. If no problems are found, replace the stacks.

B-2.14 Anode Bed.

Before a great deal of time is expended troubleshooting an anode bed, it should be determined from records if there is sufficient anode material to attempt locating and repairing the fault. Generally, if the current and time are calculated to amp-years, comparing that number to the weight of the installed anodes and the weight loss of the anode material indicates if the anodes are expended or have significant life remaining. Another indicator is that if a gradual failure occurred over a period of time, the anodes have failed. If the failure was sudden, a cable break can be expected. If failed anodes are found, replace the anode bed. If a broken anode lead is found, repair the cable. The first step to locating the break is to find the location of any excavations that have occurred in the area of the anode cable. There are two methods of troubleshooting anode beds, depending upon whether all anodes have failed (no current) or some (or most) of the anodes have failed. If one or more anodes are functioning, see paragraph B-2.14.2. If no anodes are functioning, see paragraph B-2.14.3.

If one or more anodes are functioning, the best method is first to locate the functioning anodes, then an anode bed gradient graph to isolate and locate the problem.

Note: If separate anode lead wires in a junction box were installed, use these to measure the anode current and determine the functioning anodes.

B-2.14.1 Linear Anode ICCP Systems.

These systems are commonly used to protect long line structures, such as pipelines. This is usually the most economical choice when the pipeline due to poor or aged coating requires a continuous and close coupled current. This type of anode bed is used to protect pipelines with poor coating and can be installed up to several miles along a pipeline. The distance from the structure is normally 5 to 10 feet (1.5 to 3 meters). In most cases, the anode is installed with a separate header cable to minimize voltage drop. Mixed metal oxide (MMO) anodes or polymer anodes are typically used for this type of installation.

B-2.14.1.1 Mixed Metal Oxide Anodes.

MMO anodes exhibit favorable design life characteristics while providing current at very high density levels. The oxide film is not susceptible to rapid deterioration due to anode acid generation, rippled DC, or half wave rectification, as is common with other precious metal anodes. The composition of the anode consists of a titanium rod, wire, tube, or expanded mesh with the oxide film baked on the base metal. In oxygen evolution environments, such as soils, the oxide consists of ruthenium crystals and titanium halide salts in an aqueous solution that is applied like paint on the base metal and baked at 400ºC to 800ºC, forming a rutile oxide. Normally, titanium experiences physical breakdown around 10 V, but the oxide film is so highly conductive (10^{-5} ohm-cm resistivity) that the current, which takes the path of least resistance, is discharged from the oxide rather than the base metal, even with a rectifier voltage of 90 V in soils. This contrasts with the insulating titanium dioxide film that naturally forms on the surface of bare titanium. When the MMO film has been consumed, the insulating titanium dioxide film covers the anode and does not allow current to discharge unless the applied voltage is greater than 10 V in seawater or 50 to 70 V in fresh water.

The anode life is based on the thickness of the oxide film. Typical thicknesses result in a 30- to 50-year anode life.

Anodes in soil or mud should be backfilled with fine, low-resistance, calcined petroleum coke breeze for maximum life and performance. Consumption rates range from 0.5 milligrams per amp-year in seawater to 5 milligrams per amp-year in coke breeze, fresh water, and sea mud. As with any anode, the connection must be constructed to be moisture proof, watertight, and have no more than 0.001 ohms of resistance.

B-2.14.2 Close Interval Survey.

Perform a CIS over the anode bed. For the purpose of troubleshooting, adjust the rectifier to the highest voltage setting that would not result in coating damage to the structure to allow easier location of the anodes. Measure the potentials over the anodes with a handheld multimeter on the volts DC scale. With power ON, connect the positive lead of the multimeter to the structure lead (N4) of the rectifier. Using a saturated copper/copper sulfate reference cell connected to the negative lead of the multimeter, locate the point of highest voltage on the surface of the ground (directly over an anode). Repeat by locating all operational anodes. Mark each anode found and compare to system drawings. Starting in a straight line 10 feet (3 meters) from the first anode, perform a potential test every 2 feet (0.6 meters) over the entire length of the anode bed to a point 10 feet (3 meters) past where the last anode is (or is supposed to be) located. Using graph paper and using vertical lines to represent the measured potentials and horizontal lines to represent the 2-foot (0.6-meter) intervals, graph all readings. This shows the condition of all anodes and indicates if a broken header cable (anode lead) or failed anodes exist. It shows a broken cable between functional and non-functional anodes. If anodes are failing, the gradients peak differently, or the gradients fall and then rise intermittently.

B-2.14.3 Anodes Are Non-operational.

If no anodes are operational, use the fault detector and cable locator connected directly to the anode cable P4 to trace the anode lead from the rectifier toward the anode bed. This can be extremely difficult in some cases. An alternative method is to locate the first anode (from drawings, markers, or induction methods). Excavate to the first anode and measure continuity back to the rectifier using a CP multi-combination meter continuity check circuit. Use the fault detector and cable locator, connected directly to the anode, to trace the anode lead from the anode toward the rectifier. If this is still unsuccessful, replace the anode lead from the rectifier to the anode.

Note: When using the direct connection method, it is essential to have a low-resistance, isolated ground for the fault detector or cable locator in order to allow a strong locator signal on the cable under test.

B-2.15 Rectifier Taps.

Measure the AC voltage on the taps of the rectifier with a handheld multimeter on the AC volts scale. Remove the tap bars or shorting wires. Measure the voltage from F5 to F4, F4 to F3, F3 to F2, F2 to F1, and F1 to C1. All readings should be approximately the same. Measure the voltage from C5 to C4, C4 to C3, C3 to C2, and C2 to C1. All readings should be approximately the same. Any lead that tests differently must be checked for connection (proceed to paragraph B-2.15.1).

Note: On some rectifiers, F1 to C1 may be a unique voltage.

B-2.15.1 With Power Off.

Note: Loose connections are characterized by heat, discoloration of the connection, and melted insulation.

- Check for loose connections from F1 through F5 and C1 through C5, including any tap bar or shorting wire, and continuity of all wires between those points. Repair or replace loose connections and replace damaged or broken wires, if possible. If only one tap is inoperative, a different tap setting may be operational, and testing reveals functioning taps. If replacement of wire is not possible, replace the transformer. If no problems are found, proceed with the next step.
- Check for loose connections from A2 through A4 and continuity of all wires between those points. Repair or replace loose connections and replace damaged or broken wires, if possible. If replacement of wire is not possible, replace the transformer.

Note: Checkout of transformers or pole fuses requires personnel certified for work on high-voltage lines and proper equipment beyond the scope of these procedures.

B-2.16 Rectifier Input Voltage.

First, verify that the circuit breaker has not tripped or the fuse has not blown. If properly operating, measure the AC voltage from the circuit breaker or fuse where power is supplied to the rectifier with a handheld multimeter on the AC volts scale. For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect meter to the output of circuit breaker or the output side of the fuse and ground or neutral bar. For 220/240 V, single-phase systems, use the same procedures, but connect the meter to the output lugs of the circuit breakers or the output side of the fuses.

If voltage is present, locate the break in the power feed from that point to the rectifier circuit breaker (or rectifier fusible disconnect, whichever was last tested).

If voltage is not present, measure the AC voltage to the circuit breaker or fuse supplying power to the rectifier with a handheld multimeter on the AC volts scale.

- For 110/120 V, single-phase systems, open the circuit breaker panel or fuse panel and connect the meter to the main lugs of the circuit breaker panel or the input side of the fuses and ground.
- For 220/240 V, single-phase systems, use the same procedures, but check individual lugs separately. If voltage is not present, locate the circuit breaker panel or transformer supplying power to the panel and repeat paragraph B-2.15; if voltage is present, replace the circuit breaker or fuses.

WARNING

AC voltage is still present inside the rectifier with the rectifier circuit breaker or power switch OFF. All connections should be made with alligator clip leads with the rectifier circuit breaker or power switch OFF. To prevent possible injury or death, employ electrical safety practices for working with live circuits when needlepoint leads are used with power ON.

WARNING

For Navy projects, when conducting work on or near circuits, energized lines, or parts of equipment operating at or above 50 V, utilize work practices identified in OPNAV P-45-117-6-98.

APPENDIX C SERVICE-SPECIFIC GUIDANCE

C-1 ARMY.

C-1.1 If Required.

C-2 AIR FORCE.

C-2.1 Sample Base Corrosion Control Operating Instructions.

C-2.1.1 Purpose.

The following sections outline responsibilities and procedures required to establish and conduct a continuing and recurring Corrosion Control Program for Sample Air Force Base (AFB), XX.

C-2.1.2 Criteria.

This UFC is applicable to all Civil Engineering Squadron personnel involved, directly or indirectly, in the development and maintenance of an effective Corrosion Control Program.

C-2.1.3 Responsibility.

C-2.1.3.1 AFCEC.

AFCEC has overall responsibility for the Air Force Facility and Infrastructure Corrosion Control Program. AFCEC is responsible for the functional adequacy of Air Force new construction.

C-2.1.3.2 Base Engineering.

Base Engineering with AFCEC consultation is responsible for its Corrosion Control Program and ensures it develops, establishes, and maintains Infrastructure Systems that ensure an effective comprehensive Corrosion Control Program with personnel adequately trained to carry out their responsibilities.

Base Engineering must establish and maintain a Corrosion Control Program for each activity within the squadron at Sample AFB. The Chief of the Engineering Flight and the Chief of Operations Flight work together to assign the Base Corrosion Control Engineer (BCCE). They also appoint a Base Industrial Water Treatment Engineer and a Base Protective Coatings Engineer as required. The Chief of Operations appoints the CP and industrial water treatment craftsmen in consultation with the Chief of Infrastructure Systems.

C-2.1.3.3 BCCE.

The BCCE is responsible for the overall management of the base Corrosion Control Program and coordinates this program with the Chief of Operations Flight, Chief of

Operations Engineering Element, Chief of Infrastructure Support Element, CP craftsmen, industrial water treatment craftsmen, protective coatings personnel, and other appropriate functions within the operations flight. The BCCE establishes and chairs a Base Corrosion Control committee that meets at least quarterly. Minimum participants are: (1) Chief of Operations, (2) Chief of Operations Engineering, (3) Chief of Infrastructure Systems, (4) Lead craftsmen in Mechanical, Electrical, Structural, and Sanitation, (5) Lead planner, and (6) Others as appropriate.

C-2.1.3.4 Engineering Construction Management.

Engineering Construction Management and/or Service Contract personnel monitor every phase of coatings operations to include Simplified Acquisition of Base Engineering Resources (SABER) contract and general contract operations. For all other corrosion work, whether contract or in-house, this office provides the coatings test equipment and expertise to evaluate work and investigate coating failures.

C-2.1.4 Reference.

See AFI 32-1054, Attachment 1, for directives and guidance that have an impact on corrosion control engineering.

C-2.1.5 Work Procedures.

C-2.1.5.1 Operations/Engineering.

- The Civil Engineer (CE) appoints, by letter, a Corrosion Control Engineer with the advice of the Chief of Engineering, Chief of Operations, and Chief of Operations Engineering.
- Chief of Operations and/or Engineering assigns corrosion control duties to the engineer appointed by the CE and ensures the appointee receives adequate training to carry out these responsibilities (see AFI 32-1054).
- Chief of Operations appoints at least 2 CP craftsmen and other corrosion control craftsmen from the appropriate shops as he or she deems necessary to facilitate corrosion control duties. Personnel involved in corrosion control duties should receive adequate training on an annual basis and be appointed in writing. A file containing a current roster of corrosion control personnel is in the Operations Branch and contains training status and training program information. Send updated copies of appointment letters for corrosion control duties to the BCCE.

C-2.1.5.2 BCCE.

The BCCE manages the overall Engineering Squadron Corrosion Control Program. This includes the following tasks:

- Develop program and management procedures.

- Review engineering drawings and specifications developed under base direction for adequacy of corrosion control.
- Review engineering drawings for Military Construction (MILCON) projects for adequacy of corrosion control.
- Maintain base corrosion control records.
- Retain logs compiled by appropriate shops to be collected at the end of the calendar year. CP craftsmen shall retain and log readings on the appropriate forms during the year and forward to the BCCE at the end of the calendar year.
- Review corrosion records monthly.
- Complete a CIS every 5 years.
- Include requirements and criteria of AFI 32-1054 in the Corrosion Control Program.
- Establish a CP system master plan and show all installed rectifiers, ground beds, test stations, and anodes. Update the maps to show any modifications made on the systems. Indicate the location of neighboring structures.
- Conduct an annual CP performance survey with qualified CP craftsmen; accomplish by contract if capability is not available with shop. This includes:
    - Taking S/E potential measurements on all pipelines (building gas service risers), both sides of isolating insulation, hydrant outlets in petroleum, oil, and lubricant (POL) systems, and surface and underground tanks.
    - Internally inspecting water storage tanks.
    - Updating the Cathodic Protection Annual Performance Booklet.
    - Updating the CP program record.
    - Determining actions required to provide complete protection and preparing maintenance action sheets.
- Ensure the necessary corrosion tests and system examinations are performed on boiler water.
- Ensure the treatment equipment is adequate and working for cooling water.
- Investigate all reported leaks and corrosion failures, determine cause of failure and corrective action required to prevent recurrence. Do not restrict viewpoint to fluid-carrying systems or high-value steel structures, expand

to include other items, such as metal roofing and flashing, that leak and cause water damage to structures and contents.

- Maintain data on corrosion failures and record each location where an underground failure occurs on a base layout map.
- Analyze data for patterns that indicate major problem areas.
- Assist Operations in procuring proper CP test equipment.
- Assist Engineering in procuring necessary paint inspection equipment.
- Assist other corrosion control craftsmen in procuring leak detection equipment, test instruments, chemical treatment equipment, and consumables as necessary to conduct an effective Corrosion Control Program.
- Perform life cycle cost analysis of corrosion control measures.
- Arrange for technical assistance as required through AFCEC.
- Call corrosion control committee meetings, establish agenda items, and ensure coordination of all corrosion control activities through this committee.

C-2.1.5.3 CP Craftsmen.

CP craftsmen perform tests consisting primarily of electrical measurements to indicate the condition of system components. Maintenance duties include:

- Performing rectifier checks for current and voltage output, meter function, proper operation, and adjustment to maintain the current required (as recorded at the last annual survey) for adequate protection.
- Conducting S/E potential measurements at the four test points established by annual surveys of impressed current systems.
- Conducting S/E potential measurements and current output of anode systems, and the addition of anodes as required for complete protection.
- Performing minor system repairs.
- Submitting maintenance requirements for major work.
- Entering operational data in appropriate logs and forwarding to the BCCE for filing and maintenance.
- Conducting an annual CP survey under the BCCE. Accomplish by contract if capability is not available with shop.
- Procuring and retaining custody of instruments authorized and required in routine maintenance of installed CP systems.

C-2.1.5.4 Engineering Construction Management.

Engineering Construction Management and/or Service Contract personnel keep every phase of coating operations under surveillance. This includes:

- Recording coating type, thickness, and bonding.
- Checking the above items against specifications.
- Checking surface preparation prior to coating application.
- Documenting subsequent coating performance.
- Reporting any damage found during inspections.
- Assuring repair of reported damage by recommended methods.
- Procuring and retaining custody of test equipment necessary for inspection (film thickness gauges, blasting standards, holiday detector, and paint test kit).
- Coordinating requirements for coating operations with the BCCE, SABER contractor, service contractor and general contractors as required, ensuring adequate corrosion control operations.
- Forwarding all test data to the BCCE for filing and retention.

C-2.1.5.5 Corrosion Control Craftsmen.

Corrosion control craftsmen perform tasks necessary to accomplish corrosion control to the maximum extent possible in their areas of responsibility. The following areas may require a corrosion control craftsman.

C-2.1.5.6 Potable Water Systems.

Potable water systems and treatment corrosion control craftsman will (OPR: Infrastructure Systems Element):

- Perform raw analysis every 3 years; accomplish by contract if capability is not available with shop.
- Record treatment performed daily on AF Form 1461, Water Utility Operating Log.
- Determine and record consumption monthly.
- Maintain water treatment logs in Facility 62515, Water and Waste Building, for review by the BCCE.
- Use AF Form 1687, Leak/Failure Data Record, as appropriate, and forward to the BCCE.
- Monitor water distribution systems' pressure meters hourly to determine possible water leaks.

C-2.1.5.7 Boiler Water Systems and Treatment.

Boiler water systems and treatment corrosion control craftsmen will (OPR: Facility System Elements):

- Maintain complete records of boiler water treatment daily on AF Form 1459, Water Treatment Operating Log for Steam and Hot Water Boilers. This includes internal treatment with chemicals and external treatment with deaerators, softeners, and decarbonators.
- Test make-up water, quantity, and quality monthly.
- Check for leaks in steam valves, flanges, and unions in boiler plants daily.
- Test heat exchangers for leaks monthly.
- Check pressure and temperature of deaerating heater daily.
- Determine conductivity of return condensate daily at a minimum; hourly for large plants.
- Have condensate corrosion tests performed monthly.
- Test ion exchanger output quality daily at a minimum; more often if required.
- Check mechanical rooms with hot water heat exchangers for signs of corrosion problems semiannually.
- Check all tanks annually.
- Check boiler plant piping systems daily.
- Use AF 1687, Leak/Failure Data Record, as appropriate, and forward to the BCCE.
- Procure and retain custody of test equipment necessary for corrosion control testing of boiler water systems.

C-2.1.5.8 Cooling Water Systems and Treatment.

Cooling water systems and treatment corrosion control craftsmen will (OPR: Facility System Elements):

- Maintain complete records of cooling water treatment as required. Use AF Form 1457, Water Treatment Operating Log for Cooling Tower Systems at a minimum. Maintain these records in the shop for review by the BCCE.
- Check cooling towers for algae and scale buildup monthly.
- Together with the BCCE, ensure monthly that treatment equipment is adequate and is working.
- Calculate cycles of concentration and maintain according to survey recommendations monthly.

- Procure and retain custody of test equipment necessary for corrosion control testing of cooling water systems.
- Use AF Form 1687, Leak/Failure Data Record, as appropriate, and forward to the BCCE.

C-2.1.5.9 Water Distribution Systems.

Water distribution systems corrosion control craftsmen will (OPR: Infrastructure Systems Element):

- Perform leak/failure inspections as required. Notify the BCCE of leaks and failures in the water distribution systems.
- Use AF Form 1687, Leak/Failure Data Record, for all leaks detected in the water distribution systems and forward to the BCCE.
- Coordinate with the water systems and treatment corrosion control craftsmen (Water & Waste) on possible water distribution leaks.
- Procure and retain custody of test equipment necessary for leak detection in the water distribution system.

C-2.1.5.10 Protective Coating Corrosion Control.

Protective coating corrosion control is normally accomplished by Service Contract (OPR: Operations Engineering):

- Update painting records as required.
- Report any damage found to the BCCE for subsequent repair or recommendations.
- Ensure Service Contractor applies suitable coatings to the structure and environment and ensure compatibility with previously applied coatings and other protective methods, such as CP.
- Together with the BCCE, inspect coatings on all high-cost steel structures semiannually.
- Coordinate closely with Operations Engineering to ensure compliance.
- Use AF Form 1687, Leak/Failure Data Record, an appropriate, and forward to the BCCE.

C-2.1.5.11 POL/JP4 Distribution Systems.

POL/JP4 distribution systems corrosion control craftsmen will (OPR: Infrastructure Systems Element):

- Perform leak/failure inspections as required. Notify the BCCE of leaks and failures in the POL/JP4 distribution systems.

- Use AF Form 1687, Leaks/Failure Data Record, for all leaks detected in the POL/JP4 distribution systems and forward to the BCCE.
- Procure and retain custody of test equipment necessary for leak detection in the POL/JP4 distribution systems.

C-2.1.6 Record Procedures.

Maintain the following records to support the Corrosion Control Program at Sample AFB as indicated.

C-2.1.6.1 Personnel Files.

Operations Flight and the BCCE maintain a current roster of corrosion control craftsmen. File contains training status and training program information.

C-2.1.6.2 Equipment Information.

BCCE maintains a list of corrosion control equipment with operational status. File contains the following information:

- Manufacturers' data on installed equipment.
- Lists of repair parts.
- Names and addresses on sources and parts.
- Current price lists.
- Repair, operating, and maintenance instructions.

C-2.1.6.3 System Information.

BCCE maintains files on water treatment systems, CP installations, protective coatings, and all other systems of corrosion control. File includes the following information:

- Standard design and construction specifications.
- Cross-reference listing of projects containing corrosion control.
- Shop and as-built drawings updated to show modifications.
- Cathodic Protection Program Records Booklet.
- Cathodic Protection Annual Performance.

C-2.1.6.4 Failure Records.

BCCE maintains records of corrosion control damage and facility failures. Forward to the BCCE the AF Form 1687, Leak/Failure Data Record, after completion by the appropriate corrosion control craftsmen. The BCCE further investigates the failure as appropriate. The BCCE indicates the location of the leak or failure on the base layout map. The BCCE records the corrective maintenance, repair, or applied corrosion control measures, including costs. Distribution of this form is one copy to each of the following:

- BCCE's record.
- Facility jacket.
- Cathodic Protection Annual Performance Booklet.
- AFCEC corrosion control Subject Matter Expert (SME).

C-2.1.6.5 Survey Records.

The BCCE maintains a continuous and current file of corrosion survey results and recommendations. These records contain the following information:

- Corrosion analysis team surveys, recommendations, and implementation plans.
- Architecture - Engineering (A-E) surveys and recommendations.
- Water and gas leak surveys.
- AF Form 1688, Annual Cathodic Protection Performance Survey.

C-2.1.6.6 Test Results.

The BCCE maintains records of test data and results. This file contains the following information:

- Boiler water analysis.
- Corrosion tester/coupon reports.
- Interference testing record sheets.
- Area of Influence Test Worksheet, using a modified AF Form 1688, Annual Cathodic Protection Performance Survey.
- AF Form 1689, Water Tank Calibration (for tank interiors).

C-2.1.6.7 Operational Logs.

The BCCE periodically reviews all operational logs. Distribute the following logs as indicated:

- The Non-Commissioned Officer in Charger (NCOIC), Water and Fuels Systems Maintenance, completes AF Form 1461, Water Utility Operating Log, and maintains it in Building 417. Upon request from BCCE, the NCOIC forwards a copy for review.
- The CP craftsman completes AF Form 491, Cathodic Protection Operating Log for Impressed Current System, and AF Form 1686, Cathodic Protection Operating Log for Sacrificial Anode System, and forwards copies to the BCCE for inclusion in the CP facility jacket folder and the Cathodic Protection Annual Performance Booklet.

- Heating, ventilation, and air conditioning (HVAC) boiler water systems and treatment corrosion control craftsman completes AF Form 1459, Water Treatment Operation Log for Steam and Hot Water, and forwards a copy to the BCCE.
- The cooling water systems and treatment corrosion control craftsman forwards one copy of all records maintained by their function to the BCCE.

C-2.1.6.8 Equipment Maintenance.

Maintain equipment maintenance records and maintenance action sheets (MASs) according to AFI 32-1001, *Operations Management*. Keep a copy of the AF Form 1841, *Maintenance Action Sheet*, in the facility jacket folder for corrosion control activities.

C-2.1.6.9 Cost Records.

The BCCE maintains continuous records. This file includes the following information:

- Failure costs from AF Form 1687, *Leak/Failure Data Record*.
- All other corrosion control costs, to include projects containing corrosion control measures. These costs include initial installations, recurring maintenance, and surveys. It is especially important to include all repairs by replacement projects and work orders to historically record the life cycle costs of the base infrastructure.

C-2.1.6.10 Requirements and Management Plans.

The BCCE includes corrosion control items for each system and component to minimize system life cycle costs.

C-2.2 Air Force Forms.

C-2.2.1 Form 491.

Entries on AF Form 491 must be made on a monthly basis. No readings of the S/E potentials are to be taken where the electrode is in contact with frozen ground. Readings are to be made with the authorized meters only (see note under item 10 of instructions). See Tables C-1 and C-2 for form items and specific instructions for completing each item. See Figures C-1 and C-2 for completed example forms.

Table C-1 Form 491 Item Descriptions

Item	Name	Description
1	Installations	Enter the official name and location of the installation (i.e., ROBINS AFB, GA). Do not abbreviate or use unit designations.
2	Year	Enter calendar year.
3	Protected Structure	Enter the name of the protected structure and its number as shown on United States Air Force (USAF) Real Property Report (RCS: HAF-PRES(SA)7115) as “Water Tank 603” or “Gas piping system family housing.”
4	Rectifier Number	Enter the number of the rectifier as assigned by the corrosion engineer. Numbers are consecutive starting with number 1 and are conspicuously shown on the rectifier.
5	Rectifier Data (from nameplate)	• **Manufacturer:** Enter full name and address of manufacturer. • **Model Number:** Enter model number as shown on nameplate. • **Serial Number:** Enter serial number as shown on nameplate. • **AC Rated Capacity:** Enter AC voltage and phase. • **DC Rated Capacity:** Enter DC voltage and amperage. • **Date Installed:** Enter date installed. This information is to be obtained from the BCCE. Where no detailed information is available, estimate and enter approximate date.
6	Ground Bed Data	• **Anode Material:** Enter the name of the material and alloy designation, if known, as “graphite,” “aluminum 3003,” or “high-silicon cast iron.” • **Size of Anode:** Enter the dimensions or the standard size designation as 1½" x 60" or 3" x 60." • **Number of Anodes:** Enter number of anodes. • **Type of Backfill:** Enter the type of backfill used around the anodes as “coke breeze” or “natural soil.” • **Date Installed:** Enter the date when the anode bed was installed.

Item	Name	Description
7	Location Reference Drawing Number	Enter the location of rectifier and test stations as recorded on the drawings. Enter the number of the drawing and the sheet number for easy reference.
8	Current Required	Enter the amount of current needed to give complete protection and the date such determination was made.
9	Location and Description	Enter a brief description of the location of the rectifier and test points in order to easily find them, as “west leg of tower,” “pole 468-1,” or “300 feet east of the side entrance of building 1450.” The test points indicated here and in items 10H through 10K for recording values are the same test points.
10	Operating Record	See Table C-2.
***Signature:** Each monthly log must be signed by the cathodic protection technician (CPT) and the BCCE before submission to higher headquarters.		

Table C-2 Form 491 Item 10 Operating Record

Name	Description
A	Enter the month tests are performed.
B	Enter the date of the month.
C* & E*	Enter the as found (before any adjustments are made) DC voltage in Column C and the DC current in column E.
D* & F*	If required, adjust the DC voltage level until the DC current is equal to or greater than the current requirement (item 8) and enter the as adjusted DC voltage in column D and DC current in column F.
G	The corrosion engineer must compute the circuit resistance using Ohm’s Law and enter the value in column G. $$Resistance = \frac{Adjusted\ Voltage}{Adjusted\ Amperage}$$
H	Test point 1 (referred to as “maximum potential area”) must be determined using data obtained from the annual performance survey. This point is located closest to the ground bed and is to be taken over the structure in that area. Enter this value in column H. Care must be taken to read the correct polarity.
I-K	Test points 2, 3, and 4 are the lowest potential points of the protected structure being protected by the rectifier. These test points must be determined using data obtained from the annual performance survey. They are subject to change as directed by the corrosion engineer. Enter the values found for the appropriate points.
L	State whether soil is wet, moist, dry, or powdery. **Note:** For the testing of S/E potentials, only authorized multimeters and potentiometers are used. For S/E potential readings, the potentiometer circuit must be used. If the ground is frozen, do not take readings and state so in column L by entering “GF.”
*Columns C through F are readings of DC voltage and DC current only. Readings must be taken with handheld calibrated meters, not rectifier meters.	

Figure C-1 Sample Completed Form 491 (Front)

CATHODIC PROTECTION OPERATING LOG FOR IMPRESSED CURRENT SYSTEM

1. INSTALLATION Tyndall AFB, FL	2. YEAR 2018
3. PROTECTED STRUCTURE Underground Gas Distribution, Base Housing	4. RECTIFIER NUMBER 3

5. RECTIFIER DATA (From Nameplate)	6. GROUND BED DATA	
A. MANUFACTURER Universal	A. ANODE MATERIAL HSCI	
B. MODEL NUMBER ASAI	B. SIZE OF ANODE 2.9" x 84" (3884Z)	
C. SERIAL NUMBER 980427	C. NUMBER OF ANODES 12	
D. AC RATED CAPACITY 120/240V 14/7A	D. TYPE OF BACKFILL Loresco DW-1	
E. DC RATED CAPACITY 60V 28A	E. DATE INSTALLED (YYYY MM DD) 1998 04 16	7. LOCATION (REFERENCE DRAWING NO.) 473 Sheet 3

8. CURRENT REQUIRED		9. OPERATING RECORD (Complete on three month intervals)
DATE	ADJUSTED CURRENT (AMPS)	RECTIFIER Felix Lake Dr S of Prime Beef Rd
2017 04 12	16.4	TEST POINT 1 Youth Center Regulator
2017 06 15	16.55	TEST POINT 2 T/S Andrews Loop @ S Bullard Cr
		TEST POINT 3 T/S Hackney Ct
		TEST POINT 4 T/S Eagle Dr + Phantom St

OPERATING RECORD

10. MONTH A	DAY B	RECTIFIER VOLTS AS FOUND C	VOLTS AS ADJUSTED D	AMPS AS FOUND E	AMPS AS ADJUSTED F	CIRCUIT RESISTANCE G	TEST POTENTIAL TEST POINTS (Vo.rs) 1 H	2 I	3 J	4 K	SOIL CONDITION L	INITIALS OF TECHNICIAN M
JAN	14	34.7		16.71		2.08	-1.482	-1.217	-1.040	-.979	Moist	NCP
FEB	20	34.8		16.64		2.10	-1.447	-1.211	-1.033	-.970	Dry	NCP
MAR	17	34.8		16.60		2.10	-1.460	-1.301	-1.011	-.962	Dry	GF
APR	20	36.2	34.9	9.41	17.11	2.04	-1.412	-1.229	-1.001	-.955	Wet	NCP
MAY	15	35.0		16.77		2.09	-1.441	-1.241	-1.004	-.947	Moist	GF
JUN	15	34.8		16.55		2.10	-1.437	-1.246	-.999	-.939	Dry	GF
JUL	22	35.0		16.60		2.11	-1.411	-1.217	-.988	-.927	Dry	NCP
AUG	18	36.2	41.1	14.80	16.9	2.43	-1.404	-1.201	-.977	-.918	Wet	GF
SEP	12	41.3		16.65		2.48	-1.441	-1.197	-.974	-.909	Wet	GF
OCT	18	41.4		16.54		2.50	-1.462	-1.202	-.982	-.898	Moist	NCP
NOV	14	41.1	46.2	16.31	18.26	2.53	-1.455	-1.124	-.991	-.894	Dry	NCP
DEC	4	46.1		18.25		2.53	-1.450	-1.201	-.982	-.910	Dry	NCP

SIGNATURE OF CATHODIC PROTECTION TECH	DATE (YYYY MM DD)	SIGNATURE OF BASE CORROSION ENGINEER	DATE (YYYY MM DD)
George Freeman	2018 12 04	*Marshall J Monroe, P.E.*	2018 12 07

AF IMT 491, JAN 81, V2 PREVIOUS EDITION IS OBSOLETE

Figure C-2 Sample Completed Form 491 (Back)

REMARKS (Date and Initials)	CORRECTIVE ACTION (Date and Initials)
20 April 2018 NCP	Current dropped, troubleshooting determined bad Diode, replaced stacks.
15 June 2018 NCP	Cleaned rectifier cabinet and tightened connections.
18 August 2018 GF	Performed anode bed CIS, one failed anode, adjusted rectifier to meet current requirement.
14 Nov 2018 NCP	Current dropped below the current requirement, adjusted rectifier up one fine.

SIGNATURE OF CORROSION ENGINEER	DATE (YYYY MM DD)
Michael J. Monroe, P.E.	2018 12 07

AF IMT 491, JAN 81, V2 (Reverse)

C-2.2.2 Form 1686.

Entries on AF Form 1686 are made biannually or more often if required by the parent command. No readings of the S/E potentials are to be taken where the ground is frozen. Readings are to be made with the authorized meters only. See Tables C-3 and C-4 for items and descriptions. Figures C-3 and C-4 depict examples of a completed form.

Table C-3 Form 1686 Items and Descriptions

Item	Name	Description
1	Installations	Enter the name of the protected structure and its number as shown on USAF Real Property Report (RCS: HAF-PRE(SA)7115), such as "Underground Gas Pipeline Capehart Hsg Nr 220."
2	Year	Enter calendar year.
3	Protected Structure	Enter the name of the protected structure and its number as shown on USAF Real Property Report (RCS: HAF-PRE(SA)7115), such as "Underground Gas Pipeline Capehart Hsg Nr 220."
4	Test Station Number	Enter the number of the test station where the reading of the potential is to be taken. Test stations should be numbered consecutively starting with number 1 for the entire base.
5	System Data	• **Number of Anodes:** From record, find the number of existing anodes on this system and enter it on the form. Also, note under remarks on back of form if any new anodes were installed during the last year and how many. • **Number of Test Stations:** Enter here the total number of test stations for this piping system. List the test stations by number.
6	Anode Data	• **Type:** Enter the name of the anode, trade name, its manufacturer, and the name of the material, as "magnesium H-1" or "zinc." • **Size:** Enter the dimensions or the standard size designations as "2" by 5' long" or "17 lbs.," or "32 lbs." • **Type of Backfill:** Enter the type of backfill used around the anodes as "prepackaged," "bentonite," "coke breeze," or "none." • **Location:** Enter a brief description of the location of the anode so that it can be located easily, as "gas line 50' W to 10' N of building 2263." • **Date Installed:** Enter date of installation. This date is supplied by the corrosion engineer. Where no detailed information is available, estimate and enter the approximate date.
7	Operating Record	See Table C-4.
***Signature:** Each log must be signed by the CPT and the BCCE before submission to higher headquarters.		

Table C-4 Form 1686 Item 7 Operating Record

Column	Description
A	Enter the month tests are performed.
B	Enter the date of the month of the survey.
C	S/E Potentials At Test Station (Volts). This reading is usually taken at the test station(s) of the system. Where no test stations are installed, readings must be taken at point as directed by the corrosion engineer. Enter the value found in column C.
D	S/E Potential Between Anodes (Volts). This is the potential-to-ground of the structure halfway between two anodes (or the most remote point of a structure from the anode protecting it). It is important to know how far the protection of an anode extends. Enter the value in column D.
E	Anode-to-Soil (Volts). This reading represents the open-circuit voltage of the anode with the structure (load) disconnected. Enter the reading in Column E.
F	Anode-to-Structure (Milliamps). Connect the milliamp meter between the structure and anode at the test station and enter the value in column F.
G	Soil Conditions. State whether soil is wet, moist, dry, or powdery. The condition of soil is approximately 1 foot below surface. If the ground is frozen, do not take readings and so state by entering “GF.”
H	Initials of Technician. The initials of the CPT must be shown in this column.

Figure C-3 Sample Completed Form 1686 (Front)

CATHODIC PROTECTION OPERATING LOG FOR SACRIFICIAL ANODE SYSTEM

1. INSTALLATION	2. YEAR
Keesler AFB, MS	2018
3. PROTECTED STRUCTURE	4. TEST STATION NUMBER
Underground Hospital Oxygen Pipeline	27

5. SYSTEMS DATA	6. ANODE DATA
A. NUMBER OF ANODES 4	A. TYPE High Potential Magnesium (20D2)
B. NUMBER OF TEST STATIONS 1	B. SIZE 2 3/4" x 3 3/4" x 59 3/4"
	C. TYPE OF BACKFILL Gypsum/Bentonite/Sodium Sulfate
	D. LOCATION DESCRIPTION NE Corner by Mechanical Room
	E. DATE INSTALLED April 1981

7. OPERATING RECORD (Complete on three month intervals)

MONTH A	DAY B	STRUCTURE TO SOIL/WATER (Volts) C	REMOTE STRUCTURE TO SOIL/WATER (Volts) D	ANODE TO SOIL/WATER (Volts) E	ANODE TO STRUCTURE (Milliamps) F	SOIL CONDITION G	INITIALS OF TECHNICIAN H
JAN							
FEB							
MAR	15	-1.029	-.991	-1.748	27	Moist	LRS
APR							
MAY							
JUN							
JUL							
AUG							
SEP	16	-1.017	-.985	-1.729	24	Dry	LRS
OCT							
NOV							
DEC							

SIGNATURE OF CATHODIC PROTECTION TECHNICIAN	DATE (YYYY MM DD)	SIGNATURE OF BASE CORROSION ENGINEER	DATE (YYYY MM DD)
Lauren R Smith	20181210	*Sanford Mason PE*	20181214

AF FORM 1686, JAN 81 (EF-V2)

Figure C-4 Sample Completed Form 1686 (Back)

REMARKS (Date and Initials)	CORRECTIVE ACTION (Date and Initials)	
15 Mar 2018 LRS	Cleaned wires and replaced split bolt during Semi Annual Inspection.	
16 Sept 2018 LRS	Annual Survey Completed.	
SIGNATURE OF CORROSION ENGINEER *Sanford Mason P.E*		DATE (YYYY MM DD) 2018 12 14

AF FORM 1686, JAN 81 (EF-V2)

C-2.2.3 Form 1687.

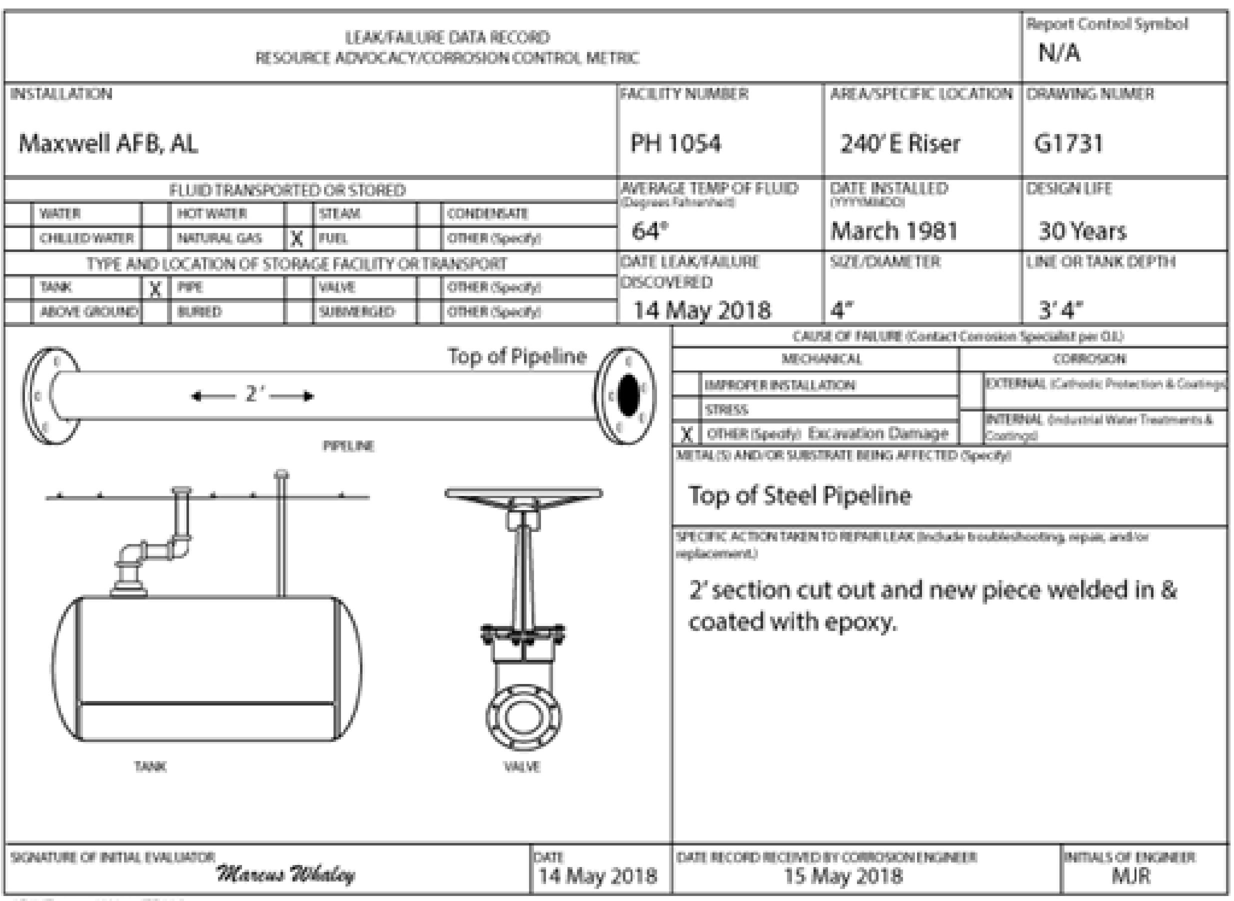
Table C-5 lists the items and descriptions for Form 1687. See Figures C-5 and C-6 for completed example forms.

Table C-5 Form 1687 Items and Descriptions

Item	Description
Report Control Symbol	N/A
Installation	Enter the official name and location of the installation, such as “Fairchild AFB, WA.” DO NOT ABBREVIATE OR USE UNIT DESIGNATIONS, SUCH AS “FAFB.”
Facility Number	Enter the number of the facility, such as “Building 1376”or “Water Tank 904.”
Area/Specific Location	Enter the area, such as “North side of building 1376, 50' west of the fire hydrant.”
Drawing Number	Show drawing number of the map upon which this leak is located for the purpose of recording installation leak history.
Fluid Transported or Stored	Mark (x) in the block for the type of fluid or fill in the other (specify) block with the appropriate name of the fluid.
Average Temperature of Fluid	Enter average temperature in degrees Fahrenheit (°F).
Date	Enter the date of the structure (i.e., pipe, valve, or tank) installation.
Design Life	Enter the number of years (life expectancy) of the structure.
Type and Location of Storage Facility or Transport	Mark (x) in the appropriate block or fill in the other (specify) block for those not listed.
Date Leak/Failure Discovered	Enter the appropriate date, in day, month, and year format, such as “1 Feb 98.”
Size/Diameter	Enter the size of the storage facility or transport, such as “6"” or “500-gallon capacity.”
Line or Tank Depth	Enter the depth of the corroded structure.
Cause of Failure	Mark (x) in the appropriate block or enter the information in the block for other (specify).
Metal(s) and/or Substrate Affected	Write in the appropriate type of metal or substrate.
Specific Action Taken to Repair Leak	Write in the specific action taken to make repairs and identify the specific area(s) affected on the drawing.
*Cathodic Protection	Mark (x) if applicable.

Item	Description
Type System	Mark (x) in the appropriate block.
Protective Coatings	Mark (x) if applicable.
Coatings System Used	Specify the type of coating and/or wrap used if applicable.
Industrial Water Treatment	Mark (x) if applicable.
Type System	Mark (x) in the appropriate block.
As Found Condition	Describe the condition of the structure when the problem was discovered.
As Left Condition	Describe the work accomplished to repair the structure.
Specific Action Taken to Repair Cause of Leak or Failure	Describe the measures taken to prevent a reoccurrence of this problem.
Signatures	The form must be signed by the CPT and the BCCE before submitting to a higher authority.
*Second page – corrosion engineer directs.	

Figure C-5 Sample Completed Form 1687 (Front)



LEAK/FAILURE DATA RECORD
RESOURCE ADVOCACY/CORROSION CONTROL METRIC
Report Control Symbol: N/A

INSTALLATION: Maxwell AFB, AL
FACILITY NUMBER: PH 1054
AREA/SPECIFIC LOCATION: 240' E Riser
DRAWING NUMER: G1731

FLUID TRANSPORTED OR STORED: WATER; HOT WATER; STEAM; CONDENSATE; CHILLED WATER; NATURAL GAS; X FUEL; OTHER (Specify)
AVERAGE TEMP OF FLUID (Degrees Fahrenheit): 64°
DATE INSTALLED (YYYYMMDD): March 1981
DESIGN LIFE: 30 Years

TYPE AND LOCATION OF STORAGE FACILITY OR TRANSPORT: TANK; X PIPE; VALVE; OTHER (Specify); ABOVE GROUND; BURIED; SUBMERGED; OTHER (Specify)
DATE LEAK/FAILURE DISCOVERED: 14 May 2018
SIZE/DIAMETER: 4"
LINE OR TANK DEPTH: 3' 4"

CAUSE OF FAILURE (Contact Corrosion Specialist per OI.)
MECHANICAL: IMPROPER INSTALLATION; STRESS; X OTHER (Specify) Excavation Damage
CORROSION: EXTERNAL (Cathodic Protection & Coatings); INTERNAL (Industrial Water Treatments & Coatings)

METAL(S) AND/OR SUBSTRATE BEING AFFECTED (Specify): Top of Steel Pipeline

SPECIFIC ACTION TAKEN TO REPAIR LEAK (Include troubleshooting, repair, and/or replacement.): 2' section cut out and new piece welded in & coated with epoxy.

SIGNATURE OF INITIAL EVALUATOR: *Marcus Whaley*
DATE: 14 May 2018
DATE RECORD RECEIVED BY CORROSION ENGINEER: 15 May 2018
INITIALS OF ENGINEER: MJR

AF IMT 1687, JAN 98 (EF-V1)

Figure C-6 Sample Completed Form 1687 (Back)

CORROSION ENGINEER DIRECTS:

X | CATHODIC PROTECTION

TYPE SYSTEM ("X" one)

☐ GALVANIC ☒ IMPRESSED CURRENT ☐ NONE

X | PROTECTIVE COATINGS

COATING SYSTEM USED (Specify)

Fusion Bonded Epoxy

☐ | INDUSTRIAL WATER TREATMENT N/A

TYPE SYSTEM ("X" one)

☐ HEATING ☐ COOLING

SYSTEM TREATMENT (Specify)

AS FOUND CONDITION (Describe specifics.)

Deep scratch 2' in length with puncture on East side.
No corrosion found.

AS LEFT CONDITION (Describe specifics.)

New pipe welded in, x-ray completed, recoated with epoxy, allowed to cure for 24 hours, inspected with high voltage holiday detector with 2 minor repairs.

SPECIFIC ACTION TAKEN TO REPAIR CAUSE OF LEAK OR FAILURE

Review Digging Permit Location Procedures & have personnel on-site during excavations in areas of pipelines.

COST

1801512

JOB ORDER/WORK ORDER NO.

$ 12,450.00

SIGNATURE OF SPECIALIST *Bill Regan*	DATE 16 May 2018
SIGNATURE OF CORROSION ENGINEER *Sanford R Monroe P.E.*	DATE 22 May 2018

AF FORM 1687, JAN 98, (EF-V1) (REVERSE)

C-2.2.4 Form 1688.

Figure C-7 depicts an example of a completed Form 1688.

Figure C-7 Sample Completed Form 1688

ANNUAL CATHODIC PROTECTION PERFORMANCE SURVEY

DATE (YYYYMMDD): 2018 08 12

[X] IMPRESSED CURRENT SYSTEMS
[ ] SACRIFICIAL ANODE SYSTEMS

INSPECTOR: Roger Mason

RECTIFIER NO.: 7

LOCATION: Sabre Dr. @ 7th St.

ANODE TEST STATION: N/A

RECTIFIER SETTING: DC VOLTS 22.8; DC AMPS 7.43

PROTECTED STRUCTURE: U/G Gas Distribution

NO.	TEST STATION LOCATION	ON(1)(2)	OFF(1)	REMARKS
1	@ Rectifier	-2.711	-1.218	
2	2712 Sabre Dr.	-1.812	-1.147	
3	Sabre Dr. + 11th St.	-1.772	-1.140	
4	1480 E. 11th St.	-1.624	-1.121	
5	Mitchell Dr. + 11th St.	-1.552	-1.108	
6	2284 E. 11th St.	-1.509	-1.049	
7	Mitchell Dr. Reg. Stat.	-1.447	-1.023	
8	Mitchell Dr. Reg. Stat.	-.410	-4.27	Dielectric house side
9	Bldg #1472	-1.202	-.992	
10	Bldg # 1570	-1.191	-.984	Back of Mech. Room
11	4th St. at Market Ave.	-1.219	-.992	
12	4th St. at Beach Blvd.	-1.227	-1.019	
13	Beach Blvd. at Main St.	-1.241	-1.108	
14	2912 Beach Blvd.	-1.221	-1.119	
15	Beach Elementary	-1.240	-1.122	(reg.)
16	Beach Elementary	-.272	-.289	Dielectric house side
17	4750 Beach Blvd.	-1.118	-.917	
18	Oscar Dr. at 9th St.	-1.107	-.923	
19	3218 Oscar Dr.	-1.121	-.974	
20	Oscar Reg. Stat	-1.202	-1.109	
21	Oscar Reg. Stat	-.243	-.243	Dielectric house side
22	2280 Oscar Dr.	-1.191	-1.011	
23	Farley Dr. + Oscar Dr.	-1.172	-1.101	

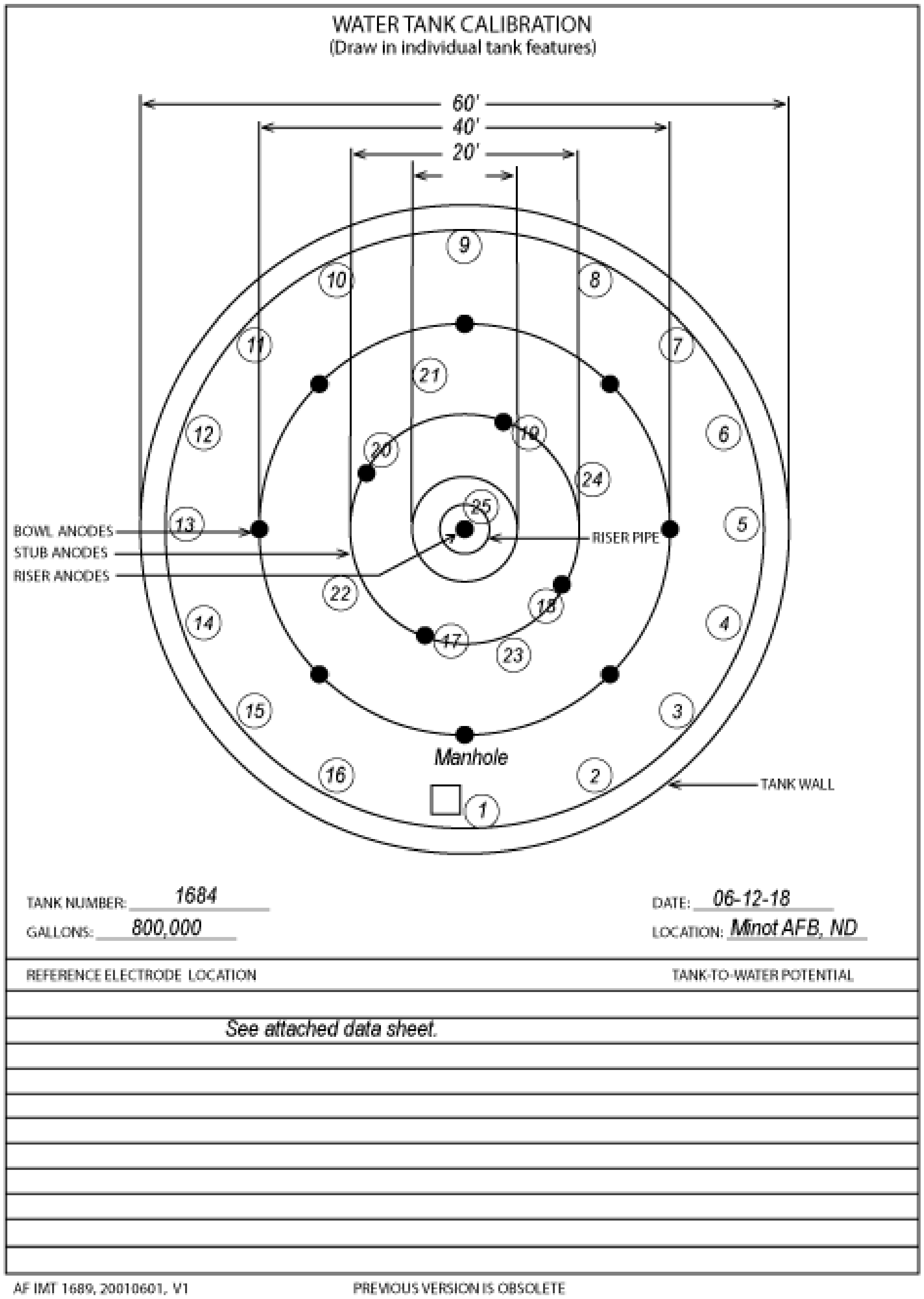
(1) Structure to electrolyte potentials in volts to a copper-copper sulfate electrode.
(2) For sacrificial anode systems, enter reading here.

AF IMT 1688, 19850201, V3 PREVIOUS EDITION WILL BE USED.

C-2.2.5 Form 1689.

Figure C-8 depicts an example of a completed Form 1689, used to record data for water tank calibration. Because the form does not include adequate space to record I.O. potential data, it is recommended to record the data in a separate spreadsheet document, as depicted in Figure C-9.

Figure C-8 Sample Completed Form 1689



WATER TANK CALIBRATION
(Draw in individual tank features)

TANK NUMBER: 1684
GALLONS: 800,000
DATE: 06-12-18
LOCATION: Minot AFB, ND

REFERENCE ELECTRODE LOCATION	TANK-TO-WATER POTENTIAL
See attached data sheet.	

AF IMT 1689, 20010601, V1 PREVIOUS VERSION IS OBSOLETE

Figure C-9 Sample Completed Data Sheet for Form 1689

SAMPLE EXCEL SPREADSHEET FOR ON/I.O. POTENTIAL DATA FOR WATER TANK CALIBRATION

	ON TOP	I.O	ON MIDDLE	I.O	ON BOTTOM	I.O
1	-1.220	-1.114	-1.278	-1.202	-1.257	-1.191
2	-1.232	-1.211	-1.319	-1.223	-1.268	-1.197
3	-1.237	-1.214	-1.337	-1.202	-1.266	-1.212
4	-1.254	-1.221	-1.355	-1.227	-1.292	-1.214
5	-1.227	-1.207	-1.307	-1.194	-1.283	-1.207
6	-1.208	-1.199	-1.266	-1.136	-1.256	-1.191
7	-1.244	-1.140	-1.250	-1.130	-1.240	-1.184
8	-1.273	-1.186	-1.314	-1.154	-1.287	-1.193
9	-1.294	-1.205	-1.344	-1.169	-1.312	-1.212
10	-1.303	-1.233	-1.447	-1.174	-1.372	-1.231
11	-1.284	-1.211	-1.388	-1.152	-1.348	-1.223
12	-1.288	-1.220	-1.360	-1.140	-1.312	-1.209
13	-1.260	-1.200	-1.291	-1.119	-1.273	-1.172
14	-1.251	-1.193	-1.279	-1.108	-1.260	-1.163
15	-1.255	-1.198	-1.312	-1.144	-1.292	-1.181
16	-1.303	-1.221	-1.376	-1.201	-1.337	-1.199
17					-1.372	-1.202
18					-1.384	-1.210
19					-1.419	-1.227
20					-1.404	-1.221
21					-1.322	-1.208
22					-1.327	-1.210
23					-1.331	-1.212
24					-1.309	-1.197
RISER						
	ON TOP	I.O	ON COLUMN 2	I.O	ON COLUMN 3	I.O
25	-1.414	-1.220	-1.527	-1.202	-1.519	-1.200
3'	-1.472	-1.231	-1.662	-1.214	-1.412	-1.191
3'	-1.577	-1.221	-1.513	-1.199	-1.332	-1.104
3'	-1.626	-1.227	-1.499	-1.192		
3'	-1.505	-1.216	-1.592	-1.195		
3'	-1.412	-1.191	-1.488	-1.187		
3'	-1.622	-1.212	-1.499	-1.189		
3'	-1.525	-1.210	-1.620	-1.212		
3'	-1.418	-1.191	-1.512	-1.197		
3'	-1.720	-1.222	-1.552	-1.199		
3'	-1.417	-1.190	-1.571	-1.201		
3'	-1.488	-1.191	-1.498	-1.188		
3'	-1.620	-1.207	-1.412	-1.174		
3'	-1.595	-1.202	-1.527	-1.182		
3'	-1.472	-1.191	-1.612	-1.211		
3'	-1.712	-1.209	-1.592	-1.204		
3'	-1.520	-1.204	-1.487	-1.192		
3'	-1.572	-1.205	-1.606	-1.217		

C-2.3 Annual Performance Booklet.

The annual survey should be a hard cover, three-ring binder, and only one copy of the Cathodic Protection Annual Performance Booklet should be prepared. The booklet must be completed by 1 February following the year of survey for review and kept for review by any higher headquarters personnel.

The binder contains basic information and the annual survey data. Table C-6 lists the order of this information.

Table C-6 Annual Performance Booklet Binder Information

Tab	Tab Title	Description
A	Title Page	List the base, type of survey, date survey was completed, and the names of the corrosion engineer and the CPT.
B	Index	
C	General Description	Describe in detail and in numerical order what the CP systems on the base consist of: impressed current or galvanic, sacrificial anode system; how many systems installed and for which utilities or structures, such as: water distribution systems, gas distribution systems, POL, heating, and storage tanks. Add information on type of metal used in mains and service lines, types of coatings, when installed, and by whom.
D	Summary of Survey Analysis and Actions Required	Describe in detail reasons or probable reasons for either high- or low-potential measurements. Describe actions needed to provide protective potentials, estimated costs, and completion dates.
E	Base Cathodic Protection Operation and Maintenance Procedures	Provide a copy of the CP operations and maintenance procedures.
F	Cathodic Protection Program Record	Provide a copy of the CP program record. This record must be updated yearly, as necessary. It must have its individual data sheets, showing location of test points by building number or other landmarks. Maximum and minimum test points as required by AF Form 491 must be identified, such as 7h, 7i, 7j, 7k, for rectifier number 7.
G	Maintenance Action Sheet	

Tab	Tab Title	Description
H	Leak/Failure Data Records	Complete and provide one copy of AF Form 1687 for each failure that was caused by corrosion during the preceding year. This record must be kept on all systems without regard to the application of CP.
I	Master Plan Tab G-8	A copy of Tab G-8 of the master plan must be included.
J	Cathodic Protection Operating Logs	The operating logs from the preceding year must be included for each system.
K	Equipment	This tab should be used to list all CP equipment on hand and the condition of equipment.
L	Annual Performance Survey Data	All survey data must be provided, including areas that are resurveyed after rectifier adjustments are made. Each system as listed in the program record (Tab F) must have its individual data sheets, showing location of test points by building number or other landmarks. Maximum and minimum test points as required by AF Form 491 must be identified, such as 7h, 7i, 7j, 7k, for rectifier number 7.
M	Sketches and Drawings	A sketch must be provided for each underground tank system indicating location of tank and where readings were taken. Include any additional drawings that will assist in the evaluation of the survey data.
N	Personnel Roster	Provide a list of names and grades of the corrosion engineer and CPT, along with a description of their training in CP and along with the date received.

C-3 NAVY.

C-3.1 Naval Shore Facilities Corrosion Control Report.

C-3.1.1 Introduction.

The annual cost of corrosion within the Navy shore establishment is estimated to exceed $10 million, and facilities and equipment with a plant value of over $60 million are at risk of failure due to corrosion. Corrosion of Navy facilities is a common and serious problem and must be addressed to ensure their safe and economical operation. Corrosion impacts shore facilities in many more ways and to a far greater degree than regularly considered:

- Costly system repairs and replacements.
- Downtime and disruption of service.
- Expensive loss of product.

- Environmental and safety hazards.
- Decreased system capacities.
- Adverse impacts on operational readiness.

Action to control corrosion and to repair corrosion damage is among the most frequent reasons for performing maintenance on our facilities. By formulating and executing a facility corrosion protection plan, system life is extended and operational costs are reduced. It is important that we obtain maximum benefit from our facilities by applying corrosion control measures as lessening amounts of funds are available for maintaining and repairing facilities to meet critical mission requirements.

It is important to consider corrosion control during the design and construction of new facilities or the repair/replacement of existing facilities. In most cases, it is less costly to eliminate causes of corrosion and include corrosion control measures during the design and construction phase than to correct the problem after construction is complete.

C-3.1.2 Corrosion Control Program.

Corrosion control **is** considered as an integral part of the design, construction, operation, and maintenance of all facilities under the cognizance of Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC). POL systems, waterfront structures, utility systems, and antenna systems have been found to be the most critical facilities in terms of a combination of risk from corrosion, the need to provide a continuity of direct fleet support, and the cost effectiveness of utilizing appropriate corrosion control systems.

Corrosion control systems are planned, designed, installed, monitored, and maintained for:

- All POL liquid fuel pipelines and storage facilities in accordance with the provisions of Code of Federal Regulations (CFR) Title 49 Chapter 1, Part 195, Transportation of Liquids by Pipeline and CFR Title 40 Chapter 1, Part 112, Oil Pollution Prevention.
- All natural gas pipelines in accordance with the provisions of CFR Title 49 Chapter 1, Part 192, Transportation of Natural and Other Gas by Pipeline.
- All steel underground storage tank systems in accordance with CFR 40 Part 280, Technical Standards and Corrective Action for Owners and Operators of Underground Storage Tanks, or more stringent state/local regulations as applicable.
- All buried or submerged metallic shore facilities in which the electrolyte (soil or water) resistivities are below 10,000 ohm-cm at the installation depth at any point along the installation.
- Other facilities as indicated in NAVFACENGCOM letter 11012 04C/cmm of 31 May 1994, Cathodic Protection Systems, Interim Technical Guidance.

- Overseas activities should comply with the requirements of the DoD Overseas Environmental Baseline Guidance Document and applicable area governing standards.

NAVFACENGCOM letter 11012 04C/cmm of 31 May 1994, Cathodic Protection Systems, Interim Technical Guidance describes the policy in more detail. For any questions on the policy, please contact your Engineering Field Division (EFD) CP program manager or the NAVFACENGCOM Cathodic Protection Technical Expert at the Naval Facilities Engineering Service Center (NFESC).

C-3.1.3 Corrosion Control.

The corrosion control systems described below are those most commonly used on shore facilities.

C-3.1.3.1 Protective Coatings.

Coatings provide protection to a variety of substrates (e.g., metals, wood, concrete) by forming a barrier to the surrounding environment. The continuing integrity of this barrier film is necessary for continuing protection.

C-3.1.3.2 Cathodic Protection.

Metal structures (including rebar), buried or immersed in electrolyte (e.g., soil, water, concrete), can be cathodically protected from external corrosion. This method of protection, normally used in conjunction with coatings, is achieved by transferring the corrosion to other cheaper “anode” materials that are sacrificed to protect the structure. The two basic types of CP systems are “sacrificial (galvanic) anode” and “impressed current.” All CP systems require periodic maintenance and adjustment to ensure system integrity and continuous control of corrosion.

C-3.1.3.3 Other Methods.

Other corrosion control methods include:

- Proper design techniques to eliminate conditions conducive to corrosion (e.g., contact of dissimilar metals).
- Selection of materials resistant to the particular environment.
- Use of chemical inhibitors or treatments in a closed system.

C-3.1.4 NAVFACENGCOM Headquarters.

NAVFACENGCOM Headquarters establishes policy, provides oversight, and provides budget guidance.

C-3.1.5 CP System Reporting.

Figures C-10, C-11 and C-12 are sample report forms. Similar report forms having the test data described below may be substituted. Contact the cognizant EFD for more information on CP system reporting, special report form requirements, and approval of substitute report forms.

- Structure-to-electrode potential readings generally shall be recorded quarterly, but no less than annually.
- Rectifier settings and outputs generally shall be recorded no less than bimonthly.

Figure C-10 Cathodic Protection Installation Report

UFC 3-570-06
JANUARY 31 2003

CATHODIC PROTECTION INSTALLATION REPORT

ACTIVITY: ______________________ DATE: ______________

IMPRESSED CURRENT SYSTEM

Location of Rectifier					
Identification Number					
Structure(s) Protected					
Reference Drawing Number(s) Showing CP System					
Anode Description	Type:	Quantity:	Size: dia. X long		
Rectifier Manufacturer					
Rectifier Rated Capacity					
A.C. Input	Amps:	Volts:	Phases:	Cycles: Hz	
D.C. Output	Amps:	Volts:			
Date Unit Turned On					
Number of Test Stations					
System Maintained By					

SACRIFICIAL SYSTEM

Location of Sacrificial Anodes				
Structure(s) Protected				
Reference Drawing Number(s) Showing CP System				
Anode Description	Type:	Quantity:	Weight:	Size:
Date Unit Turned On				
Number of Test Stations				
System Maintained By				

Notes:

1. Submit a one-time report for each impressed current rectifier.
2. Submit a one-time report for each structure protected by a sacrifical anode system.
3. Report CP installations within three months of installation. Attach initial test data information.

Figure C-11 CP Quarterly Structure-to-Electrode Potential Report

UFC 3-570-06
JANUARY 31 2003

CATHODIC PROTECTION

QUARTERLY STRUCTURE-TO-ELECTRODE POTENTIAL REPORT

ACTIVITY:	PERIOD ENDING
CP SYSTEM ID:	

TS NO.	LOCATION OR IDENTIFICATION	S/E (VOLT)	SHUNT			INSPECTOR	DATE	REMARKS*
			MV	RES	MA			

* IDENTIFY TEST ELECTRODE IF OTHER THAN COPPER SULFATE

SHEET _____ OF ______

Figure C-12 Cathodic Protection Rectifier Report

UFC 3-570-06
JANUARY 31 2003

CATHODIC PROTECTION RECTIFIER REPORT

ACTIVITY:				PERIOD ENDING:	
DESCRIPTION OF SYSTEMS PROTECTED:					
RECTIFIER ID NO. & LOCATION:					
RECTIFIER MANUFACTURER:				RECTIFIER TYPE:	
MODEL NO.:			SERIAL NO.:		
RECTIFIER RATED CAPACITY					
AC INPUT	AMPS	VOLTS	PHASE		AMP CYCLES
DC OUTPUT	AMPS	VOLTS	SHUNT SIZE:	MV	
ANODE MATERIAL	TYPE:	QTY:	WT:	SIZE: DIA. X LONG	
DATE TURNED ON:					

MONTHLY READINGS

RECTIFIER AC SETTING		DC OUTPUT		CHECKED BY	DATE	REMARKS

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APPENDIX D TRAINING AND CERTIFICATION

D-1 INTRODUCTION.

All personnel assigned to CP duties must receive initial, annual, and/or refresher training and/or required certifications. This training should equip personnel with the ability to apply NACE criteria to determine the effectiveness of applied CP and the ability to troubleshoot the CP system if inoperative. Applicable personnel may require specialized training for protective coatings, industrial waste treatment, and/or for design and construction projects.

D-2 SOURCES.

CorrDefense is a DoD web site for the Office of Corrosion Policy and Oversight and is operated and maintained by the Logistics Management Institute. CorrDefense offers technical papers, key corrosion documentation, briefs by academia, Government, and Industry, and links to training opportunities. These resources can be accessed at www.corrdefense.org.

NACE International® - NACE is a professional organization for corrosion control offering CP training opportunities. For more information on available courses and upcoming seminars providing training opportunities, see NACE International (www.nace.org).

NACE International Educational Courses
P.O. Box 218340
Houston, TX 77218
Phone: Comm (281) 228-6200/1-800-797-6223
www.nace.org

Center for Professional Advancement
Contact: General Information
P.O. Box H
East Brunswick, NJ 08816-0257
Phone: Comm (201) 613-4500

JA Electronics
13715 North Promenade Boulevard
Stafford, TX 77477
Phone: (281) 879-9903
www.jaelectronics.com

- Rectifier Maintenance Course, 2 to 4 days

Heath Consultants
9030 Monroe Road
Houston, TX 77061
Phone: Comm (713) 844-1300
info@heathus.com
http://heathus.com

- Pipe and Cable Locating Seminar

Institute of Corrosion
Barratt House
Suite S3, Kingsthorpe Road
Northampton
NN2 6EZ UK
Phone: Comm + 44 (0)1604 438222
admin@icorr.org
www.icorr.org

- The Institute of Corrosion provides online and classroom corrosion and CP training in the areas of Coating Inspector, Cathodic Protection Technician, and Pipelines Coating Inspector. Registration for these courses may be done at https://www.icorr.org/training-qualifications-2/.

M.C. Miller Training Course
1580 US Highway 1
Sebastian, FL 32956
Phone: (772) 388-8588
sales@mcmiller.com
www.mcmiller.com

- Cathodic Protection Corrosion Software & Datalogger Course, 4 days
- Cathodic Protection Tester Training & Certification Program, 3 days

Oklahoma University Corrosion Control Course
College of Professional and Continuing Studies
University of Oklahoma
1700 Asp Avenue
Norman, OK 73037-0001
Phone: Comm (405) 325-3136

- Annual Course, 3 days

Puckorius & Associates, Inc.
7828 West 90th Avenue
Westminster, CO 80021
Phone: Comm (303) 674-9897

- Boiler Water Treatment, 2 days
- Cooling Water Treatment, 3 days
- Cooling Water Treatment for Utility Power Stations, 3 days

Purdue University Annual Corrosion Short Courses
Purdue University
Division of Conferences
Stewart Center, Room 116
128 Memorial Mall
West Lafayette, IN 47907
Phone: Comm (866) 515-0023
John2145@purdue.edu
www.conf.purdue.edu/corrosion

- Basic Course
- Oil and Gas Section Course
- Water Section Course
- Power and Communications Section Course
- Special Topics Course

Technical Training School
366 TRS/TSIE
727 Missile Road
Sheppard AFB, TX 76311-5334
Phone: DSN 736-5847

- J3AZR3E051003, Cathodic Protection Course, 8 days

SSPC – The Society for Protective Coatings
800 Trumbull Drive
Pittsburgh, PA 15205, USA
Phone: 412.281.2331 Toll-free: 877.281.7772
www.sspc.org

Transportation Safety Institute
Joint Services Safety Division
P.O. Box 25082
6500 S. MacArthur Boulevard
Oklahoma City, OK 73125-5050
DSN 940-2880 Ext 4472
Comm: (405) 954-4472

- Course JS00425 Pipeline Corrosion Control 1
- Course JS00426 Pipeline Corrosion Control 2

West Virginia University
Appalachian Underground Corrosion Short Course
Contact: AUCSCP.O. Box 926
Morgantown, WV 26505
info@aucsc.com
www.aucsc.com

WebCorr
1 Scotts Road #24-10
Shaw Centre, Singapore 228208
Phone: Comm (+65) 64916456

- WebCorr Corrosion Consulting Services provides online and classroom corrosion and CP training. Registration for these courses may be done at http://www.corrosionclinic.com/index.html.

Whole Building Design Guide Corrosion Prevention & Control (CPC) Source Overview

- https://www.wbdg.org/ffc/dod/cpc-source/corrosion-prevention-control-source-overview

APPENDIX E TYPES OF CORROSION

It is convenient to classify corrosion by the forms in which it manifests itself, the basis for this classification being the appearance of the corroded metal. Each form can be identified by visual observation, although, in some cases, magnification is required. Valuable information for the solution of a corrosion problem can often be obtained through careful observation of the corroded test specimens or failed equipment. Examination before cleaning is particularly desirable.

Some of the eight forms of corrosion are unique, but all of them are more or less interrelated. The eight forms are: (1) uniform, or general attack, (2) galvanic, or two-metal corrosion, (3) crevice corrosion, (4) pitting, (5) intergranular corrosion, (6) selective leaching, or parting, (7) erosion corrosion, and (8) stress corrosion. This listing is arbitrary but covers practically all corrosion failures and problems. The forms are not listed in any particular order of importance. Below, the eight forms of corrosion are discussed in terms of their characteristics, mechanisms, and preventive measures. Hydrogen damage, although not a form of corrosion, often occurs indirectly as a result of corrosive attack and is, therefore, included in this discussion.

E-1.1 Uniform Attack.

Uniform attack is the most common form of corrosion. It is normally characterized by a chemical or electrochemical reaction that proceeds uniformly over the entire exposed surface or over a large area. The metal becomes thinner and eventually fails. For example, a piece of steel or zinc immersed in dilute sulfuric acid normally dissolves at a uniform rate over its entire surface. A sheet iron roof shows essentially the same degree of rusting over its entire outside surface.

Uniform attack, or general overall corrosion, represents the greatest destruction of metal on a tonnage basis. This form of corrosion, however, is not of too great concern from the technical standpoint, because the life of equipment can be accurately estimated on the basis of comparatively simple tests. Merely immersing specimens in the fluid involved is often sufficient. Uniform attack can be prevented or reduced by (1) proper materials, including coatings, (2) inhibitors, or (3) cathodic protection.

E-1.2 Galvanic or Two-Metal Corrosion.

A potential difference usually exists between two dissimilar metals when they are immersed in a corrosive or conductive solution. If these metals are placed in contact (or otherwise electrically connected), this potential difference produces electron flow between them. Corrosion of the less corrosion-resistant metal is usually increased, and attack of the more resistant material is decreased, as compared with the behavior of these metals when they are not in contact. The less resistant metal becomes anodic and the more resistant metal becomes cathodic. Usually the cathode or cathodic metal corrodes very little or not at all in this type of couple. Because of the electric currents and dissimilar metals involved, this form of corrosion is called galvanic, or two-metal, corrosion. It is electrochemical corrosion, but we shall restrict the term galvanic to dissimilar-metal effects for purposes of clarity.

E-1.3 Crevice Corrosion.

Intense localized corrosion frequently occurs within crevices and other shielded areas on metal surfaces exposed to corrosives. This type of attack is usually associated with small volumes of stagnant solution caused by holes, gasket surfaces, lap joints, surface deposits, and crevices under bolt and rivet heads. As a result, this form of corrosion is called crevice corrosion or, sometimes, deposit or gasket corrosion.

E-1.4 Pitting.

Pitting is a form of extremely localized attack that results in holes in the metal. These holes may be small or large in diameter, but in most cases they are relatively small. Pits are sometimes isolated or so close together that they look like a rough surface. Generally a pit may be described as a cavity or hole with the surface diameter about the same as or less than the depth.

Pitting is one of the most destructive and insidious forms of corrosion. It causes equipment to fail because of perforation with only a small percent weight loss of the entire structure. It is often difficult to detect pits because of their small size and because the pits are often covered with corrosion products. In addition, it is difficult to measure quantitatively and compare the extent of pitting because of the varying depths and numbers of pits that may occur under identical conditions. Pitting is also difficult to predict by laboratory tests. Sometimes the pits require a long time—several months or a year—to show up in actual service. Pitting is particularly vicious because it is a localized and intense form of corrosion, and failures often occur with extreme suddenness.

E-1.5 Intergranular Corrosion.

Grain boundary effects are of little or no consequence in most applications or uses of metals. If a metal corrodes, uniform attack results since grain boundaries are usually only slightly more reactive than the matrix. However, under certain conditions, grain interfaces are very reactive and intergranular corrosion results. Localized attack at and adjacent to grain boundaries, with relatively little corrosion of the grains, is intergranular corrosion. The alloy disintegrates (grains fall out) and/or loses its strength.

Intergranular corrosion can be caused by impurities at the grain boundaries, enrichment of one of the alloying elements, or depletion of one of these elements in the grain-boundary areas. Small amounts of iron in aluminum, wherein the solubility of iron is low, have been shown to segregate in the grain boundaries and cause intergranular corrosion. It has been shown that, based on surface tension considerations, the zinc content of a brass is higher at the grain boundaries. Depletion of chromium in the grain-boundary regions results in intergranular corrosion of stainless steels.

E-1.6 Selective Leaching.

Selective leaching is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Similar processes occur in other alloy systems in which aluminum;

iron, cobalt, chromium, and other elements are removed. Selective leaching is the general term to describe these processes, and its use precludes the creation of terms such as dealuminumification, decobaltification, etc. Parting is a metallurgical term that is sometimes applied, but selective leaching is preferred.

E-1.7 Erosion Corrosion.

Erosion corrosion is the acceleration or increase in rate of deterioration or attack on a metal because of relative movement between a corrosive fluid and the metal surface. Generally, this movement is quite rapid, and mechanical wear effects or abrasion are involved. Metal is removed from the surface as dissolved ions, or it forms solid corrosion products, which are mechanically swept from the metal surface. Sometimes, movement of the environment decreases corrosion, particularly when localized attack occurs under stagnant conditions; this is not erosion corrosion because deterioration is not increased.

Erosion corrosion is characterized in appearance by grooves, gullies, waves, rounded holes, and valleys and usually exhibits a directional pattern. In many cases, failures because of erosion corrosion occur in a relatively short time, and they are unexpected largely because evaluation corrosion tests were run under static conditions or because the erosion effects were not considered.

E-1.8 Stress-Corrosion Cracking.

Stress-corrosion cracking refers to cracking caused by the simultaneous presence of tensile stress and a specific corrosive medium. Many investigators have classified all cracking failures occurring in corrosive media as stress-corrosion cracking, including failures due to hydrogen embrittlement. However, these two types of cracking failures respond differently to environmental variables. To illustrate, cathodic protection is an effective method for preventing stress-corrosion cracking; whereas, it rapidly accelerates hydrogen-embrittlement effects. Hence, the importance of considering stress-corrosion cracking and hydrogen embrittlement as separate phenomena is obvious. For this reason, the two cracking phenomena are discussed separately in this chapter.

During stress-corrosion cracking, the metal or alloy is virtually unattacked over most of its surface, while fine cracks progress through it. This cracking phenomenon has serious consequences, since it can occur at stresses within the range of typical design stress. Exposure to boiling $MgCl_2$ at 310°F (154°C) is shown to reduce the strength capability to approximately that available at 1200°F.

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APPENDIX F GLOSSARY

F-1 ACRONYMS

AC	alternating current
ACVG	alternating current voltage gradient
AFCEC	Air Force Civil Engineer Center
ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	ASTM International (formerly American Society for Testing and Materials)
AWWA	American Water Works Association
BCCE	Base Corrosion Control Engineer
BIA	Bilateral Infrastructure Agreement
CIS	close-interval potential survey
CMP	Centrally Managed Program
CP	cathodic protection
DC	direct current
DCVG	direct current voltage gradient
DIPRA	Ductile Iron Pipe Research Association
DLA	Defense Logistics Agency
DoD	Department of Defense
DOT	Department of Transportation
EFD	Engineering Field Division
EPA	Environmental Protection Agency
GACP	galvanic anode cathodic protection
HCA	high consequence area

HNFA	Host Nation Funded Construction Agreement
HQUSACE	Headquarters U.S. Army Corps of Engineers
ICCP	impressed current cathodic protection
IEEE	Institute of Electrical and Electronic Engineers
IMP	Integrity Management Program
kWh	kilowatt hours
LRA	Local Reproduction Authorized
MILCON	Military Construction
NAVFAC	Naval Facilities
NAVFACENGCOM	Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NSF	National Sanitation Foundation
NOV	Notice of Violation
OSHA	Occupational Safety and Health Administration
POL	petroleum, oil, and lubricant
SABER	Simplified Acquisition of Base Engineering Resources
S/E	structure-to-electrolyte
SOFA	Status of Forces Agreement
STI	Steel Tank Institute
UFC	Unified Facilities Criteria
WBDG	Whole Building Design Guide

F-2 DEFINITIONS

amphoteric metal: A metal that is susceptible to corrosion in both acid and alkaline environments.

anode: The electrode of an electrochemical cell at which oxidation occurs. (Electrons flow away from the anode in the external circuit. It is usually the electrode where corrosion occurs and metal ions enter solution.)

anode bed: One or more anodes installed—underground or submerged—for the purpose of supplying cathodic protection. It is often called a "ground bed."

backfill: Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system. For the purposes of this standard, "backfill" is also defined as the material (native or imported) used to fill a pipeline trench.

beta curve: A plot of dynamic (fluctuating) stray current or related proportional voltage (ordinate) versus the corresponding structure-to-electrolyte potentials at a selected location on the affected structure (abscissa). For the purposes of this standard, "beta curve" is defined as a correlation between the pipe-to-soil potential of the affected pipeline and the open-circuit potential between the affected pipeline and the stray current source.

cable: One conductor or multiple conductors insulated from one another.

casing: A metallic pipe (normally steel) installed to contain a pipe or piping.

cathode: The electrode of an electrochemical cell at which reduction is the principal reaction. (Electrons flow toward the cathode in the external circuit.)

cathodic disbondment: The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.

cathodic polarization: (1) The change of electrode potential caused by a cathodic current across the electrode/electrolyte interface; (2) a forced active (negative) shift in electrode potential. See *polarization*.

cathodic protection: A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.

cathodic protection criterion: Standard for assessment of the effectiveness of a cathodic protection system.

coating: (1) A liquid, liquefiable, or mastic composition that, after application to a surface, is converted into a solid protective, decorative, or functional adherent film; (2) (in a more general sense) a thin layer of solid material on a surface that provides improved protective, decorative, or functional properties. Coatings used in conjunction with cathodic protection are electrically isolating materials applied to the surface of the metallic structure that provide an adherent film that isolates the metallic structure from the surrounding electrolyte. The thickness and structure of the coating type vary according to the environment and application parameters.

coating disbondment: Loss of adhesion between a coating and the pipe surface.

coating system: The complete number of coats and type applied to a substrate in a predetermined order. (When used in a broader sense, surface preparation, pretreatments, dry film thickness, and manner of application are included.)

conductor: A material suitable for carrying an electric current. It can be bare or insulated.

continuity bond: A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.

correlation: (1) A causal, complementary, parallel, or reciprocal relationship, as by having corresponding characteristics. (2) (As used in Section 9) Simultaneous measurement of two dynamic (time-varying) parameters, e.g., voltage and current, presented in an X-Y plot to determine the relative relationship between the two parameters and whether the fluctuations over time are caused by one or more sources of stray current.

corrosion: The deterioration of a material, usually a metal, that results from a chemical or electrochemical reaction with its environment.

corrosion potential (Ecorr): The potential of a corroding surface in an electrolyte measured under open-circuit conditions relative to a reference electrode (also known as “electrochemical corrosion potential,” “free corrosion potential,” and “open-circuit potential”).

corrosion rate: The time rate of progress of corrosion. (It is typically expressed as mass loss per unit area per unit time, penetration per unit time.)

current applied potential: The half-cell potential of an electrode measured while protective current flows through the electrolyte environment, typically measured with respect to a reference electrode placed at the soil surface.

current density: The electric current to or from a unit area of an electrode surface.

diode: A bipolar semiconducting device having a low resistance in one direction and a high resistance in the other.

disbondment: The loss of adhesion between a coating and the substrate.

distributed-anode impressed current system: An impressed current anode configuration in which the anodes are “distributed” along the structure at relatively close intervals such that the structure is within each anode’s voltage gradient. This anode configuration causes the electrolyte around the structure to become positive with respect to remote earth.

electrical isolation: The condition of being electrically separated from other metallic structures or the environment.

electrical shielding: Preventing or diverting the cathodic protection current from its intended path.

electrical survey: Any technique that involves coordinated electrical measurements taken to provide a basis for deduction concerning a particular electrochemical condition relating to corrosion or corrosion control.

electrode: A material that conducts electrons and is used to establish contact with an electrolyte and through which current is transferred to or from an electrolyte.

electrolyte: A chemical substance containing ions that migrate in an electric field. For the purposes of this standard, “electrolyte” refers to the soil or liquid adjacent to and in contact with an underground or submerged metallic piping system, including the moisture and other chemicals contained therein.

electrolytically contacted pipeline casing: A casing that contains soil or water electrolyte in contact with both the casing and the carrier pipe.

electro-osmotic effect: Passage of a charged particle through a membrane under the influence of a voltage. Soil or coatings can act as the membrane.

empirical: Originating in or based on observation or experience.

foreign structure: Any metallic structure that is not intended as a part of a system under cathodic protection.

free corrosion potential: See *corrosion potential*.

galvanic anode: A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

galvanic series: A list of metals and alloys arranged according to their corrosion potentials in a given environment.

holiday: A discontinuity in a protective coating that exposes unprotected surface to the environment.

impressed current: An electric current supplied by a device employing a power source that is external to the electrode system. (An example is direct current for cathodic protection.)

in-line inspection: The inspection of a pipeline using an electronic instrument or tool that travels along the interior of the pipeline.

instant off potential: The polarized half-cell potential of an electrode taken immediately after the cathodic protection current is stopped, which closely approximates the potential without IR drop (i.e., the polarized potential) when the current was on.

interference: Any electrical disturbance on a metallic structure as a result of stray current.

interference bond: An intentional metallic connection between metallic systems in contact with a common electrolyte designed to control electrical current interchange between the systems.

IR drop: See *voltage drop*.

isolation: See *electrical isolation*.

line current: The direct current flowing in a pipeline.

linear anode impressed current system: An impressed current anode configuration in which a continuous anode is installed parallel to the structure such that the structure is within the anode voltage gradient.

long line current: Current through the earth between an anodic and a cathodic area that returns along an underground metallic structure (usually used only where the areas are separated by considerable distance and where the current results from concentration-cell action).

mechanical damage protection: Any material or equipment used to eliminate or minimize damage to the piping system (as might be caused from soil stresses and damage caused from rocks, debris, or other outside forces) without inhibiting or interfering with CP.

mechanical damage protection system: Consists of multiple processes and products to achieve protection for the piping and coating system.

mechanical shielding: Protective cover against mechanical damage. See *mechanical damage protection* and *mechanical damage protection system*.

microbiologically influenced corrosion (MIC): Corrosion affected by the presence or activity, or both, of micro-organisms.

mixed potential: A potential resulting from two or more electrochemical reactions occurring simultaneously on one metal surface.

nonadhered: Not bonded to the surface by chemical reaction or mechanical means.

nonshielding coating system: A coating system with a failure mode (e.g., loss of adhesion) that does not prevent distribution of cathodic protection current to the metal substrate.

oxidation: (1) Loss of electrons by a constituent of a chemical reaction; (2) Corrosion of a material that is exposed to an oxidizing gas at elevated temperatures.

pipe-to-electrolyte potential: See *structure-to-electrolyte potential*.

pipeline casing: See *casing*.

polarization: The change from the open-circuit potential as a result of current across the electrode/electrolyte interface.

polarized potential: (1) (general use) The potential across the electrode/electrolyte interface that is the sum of the corrosion potential and the applied polarization; (2) (cathodic protection use) The potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

reduction: Gain of electrons by a constituent of a chemical reaction.

reference electrode: An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials.

reverse current switch: A device that prevents the reversal of direct current through a metallic conductor.

shielding: (1) Protecting; protective cover against mechanical damage; (2) Preventing or diverting cathodic protection current from its natural path. For the purposes of this standard, see *electrical shielding* and *mechanical shielding*.

shorted pipeline casing: A casing that is in direct metallic contact with the carrier pipe.

sound engineering practices: Reasoning that exhibits or is based on thorough knowledge and experience, is logically valid, and has technically correct premises that demonstrate good judgment or sense in the application of science.

stray current: Current through paths other than the intended circuit.

stray-current corrosion: Corrosion resulting from stray current.

structure-to-electrolyte potential: The potential difference between the surface of a buried or submerged metallic structure and electrolyte that is measured with reference to an electrode in contact with the electrolyte.

telluric current: Current in the earth as a result of geomagnetic fluctuations.

unbonded: To have lost the ability to adhere to a surface to which it has been applied and has become disbonded or to have never been adhered (nonadhered) to a surface to which it has been applied.

voltage: An electromotive force or a difference in electrode potentials expressed in volts.

voltage drop: The voltage across a resistance when the current is applied in accordance with Ohm’s Law. This term is also referred to as “IR drop.”

weak acids: Acids that only partially dissociate to form hydrogen (H+) ions at moderate concentrations.

wire: A slender rod or filament of drawn metal. In practice, the term is also used for smaller-gauge conductors.

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Air Force Technical Order (TO) 00-25-172, *Ground Servicing of Aircraft and Static Grounding/Bonding*
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Air Force TO 37-1-1, *General Operation and Inspection of Installed Fuel Storage and Dispensing Systems*

(https://www.e-publishing.af.mil/Product-Index/#/?view=cat&catID=8)

Air Force Form 491, *Cathodic Protection Operating Log for Impressed Current Systems* (Not LRA)

G-3.4 Navy.

MIL-HDBK 419A, *Grounding, Bonding, and Shielding for Electronic Equipment and Facilities Volume 1* (https://www.wbdg.org/ffc/navy-navfac/criteria-manuals/mil-hdbk-419a-v1)

MIL-HDBK 1004/10, *Electrical Engineering Cathodic Protection* (https://webstore.ansi.org/Standards/DOD/MILHDBK100410)

NAVFACENGCOM letter 11012 04C/cmm of 1 April 1994, *Cathodic Protection Systems, Interim Technical Guidance* (https://www.wbdg.org/ffc/navy-navfac/interim-technical-guidance-itg/fy94-01)

OPNAV P-45-117-6-98, *Electrical Safety Field Guide* (https://www.safety.marines.mil/Portals/92/Docs/Electrical_Safety_Field_Guide.pdf)

G-4 UNIFIED FACILITIES CRITERIA.

(http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc)

UFC 3-190-06, *Protective Coatings and Paints*

UFC 3-230-02, *Operation and Maintenance: Water Supply Systems*

UFC 3-240-13FN, *Industrial Water Treatment Operation and Maintenance*

UFC 3-430-09, *Exterior Mechanical Utility Distribution, with Change 1*

UFC 3-440-05N, *Tropical Engineering, with Changes 1-2*

UFC 3-460-01, *Design: Petroleum Fuel Facilities, with Change 3*

UFC 3-501-01, *Electrical Engineering*

UFC 3-560-01, *Operation and Maintenance: Electrical Safety with Change 1*

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*

UFC 3-601-02, *Operation and Maintenance: Inspection, Testing and Maintenance of Fire Protection Systems*

UFC 4-150-07*, Maintenance and Operation: Maintenance of Waterfront Facilities, with Change 1*

G-5 UNIFIED FACILITIES GUIDE SPECIFICATIONS.

(http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs)

UFGS 26 42 13.00 20 *Cathodic Protection by Galvanic Anodes*

UFGS 26 42 14.00 10 *Cathodic Protection System (Sacrificial Anode)*

UFGS 26 42 15.00 10 *Cathodic Protection System (Steel Water Tanks)*

UFGS 26 42 17.00 10 *Cathodic Protection System (Impressed Current)*

UFGS 26 42 19.00 20 *Cathodic Protection by Impressed Current*

UFGS 26 42 22.00 20 *Cathodic Protection System for Steel Water Tanks*

UFC 3-575-01
1 July 2012
Change 1 October 1, 2021

UNIFIED FACILITIES CRITERIA (UFC)

LIGHTNING AND STATIC ELECTRICITY PROTECTION SYSTEMS

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

LIGHTNING AND STATIC ELECTRICITY PROTECTION SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by \1\…/1/)

Change No.	Date:	Location
1	1 October 2021	Critical and substantive CCRs and service-specific requirements throughout Chapters 1-3; new Chapter 4.

This UFC supersedes MIL-HDBK 1004/6, *Lightning Protection*, and Army TM 5-811-3/ Air Force AFM 88-9 Chapter 3, *Electrical Design, Lightning and Static Electricity Protection*.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFCs will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFCs are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Center for Engineering and the Environment (AFCEE) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFCs are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFCs printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
CHANGE SUMMARY SHEET

Document: UFC 3-575-01, *Lightning and Static Electricity Protection Systems*

Superseding: MIL-HDBK 1004/6, *Lightning Protection*, and Army TM 5-811-3/ Air Force AFM 88-9 Chapter 3, *Electrical Design, Lightning and Static Electricity Protection*.

Description: **\1** UFC 3-575-01 provides guidance for design criteria, establishes standards for static electricity protection and lightning protection from both direct and indirect strikes and surges, and describes bonding and grounding methods related to those static and lightning protection systems. This UFC applies to facilities and other structures. **/1/**

Reasons for Document:

- **\1** Incorporate new and revised industry standards applicable to DoD.
- Provide technical requirements for systems that protect assets and personnel.
- Describe and allow the use of equivalent protection when supported by calculations or justification.
- Clarify who is qualified to decide “equivalency” of substitutions in material and equipment submittals.
- Provide standard methods of inspection to ensure LPS systems remain compliant with codes and regulations (NFPA and OSHA). **/1/**
- Standardize the Tri-service criteria using NFPA 780. Applicable portions of UL 96A are incorporated, but UL 96A is no longer relied upon as a basis for compliance.

\1\ Impact: The following benefits should be realized:

- Improved guidance for surge protective device requirements. **/1/**
- Standardized guidance to assist engineers in the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP).
- **\1** Standardized guidance to assist maintenance and inspection personnel in repairs which involve minimal design.
- Coordination with all electrical-related UFCs and UFGSs and consistency in guidance with the other electrical-related UFCs and UFGSs. **/1/**

Unification Issues:

- The Air Force uses a Shepherd's Crook design for static ground protection, which is shown in Figure 2-2. Although not considered a unification issue, it is listed as an Air Force-only criterion since the Army no longer uses this style and the Navy never did use this style.
- A 100% test point inspection is required by all services. This inspection must be performed by a third party (not the designer and not the installer). This must also be accomplished on smaller projects, such as roofing and HVAC, where lightning protection systems are installed on the facility **\1** to ensure the LPS is not damaged or reconfigured during construction.
- **For Navy:** Explosives Safety must be involved in a 100 percent test point inspection prior to acceptance, with 100 percent testing repeated at six months and one year.
- **For Army:** 100 percent review of test points plus requirements in Army Pamphlet 385-64 will be the basis of approval. **/1/**

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE.

This UFC provides policy and design requirements for static electricity protection, and for lightning protection systems and related grounding for facilities and other structures. The information provided herein must be utilized by electrical engineers, including A/Es, in the development of the plans, specifications, calculations, and Design/Build requests for Proposal (RFP) and must serve as minimum electrical design requirements. It is applicable to the traditional electrical services customary for Design-Bid-Build construction contracts. Project conditions may dictate the need for a design that exceeds these minimum requirements. A design analysis is required.

UFC 3-501-01, *Electrical Engineering*, provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-575-01 for static electricity protection and lightning protection system requirements. Refer to UFC 3-501-01 for design analysis, calculation, and drawing requirements.

\1\ For Air Force: One set of half-size drawings is required for AFCEC/COSM at each design milestone. **/1/**

1-2 APPLICABILITY.

Compliance with this UFC is mandatory for DoD facilities located on or outside DoD installations, whether acquisition is by appropriated or non-appropriated funds or by third party finance and construction. Facilities cover all temporary or permanent structures, including waterfront facilities, outside storage, and shore protection for ships and aircraft.

Criteria in this UFC apply to DoD-leased facilities outside DoD installations, whether by appropriated or non-appropriated funds, or by third party finance and construction, when DoD or DoD contractor maintains the facility.

1-3 GENERAL BUILDING REQUIREMENTS.

UFC 1-200-01, *General Building Requirements*, provides applicability of model building codes and government-unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, sustainability, and safety.

Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein. **\1** If conflicts between UFCs are noted, this UFC takes precedence for LPS and static systems. **/1/**

\1

1-4 EQUIVALENCY.

Equivalency is an alternative to codes and specifications that has the same protective results as the method or equipment specified. Equivalency must be determined only by a certified person trained to perform installation, maintenance, testing, and repair of the systems addressed in this UFC, or by an electrical engineer. **/1/**

1-5 REFERENCES.

Appendix B contains a list of references used in this UFC. References applicable to a specific topic are also listed and described in the appropriate sections of this UFC.

1-6 KEY CODES AND STANDARDS.

Comply with the following codes and standards:

- IEEE 142, *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems*
- **\1** IEEE 1100, Powering and Grounding Electronic *Equipment*, “Emerald” Book **/1/**
- NFPA 70, *National Electrical Code*
- NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*
- NFPA 77, *Recommended Practice on Static Electricity*
- NFPA 780, *Standard for the Installation of Lightning Protection Systems*
- UL 96, *Lightning Protection Components*
- UL 467, *Grounding and Bonding Equipment*
- **\1** (ANSI/)UL 1449, *Standard for Surge Protective Devices*, Fourth Edition or later **/1/**

Ordnance facilities or locations where ordnance and explosives are handled and stored require special protective measures. Comply with the following documents for these systems:

- UFC 4-420-01, *Design: Ammunition and Explosives Storage Magazines* (DRAFT)
- NAVSEA OP-5, Volume 1, *Ammunition and Explosives Ashore*
- **\1** AFMAN 32-1065, *Grounding Systems*
- Air Force Manual (AFMAN) 91-201, *Explosive Safety Standards*
- Air Force Manual (AFMAN) 91-118, *Safety Design and Evaluation Criteria for Nuclear Weapon Systems* **/1/**
- Department of the Army Pamphlet 385-64, *Ammunition and Explosives Safety Standards*
- **\1** MIL-STD 188-124B, *Grounding Bonding and Shielding for Common Long Haul Tactical Communication Systems Including Ground Based Communications Electronics Facilities and Equipment* (U. S. Navy) **/1/**

Additional requirements associated with grounding, bonding, and shielding of communications facilities are provided in MIL-HDBK 419A, *Grounding, Bonding and Shielding for Electronic Equipment and Facilities*.

\1 Note: Ground testing of equipment is the responsibility of the equipment owner/user. **/1/**

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CHAPTER 2 STATIC ELECTRICITY PROTECTION

2-1 STATIC GROUNDING AND BONDING REQUIREMENTS.

Identify hazardous classified locations in accordance with NFPA 70. Provide grounding and bonding for these areas in accordance with NFPA 77 to support the intended operations.

Include a listing of hazardous materials, containers, and operating units in the design, and indicate fixed operating equipment locations on the drawings. Identify portable and movable equipment requiring static electricity grounding distinctively by location and with type of grounding method each location requires.

\1

2-1.1 Bonding and Grounding Conductors.

Bonding and grounding conductors must be sturdy enough to withstand mechanical damage and must not be smaller than 6 AWG copper. For added flexibility, use braided cable or flexible bonding straps for static grounds on portable or movable equipment. Install at least two separate braided cables or flexible bonding straps on portable or movable equipment such as doors, hinged shelves, or tables, for redundancy. Flexible cables or straps have a shorter life than solid copper, especially since they must be replaced once 50% of the strands are broken. Conductors are typically uninsulated. Apply bonding for other facilities in accordance with NFPA 70 and NFPA 780. Before securing any bond, prepare for electrical continuity by removing any paint, oil, dirt, or rust on contact surfaces. If factory coatings are removed by chemicals used in the preparation process, that coating must be reapplied to protect against corrosion. A resistance reading of one ohm or less is required across bonds, to indicate continuity. **/1/**

2-1.2 Connections.

Do not connect static grounds above grade to:

- Electrical equipment grounding systems.
- Telecommunications systems grounds.
- Gas, steam, oil, hydraulic, hot water or airlines.
- Sprinkler systems.
- Any component of the lightning protection system (LPS).
- **\1** Down conductors. **/1/**

These systems must be interconnected below grade. As an exception to performing the calculations required by NFPA 780, the 6 foot (1.83 m) bonding requirement allowed by UL 96A may be used. The preferred method for reducing the potential for side-flash is to increase the separation distance between the static ground and the six items above, so that a bond is not required. The minimum size of the bonding conductor is 6 AWG copper.

\1 A static ground should never be bonded to a down conductor. It should be bonded to the building power system ground either at the service ground rod or at the main distribution panel or motor control center where the neutral bus bar and ground bus bar are bonded together.

Static bonds must be bonded only to component paths designed for static dissipation. **/1/**

2-1.3 Static Bus Bars.

A static bus typically consists of 2 inch x ¼ inch (51 mm x 6 mm) copper bars installed on the interior wall of the facility, as shown in Figure 2-1. Static bus bars must be used only for static grounding. Bus bars, especially those used in the telecommunications industry, may come with insulators, if specified when ordering. Static bus bars must be isolated from other grounding subsystems as much as possible and must be isolated when used for ordnance grounding and from lightning protection down conductors including steel columns used as the down conductor. The grounding system for the static bus bars is typically connected to the building grounding system by running at floor level on the interior until it can be routed to the exterior to the single point facility ground rod or be bonded to a ground rod and the ground rod bonded to the ground ring electrode. This configuration will allow the static bus bar to be grounded even if the ground ring electrode is broken or compromised, or requires replacement.

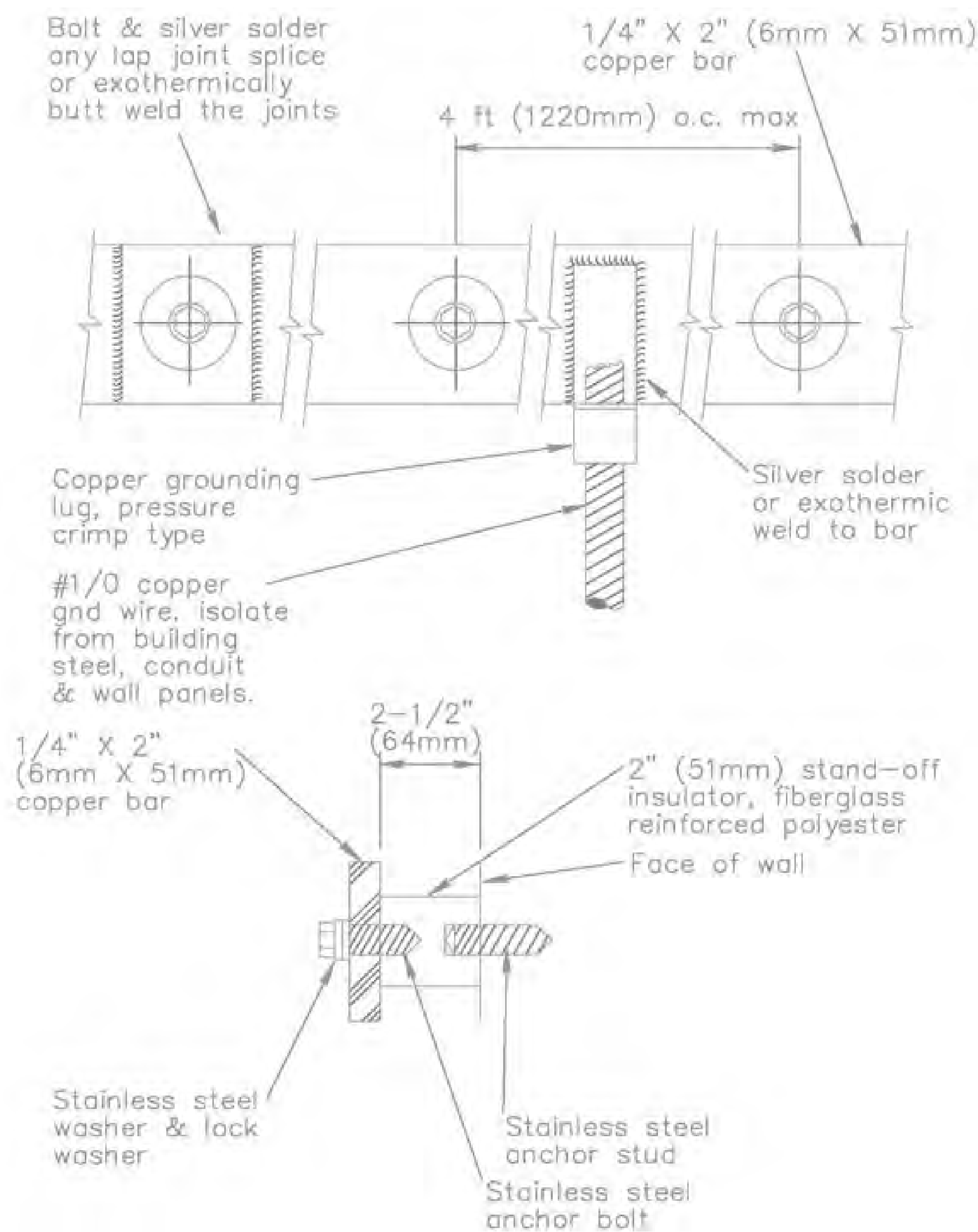
2-1.4 Resistance to Ground.

Current caused by static electricity is typically on the order of milliamperes. A resistance to ground of 10,000 ohms is more than adequate to bleed off normal static charges. All grounds used for static protection in DoD facilities, including those for aircraft and fuel tanks, must have a maximum resistance of 10,000 ohms. Any danger of electrical shock hazard caused by the 10,000 ohm value can be eliminated by proper bonding to other grounding media.

2-1.5 Ground Grab Bars.

Ground grab bars **\1** should **/1/** be installed immediately outside entrance doors to operating buildings, rooms or structures where special hazards exist. A ground grab bar consists of a length of non-corroding conductive pipe or bar which is connected to the earth electrode system (EES).

Figure 2-1 Static Bus Bar



2-2 GENERAL APPLICATIONS.

2-2.1 Conditions.

\1 This UFC does not identify all applications where static electricity protection should be provided. The electrical designer must analyze suspected potential static electrical charges and address the conductive paths that could reasonably exist between them. The following conditions are critical examples. For other concerns such as wrist stats, gloves, or boots, contact the Electrostatic Dissipation Association (ESDA). **/1/**

- Hazardous area classifications and locations, as listed in the NFPA 70. The electrical design must incorporate the requirements of the using service relative to hazardous materials, equipment, and containers to enable the construction contractor to proceed with a full understanding of static electricity protection requirements.
- **\1** Locations where hazardous materials are handled need to be assessed on an individual basis to determine if static electricity is a problem. **/1/**
- Relocatable and portable equipment having static-electricity-generating capabilities potentially dangerous to personnel.
- Locations containing explosives or related types of materials must comply with applicable Service requirements for ordnance facilities; refer to the paragraph entitled “Key Codes and Standards.”

2-2.2 Applications.

Comply with NFPA 77, including the following types of applications:

- Spray painting operations; also apply NFPA 33.
- Conductive flooring.
- Conductive conveyor belts and V-belts.
- Humidification. If humidification is used to control static electricity discharges, daily checks are required to ensure humidity levels are maintained within specified levels.

Static electricity protection for other facilities must satisfy the requirements within this UFC. Protection for other facilities must be assessed on a project-by-project basis only. Where criteria of other Federal agencies conflict with criteria contained in this UFC, the more stringent criteria apply.

Ionization techniques are covered in NFPA 77. Ionization techniques are not to be used in hazardous areas. Radioactive ionization sources are not allowed.

2-3 SPECIFIC APPLICATIONS.

\1

2-3.1 Petroleum Oil Lubricants (POL) Facilities.

This paragraph pertains to static electricity protection for pumping, distribution, and fueling and defueling storage and handling facilities. Fueling and defueling of fixed wing aircraft on the ground is discussed in the paragraph entitled “Aircraft Parking Aprons”. Comply with UFC 3-460-01.

Impressed current type cathodic protection systems can cause voltage gradients on the surface. The aircraft requires protection from those gradients, so an isolation flange is installed. Since we are protecting aircraft and personnel from those gradients, the grounding points are required on the aircraft side of the flange.

The following items must be grounded directly to an earth electrode system (EES). Resistance to ground must not exceed 10,000 ohms.

- Installations that use a static grounding/bonding reel must ensure the resistance through the reel is 10 ohms or less. This means the resistance to ground plus the resistance of the reel must be 10 ohms or less.
- For aircraft direct fueling stations and hydrant fuel pits, locate grounds on the aircraft side of any insulating flange used for cathodic protection isolation systems. Cathodic protection systems (impressed current) can cause voltage gradients on the surface. The aircraft needs to be protected from those gradients, so an isolation flange is installed. Since we are protecting aircraft and personnel from those gradients, the grounding points need to be on the aircraft side of that flange. **/1/**

2-3.2 Hospitals.

Comply with NFPA 99 for static protection required for hospitals.

2-3.3 Aircraft Parking Aprons and Hangar Floors.

Do not use static grounds or grounding receptacles for **\1** aircraft lightning protection. **/1/**

2-3.3.1 Aircraft Parking Aprons.

2-3.3.1.1 Static Grounds.

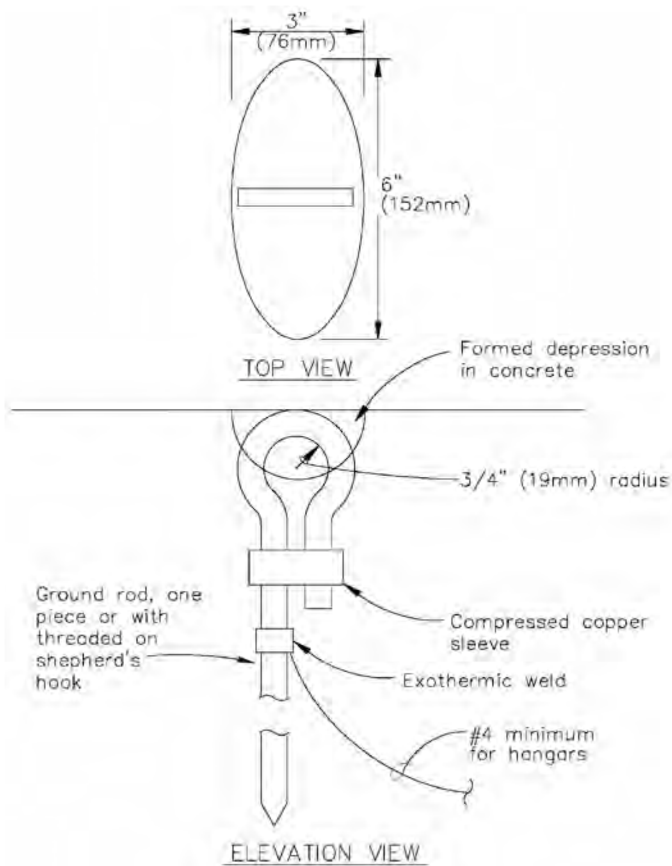
Provide static grounds with less than 10,000 ohms on aprons, in airplane parking-hydrant fueling and defueling areas, and near each hydrant pit.

- **\1** Mooring eyes/tiedowns are permitted to be used as static grounding points if criteria are met. When the dimensions of the mooring eye rebar are larger than the normal static ground clamp used by the Activity for the aircraft, determine if the Activity will utilize adapters on their clamps, or if they require a separate ground system. If a ground system is required to obtain a power ground (25 ohms), use the grounding receptacle, per Figure 2-3 with a grid arrangement as described in Section 2-3.3.2. Coordinate with Activity on whether or not the receptacle cover and ball chain are required to be removed for Foreign Objects and Debris (FOD) prevention. **/1/**

\1\ For the Air Force: Provide static grounds in concrete as illustrated in Figure 2-2, commonly called a Shepherd's Crook. **/1/**

- **\1** Static grounds may not be used as tie-downs. Tie-downs may be used as static grounds if testing indicates less than 25 ohms to ground. If tiedowns are intended to also be used as static grounds, soil conditions may require that a ground rod be installed. When a ground rod is included, it <u>must</u> be bonded to the tie-down bar. **/1/**

Figure 2-2 Air Force Static Grounding Point



2-3.3.1.2 Power Grounds.

If a power ground system with less than 25 ohms is required on an apron, use the grounding receptacle with grid per Figure 2-3.

2-3.3.1.3 Aircraft Fueling.

In addition to the criteria given herein, apply NFPA 407 when aircraft fueling is involved.

2-3.3.2 Aircraft Hangar Floors.

Grounding devices installed in floors are intended to serve as aircraft static and equipment grounding. A static grounding system conforming to NFPA 77 is suitable for dissipation of any aircraft static electricity to ground. However, because NFPA 70 requires a maximum of 25 ohms resistance to ground for equipment grounding, the 25-ohm requirement governs for this dual-purpose grounding system. Interconnect floor grounding systems electrodes below concrete in a grid arrangement, and interconnect to the hangar electrical service grounding system. Use a minimum of 4 AWG bare copper for interconnections. Where hangar floors are modified, extensions to grounding receptacles must remain load bearing to match original installation and the cover must be kept level with the finished floor.

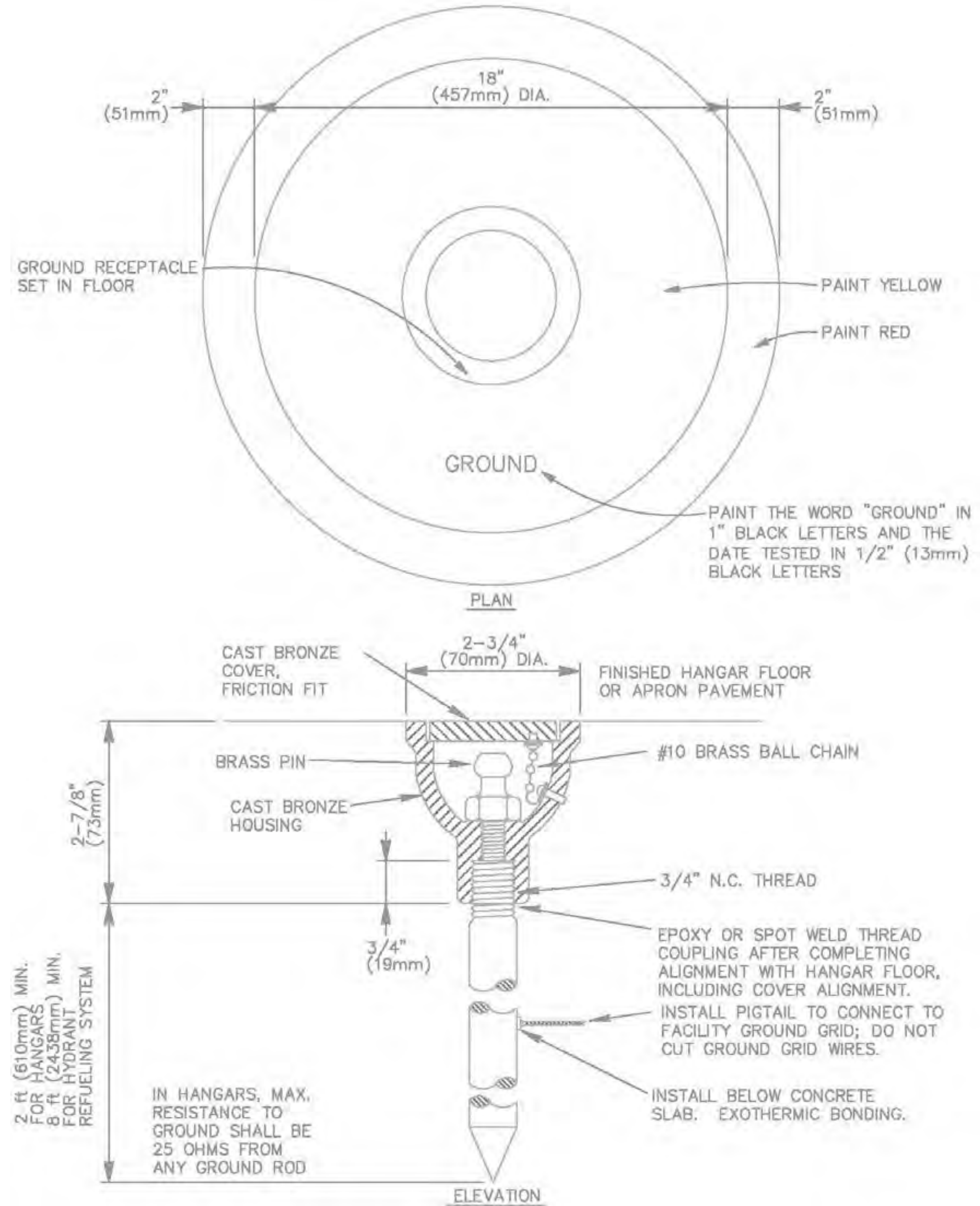
The tie-downs or grounding receptacles must be interconnected with bare copper cable. UFC 3-260-01, Appendix B, Section 11, provides guidance on layout and configuration of the grounding receptacles, relative to some aircraft. Floor layouts for receptacles must conform to the following:

- In the absence of other guidance, hangars that will be used for a specific number and type of aircraft must provide one grounding electrode for each aircraft space, approximately 10 ft (3 m) from the centerline of the aircraft space in the vicinity of one of the main landing gears.
- For general purpose hangars, provide electrodes for each aircraft space approximately 10 ft (3 m) from the centerline of the aircraft space, installed at 50 ft (15 m) intervals. Spacing of electrodes from wall lines or columns must not exceed 50 ft (15 m).
- Additional aircraft grounding guidance (operations and maintenance) is provided in MIL-HDBK-274 (AS).

2-3.3.3 Grounding Receptacle.

- Aircraft hangar floors must use a grounding receptacle as illustrated in Figure 2-3.
- If a separate ground system is required for aircraft parking aprons, use the grounding receptacle with grid as illustrated in Figure 2-3.
- **\1** Do not paint grounding receptacles.
- Receptacles with brass ball chain for cover attachment are required inside hangars.
- Receptacles within hangars may have double pin for multiple grounding. **/1/**

Figure 2-3 Grounding Receptacle



Note 1: Paint colors associated with static grounding services vary with application and service. The paint is applied directly to the hangar floor or apron pavement, and is not applied to the receptacle.

Note 2: When directed by the using activity, receptacle covers with brass ball chain shown on Figure 2-3 are not required for apron pavement areas.
\1 Note 3: Inside hangars, a grounding grid is recommended.

In general, any aircraft parked in hangar should be electrically grounded. The grounding should be done from basic aircraft structure to a low resistance ground. Grounding of the aircraft is usually done to:

- protect aircraft and personnel against hazards from lightning discharge.
- provide current return paths.
- protect personnel from shock hazard.
- prevent accumulation of static charge.

During de-fueling or refueling, the aircraft is grounded to the fuel truck. In general, the aircraft are grounded to a point where the impedance is less than 10,000 ohms referenced to earth for static grounding. For power grounding, it should be less than 10 ohms to power systems neutral. Aircraft are not grounded to the hangar structure as the external power supply, when connected, is grounded to that. **/1/**

Note 4: The above criteria will be reconciled with criteria in other UFCs so that the required criteria is located in a single location; the other UFCs and criteria documents will refer to UFC 3-575-01. In the event there is a conflict between this criteria and other criteria in another document, this criteria governs. The following documents are known to be affected by the above criteria:

Document	Title
MIL-HDBK-274A(AS)	Electrical Grounding for Aircraft Safety
UFC 3-260-01	Airfield and Heliport Planning and Design
UFC 4-211-01N	Aircraft Maintenance Hangars: Type I, Type II and Type III
UFC 4-211-02NF	Corrosion Control and Paint Finishing Hangars
UFC 4-211-02	Aircraft Corrosion Control and Paint Facilities (99% Draft – September 2011; included here to ensure the UFC is reconciled with this criteria)

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CHAPTER 3 LIGHTNING PROTECTION SYSTEMS

3-1 DETERMINING THE REQUIREMENTS FOR LIGHTNING PROTECTION.

\1

3-1.1 Risk Assessment.

3-1.1.1 Facilities that house explosives and critical communications facilities require lightning protection systems. For general facilities, provide a risk assessment in accordance with NFPA 780 Annex L, Section L-5, *Simplified Risk Assessment.* Summarize recommended requirements, on engineering decisions, based on experience and good engineering practice. Document reduced or enhanced requirements resulting from engineering decisions and good engineering practice, with justification for changes. Note: These assessment tools are very conservative and may not contain variables that the designer and/or the AHJ would consider in making the final decision. AHJ should be consulted during design and before written recommendation. AHJ may provide some applicable local information which could affect the installation of LPS. Depending on location, if direct strikes are not probable, and if assets are less than the cost of the LPS and its maintenance, use surge protective devices to provide protection for indirect strikes and voltage surges from other sources. SPDs will also protect against switching surges from power outages and restorations of power.

3-1.1.2 Per NFPA 780, Annex L, paragraph L.1.1 “There are some cases where the need for protection should be given serious consideration regardless of the outcome of the risk assessment. Examples are those applications where the following are factors: (1) Large crowds (2) Continuity of critical services (3) High lightning flash frequency (4) Tall isolated structure (5) Building containing explosive or flammable materials (6) Building containing irreplaceable cultural heritage.”

3-1.1.3 If, after calculations, the indication is that a LPS is “recommended,” this allows the authority having jurisdiction (AHJ) to make a decision based on local conditions, strike density, and other variables which might make an LPS necessary for one military installation where it would not be necessary for a military installation at another location, even if using the same design. Since lightning protection systems are not a one-size-fits-all, and must be truly designed anew for each facility, the NFPA 780 committee, combines Annex L with AHJ responsibilities and authorities throughout NFPA 780 to tailor the LPS to conditions that may not be the same in all situations. Consider Florida compared to North Dakota.

3-1.1.4 Even if a “required” is a result of calculation, the AHJ is still allowed to check the local conditions and variables, consider the contents, and make the final decision. We are protecting the contents of the facility/structure, not the roofs or walls. This method of decision combining Annex L with an AHJ familiar with the region of the military installation -- provides the best opportunity to “fit” the requirements to the installation without overdesign.

3-1.1.5 Decisions by the AHJ are required to be documented in the test records of the facility/structure, as future documentation. **/1/**

3-1.2 Certification of Lightning Protection Systems.

If lightning protection is required, provide an LPS in accordance with NFPA 780 criteria, using components manufactured in accordance with UL 96.

Provide certification from a commercial third-party inspection entity whose sole work is lightning protection, stating that the lightning protection system complies with NFPA 780. Third party inspection entity cannot be the system installer or the system designer.

For Army: Provide a UL Lightning Protection Inspection Master Label Certificate for each facility indicating compliance with NFPA 780.

For Navy: LPS is required for A&E facilities for DSER and Service policy and must meet NAVSEA OP-5 requirements in addition to NFPA 780. A UL Certificate is not required.

U. S. Army Corps of Engineers- and NAVFAC-managed projects for the Air Force must comply with the requirements of the Air Force; e.g., AFMAN 32-1065 and NFPA 780.

3-1.3 Additions to Existing LPS.

Projects calling for an LPS addition to an existing LPS project must consider the configuration of the final LPS in the initial design. Projects of this type must ensure the final LPS as a whole is compliant with AFMAN 32-1065 (for Air Force only) and NFPA 780 (for all services). The same third-party inspector requirements apply.

Evaluate planned facility modifications and additions, and determine if an LPS will be required or if an existing LPS will be affected by the modification/addition. The resulting LPS for the whole facility must be addressed in the planning and design stages. This may require some adjustment to the existing LPS. If the mission of a facility changes, determine if an LPS is required.

Note: Ensure that systems currently compliant with respect to lightning protection are not made noncompliant by facility modifications and additions. LPS must be considered in the design of any project for a facility that has an LPS. This includes paint projects, roofing projects, projects requiring roof penetrations, installation of new HVAC or other metallic equipment, antenna installation, or other work. Additions and modifications to the facility envelope require re-evaluation of the LPS for the completed facility as a whole. The LPS required by the addition or modification must not be a simple addition to the LPS. The LPS must be considered a single entity and must comply with requirements of a single LPS upon completion.

3-1.4 Explosives Facilities.

Facilities or locations which are used for the development, manufacturing, testing, handling, storage, inspection, holding or maintenance of ammunition or explosives are required to have lightning protection unless specific conditions are met. Provide a UL Lightning Protection Inspection Certificate for the facility. This certificate must be certified to NFPA 780, Chapter 8 and the 100 ft (30.5 m) radius rolling sphere, unless otherwise indicated by that Service; refer to the paragraph entitled "Key Codes and Standards."

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3-1.4.1 Air Force Recordkeeping and Review.

3-1.4.1.1 Inspectors and testers must compile and maintain records of their inspections and tests. Records should include a sketch of the grounding and lightning protection system, showing test points and where services enter the facility. The sketch should also show the location of the probes during the ground resistance test. (Separate sketches are suggested for static, earth ground, and lightning protection systems on large complex facilities.) Sketches should capture the following:

- Date action was performed.
- Inspector's or tester's name.
- General condition of air terminals, conductors, and other components.
- General condition of corrosion protection measures.
- Security of attachment for conductors and components.
- Resistance measurements of the various parts of the ground terminal system.
- Variations from the requirements of this UFC, citing equivalency or better.
- Discrepancies noted and corrective actions taken.
- Dates of repairs.

3-1.4.1.2 The BCE will review records for deficiencies and analyze the data for undesirable trends. If test values differ substantially from previous or original tests obtained under the same test procedure and conditions, determine the reason and make necessary repairs and document repairs.

3-1.4.1.3 Inspectors and testers will keep test and inspection records in accordance with DODD 6055.09-M-V2, *Ammunition and Explosives Safety Standards.* **/1/**

3-2 CONVENTIONAL LIGHTNING PROTECTION SYSTEMS.

Nonconventional systems, such as dissipation arrays and those using early streamer emission-type air terminals and attachments of multiple terminal points to the air terminal, are prohibited.

3-2.1 Air Terminals.

Air terminals mounted on or adjacent to equipment which is exhausting hazardous vapors must be a minimum of 60 inches (1524 mm) above the equipment to allow for the vapor to be dispersed. These air terminals require special mechanical supports per NFPA 780. **\1** Air terminals installed on "rubber" (EPDM) type roofs must use adhesive shoes with adhesive approved by the roof manufacturer. In areas of snow and/or constant wind, ensure that a section of roofing material is first glued to the roof and then the air terminal is glued to it unless the roof manufacturer recommends another solution. This section of roofing material must be a minimum 1 ft^2 (92,900 mm^2).

A nonconductive pole may be used only when heights and structural strength permit and must be provided with metal air terminals and two bare copper down conductors not less than 1/0 AWG connected to an earth electrode. The down conductors must be placed as near as possible to 180 degrees apart and must not be run inside the pole.

For Air Force: Adhesive fasteners can be a source of high maintenance and damage to the building/structure when not installed in accordance with manufacturer's instructions and the surface properly cleaned. In lieu of adhesive fasteners, consider installing a mast or catenary system. This will minimize testing and visual inspections to buildings/structures by reducing the number of test points. It will also minimize damage to the building and LPS during storms and hurricanes. If adhesive fasteners must be used, an inspector who is familiar with installation of these adhesive fasteners must watch during the installation, and verify in writing (print name after signature) in the test records for that facility/structure that the installation was in accordance with manufacturer's instructions. Note that adhesive fasteners in desert areas may be dependable for up to 10 years. The Air Force goal would be to minimize use of air terminals, taking advantage of mast/catenary systems, to minimize maintenance, testing, repair and storm damage by up to 90%. **/1/**

3-2.2 Masts.

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3-2.2.1 Steel Masts

/1/

Masts of heights up to 40 ft (12.2 m) must be of single section design. When down conductors are required because metal mast thickness is less than 3/16 inches (0.1875 inches or 4.8 mm), the down conductors must be placed as near as possible to 180 degrees apart. All conductors and connections to the ground loop must be run on, and bonded to, the outside of the mast.

Wind and ice loading on the mast and on associated overhead wires must be considered during design. Provide damping in accordance with manufacturer's recommendations.

Metal mast foundation designs must take into account wind loading and ice loading. Foundations for setting metal masts must be in accordance with the following:

- Steel or aluminum, mounted by anchor bolts set in a concrete foundation poured in place. Follow manufacturer's recommendations for foundation design and type and for setting of anchor bolts.
- Steel, mounted by means of a stub set directly into a concrete foundation.
- Corrosion-resistant steel masts may be set directly into earth where soil conditions permit.

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- Steel masts for a catenary system must be rated for transmission/distribution line use by the manufacturer because of the directional forces at the top of the mast.
- Steel masts for a single mast do not require transmission/distribution line rating because the force is all vertical.

3-2.2.2 Wooden Masts.

Wooden masts require air terminals and two paths to ground, as with all active (excluding fasteners) components of an LPS. A wooden mast as part of a system of masts in a catenary may use horizontal components (cross conductors (catenary)) as one or both path(s) to ground. If a cross conductor is used as one of the paths, the connection point between the air terminal and cross conductor attachment must be less than 25 ohms to ground.

Wooden masts of a catenary system must be transmission/distribution line rated (based on larger diameters at the tops and bases – this is a "CLASS" adjustment.) Example: A Class 4 pole may become a Class 3 or Class 2 pole, depending upon the pole height required to accomplish the rolling sphere area under which protection is provided by the LPS. The rolling sphere must be shown valid in a drawing based on a combination of pole heights and cross conductor heights.

Wooden masts of a mast system (one or more masts without cross conductors) do not require the larger class pole. The rolling sphere must be shown valid in a drawing based on pole heights. **/1/**

3-2.3 Joint Design.

Slip-joint design must meet the following requirements:

- Ensure overall structural integrity of the mast.
- Include a field assembly requirement to ensure a snug fit, so that joints of the mast will not loosen when subjected to vibration modes caused by wind or other means after erection.
- Be compatible with field erection requirements to facilitate ease of installation at the site.
- Have good metal-to-metal contact, so that electrical conductivity is equal to or better than the parent metal.

3-2.4 Down Conductors.

Do not install down conductors inside down spouts.

3-3 GROUNDING AND BONDING FOR LPS.

Bond equipment or subsystems into a single grounding system for the facility. Apply UFC 3-550-01 for general grounding system requirements. Include the following additional requirements for the LPS:

- When a power ground ring is required, install the ground ring in accordance with UFC 3-550-01. This will require the ring to be installed at a minimum depth of 30 inches (762 mm) rather than the minimum 18-inch (457 mm) depth required by NFPA 780.
- **\1** Terminate each down conductor to a grounding electrode located inside a test well for easy access, or to a ground ring electrode (counterpoise) dedicated to the LPS. Consider a ground rod/test well between the down conductor and counterpoise, so that if the counterpoise is cut, the down conductor remains adequately grounded. This could be more of a consideration for explosives facilities and communications facilities. If a ground ring is used, the ground ring is deemed to be associated with the LPS and thereby meets the requirements for a dedicated grounding electrode.
- In accordance with NFPA 780, facilities exceeding 75 feet (23 m) in height must be protected with Class II materials. Explosives facilities require a ground ring electrode of 1/0 copper (NFPA 780 change pending). **/1/**
- When a facility requires an additional dedicated ground ring for a catenary lightning protection system, this ring must be designated the primary ground ring. It must be installed not less than 3 ft (914 mm) beyond the first (inner or secondary) ground ring and the two ground rings must be bonded together in at least two locations.
- As an exception to performing the side flash calculations required by NFPA 780, the 6 foot (1.83 m) bonding requirement allowed by UL 96A can be used.
- Bond metal ladders to the system at both the upper and lower ends of each ladder.

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- Ensure that LPS ground rods (grounding electrodes) meet the size and dimensions for LPS in NFPA 780, which is 5/8” by 8’, with bottom of rod buried 10 feet below grade (top of ground rod approximately 2’ below grade). **/1/**

3-4 SURGE PROTECTION.

\1 Surge protection is required to provide protection against the high magnitudes of voltage present with indirect lightning strikes and other surges like power outages and power faults, particularly in this environment of increasing electronics. **/1/**

Provide appropriate class surge arresters at the distribution transformer supplying the facility. Provide surge protective devices for all systems identified in NFPA 780. Refer to UFC 3-520-01 for the requirements.

\1\ For Air Force: Surge protective devices must comply with the following requirements for WSAS, MSAS, and communications facilities. **/1/**

- Standard, published, minimum 10-year unlimited replacement warranty on product. Entire unit must be replaced upon detection of the failure of any mode.
- All mode (10 modes), directly connected protection elements (l-n, l-g, l-l, n-g). Direct clamping l-n and l-l is required.
- F1 polycarbonate enclosure or National Electrical Manufacturers Association (NEMA) 4 or NEMA 4X steel enclosure: Inaccessible to unqualified persons.
- Internal over-current fusing on each phase for self-protection from failed component(s) and an internal disconnect for each phase.
- Individual component level thermal fusing.
- Bi-polar protection.
- The SPD must contain continuous self-monitoring devices with indicator lamps for each mode. These may be located inside the enclosed areas such as mechanical rooms if an indicator lamp is provided in a visible area. For WSAs and MSAs, the indicator lamp should be installed in a location that can be seen from a vehicle, allowing maintenance personnel to drive through the large areas and quickly identify devices that have operated. Indicator lamps that can be seen in this way will allow maintenance personnel to determine whether a group of SPDs have operated, providing information about the circuit.
- Cable connections between a bus and SPD must be minimum No. 10 AWG for installation at main distribution panels and branch panels.
- **\1** SPDs may not be manufacturer-installed inside the service panel. The wrong panel has been known to be ordered, resulting in a long lead from the SPD to the bus, rendering the SPD useless. In addition, the SPD may not be installed inside a panel, in accordance with UFC 3-520-01, para 3-4.1.
- Visible indicators of SPD operation on the exterior of facilities. Drive-by visual inspections may be an effective means of inspecting SPDs.
- Non-modular. The entire unit must be replaced upon detection of the failure of one mode of operation. Ease of installation must not be traded for possible minimized protection levels. **/1/**

3-5 REQUIREMENTS FOR ORDINARY FACILITIES AND STRUCTURES.

3-5.1 Non-Reinforced Concrete or Wood Frame Building.

The fastener selected must be appropriate for the application and suitable for attachment to concrete or wood. Aluminum fasteners must not be mounted to concrete.

3-5.2 Reinforced Concrete Buildings.

Do not use reinforcing steel for down conductors.

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3-5.3 Steel Frame Buildings.

Down conductors may not be required when air terminals are mounted on steel which is at least 3/16 inch (4.763 mm) thick and in direct contact with the ground. Steel used as structural components is typically in the form of an I-beam or other steel members. I-beams under 7/32 inch thickness do not exist according to Standard I-Beam Sizes Chart at https://amesweb.info/Profiles/Standard-Steel-I-Beam-Sizes-Chart.aspx and exceed the requirement for thickness. At the thicknesses and weights indicated in this chart, unless some kind of insulation is between joined sections, the steel is inherently continuous due to the weight of the steel. Use of steel framework in lieu of down conductors is permitted only if documentation is provided at the base of each column that the resistance to ground (ground rod or ground loop conductor, if present) at the base of the column is less than or equal to 25 ohms. Provide initial test readings between connected steel (beams and columns) components to validate the electrical continuity of the steel framework tests at less than 1 ohm at the time of construction.

3-5.3.1 Air Terminal Construction.

For areas subject to hurricanes and other areas of high winds, follow these recommendations:

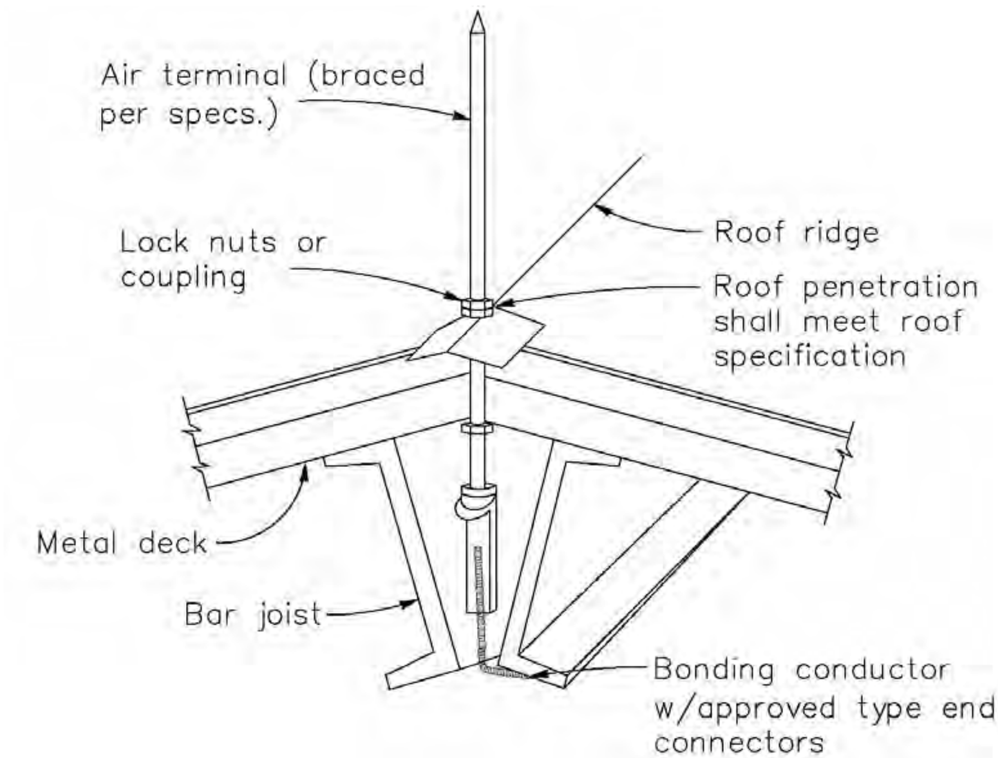
a. In lieu of attaching conductors with conductor connectors, attach with strips of membrane installed by the roofing contractor. For built-up and modified bitumen membranes, use strips of modified bitumen cap sheet, approximately 9 inches wide minimum. If strips are torch-applied, avoid overheating the conductors. For single-ply membranes, use self-adhering flashing strips, approximately 9 inches wide, minimum. Start the strips approximately 3 inches from either side of the air terminal base plates. Place strips that are approximately 3 ft long, followed by a gap of approximately 3 inches.

b. In lieu of pronged splice connectors, use bolted splice connectors.

For Air Force: Do not use adhesive fasteners for air terminals or down conductors. Lack of proper preparation of the surfaces and uses on surfaces unapproved by the fastener manufacturer has led to adhesive not performing to the standards of the manufacturer. Result has been costly damage to facilities.

For Air Force: If steel I-beams or round steel beams are used as structural elements with sufficient cross sectional area, no air terminals are required if structural elements are verified as continuous by conducting continuity checks on questionable joints. If those are verified to be continuous, then the remaining joints may be considered inherently bonded. Figure 3-1 would not apply to the Air Force. If steel is continuous, the entire building acts as a single air terminal. Nothing is gained by installing an air terminal on an air terminal. Protection of a sheet metal roof or a canvas cover is not considered; the purpose of an LPS is to protect contents. A direct strike will routinely involve repair of the roof at the point of the strike. **/1/**

Figure 3-1 Typical Air Terminal Assembly Using Steel Framing As Conductor



3-5.3.2 Nonmetallic Exterior Walls with Metallic Roof.

When roof sections are insulated from each other, bond the metal roof sections together so that they are electrically continuous.

3-5.4 Metal Roof with Metal Walls.

Bond metal roof and metal walls so that they are electrically continuous.

3-5.5 Ramps and Covered Passageways.

Verify that ramps and covered passageways do not extend beyond the zone of protection of a facility. If ramps and covered passageways do extend beyond the zone of protection or if an existing structure is affected, refer to the paragraph "Determining the Requirements for Lightning Protection" to ensure that the facility certification is maintained.

3-5.5.1 Post Tension Systems.

On construction utilizing post tension systems to secure precast concrete sections, the post tension rods must not be used as a path for lightning to ground. Provide down conductors on structures using post tension systems; down conductors must have sufficient separation from post tension rods to prevent side-flashing. Bond post tension rods to the lightning protection and grounding systems only at the base of the structure; perform this bonding in accordance with the recommendations of the post tension rod manufacturer.

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3-5.6 Buildings Containing Hazardous Areas.

Bond metallic objects located within hazardous areas (as defined in NFPA 70) and within 10 ft (3 m) of an LPS, to the nearest down conductor. Per NFPA 780, do not use structural members in hazardous areas as a replacement for down conductors. Bond metal frames of doors and windows located within hazardous areas to the structural column, or provide a bond from the frames to the building counterpoise system or a ground rod. Bond doors to metal frames using flexible braid-type copper conductors. Where tested resistance is less than 1 ohm between doors and their respective doorframes (this may be measured across hinges), and a test plan is maintained identifying that location, a flexible braid-type copper conductor connection is not required if the door is inherently bonded to the door frame (measure across the hinge from the door to the frame). Remove paint sufficiently so that meter probes are in contact with the steel door and steel frame. Identify the test points on LPS bonding records. **/1/**

3-5.7 Aircraft Control Navigation Aids.

Protect one-floor frame buildings which house equipment for Instrument Landing System (ILS) and Tactical Air Navigation (TACAN) facilities and other similar type structures with no fewer than two air terminals on each facility. **\1** Ideally, air terminals should be on opposite corners. **/1/**

3-5.8 Weapons Systems Electronic Facilities, Above Grade.

This section pertains to designs for the protection of radars, antennae, electronic equipment vans, launchers, missile controls, and guided missile batteries when permanently installed. Perform the following in the absence of any specific guidance from the agency in charge of the installation:

- **\1** The protection patterns must comply with NFPA 780 and consist of a mast or mast with catenary style LPS, unless specific guidance is provided for that weapons system platform. Ensure patterns are not interrupted by penetration of the pattern by any part of the LPS. **/1/**
- Locate and arrange protection equipment so as not to obstruct or interfere with the operation of any radar electronic acquisition or tracking beam.
- Where vans are clustered, ground rods for the vans must be interconnected in compliance with MIL-HDBK 419A.

Protect separate buildings containing support equipment for weapons systems electronic facilities in accordance with the building construction type.

3-5.9 Weapons Systems Electronic Facilities, Below Grade.

3-5.9.1 Protection Included with Other Protection Systems.

When an external grounding system design is included for electromagnetic pulse (EMP) protection, electromagnetic interference (EMI) shielding or other protection system, additional lightning protection is not required. Lightning protection is provided by the EMP/EMI system.

3-5.9.2 Requirements Not Included in Other Protection Systems.

When external grounding system design does not include EMP, EMI shielding, or other protection, provide a ground ring including connections to underground metallic objects, such as the following:

- Electrical conduit.
- Mechanical piping.
- Metal tanks.
- Manhole grounds.
- Missile cells or equivalent.
- Internal grounding system of control buildings and power plants.
- Metal ducts for fans.
- Tunnels.

The ground ring is not required if validated by mission operations and documented in the design analysis.

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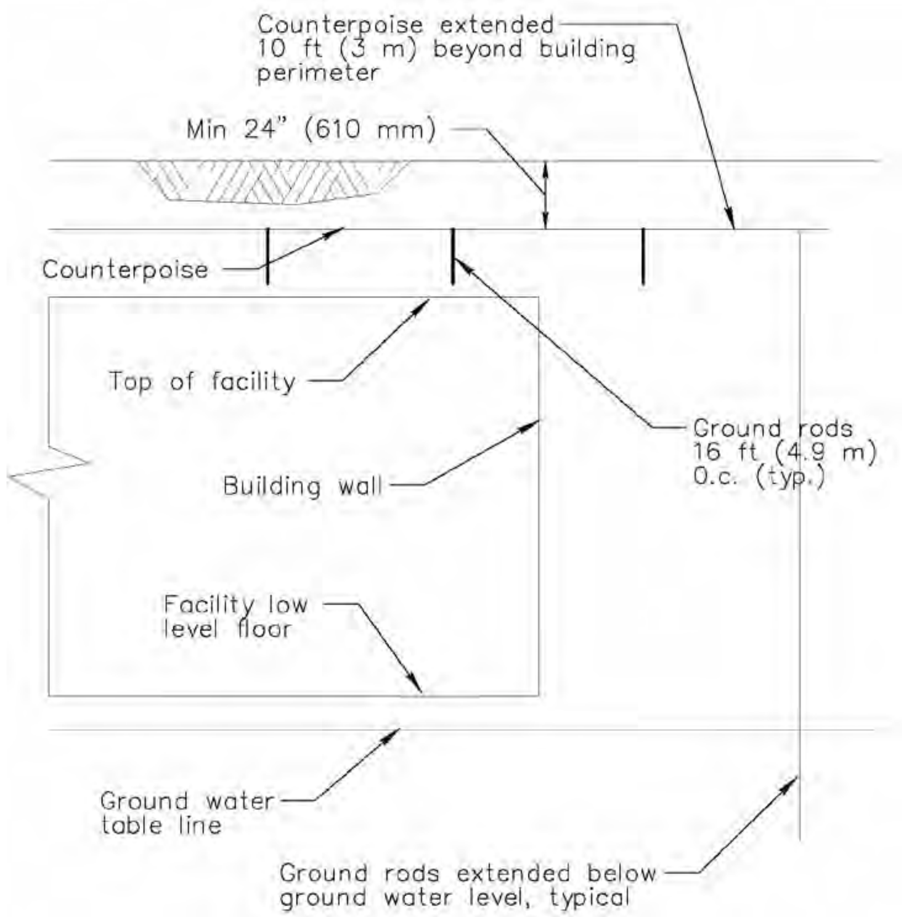
3-5.9.3 Installation of Ground Ring.

Install the ground ring above each buried weapons system building, at least 18 inches (460 mm) below finished grade, and extend beyond the building perimeter not less than 3 ft (914 mm) nor more than 10 ft (3 m). Connect the ground ring to ground rods located as in Figure 3-2, and driven to a point at least 6 inches (152 mm) below normal ground water table level, where earth is available for driving. Metal equipment and metallic enclosures of equipment extending above ground must be bonded to a ground rod and the ground rod bonded to the ground ring.

For Air Force: Installation of a ground rod between the equipment/metallic enclosures and the ground ring will ensure that the ground ring is not compromised if equipment is relocated. The ground rod can remain. **/1/**

Figure 3-2 Below-Grade Weapons Systems Electronics Facilities – Ground Ring, Cross Section Elevation



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3-5.10 Electrically-Controlled Target Training System.

In the absence of any specific guidance or standards for targeting systems, apply the following. Run shielded control cables (from targets to controls) or enclose the cables in metal conduit. Provide surge protection on all incoming and exiting signal and power lines in accordance with NFPA 780 and UL 1449*, Standard for Surge Protective Devices*, Fourth Edition. ***/1/***

3-5.10.1 Control Tower.

Provide a complete protection system with at least two air terminals installed on the roof.

3-5.10.2 Target Control System.

Where each target mechanism box assembly station has a separate control relay, a lightning protection ground ring or grid is not required for protection of the down-range target area. Where such control relays are not provided, a ground ring or grid must be provided below grade above wiring in trenches to all targets.

3-5.10.3 Remote Targeting Engagement System (RTES).

Ensure the LPS and grounding comply with NFPA 780. Bonding is the more important for this unmanned system. Weapon enclosure, hatch, and stairway must be bonded to the LPS.

3-5.11 Petroleum Oil Lubricants (POL) Storage Tanks.

Where above-ground steel storage tanks are constructed on foundations of concrete or masonry, provide grounding in accordance with the grounding schedule shown in Table 3.1, regardless of tank height. Where underground steel tanks are constructed in direct contact around the entire perimeter with not less than 18 inches (458 mm) of earth cover, grounding is not required.

Table 3-1 Fuel Storage Tank Grounding Schedule

Tank Circumference (Feet)	Tank Circumference (Meters)	Ground Connections Minimum Number
200 and less	61 and less	2
201 through 300	61.2 through 91.5	3
301 through 400	91.7 through 122	4
401 through 500	122.2 through 152	5
501 through 600	152.7 through 183	6
601 through 800	183.2 through 244	7
801 and more	244.2 and more	8

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3-5.12 Satellite Dishes.

Locate a satellite dish within a zone of protection. One or more of the following methods must be used to determine the overall zones of protection: air terminal placements, as described in Section 4.7; the angle (geometric) method, as described in Section 4.8.2; and the rolling sphere method, as described in Section 4.8.3, all of NFPA 780.

3-5.13 Aircraft Sunshades and Shelters.

Apply NFPA 70 grounding and bonding requirements to aircraft sunshades and shelters. Obtain current guidance from each service. Additional requirements are being developed and will be included in the next change to this UFC. Obtain interim requirements from the AHJ at the associated service. Validate (document in writing and date) confirmation of additional requirements or no additional requirements as of that date.

For Air Force: If lightning protection is required and the structure is steel I-beam or round heavy beam construction and continuous to ground, air terminals are not necessary as the structural steel forms a large air terminal. Grounding will be addressed specific to each facility. Tubular steel assemblies do not meet the intent of protection against lightning. **/1/**

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CHAPTER 4 \1\ AIR FORCE LPS INSPECTION REQUIREMENTS

4-1 EXISTING FACILITIES.

The contract for a lightning protection system project, or for any project on/to a facility which possesses a lighting protection system, requires an in-house LPS inspection and documentation of condition prior to contract start and completion. BCE repairs to existing facilities do not require a commercial third-party inspection. A BCE representative must certify the work.

4-2 NEW FACILITIES.

A third-party inspection is required for the LPS of the project, prior to acceptance of the project. The inspection must be a 100% inspection using the test point locations identified by the contractor. Test readings must either be observed by the inspector as the contractor is performing the initial tests, or test readings must be independent matching those documented by the contractor, within tenths of ohms. Note the intent is to validate integrity, not to obtain the exact reading.

4-3 ADDITIONS TO EXISTING FACILITIES.

The design and construction of LPS additions to existing facilities must ensure that the LPS, if required, joins to the existing LPS to form a single LPS, not an LPS attached to an LPS. Deviations to the existing LPS may be caused by an uncoordinated design between the existing LPS and the LPS addition. Changes may be required to the existing LPS at or near points of inter-connection for the two systems.

4-4 INSPECTIONS FOR NEW FACILITIES AND ADDITIONS TO EXISTING FACILITIES.

This final LPS project inspection must be performed by a third-party inspector ("third-party" excludes the designer or any part or subsidiary of his/her company, and the installer). whose sole work is lightning protection, or by an LPS maintenance person from the base, delegated the authority to accept LPS by the BCE in writing, by virtue of experience and training which requires an examination prior to certification of qualification.

4-5 CERTIFICATION STATEMENT.

LPS must be certified in writing by this third-party inspector as compliant with AFMAN 32-1065 and NFPA 780, prior to project acceptance. A UL certification on its own is not adequate for acceptance of any Air Force LPS project. A comprehensive inspection and compliance with this UFC and AFMAN 32-1065 is also required and UL does not inspect to these documents. Inspections may not be posted to any web site available to the public. Note that, for in-house repairs and construction, and for in-house replacement design (i.e., replacement of poles, repairs of catenary), certification by the BCE representative in lieu of a commercial third party inspection is sufficient. **/1/**

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APPENDIX A GLOSSARY

A-1 ACRONYMS.

AFMAN	Air Force Manual
AFI	Air Force Instruction
AHJ	Authority Having Jurisdiction
AWG	American Wire Gauge
\1 BCE	Base Civil Engineer **/1/**
DoD	Department of Defense
EES	earth electrode system
EMI	electromagnetic interference
EMP	electromagnetic pulse
EPDM	ethylene propylene diene monomer (m-class) rubber feet (or foot)
ft^2	foot squared or square feet
HQUSACE	Headquarters, US Army Corps of Engineers
IEEE	formerly Institute of Electrical and Electronics Engineers
in	inch, inches
ILS	instrument landing system
LPS	lightning protection system
m	meter
m^2	meter squared or square meter
mm	millimeter
NAVFAC	Naval Facilities Engineering Command
NFPA	National Fire Protection Association
POL	petroleum oil lubricants

USACE	US Army Corps of Engineers
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UL	Underwriters Laboratories

A-2 DEFINITION OF TERMS.

Activity: The end use of a facility.

Approved: Acceptable to the Authority Having Jurisdiction.

Bonding: An electrical connection between an electrically conductive object and a component of a lightning protection system intended to significantly reduce potential differences created by lightning currents.

Catenary System: A lightning protection system consisting of one or more overhead wires. Each overhead wire forms a catenary between masts, and serves the function of both a strike termination device and a main conductor.

Conductor, Bonding: A conductor used for equalizing potential between metal bodies and the lightning protection subsystem.

Contractor: Person(s) doing actual construction portion of a project.

Copper Clad Steel: Steel with a coating of copper bonded on it.

Designer of Record: The engineer responsible for the actual preparation of the construction documents.

Down Conductor, Lightning: The conductor connecting the roof conductors or overhead ground wire to the earth ground subsystem.

Labeled: Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed: Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

Power Ground: Driven electrode at service entrance.

Qualified: Compliant with NEC/NFPA definitions and, for Air Force, experience and training meeting AFI 32-1065.

User: Facility occupants or Facility Manager.

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APPENDIX B REFERENCES

DEPARTMENT OF DEFENSE

\1 DODD 6055.09-M-V2, *Ammunition and Explosives Safety Standards* **/1/**

\1 MIL-STD 188-124B, *Grounding Bonding and Shielding for Common Long Haul Tactical Communication Systems Including Ground Based Communications Electronics Facilities and Equipment* **/1/**

MIL-HDBK 274A (AS), *Military Handbook Electrical Grounding for Aircraft Safety*

MIL-HDBK 419A, *Grounding, Bonding, and Shielding for Electronic Equipment and Facilities*

AIR FORCE

\1 AFMAN 32-1065, *Grounding Systems* **/1/**

\1 Air Force Manual (AFMAN) 91-118, *Safety Design and Evaluation Criteria for Nuclear Weapon Systems* **/1/**

Air Force Manual (AFMAN) 91-201, *Explosive Safety Standards*

ARMY

DA Pamphlet 385-64, *Ammunition and Explosives Safety Standards*

NAVY

NAVSEA OP-5, Volume 1, *Ammunition and Explosives Safety Ashore*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 3-260-01, *Airfield and Heliport Planning and Design*

UFC 3-260-02, *Pavement Design for Airfields*

UFC 3-460-01, *Petroleum Fuel Facilities*

UFC 3-501-01, *Electrical Engineering*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-550-01, *Exterior Electrical Power Distribution*

\1 UFC 4-420-01, *Design: Ammunition and Explosives Storage Magazines* (DRAFT) **/1/**

UFC 4-510-01, *Design: Medical Military Facilities*

IEEE (INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS)

IEEE 142, *Recommended Practice for Grounding Industrial and Commercial Power Systems* (Green Book)

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 33, *Standard for Spray Applications Using Flammable or Combustible Materials*

NFPA 70, *National Electric Code*

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*

NFPA 77, *Recommended Practice on Static Electricity*

NFPA 99, *Health Care Facilities Code*

NFPA 407, *Standard for Aircraft Fuel Servicing*

NFPA 780, *Standard for the Installation of Lightning Protection Systems*

UNDERWRITER'S LABORATORIES

UL 96, *Lightning Protection Components*

UL 96A, Installation Requirements for Lightning Protection Systems

UL 467, *Grounding and Bonding Equipment*

UL 1449, *Installation for Surge Protective Devices*, Fourth Edition

UNIFIED FACILITIES CRITERIA (UFC)

INFORMATION AND COMMUNICATIONS TECHNOLOGY INFRASTRUCTURE PLANNING AND DESIGN

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UFC 3-580-01
21 November 2024

UNIFIED FACILITIES CRITERIA (UFC)

INFORMATION AND COMMUNICATIONS TECHNOLOGY INFRASTRUCTURE PLANNING AND DESIGN

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes MIL-HDBK-1012/3, dated 31 May 1996 and UFC 3-580-01, dated 1 June 2016.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides design criteria for telecommunications spaces, pathways, cabling, and interconnecting components necessary to support the infrastructure for voice, data, video, smart buildings, and Internet of Things (IoT) systems. It does not address the design and specifics of the technologies that employ information communications technology infrastructure. "Video systems" includes the necessary infrastructure for closed circuit television (CCTV); community antenna television (CATV), commonly referred to as cable TV; video teleconferencing (VTC); and video walls.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-580-01, 1 June 2016; MIL-HDBK-1012/3, dated 31 May 1996; and Army publications *Installation Information Infrastructure Architecture (I3A)*," dated February 2010, "*Installation Information Infrastructure Architecture (I3A) for Outside Plant Only*," dated November 2017, "*Outside Plant Design and Performance Requirements (OSPDPR)*," dated February 2009, "*OSPDPR Addendum 1 – Core and Distribution Fiber Sizing Criteria for Installation Campus Area Network Design and Implementation*," dated September 2014.

1-3 APPLICABILITY.

This UFC applies to planning, design, construction, sustainment, restoration, and modernization of DoD-owned facilities. It applies to all methods of project delivery and levels of construction as defined by UFC 1-200-01, Section 1-3.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicable model building codes and government-unique criteria for typical design disciplines and building systems, as well as accessibility, antiterrorism, security, high performance and sustainability, and safety requirements. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced within.

1-5 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service implementation policy.

1-6 Governing Criteria for Electrical Systems.

UFC 3-501-01 provides the criteria for electrical systems, delineates among electrical-related UFCs, and refers to UFC 3-520-01 for interior electrical system requirements.

1-7 Modernization Within Existing Facilities.

Modernization of information communications technology systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required.

1-8 Activity Specific Telecommunications Managers.

Throughout this UFC, the term “Telecommunications Manager” refers to:

- Army – the Network Enterprise Center (NEC) or the Information Officer (G6, S6, J6)
- Navy – a group of individuals with responsibilities as shown in Figure 6-1.
- Marine Corps – G6.
- Air Force – A6.

1-9 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms.

1-10 References.

Appendix C contains a list of references used in this UFC. Publication dates are not included; the most recent issuances apply unless otherwise specified.

CHAPTER 2 DESIGN REQUIREMENTS

2-1 General Guidance.

Design information communications technology infrastructure to meet the needs of the activity and supporting facilities in accordance with this UFC. Final drawings and specifications for design-bid-build and design-build projects must be stamped by a Building Industry Consulting Service, International (BICSI), Inc., Registered Communications Distribution Designer (RCDD).

Because construction phases may be concurrent with design in design-build projects, and because multiple phases of construction may be approved, the final documents for each construction phase must be stamped when approved.

2-1.1 U.S. Government- (USG-) Designed Projects.

On USG-designed projects (in-house design), the USG designer must:

- Obtain the approval of the Service-appointed information communications technology agent at the beginning of design in accordance with regulations, policies, memorandums, and guidance.
- Ensure that the bid documents require an RCDD stamp on the contractor's telecommunications shop drawings submitted for approval.
- Ensure final drawings and specifications for design-bid-build and design-build projects have been reviewed and approved by a BICSI RCDD.

2-1.2 Small Scale Projects.

Small scale projects limited to adding work area outlets from existing telecommunications rooms do not require an RCDD stamp, provided the work is being accomplished under the technical authority of an RCDD or the USG Information Communications Technology Manager.

2-1.3 Design Elements.

The complexity of Information and Communications Technology (ICT) design requires that the Designer of Record (DOR) engage early to achieve successful outcomes. Tables 2-1 and 2-2 list expected submissions and when they are due in the process. These timeframes may be adjusted for fast-tracked or other delivery mechanisms to align with design processes.

Table 2-1 ICT Design Submittal Schedule

DESIGN LEVEL	0%	30%	60%	90%	100%
	Charrette	Design Development	Interim Design	Final Design Submittal	Corrected Final Design
	SD	DD	ID	FD	CFD
Drawings					
T0		$T0^{DD}$	$T0^{ID}$	$T0^{FD}$	$T0^{CFD}$
T1			$T1^{ID}$	$T1^{FD}$	$T1^{CFD}$
T2			$T2^{ID}$	$T2^{FD}$	$T2^{CFD}$
T3		$T3^{DD}$	$T3^{ID}$	$T3^{FD}$	$T3^{CFD}$
T4				$T4^{FD}$	$T4^{CFD}$
T5 T6				$T5^{FD}$	$T5^{CFD}$
Specifications					
S			S^{ID}	S^{FD}	S^{CFD}
Design Analysis					
DA	DA^{SD}	DA^{DD}	DA^{ID}	DA^{FD}	DA^{CFD}

Table 2-2 Required Drawings

DRAWINGS	DESCRIPTION*
T0	Site information
$T0^{DD}$	Site drawing should show existing ICT utilities at DD
$T0^{ID}$	Routing and quantities of new ICT utilities
$T0^{FD}$	Final site ICT drawings
T1	Buildings
$T1^{ID}$	Show all workstation outlets, service oulets, and ICT elements on floor plans
$T1^{FD}$	Complete ICT design
$T1^{CFD}$	Incorporate approved comments generated during the final review into final design
T2	Serving zone information
$T2^{ID}$	Show all serving zones and ICT spaces with primary and secondary pathways, as applicable
$T2^{FD}$	All pathways and drop locations and other elements are complete
$T2^{CFD}$	Incorporate the approved comments generated during the final review into the final design
T3	Telecommunications rooms

DRAWINGS	DESCRIPTION*
$T3^{DD}$	The floor plan needs to be locked in early. The ICT designer must perform work early and up-front preparing T3 telecommunication rooms plan views to ensure that adequate space is allocated for the equipment, including working clearances for the life cycle of the facility.
$T3^{ID}$	Show all equipment including Facility Related Control System (FRCS) and other OT along with IT.
$T3^{FD}$	Complete ICT design.
$T3^{CFD}$	Incorporate approved comments generated during the final review into the final design.
T4	Details
$T4^{FD}$	All details complete, including labeling schemes, rack elevations, work station outlet details, wireless access points (WAP) mounting.
$T4^{CFD}$	Incorporate approved comments generated during final review into final design.
T5	Schedules
$T5^{FD}$	All schedules complete and cable plant management including cut-overs complete
$T5^{CFD}$	Incorporate approved comments generated during final review into final design
T6	Network diagrams, riser diagrams, and boundary diagrams
$T6^{DD}$	The floor plan needs to be locked in early. The ICT designer must perform work early and up-front preparing T3 telecommunication rooms plan views to ensure that adequate space is allocated for the equipment, including working clearances for the life cycle of the facility.
$T6^{ID}$	Show all equipment including Facility Related Control System (FRCS) and other OT along with IT.
$T6^{FD}$	Complete ICT design.
$T6^{CFD}$	Incorporate approved comments generated during the final review into the final design.
S^{ID}	List all applicable specifications and include even if unedited.
S^{FD}	All ICT specifications complete
S^{CFD}	Incorporate approved comments generated during final review into final design.
DA^{SD}	All ICT systems identified in the design scope should be listed with points of contact (POC) for systems.
DA^{DD}	A subsection for each ICT system and all design criteria should be listed.

DRAWINGS	DESCRIPTION*
DA^{ID}	The design analysis must be an entirely updated analysis (not amendments to 30% submittal) to permit verification that the design complies with the criteria furnished, the approved 30% design phase, and approved review comments. Information required at the 30% design phase must be included with more detail.
DA^{FD}	ICT sections of design analysis complete
DA^{CFD}	Incorporate approved comments generated during final review into final design.

* Refer to TIA 606 for additional details.

2-2 SECURE SPACE INFRASTRUCTURE.

Secure spaces include classified networks such as Secret Internet Protocol Router Network (SIPRNet), Joint Worldwide Intelligence Communications System (JWICS), or National Security Agency Intranet (NSANet). These networks process National Security Information (NSI) and have unique requirements.

2-2.1 RED/BLACK Telecommunications Systems.

All equipment, wirelines, components, and systems that process NSI are considered RED. Equipment, wirelines, components, and systems that process encrypted NSI and non-NSI are considered BLACK. BLACK lines and other electrically conductive materials that egress the inspectable space are potential carriers of compromising emanations (CE) that can inadvertently couple to the RED lines. Various signal line isolation techniques such as separation and filtering are used to protect the signal line, the distribution system, or other fortuitous conductors from conducting compromising signals beyond secure areas.

Apply fundamental RED/BLACK separation in accordance with Committee on National Security Systems Advisory Memorandum (CNSSAM) 1-13 to prevent inadvertent transmission of classified data over telephone lines, power lines, signal lines, and electrical components, circuits, and communication media. Application of RED/BLACK separation establishes areas where equipment that processes classified information (RED) is isolated from areas where equipment processing unclassified (BLACK) is located.

2-2.2 Telecommunications Space.

Account for the space required for equipment rooms and telecommunications rooms and ensure it is adequate to meet separation requirements before floor plans are locked in. The minimum sizing in this UFC is presented with a single black network and does not account for RED networks and the separations between the racks or cabinets in the space. A telecommunications space that contains equipment for multiple networks such as SIPRNet, JWICS, and NIPRNet all requiring RED/BLACK separation is considered as substantial information technology (IT) electronics which would require use of an equipment room.

2-2.3 Telecommunication Cabling System.

Cabling, patch panels, connector blocks, work area outlets, and cable connectors must be color-coded to distinguish their classification level. If color-coding is not possible, cabling must be clearly marked to indicate classification level. Provide detail sufficient for the security officer to submit and obtain approval from the certified TEMPEST technical authority. Design submittals must document RED/BLACK and checklist items from Intelligence Community Directive (ICD) Tech Spec, including the TEMPEST checklist items specific to telecommunications systems.

2-2.4 Protected Distribution Systems.

Use a protected signal distribution system (PDS) to protect unencrypted NSI that enters an area of lower classification, unclassified area, or uncontrolled (public) area. The PDS must comply with Committee on National Security Systems Instruction (CNSSI) No. 7003. Mount standard PDSs 1 inch (25 millimeters) from walls and other objects. To prevent obfuscating repairs made to the raceway, paint must not be field-applied. With prior approval from the Telecommunications Manager, galvanized rigid steel conduit (GRC) or electrical metallic tubing (EMT) may be used in addition to other approved surface mount raceways. Compression-type fittings are required with black epoxy glue applied to prevent tampering and as an aid to visual inspection. GRC compression or threaded fittings may be used with epoxy.

Due to inspection requirements, avoid using PDS whenever possible. To avoid PDS, keep cabling that transmits unencrypted NSI within the protected perimeter.

2-2.5 Alarmed Carrier.

An alarmed carrier may be used as an alternative to a physical PDS. Refer to CNSSI 7003.

2-2.6 Sensitive Compartmented Information Facility (SCIF) and Special Access Program Facility (SAPF).

Refer to UFC 4-010-05 and CNSSAM 1-13 RED/BLACK installation guidance.

2-2.7 Stand Alone SIPRNet Terminal Space.

Paragraphs 2-2.7.1 through 2-2.7.3 describe where a SIPRNet workstation outlet is required in a facility that lacks secure telecommunications spaces.

2-2.7.1 Pathways.

Provide PDS between the telecommunications enclosure and the lockable workstation outlet. Maintain a 6-inch (150-millimeter) separation between the workstation outlet and any other workstation outlet.

2-2.7.2 Telecommunication Equipment Enclosure.

When secure telecommunications spaces in a facility build-out are not equipped, specify a GSA-approved information processing system (IPS) container to house electronics that will permit a black-to-red transition. The container door must be specified and equipped with a Federal Specification FF-L-2740 lock.

2-2.7.3 Workstation Outlet Enclosure.

Enclosures must not have knockouts and must be metallic 16 gauge or greater. Hinges must be continuous and non-removable. Enclosures must not be field-painted, but may have factory-baked enamel or be galvanized. Enclosures must be continuously sealed with epoxy or welding of all joints except the hinged opening. Non-removable hasps must be equipped that will accept a lock meeting FF-P-110-J. Enclosures for workstation outlets must be GSA-approved.

2-3 SYSTEM DESIGN REQUIREMENTS.

Provide a complete, standards-based, flexible information communications technology design, including telecommunications spaces, pathways, outlets, connectors, cabling, grounding, bonding, and static protection in accordance with paragraphs 2-3.1 through 2-4.

2-3.1 Telecommunications Spaces.

Provide telecommunications spaces in accordance with Telecommunications Industry Association (TIA)-569. Refer to Figure 2-1.

Note: This UFC uses commercial terminology for spaces in accordance with the TIA-569-E errata sheet (e.g., telecommunications room, equipment room versus distributor room A and B, and telecommunications enclosure versus distributor enclosure).

2-3.1.1 Types of Telecommunications Spaces.

a. Telecommunications Entrance Facility. An entrance facility (EF) is the space housing the point of entrance of the information communications technology service. The EF is also the space where the inter-building backbone and intra-building backbone facilities join. Telecommunication-related antenna entrances and electronic equipment may be located in the EF. The demarcation point between the outside plant (OSP) cabling and the inside plant distribution cabling is the protected entrance terminal (PET). See Chapters 2 and 3 for PET requirements.

The DOR should coordinate with the Telecommunications Manager for additional physical security requirements inside the EF including, but not limited to, colocation cabinet(s) if required for commercial or other carriers.

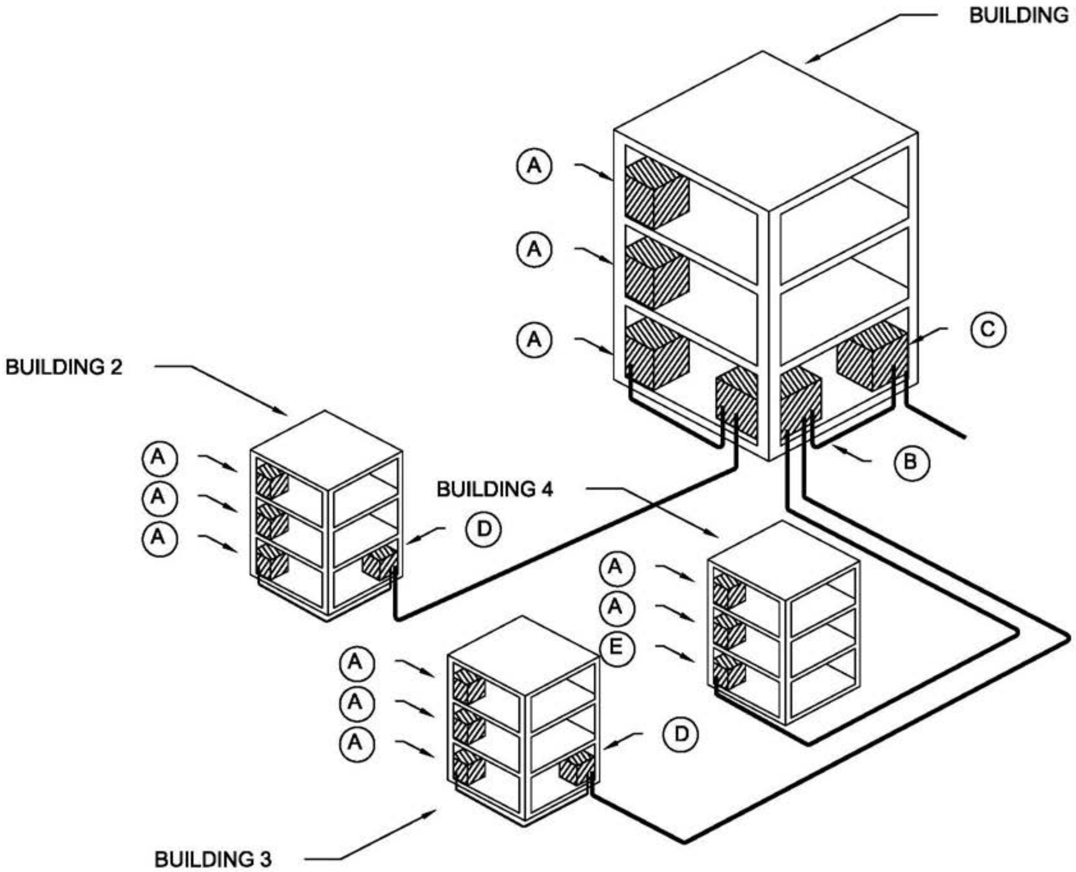
b. Telecommunications Room. A telecommunications room (TR) is an architectural space designed to contain information communications technology equipment, cable terminations, and cross-connect cabling. It contains the information communications technology equipment for connecting the horizontal cabling with the backbone cabling system. The TR may also function as the telecommunications EF.

c. Equipment Room. An equipment room (ER) is an environmentally-controlled, centralized space for information communications technology equipment that typically houses a main or intermediate cross-connect. Any or all the functions of a TR or EF may be provided by an equipment room.

d. Telecommunications Enclosure. A telecommunications enclosure (TE) is a case or housing for telecommunications equipment, cable terminations, and cross-connect cabling.

Although TEs serve much like TRs, a TE must not replace a TR. TEs may be considered for buildings with fewer than 10 occupants when approved by the COR for contract designs or the Government design lead for in-house designs. The TE is referred to as a distributor enclosure in TIA-569. TEs must meet TIA-569's requirements for distributor enclosures.

Figure 2-1 Telecommunications Spaces and Cabling



LEGEND	
TR	TELECOMMUNICATIONS ROOM
ER	EQUIPMENT ROOM
EF	ENTRANCE FACILITY
HC	HORIZONTAL CROSSCONNECT
IC	INTERMEDIATE CROSSCONNECT
MC	MAIN CROSSCONNECT
FD	FLOOR DISTRIBUTOR
BD	BUILDING DISTRIBUTOR
CD	CAMPUS DISTRIBUTOR

A	SPACE	CONTAINS	
Ⓐ	TR	HC (FD)	DA
Ⓑ	ER	MC (CD)	DC
Ⓒ	EF		
Ⓓ	ER	IC (BD)	DB
Ⓔ	EF	IC/HC(BD/FD)	DA/DB

2-3.1.2 Architectural Considerations.

2-3.1.2.1 Location and Access.

Locate telecommunications spaces so that the maximum cable length from the patch panel through the structured cabling system to the furthest outlet does not exceed 295 feet (90 meters). Telecommunications spaces must be dedicated spaces not shared with other non-information communications technology functions (electrical rooms, mechanical rooms, plumbing). Avoid locations that are restricted by building components that may limit expansion, such as elevators, outside walls, or other fixed building walls. Spaces must be capable of expanding on no less than two sides. Evaluate locations for risk to critical infrastructure (water, dust, electromagnetic impulse (EMI) influence). Locate the telecommunications space away from sources of electromagnetic interference or design the space to mitigate the effects of this interference. Give special attention to electrical power supply transformers, motors and generators, x-ray equipment, and radio or radar transmitters. Locate spaces in an accessible area of the building (e.g., common hallway), but limit access to personnel having an information communications technology requirement or mission. The space must be accessible for delivery of equipment such as network switches, equipment racks, and cabinets.

In renovation projects, avoid rooms containing transformers, air handling units, and similar equipment. If shared facilities cannot be avoided, comply with TIA-569.

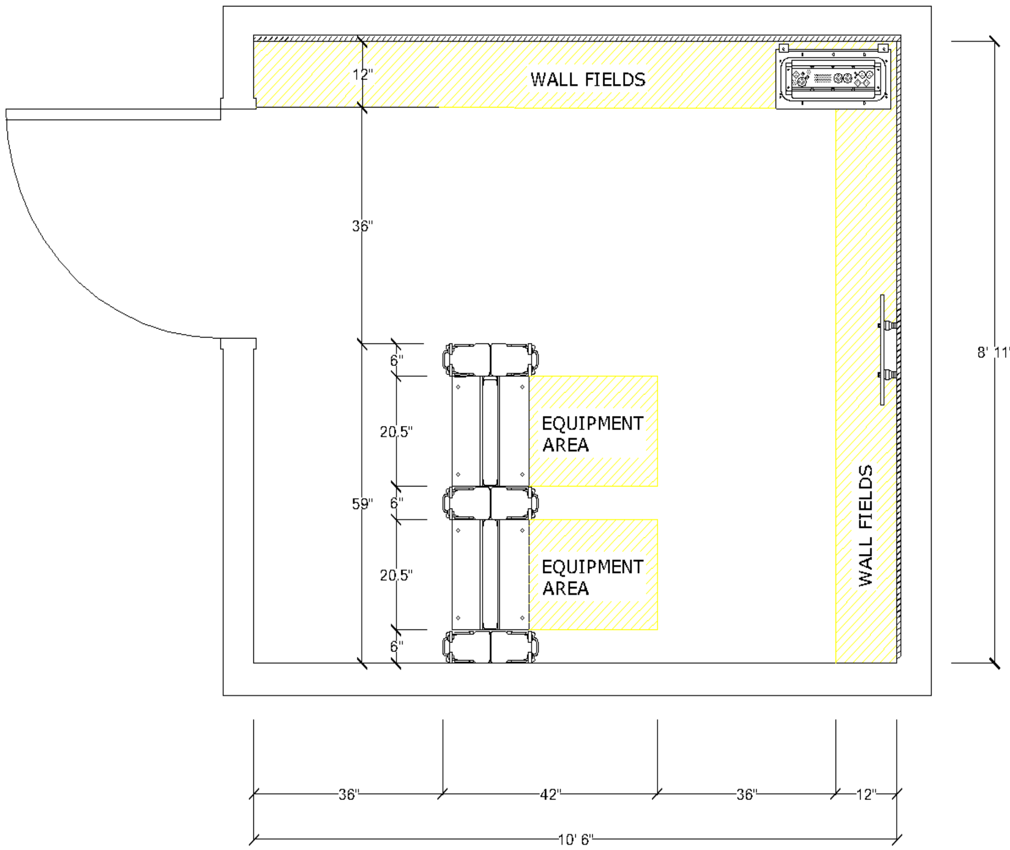
2-3.1.2.2 Telecommunication Spaces Sizing and Quantity.

a. Space for working clearances is critical to allow maintenance activities including moves and changes.

b. Size each TR in accordance with ANSI/TIA-568, with the exception that the minimum TR size for DoD buildings is 10 feet, 6 inches by 9 feet (3.2 meters by 2.7 meters) in buildings larger than 5,000 square feet (464.5 square meters) (Figure 2-2). This will allow a minimum of one spare rack for telecommunication spaces that can be served by one rack to comply with paragraph 2-3.1.5.3 and allows space for equipment mounted on walls.

Adjust the dimensions if vertical cable management for cable longer than shown in Figure 2-2 is required.

Figure 2-2 Minimum Telecommunications Spaces Sizing



c. As best practice, size TRs to approximately 1.1 percent of the area it serves. For example, a 10,000 square foot (929 square meter) area should be served by a minimum of one 10 foot-by-11 foot (3 meter-by-3.4 meter) TR. Divide large floor areas into "serving areas" with TRs for each serving area. Serving area must be no larger than 10,000 square feet (929 square meters) and must not serve more than 20,000 square feet (1,858 square meters). When a TR is designed to serve spaces larger than 10,000 square feet, verify the size of the TR is adequate. Allow for code-required clearances in space allocations.

d. Heating, ventilation, and air conditioning (HVAC) requirements may be substantially affected if additional systems are required in the TR. Consult with the architectural designer or facilities engineer when additional systems requirements (audio visual systems, servers, disk storage arrays) are integrated into the TR.

e. Consider using an ER for areas that exceed 10,000 square feet or for buildings that house substantial IT electronics.

Note: One TR may be adequate for multi-story buildings or in unique facilities. Refer to paragraph 2-3.1.2.5.

f. Ensure adequate space in TRs to accommodate tenant-owned data and information communications technology systems, including FRCS. Support equipment requirements in tenant-installed freestanding cabinets or racks. Total TR space as a percentage of the building's area must be scaled upward to reflect any increase in horizontal drops to each workspace in buildings with more than the standard number. Examples may include command and control facilities or health care facilities.

2-3.1.2.3 Floors, Walls, and Ceilings.

For floors, walls, and ceilings in telecommunications spaces, meet the requirements in TIA-569. Do not install suspended ceilings in telecommunications spaces.

2-3.1.2.4 Doors and Windows.

Exterior and interior doors must satisfy fire rating requirements for TRs in TIA-569 and National Fire Protection Association (NFPA) 101®. For security reasons, exterior windows or architectural window equivalents are not permitted

2-3.1.2.5 Multi-Story Buildings and Unique Facilities.

Provide a minimum of one TR per floor. Provide additional rooms when the floor area is greater than 20,000 square feet and/or the total cable distance to the outlet is over 295 feet (90 meters). Serve all information communications technology outlets from the TR located on that floor. Vertically align TRs on successive floors to allow the risers to align on the same walls. In the case of small and unique facilities, a single TR may be adequate for the entire facility. These facilities include, but are not limited to, air traffic control towers, warehouses, firing ranges, and range and weapons towers.

2-3.1.3 Utility Considerations.

2-3.1.3.1 Lighting.

Design lighting for telecommunications spaces in accordance with UFC 3-530-01. Illumination over aisles should coordinate with overhead runway systems.

2-3.1.3.2 Power.

Provide a dedicated electrical branch circuit panel board for each TR meeting the following minimum requirements: 120/208 volt (V), 3-phase or 120/240V, 1-phase, 24- (or 20- for 1-phase) space panel with a minimum 100 ampere (A) bus rated capacity. Feed loads within the TR from this dedicated TR panel. Loads must include, but are not limited to, convenience receptacles, dedicated rack or cabinet receptacles, and HVAC systems (including exterior units for split systems). Provide 125V, 20A duplex convenience receptacles at 6-foot (1.8-meter) intervals on-center around perimeter walls.

Unless otherwise specified by the Telecommunications Manager, provide a minimum of one receptacle at each rack. To minimize accidental shutoff, equip power strips with indicator lights, but no integral on/off switch. Provide matching (National Electrical

Manufacturers Association (NEMA) configured) twist-lock type receptacles fed from dedicated circuits in the TR panel or from a busway to power each power strip. Install twist-lock receptacles above the rack or cabinet mounted to an information communications technology cable tray. As some rack- or cabinet-mounted equipment may require more power, consult with the local information communications technology group having jurisdiction to determine exact electrical power requirements for each TR.

2-3.1.3.3 Heating, Ventilation, and Air Conditioning.

Design telecommunications spaces to meet HVAC requirements of TIA-569, including the Class B requirements for temperature and humidity as outlined in American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) *Thermal Guidelines for Data Processing Environments*. Class B space includes only temperature control. When the IT equipment (ITE) load includes enterprise servers, volume servers, storage products, and other computing environment, the space may be categorized as A4 or A3. TRs will be Class B. ERs may be Class B or Class A4, depending upon the user's equipment load. Work with the system owner to understand the environmental needs and coordinate them with the full design team.

2-3.1.3.4 Room Climate Control.

a. Provide each TR with its own independent thermostat for climate control, capable of supporting year-round ambient temperature control (24 hours per day, 365 days per year) to protect all installed electronic equipment as defined in TIA-569. The mechanical system designer of record must determine the type of system required to meet the environmental condition requirements for all telecommunications spaces. Data centers may require a narrower environmental envelope to safeguard equipment function. Do not include heating and cooling systems within TRs on building time clocks or other temperature setback mechanisms. Provide rooms with positive atmospheric pressure to minimize dust when required by system owners or equipment manufacturers.

b. Design cabinets and rows to avoid recirculation of exhaust air into equipment intakes. Specify blanking panels and baffles as needed to mitigate intra-cabinet circulation. Equipment should be arranged into hot and cold aisles when more advanced schemes of cooling are not used.

c. Do not use electrical name plate data for cooling requirement calculations. Manufacturer heat load data by equipment is best for use in calculating cooling requirements but is not always available. The mechanical designer must determine the amount of cooling required, but will need to collaborate with the telecom designer to understand requirements.

d. Design cooling load capacity to include growth capabilities for IT refresh planning in accordance with ASHRAE 90454. For calculated loads less than one ton (12,000 British thermal units per hour (BTU/hr)), provide a single air conditioning (A/C) unit with space and power capacity to install another identical unit for future load growth. For loads greater than one ton, install two identical units sized for 50% to 60% of the load each, and provide space and power capacity for an additional identically-sized unit for future load growth. For loads greater than 10 tons (120,000 BTU/hr), and where redundant uninterruptable power systems (UPS) have been installed in the telecommunications space, provide more than two A/C units to meet the N+1 redundancy criteria, where N is the number of A/C units required to meet the load (not less than 2), and 1 is the identically-sized redundant spare. In addition to the one redundant spare A/C unit, provide space and power capacity for one additional identically-sized A/C unit for future load growth. Other redundancy requirements may be required by the mission. Ensure IT, power, and mechanical cooling requirements are aligned with the mission.

e. Utility piping serving telecommunications spaces must not be routed over communications racks or cabinets or electrical panels. Where routing over sensitive areas cannot be avoided, provide all wet and drainage piping with special protection, such as double-wall containment piping or drip pans with leak detection to protect the space below from leakage and/or condensation.

2-3.1.4 Room Contaminants.

Do not install information systems equipment in spaces where moisture, liquid or gaseous spillage, or other contaminants may be present, as defined in TIA-569. Do not design spaces that will have a wet wall that can provide ingress of liquids or potentially require maintenance from inside of the telecommunications space for unrelated utilities.

2-3.1.5 Space Components.

For all ICT components, use manufacturer’s standard catalog products that conform to the latest published industry and technical society standards at the date of contract award. Do not use shop- or field-fabricated components that are not manufacturer's standard catalog products or that do not conform to the industry and technical society standards.

2-3.1.5.1 Plywood Backboards.

Provide backboards in accordance with TIA-569. Fire retardant treated wood must comply with International Building Code, Section 2303.2. Backboards must be fire-retardant-treated wood, bearing the manufacturer’s stamp. Backboards are not required to be painted unless requested by the Information Communications Technology Manager for illumination reflectance. They must display at least one fire-rated stamp after wall-mounted equipment is installed and they are painted. Cover a minimum of two adjacent walls with backboards. Allow 1 foot (305 millimeters) of depth space for wall-mounted equipment when calculating room sizes. If equipment with a known depth greater than 1 foot will be used, also allow for that space and required clearance. When renovating an existing TR that does not have adequate space, size the backboard as large as possible to accommodate wall-mounted equipment.

2-3.1.5.2 Protected Entrance Terminals.

TIA-758 identifies two types of building entrance terminals (BET) -- protected and non-protected. Provide protected entrance terminals (PET) in accordance with TIA-758. Equip PETs with modules to protect the inside plant cabling and equipment from power surges. Furnish solid state or gas tube modules adequate for all used pairs plus 25%, but not to exceed the total pair count. Provide 110-type insulation displacement connector (IDC) terminal blocks or cable stubs. See paragraph 2-4 for grounding requirements. Refer to Chapter 3 for OSP requirements.

2-3.1.5.3 Equipment Racks.

Provide 19-inch (475-millimeter) floor-mounted equipment racks. A minimum of 36 inches' (900 millimeters') space, both in front and behind the rack measured from the equipment, and a minimum side clearance of 36 inches on at least one end of the rack or row of adjacent racks is required. Allow a front-to rear-space of 42 inches (1067 millimeters) to accommodate equipment. Coordinate with the Information Communications Technology Manager to determine the space and weight requirements for the USG-provided active equipment. A four-post rack may be required to support equipment due to weight or mounting requirements. Provide 25% spare rack unit capacity within each rack used. Provide one spare rack for every four used racks, with a minimum of one spare rack per telecommunication space.

In existing facilities with narrow or crowded telecommunication spaces, equipment racks may be wall-mounted with the approval of the Information Communications Technology Manager. Workspace around the cabinet/rack is still required even if the cabinet is mounted 6.5 feet (2 meters) off the floor. Refer to Figure 2-3.

2-3.1.5.4 Equipment Cabinets.

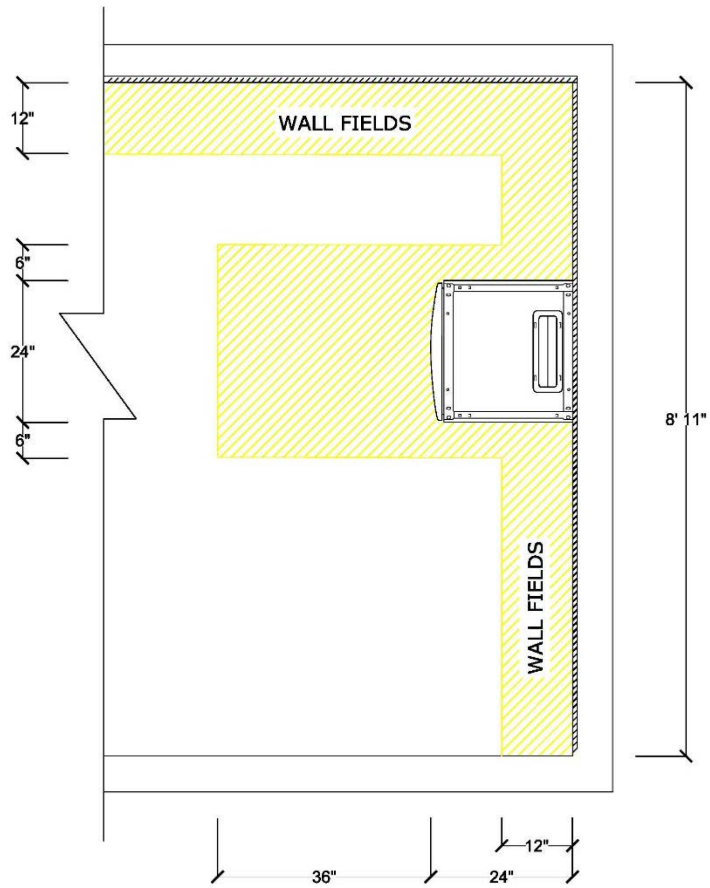
Provide equipment cabinets in lieu of racks where:

- identified by Service-specific chapters in this UFC.
- required by the Information Communications Technology Manager.
- physical security is required, such as to mount secure or mission critical equipment.
- separately controlled access is desired (when multiple systems are collocated within the room).

a. Provide a minimum 24 inch- (600 millimeter-) wide cabinets with cooling fans (when required) and internal rails to support 19-inch (475-millimeter) equipment. Locate cabinets in rows with front and rear clearance. A minimum space of 36 inches (900 millimeters), both in front and behind the cabinet, and a minimum side clearance of 24 inches (600 millimeters) on at least one end of the cabinet or row of adjacent cabinets is required. When an aisle is against a wall, cabinets should not exceed eight in a row.

b. Design cabinets with 63% mesh doors with blanks and baffling to ensure front-to-rear air flow and avoid intra-cabinet air circulation, unless another cooling method is designed. In instances where other air flow is needed, use manufacturer-approved penetrations and sealing to maintain airflow. For hot and cold aisles, use an airflow scheme engineered for the solution.

Figure 2-3 Wall Mounted or Floor Mounted Cabinet Clearance



c. Coordinate with the Information Communications Technology Manager to determine space requirements for the USG-provided active equipment. Provide 25% spare capacity within each cabinet used. Provide one spare cabinet for every four cabinets used, with a minimum of one spare cabinet per telecommunication space.

d. In existing facilities with narrow or crowded telecommunication spaces, equipment cabinets may be wall-mounted with the approval of the Information Communications Technology Manager. FRCS may require wall-mounted cabinets. Where space is limited and clearances are affected, use swing-out cabinets. See Figure 2-3.

2-3.1.6 Horizontal and Vertical Cable Management.

Provide horizontal cable management panels above and below each patch panel. The required ratio of horizontal cable management to patch panels is 1:1. Provide vertical cable management between racks and at the end of racks when required to protect, manage, and organize cables. Vertical cable management panels must be a minimum of 6 inches (150 millimeters) wide, and sized based on total anticipated cable plus 50%. Allow space against the wall for operation of vertical management covers.

2-3.1.7 Ladder and Wire Cable Tray.

Use ladder-type cable trays in telecommunication spaces to provide distribution between the plywood backboard, equipment racks, backbone conduits, and the distribution cable tray. Bond all metallic cable tray sections and bond the cable tray system to the primary bonding busbar (PBB) or secondary bonding busbar (SBB).

2-3.1.8 Copper Pair Patch Panels.

For patch panels, use 8-position, 8-contact (8P8C) modular jacks with rear-mounted 110-type IDC terminations, category rated for the copper cabling being installed, and arrange in rows or columns on 19-inch (475-millimeter) rack-mounted panels. For small projects (fewer than ten users), 19-inch TIA category-qualified wall mounted block or backboard patch panels may be used. Provide T568A jack pin/pair configuration per ANSI/TIA-568. T568B jack pin/pair configuration may be used only if required to maintain uniformity in an existing facility. Provide modular jacks that conform to the requirements of ANSI/TIA-568, rated for use with the installed cable plant. Install unshielded twisted pair (UTP) patch panels in the same rack or in the rack immediately adjacent to the local area network (LAN) equipment to minimize patch cord lengths. Provide a minimum spare capacity of 25 percent.

2-3.1.9 Fiber Optic Patch Panels.

Use patch panel connectors and couplers of the same type and configuration as used elsewhere in the system. Unless otherwise directed, use duplex lucent connectors (LC) or keyed LC connectors on 19-inch rack-mounted panels to support legacy installations. Provide a 3-foot (0.9-meter) slack loop of fiber within each panel and include strain relief for cables within the panel. Provide proper termination, splice storage, routing, radius limiting, cable fastening, strand storage, and cross-connection in all patch panels. Install fiber optic patch panels in the same rack or in the rack immediately adjacent to the LAN equipment to minimize patch cord lengths. Provide a minimum spare capacity of 25 percent.

Consider multi-fiber termination push-on (MTP®) factory-terminated fiber optic systems using cassettes to break out fibers. This has many advantages, including factory testing, shorter installation times, future-proofing connection types, and tap port options.

In existing facilities, other connector types may be used to match the current infrastructure with the approval of the Information Communications Technology Manager.

2-3.2 Telecommunications Pathways.

A pathway is a facility for placement of information communications technology cable.

2-3.2.1 Backbone Pathways.

Backbone pathways are structures that conceal, protect, support, and provide access to cables between telecommunications spaces. Examples of backbone pathways include conduit, sleeves, slots, cable trays, telecommunication spaces, and miscellaneous support facilities.

For intra-building backbone distribution, use a minimum of two 4-inch (100-millimeter) conduits between TRs located on the same floor, or a pathway that provides equivalent capacity (e.g., cable tray installed to support backbone and horizontal distribution).

In multistory buildings, use a minimum of three 4-inch conduits, sleeves, or an equivalently-sized slot between stacked TRs on successive floors in accordance with TIA-569. Design at least N+1 raceways to support moves, adds, and changes (MAC). Nationally Recognized Testing Laboratory (NRTL)-rated fire assembly is required for penetrations through telecommunication space walls.

2-3.2.2 Horizontal Pathways.

Horizontal pathways are structures that conceal, protect, support, and provide access to cables between the telecommunications spaces and the work area outlet. Examples of horizontal pathways include conduit, cable trays, ceiling distribution, access floors, and non-continuous cable supports (J-hooks).

There are many methods to distribute cable from the telecommunication space to the work area, and many buildings may require a combination of two or more types of pathway systems to meet all distribution needs. The DoD-required horizontal pathway is a ceiling distribution system employing a centralized cable tray system originating in the telecommunication space and continuing out into the serving areas. Use cable trays for horizontal distribution to the maximum extent possible (maximum horizontal distance: 50 feet (15,240 millimeters) in open face hangers). The remaining pathway to the work area outlet may be implemented in a variety of ways combining conduit, non-continuous cable supports, and stub-ups/outs.

2-3.2.2.1 Open Office Wiring.

Open office wiring refers to work space divided by modular furniture and partitions rather than fixed walls. The electrical designer, the architect, and the interior designer must coordinate layout of all furniture with electrical and information communications technology outlets during the design process. Typically, furniture is selected and ordered when construction is nearing completion; without proper coordination early in the design process, field interface problems will occur.

a. Systems Furniture. Use architectural columns and perimeter walls to the maximum extent possible for information communications technology distribution to systems furniture workstations. Where permitted, use utility columns in the absence of architectural columns or when systems furniture is located away from perimeter walls. Only if no other alternative exists, use under-floor conduits designed and installed in accordance with TIA-569. Include a spare conduit to under-floor outlet boxes for future expansion. Design systems furniture wiring connections in accordance with ANSI/TIA-568 and TIA-569.

Due to the uncertainty of final furniture type and layout, design wiring length for furniture outlets to the farthest point of each furniture group, plus 10 feet of extra wiring. If systems furniture has been selected and has pathways sufficient for pre-terminated cabling, consider consolidation points with factory patch cords.

b. Protection and Separation in Systems Furniture and Utility Columns. When systems furniture does not provide a metallic separation or have power in a metallic raceway, ensure separation between telecommunication and power wiring in the utility columns and systems furniture track in accordance with TIA-569 and NFPA 70®.

c. Horizontal Distribution in Small Facilities and Renovations. In new construction involving small, mixed-use (non-administrative) facilities or construction projects involving renovation of existing buildings, use of J-hooks, flexible cable trays, and alternative support systems specifically certified for Category 6A cable is permitted, but not desirable. In renovation projects where access to the walls for installation of conduit and outlet boxes is not possible, or where historical requirements prohibit alteration of the building structure, surface-mounted non-metallic raceway may be used.

2-3.2.3 Pathway Components.

2-3.2.3.1 Cable Trays.

Use solid bottom, slotted bottom, or welded wire cable trays to provide a centralized cable management/distribution system.

a. Use the cable tray for horizontal distribution to the maximum extent possible (80 percent to 90 percent of the horizontal cable length).

b. Design cable trays to accommodate an initial calculated fill ratio of 25 percent.

Note: This allows for future growth within the cable tray. Due to random placement of cables and space between the cables, a 25 percent fill ratio means that the tray is half filled.

c. Follow manufacturers' recommendations for weight, considering both tray capacity and cable loading capacities.

d. Maximum fill ratio of any cable tray is 50%.

e. Maximum fill depth of any cable tray is 6 inches (150 millimeters).

f. Do not use ladder cable trays for horizontal distribution outside of the TR or ER due to possible cable deformation when using large quantities of cable.

g. Maintain a minimum of 12 inches (300 millimeters) access headroom above a cable tray system or cable runway and 12 inches (300 millimeters) side access clearance on one side of the cable tray system or cable runway. Where this cannot be achieved, maintain an 8-inch (203-millimeter) clearance including seismic restraints.

h. Side and top encroachment distance may be less than 3 feet (914 millimeters) in a 20-foot (6096-millimeter) section of cable tray provided it does not prohibit access to raceways that feed into the tray. These encroachments must be approved by the AHJ with written consent by the Information Communications Technology Manager.

2-3.2.3.2 Conduit.

Design conduit systems in accordance with TIA-569. Install EMT conduit from the cable backbone distribution system, whether cable tray or enclosed duct, to each outlet, unless a conduit-less system is approved by the Information Communications Technology Manager. For standard outlets, use a minimum 1-inch (27-millimeter) EMT conduit. When cable tray or enclosed duct is not used, use individual conduits from the TR to each outlet. Coordinate conduit bend radius with cable bend radius. Arrange conduit entries at outlet and junction boxes so that cables passing through the box enter and exit at opposite sides of the box. Do not use flexible metal conduit for information communications technology wiring except when installing floor access boxes in a raised floor where the floor access box may be relocated within a specified service area. In this case, the length of the flexible metal conduit must not exceed 20 feet (6096 millimeters) for each run, per TIA-569.

Avoid using in-slab and below grade conduit systems for interior designs as these systems provide the least flexible horizontal distribution system. If an in-slab or below grade conduit system is used in the design, comply with NFPA 70® and use listed cables rated for wet locations. Do not use plenum or riser rated cable, gel-filled OSP, and unlisted cables in such an environment. Cables rated for a wet location typically have a larger outside diameter which may affect conduit fill rates and conduit sizing. Larger conduit sizing in the slab may affect the integrity of the structure. For in-floor conduit systems, provide home runs back to the TR serving that area. Serve all outlets from the TR located on that floor.

Use an optimal conduit fill ratio of 40 percent for conduit sizing. Do not exceed a fill ratio of 50 percent. Do not install more than four, four-pair cables in a 1-inch

(27-millimeter) conduit. Do not use conduit in a Family Housing project unless the project is a high-rise apartment building.

2-3.2.3.3 Non-continuous Cable Supports.

Non-continuous cable supports are not permitted in:

- place of the cable tray system or as the sole distribution system in place of home-run conduit. Design non-continuous cable supports to support the category rating of the cable.
- spaces that exceed 50 feet (15,240 millimeters) total length through a non-continuous cable support system.
- ceilings in which infection control protocol affects ceiling tile removal.
- spaces where cable must be protected.

When using non-continuous cable supports, comply with TIA-569. Supports must not exceed 20 cables or 50 percent of the fill capacity, whichever is less.

2-3.2.3.4 Pull and Splice Boxes.

A pull box is a housing located in a pathway run to facilitate placement of wire or cables. A splice box is a box located in a pathway run to house a cable splice. Place pull and splice boxes in conduit runs in accordance with TIA-569.

2-3.3 Telecommunications Cabling.

In accordance with ANSI/TIA-568, backbone and horizontal cabling is typically installed in a hierarchical star configuration. Provide alternative topology when required by the mission and approved by the technical authority. Paragraph 2-3.1.1 pertains to copper and fiber optic backbone and horizontal cabling. Cable to support CCTV and CATV is addressed in paragraphs 2-3.5.1 and 2-3.5.2.

2-3.3.1 Backbone Cabling.

Paragraphs 2-3.3.1.1 and 2-3.3.1.2 pertain to copper and fiber optic intra-building backbone cable. Use no more than two hierarchical levels of cross-connects (main and intermediate) for the intra-building backbone. Use copper backbone cable only for voice circuits. Use fiber optic cable for data backbone circuits.

2-3.3.1.1 Copper.

Comply with the following:

- Use multi-pair voice backbone cable that and satisfies requirements of ANSI/TIA-568 for riser or plenum-rated UTP cable.
- Use solid untinned copper, 24 American Wire Gauge (AWG) conductors.

- Coordinate the copper backbone design with the Information Communications Technology Manager to minimize the amount of copper used.
- Use minimal copper backbone to support traditional two-wire phones and legacy systems as the transition to an all-fiber backbone occurs.
- For facilities that will use unified communications (voice, video, and data over Internet Protocol (IP)), use a minimum 25-pair copper backbone to each TR. Provide additional cable counts to support actual legacy system requirements.
- For facilities using legacy systems, use copper backbone cables sized to support no more than 1.5 pairs for every outlet connected to the serving TR.

Terminate OSP cable on a PET. Terminate the copper backbone cable originating in the main TR or main cross-connect in each TR on 110-type, insulation-displacement wiring blocks mounted on the backboard or rack-mounted. If rack-mounted, isolated from the rack bonding busbar (RBB) and route appropriate ground to PBB for PET. Provide 110-type terminal blocks on the same backboard as the PET and in each TR for copper backbone distribution. Use intermediate cross-connects when required by the Information Communications Technology Manager.

2-3.3.1.2 Fiber Optic.

a. Use single mode fiber optic cable with a minimum of 12 strands between the main telecommunications room or main cross connect and each TR. Where required by NFPA 70® or by local regulations, fiber optic cable must be plenum-rated. Place non-armored fiber in innerduct. Furnish bullet bonding for armored fiber cabling.

b. Indicate the proper color coding of optical fiber cabling on design drawings. Use the TIA-598 jacket color coding scheme for fiber-optic (FO) cable (Table 2-3).

Table 2-3 Jacket Colors

MODE	COLOR
Single-mode (ranges between 8 and10um) (OS1)	Yellow
Single-mode (ranges between 8 and10um) (OS2)	Yellow
Multimode 62.5/125um (OM1)	Slate LEGACY
Multimode 50/125um (OM2)	Orange LEGACY
Multimode 50/125um laser optimized (OM3)	Aqua
Multimode 50/125u (OM4)	Violet or aqua
Multimode 50/125um laser optimized (OM5)	Lime green

c. Table 2-4 provides typical distances for the fiber optic cable types listed in Table 2-3. Work with the system owner to select the appropriate media type to match the requirements of the installation. Consideration technology refreshes that can be expected to occur over the life of the installed plant.

Table 2-4 Fiber Speeds

Speed Fiber Type	100 MB	1 Gb	10 Gb	40 Gb	100 Gb
OM1	1800 ft (549 m)	722 ft 220 m)	108 ft (33 m)	N/A	N/A
OM2	1800 ft (549 m)	1800 ft (549 m)	269 ft (82 m)	N/A	N/A
OM3	1800 ft (549 m)	1800 ft (549 m)	984 ft (300 m)	328 ft (100 m)	328 ft (100 m)
OM4	1800 ft (549 m)	3281 ft (1000 m)	1800 ft (549 m)	500 ft (152 m)	500 ft (152 m)
OM5	N/A	N/A	1800 ft (549 m)	500 ft (152 m)	500 ft (152 m)
SM	N/A	32800 ft (9997 m)	32800 ft (9997 m)	32800 ft (9997 m)	32800 ft (9997 m)

d. Terminate backbone fiber-optic (FO) cabling, at each end, on cabinet/rack-mounted patch panels with integrated circuit (IC) or MPT-type connectors unless otherwise required by the activity or recommended by the system manufacturer. Do not use straight tip or mechanical transfer registered jack (MT-RJ) fiber optic adapters and connectors for new construction unless specifically required for interface with existing equipment reused on installations. Provide fiber optic adapters and connectors in accordance with the appropriate TIA-604, Fiber Optic Connector Intermateability Standard (FOCIS). Fusion-splice backbone fibers to factory produced pigtails or use factory MTP® cables with breakout cassettes.

e. Coordinate with the Information Communications Technology Manager for the connector and fiber type. Table 2-5 lists some of the fiber and connector quantities and types for commercially available transceivers for 100G connections:

Table 2-5 100G Transceiver and Connector Types

Transceiver	Fiber	Qty Fiber	Connector	Distance (meters)
100G-SR10	OM3/OM4	20	24F MTP®	100/150
100G-SR10 MXP	OM3/OM4	24	24F MTP®	100/150
100G-SR4	OM3/OM4	8	12F MTP®	70/100
100G-XSR4	OM3/OM4	8	12F MTP®	300
100G-LRL4	OS2	2	LC	2,000
100G-CWDM4	OS2	2	LC	2,000
100G-LR4	OS2	2	LC/SC	10,000
10X10-LR	OS2	20	24F MTP®	1,000
100G-PSM4	OS2	8	12F MTP®	500
100G-SWDM4	OM3/OM4	2	LC	70/100
100G-SR-BD	OM3/OM4	2	LC	70/100
100G-FR	OS2	2	LC	2,000
100G-DR	OS2	2	LC	500

2-3.3.2 Horizontal Cabling.

2-3.3.2.1 Copper UTP.

a. Category 6A (CAT6A). Provide one CAT6A UTP cable to each standard 8-pin modular jack. Use only cable that has passed the Underwriter's Laboratory (UL) LAN certification program and is labeled with UL acceptable markings. Provide plenum rated cables in accordance with NFPA 70®, or when directed by the facility safety officer or UFC 3-600-01. Do not use Category 3, 5, 5e, or 6 rated cabling in new construction or rehabilitation projects for ICT. See Table 2-3 for cable types for non-IT, OT, and Power over Ethernet (PoE). See paragraph 2-3.3.3 for passive optical network (PON) fiber requirements in the horizontal.

Note: When specifically required by other criteria or needed for the application, such as high bandwidth uncompressed video, designers may use screened or shielded twisted pair (ScTP or STP) cabling (as in Europe or secure areas).

b. CAT6A Termination. Terminate UTP cabling at the work area outlet and patch panel using an 8-pin, RJ45 type modular jack rated for the category of the installed cable. Terminate horizontal cables in the telecommunications spaces on Category 6A rack-mounted patch panels. Facilities with minimal outlet requirements (normally less than 12) may use a small cabinet or backboard-mounted CAT6A patch panel. Terminate cables from the same outlet on the same patch panel and individually identify the cables. Wire all terminations to the TIA 568, T568A configuration. Do not use the T568B wiring configurations unless specifically requested by the user and approved by the AHJ and approved by the COR for contract designs or the Government design lead for in-house designs. Do not split copper cables between multiple modular connectors.

Note: Coordinate with the Information Communications Technology Manager to determine if it is necessary to separately identify and differentiate “voice” and “data” systems.

c. CAT6A UTP Patch Cords. Use 4-pair, minimum size 24 AWG stranded UTP copper patch cords rated for Category 6A (match the horizontal infrastructure), with 8-pin modular plugs at each end. Due to performance and testing requirements, only factory-manufactured patch cords of the same category as the cabling plant are permitted. Use plenum patch cords in plenum spaces. For applications requiring a male termination, a male plug terminated link (MPTL), may be used conforming to TIA standards. Use patch cords of various lengths to terminate all required connections. Use 25% spare patch cords when requested by the technical authority. Length, color, and quantity of each must be approved by the COR for contract designs or the Government design lead for in-house efforts.

d. Cable Length. In accordance with TIA 568, limit copper data cable length to 295 feet (90 meters) from patch panel termination in the TR to the data outlet termination. PONs may exceed the 295-foot (90-meter) length. See paragraph 2-3.3.3 for PON cabling.

2-3.3.2.2 Fiber Optic.

a. Cabling. Use fiber optic cable to each outlet and endpoint only when required by the mission and approved by the Information Communications Technology Manager. Use 50/125-um diameter laser optimized (OM3) multi-mode when the user requires multimode fiber optic cable. When the Information Communications Technology Manager requires it, use single-mode fiber optic cable (OS1) or (OS2). Use plenum cables in accordance with NFPA 70®, or when directed by the facility safety officer or UFC 3-600-01.

Specify legacy fiber optic cable only when mating to existing installed base including 50/125-um diameter (OM2) or 62.5/125-um diameter (OM1) multimode fiber.

b. Termination. Terminate FO cable in cabinet/rack-mounted patch panels, and at the outlet using LC or MTP® type connectors in accordance with the appropriate TIA-604 series document. Do not use ST or MT-RJ fiber optic adapters and connectors for new construction unless specifically required for interface with existing equipment reused on installations. Use fiber optic adapters and connectors in accordance with the appropriate TIA-604 FOCIS. Use individual patch panels and distribution panels with 12 duplex LC connectors on each bulkhead. Consider using MTP® connectors on cassettes with breakouts to duplex LC to allow for future upgrades to the system. When designing bulkheads, specify that vertical or horizontal be applied universally on the project to ease labeling and administration.

c. Patch Cords. Use fiber optic patch cable types and connectors of the same type as those on the patch panels with which they are interconnecting. Use duplex patch cords. Due to performance and testing requirements, use factory manufactured pre-connectorized patch cords. Provide sufficient fiber optic patch cords, of various appropriate lengths, to terminate all fiber optic patch panel appearances, plus 25% spare. Use 25% spare patch cords when requested by the technical authority. Length, color, and quantity of each must be approved by the COR for contract designs or the Government design lead for in-house designs. Consider specifying a drawer in racks and cabinets to house spare patch cords.

2-3.3.3 Passive Optical Network and Fiber to the Network Edge Active Ethernet.

2-3.3.3.1 Passive Optical Network.

PON architecture employs optical switch ports centralized with a passive optical splitter to deliver connectivity to multiple endpoints via simplex single mode optical fibers. Obtain approval from the technical authority before designing PON infrastructure, and work with the network architect to understand the type of PON being deployed, as different splitter ratios are allowed. Loss budgets must be understood and incorporated into the design.

The horizontal portion of the PON infrastructure must be installed using a simplex optical fiber cable. Consider using a duplex optical fiber cable to the work area to future-proof the installation. Terminate it in the TR to allow the network engineer to patch into and change the passive optical splitter as the network evolves. When the network will include radio frequency (RF) over fiber, use of angled physical connectors (APC) will be required to reduce back reflections. Angle polished connectors (APC) are recommended for PON network connections. Connections between backbone cabling and cassettes and splitter cassettes may be made with MTP® or other high-density fiber optic termination methods allowing use of pre-manufactured cabling systems.

Optical network terminals (ONT) can be mounted at the desktop to provide copper connectivity to workstations and IP telephones. Small form pluggable (SFP)-based ONTs can be inserted into servers to allow direct connection into servers with the PON fiber. Standards such as ANSI/TIA-568 provide both minimum and maximum channel attenuation. Use these values for passive optical LANs within a building. PONs can permit 128 ONTs per optical line terminal (OLT) or greater. Backbone designs that aggregate 32 OLT per single mode (SM) fiber in the riser serve to future-proof the installation and simplify design. Based upon backbone fiber counts typically being available in 12 counts, this allows the designer to plan for layout.

a. TR Requirements. HVAC requirements can be reduced in TRs as PONs are, by definition, passive connectivity and will not generate heat. If only PON equipment exists in a TR, no additional HVAC loads need to be accounted for.

PON has the potential to reduce telecommunication spaces in a facility, but other systems may rely upon traditional horizontal cabling. FRCS such as Building Automation Systems (BAS), wireless access points (WAP), or enterprise survivable servers (ESS) may not aggregate into the PON infrastructure. If the decision is to have only PON infrastructure in a facility, the number of TRs per floor can be reduced to one because of the distances supported by a PON. The decision to reduce the size of the TR should be weighed against the risk of future systems not fitting into the space. A shallow TR room layout in accordance with TIA 569-E for PON accommodates the passive optical system per floor, but consideration needs to be given for:

- reduced corridor access during TR work.
- security needs of equipment and the need to have doors open for moves, adds, and changes.
- FRCS needs and real estate requirements.

For these reasons, it is recommended that an appropriately-sized TR for every 20,000 square feet of floor space, as a minimum, be maintained to support building telecommunication systems. Verify this space is adequate to house all systems.

b. Fiber Types. Consult the International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) Series G recommendations for guidance on fiber specification for PON networks. For premises applications deploying 10 Gigabit-Passive Optical Network (10G-PON), ITU-T G.657 fiber can be used. For longer reaches, use bend-insensitive fiber meeting ITU-T G.652.

Loss of the optical path cannot be too high or too low. Discrete attenuation may need to be accounted for and designed into the system or the commissioning process.

Table 2-6 Maximum Attenuation

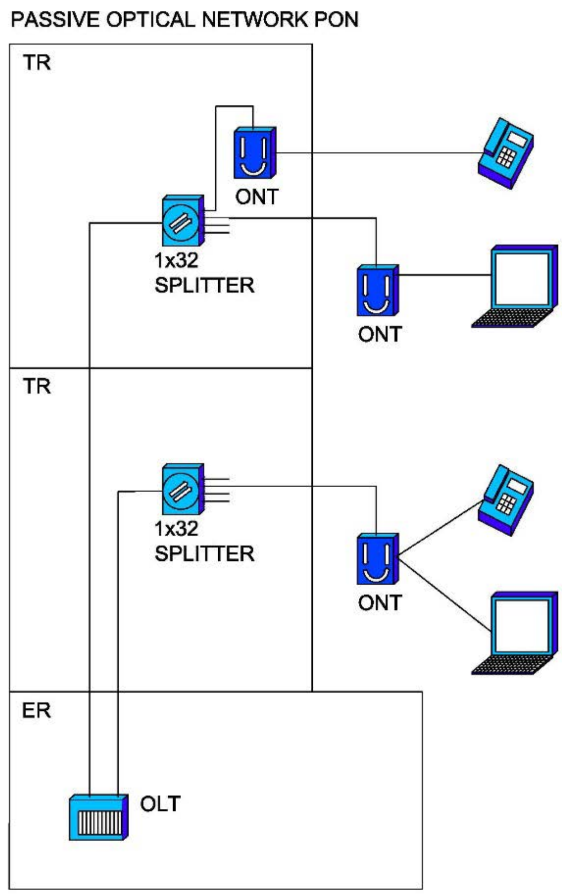
PON Type	Standard	Maximum Distance	Maximum Attenuation
EPON	IEEE 802.3ah	6.2 miles	20 dB
10G-EPON	IEEE 802.3av	12.5 miles	29 dB
GPON	ITU-T G.984	37 miles	32 dB
10G-PON	ITU-T G.987	25 miles	31 dB

Table 9 of ANSI/TIA-568 gives design parameters between 13 dB and 28 dB for premise optical network parameters. Calculate the loss budget for the network and design it to fall within this range, as follows:

Loss of cable	0.5dB/km for outside plant	1.0dB/km for inside plant
Loss of connectors	0.75 dB per connector pair	
Loss of splices	0.3 dB per splice	
Loss of splitter(s)	Varies based upon ratio and type	
Patch cord and mating loss		
Sum above losses		

Note: Plan for headroom of about 3 dB to allow for changes during the life of the cable plant.

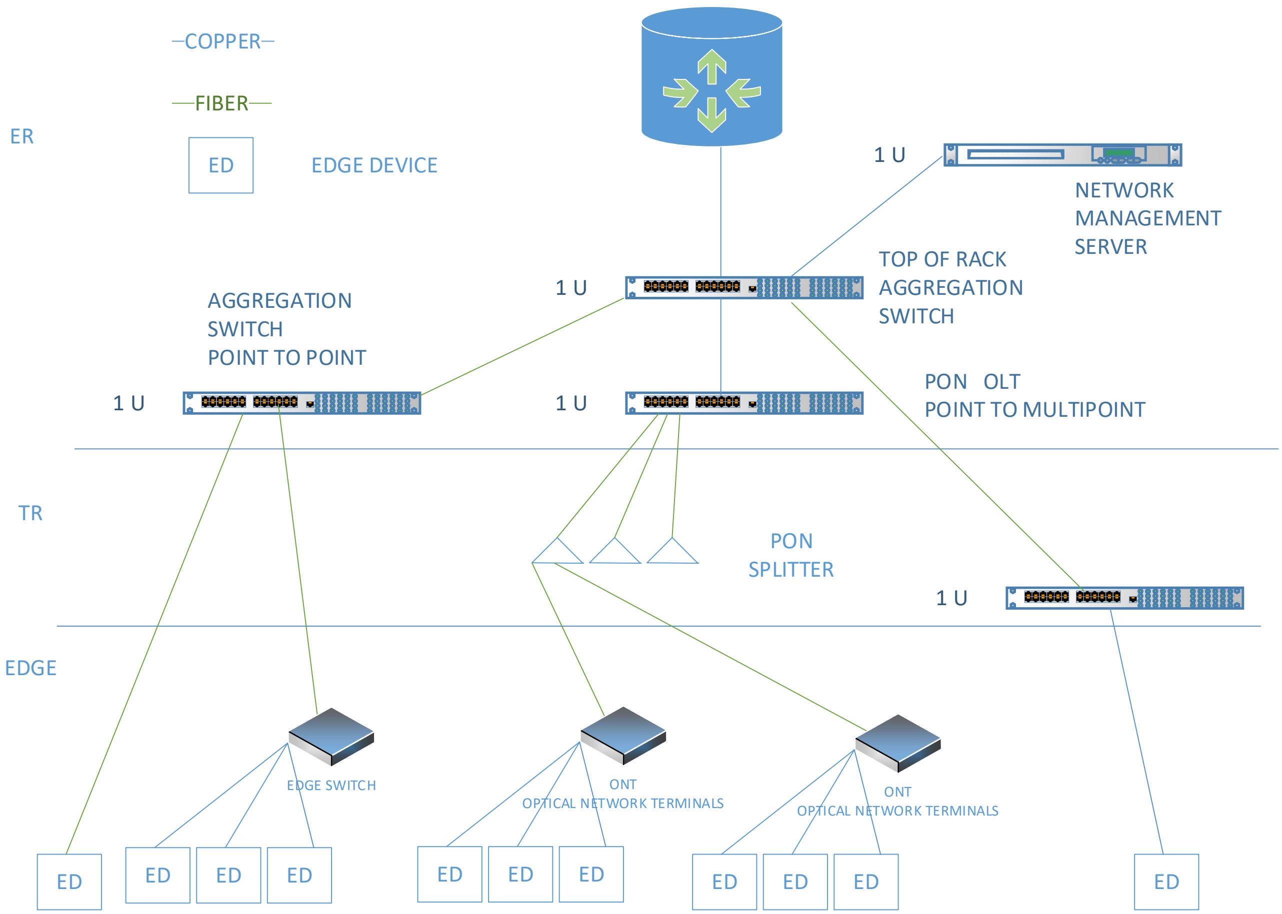
Figure 2-4 Passive Optical Network



2-3.3.3.2 Fiber to the Edge.

While most ONT/software defined access networks (SDAN) use only one fiber (standard connector (SC) angle polished connector (APC) simplex connection), consider using two fibers to each ONT/SDAN for redundancy and/or future capacity. When the network will include analog RF over glass, APC connectors will be required to reduce back reflections. Connections between backbone cabling and cassettes and splitter cassettes may be made with MTP® or other high-density fiber optic termination methods allowing use of pre-manufactured cabling systems.

Figure 2-5 Fiber to the Edge



2-3.3.3.3 Centralized Low Voltage DC Power.

a. Composite Copper/Fiber Cables. Class 2 power can be delivered via composite copper/fiber cables to ONT/SDANs and other utilization equipment that can be powered by PoE. Consider specifying cables that provide both fiber connectivity for data and copper conductors for National Electrical Code® (NEC®) Article 725 light (LPS) DC Class 2 power (low voltage at <60 volts direct current (VDC)/<100 volt-amps (VA) of power).

b. Cable Construction. Composite cables incorporate single mode fibers for network connectivity and pairs of stranded copper for low voltage direct current (LVDC) power distribution. These cables typically will have from 1 to 24 single mode fibers and 2 to 12 copper conductors ranging from 20 American Wire Gauge (AWG) to 12 AWG. Larger gauge copper will allow power to be delivered over longer distances (less voltage drop). Use a gauge of wire that will support the longest lengths needed for the application. Some composite cables also can be provided in armored configurations, indoor/outdoor jackets, or plenum rated jackets. Table 2-7 can be referred to as a guide for equipment operating between 44 and 56V input with PoE passthrough or DC power.

Table 2-7 Composite Cable Distances

Example Composite Cable Distances (1 Pair)			
	30 Watts	60 Watts	75 Watts
20 AWG	590 ft (180 m)	295 ft (90 m)	235 ft (72 m)
18 AWG	940 ft (286.5 m)	470 ft (143 m)	375 ft (114 m)
16 AWG	1,500 ft (457 m)	750 ft (228 m)	600 ft (183 m)
14 AWG	>2,000 ft (>610 m)	1,190 ft (363 m)	950 ft (290 m)
12 AWG	>2,000 ft (>610 m)	1,895 ft (578 m)	1,500 ft (457 m)

By delivering the network power over the composite cable, the power system can be centralized and provide uninterruptible power supply (UPS) backup to prevent network interruptions during building power loss.

c. Fault Managed Power (FMP). NEC® Article 726 (FMP) provides designers with the ability to deliver power for ICT appliances in excess of the 100 watts afforded to Class 2 power and PoE applications from a centralized location. Centralizing power provides centralized UPS power and administration of the system. Cabling can be routed with Class 2 power without separation in the same raceway or cable support system to the utilization equipment and is not required to be installed in conduit. Wattage available at the utilization equipment is system and cable dependent. Equipment and the cable specified must be listed by an NRTL.

2-3.3.3.4 Cabling Requirements.

Even though a PON requires only a single strand of single mode optical fiber cabling to the ONT, the ICT distribution designer should consider two or more strands at the work area to allow for future topology change. This further allows the facility owner the capability to use a mixture of peer-to-peer (P2P) and PON, as there will be instances when non-aggregated traffic will be advantageous.

2-3.3.4 Power Over Ethernet.

PoE is a method of delivering both power and data to a workstation outlet via a category cable. The proliferation of IOT devices is adding to the traditional appliances that were good candidates for PoE. In addition to WAPs, IP telephones, and IP cameras, anticipate appliances that require data and can operate on 100W will be added to the mix. Examples of these items can include displays, BAS, lighting, wayfinding, public address, clocks, and many others.

The Institute of Electrical and Electronics Engineers (IEEE) defines types of PoE according to Table 2-8.

Table 2-8 IEEE 802.3 PoE

Standard	Type	Power
802.3af	1	15.4W
802.3at	2	30W
802.3bt	3	60W
802.3bt	4	100W

2-3.3.5 Bundling

a. The table furnished in NFPA 70® and covered by Figure 2-6 is designed to keep bundles to a size that will not cause an increase in temperature that would damage the insulation. The information is presented for life safety and not performance. Elevated temperatures affect data transmission performance. This is true regardless of the source, so designers are cautioned to consider ambient temperature in the design.

b. American National Standards Institute/Telecommunications Industry Association (ANSI/TIA) TSB-184 provides information about bundle sizes. The recommendations are based upon a cable with a jacket rating of 140 °F being placed in an ambient temperature as high as 113 °F and designed to keep bundle sizes that will not allow an increase to exceed the cable rating. To comply with the NEC®, cables are not allowed to exceed their temperature ratings.

Note: The NEC® must be effective for new design projects awarded after January 1 of the year following the issuance of a revised edition unless specifically identified otherwise in contract documents.

c. Patch cords for PoE applications must be 24 AWG or larger. Bundling cable should be avoided. Reference the *Telecommunications Distribution Methods Manual (TDMM)*, 14th edition. This is a safe design parameter that will prevent problems. It allows a 48-port patch panel to have a bundle of 24 from each side.

d. Cables laid into wire basket or other non-solid tray system and not bundled do not require evaluation for heat gain, as air flow is considered sufficient. Cable trays considered 100% full generally have only 50% of the space occupied by cable, with the balance due to inefficiencies of cables not being square in shape or neatly organized.

e. It is important to understand that use of PoE is expected to increase during the life of the cabling plant. For this reason, mixing powered with non-powered devices in bundles will not remain constant throughout the life cycle of the horizontal cabling.

Figure 2-6 NFPA 70® 2020 Edition Table 725.144 Flow Chart

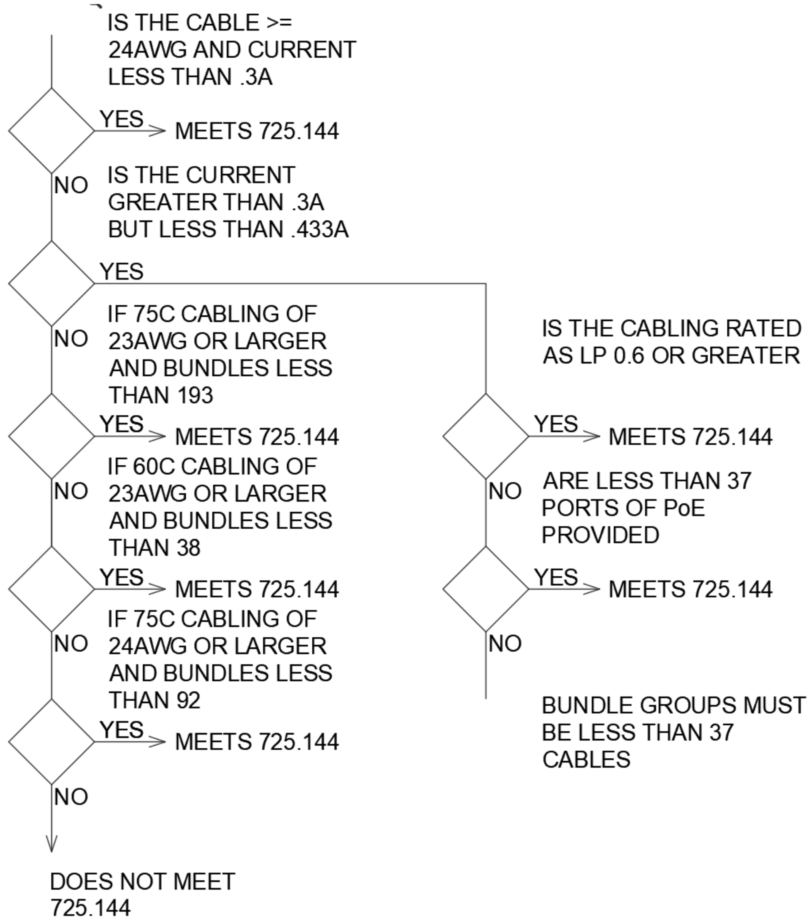


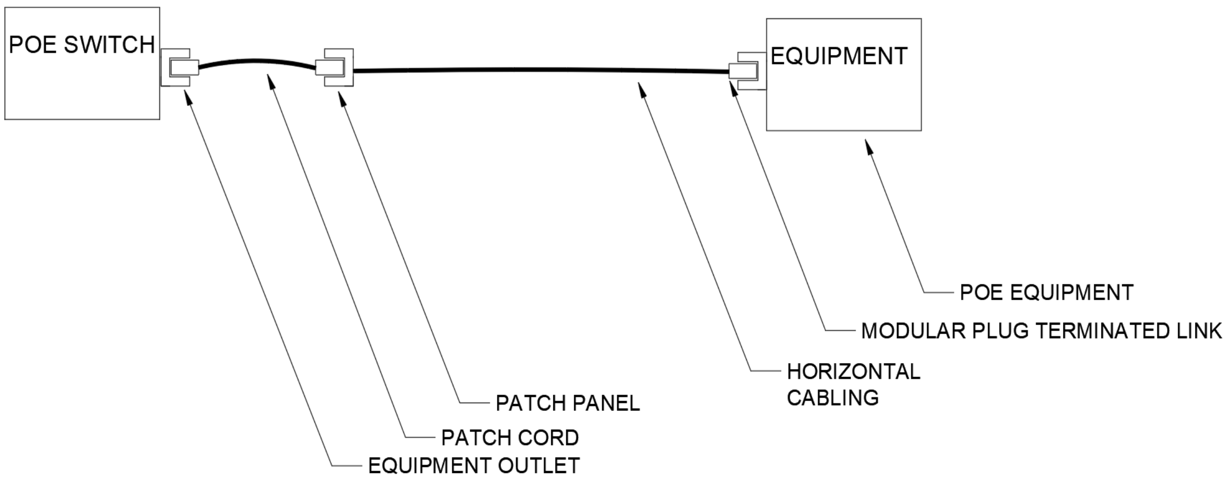
Table 2-9 Recommended Minimum Cable Types PoE

Application	Data Needs	Power Needs	Minimum Cable
BAS	Low	Low	Cat 6
AV	High	High	Shielded Cat 6A
Lighting	Low	High	Cat 6 23 AWG
WAPs	High	High	2 ea Cat 6A
Workstation outlets	High	Medium	Cat 6A

2-3.3.6 Male Plug Terminated Link Modular Plug Terminated Link.

Standards organizations including TIA and BICSI have traditionally required that horizontal cable be terminated on a workstation outlet or a patch panel. This has always precluded the field application of male RJ45 plugs because of the associated high failure rate. The proliferation of non-traditional appliances that require power and data from the horizontal equipment combined with the development of the MPTL led to inclusion and testing in the ANSI/TIA-568 standard. This is required when a female to factory patch cord is not possible.

Figure 2-7 MPTL Link Detail



MPTL connectors are designed to be field-applied to horizontal cable to allow the required quality needed for insertions over the life of the plant. The bodies have metal to assist with the dissipation of heat associated with PoE cabling. This application is useful for nontraditional IP including cameras, WAPs**,** and IOT appliances.

2-3.3.7 Single Pair Ethernet.

FRCS operational technology (OT) that relies on IEEE 802.3 Ethernet is evolving as standards are being published supporting single pair power over data line (PoDL) connections. IEEE 802.3cg standard for 10 megabits per second (Mb/s) lists the following types:

10BASE-T1S	Link segment (point-to-point), 4 connections, 15 meter reach, PoDL power
10BASE-T1L	Link segment (point-to-point), 10 connections, 1000 meter reach, PoDL power
10Base-T1S	Mixing segment (multidrop), 8 nodes, 25 meter reach

TIA single pair Ethernet topologies include:

SP1-400	23 AWG 400M maximum
SP1-1000	18 AWG 1000M maximum
10Base-T1S	Mixing segment (multidrop), 8 nodes, 25m reach

IoT devices will not require batteries or battery changes and can be powered from a switch with a UPS.

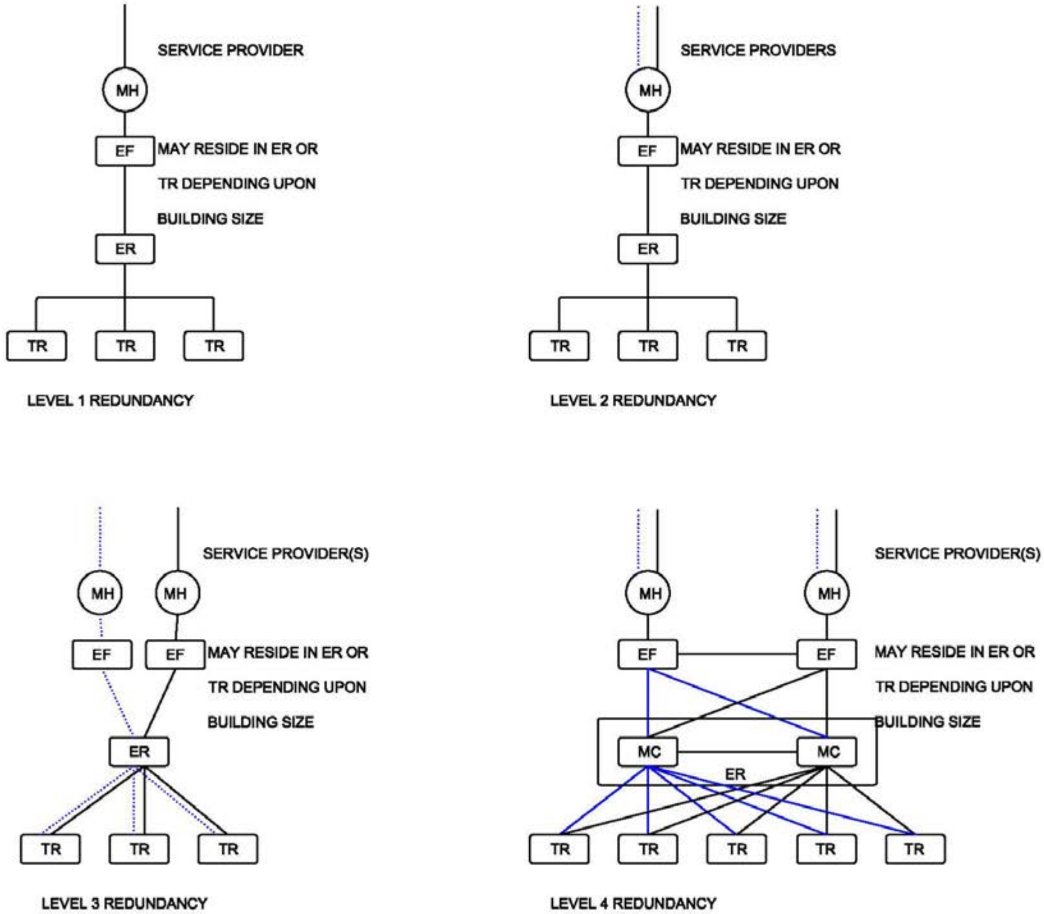
Two 10Base-T1L connectors are recognized by this UFC. They include LC style rated to IP20 and an LC style rated to IP65/67 that are included in International Electrotechnical Commission (IEC) 63171-1 and are not proprietary.

2-3.3.8 Redundancy.

Layer 1 redundancy is a function of mission requirements. Those mission requirements are covered by UFCs and other criteria and outside of the scope of this UFC. Redundancy requirements must be vetted through the proper channels. When the mission requires redundancy, the following information is included to assist in specifying a level of redundancy in the backbone to permit common understanding of the design elements. Additional information on rated levels of redundancy can be found in TIA 942 and on classes of systems in ANSI/BICSI 002 latest edition.

Four levels of redundancy are defined in this UFC. The features of each are illustrated in Figure 2-8 and further described in Table 2-10. It is important to recognize that not all areas of the building may require the same levels of redundancy. There will often be administrative areas in a facility that are collocated for efficiency of operations and will not need the same level of service. To serve all areas with the same level of redundancy would needlessly strain capital. The entire design team must be engaged early to coordinate utilities to ensure the desired outcome is reached. There will be power and cooling requirements that will need to align with the ICT to achieve a desired uptime.

Figure 2-8 Redundancy Levels



LEGEND	
TR	TELECOMMUNICATIONS ROOM
ER	EQUIPMENT ROOM
EF	ENTRANCE FACILITY
HC	HORIZONTAL CROSSCONNECT
IC	INTERMEDIATE CROSSCONNECT
MC	MAIN CROSSCONNECT
FD	FLOOR DISTRIBUTOR
BD	BUILDING DISTRIBUTOR
CD	CAMPUS DISTRIBUTOR
MH	MAINTENANCE HOLE

A	SPACE	CONTAINS	
(A)	TR	HC (FD)	DA
(B)	ER	MC (CD)	DC
(C)	EF		
(D)	ER	IC (BD)	DB
(E)	EF	IC/HC(BD/FD)	DA/DB

Table 2-10 System Levels

System Level	Description	Pathway Notes
Level 1	Non-redundant	
Level 2	Multiple service providers in the ER	
Level 3	Multiple service providers served from diverse pathways in the OSP. Backbone diversity with multiple connections but not pathway diversity in the building.	Maintenance holes (MH) should be 66 feet (20 meters) apart and ideally on opposite sides of the building.
Level 4	Multiple service providers served from diverse pathways. Backbone diversity with pathway diversity in the building.	MHs should be 66 feet (20 meters) apart and ideally on opposite sides of the building. Internal pathways should be separated by 4 feet (1.2 meters) whenever practicable or otherwise designed for pathway survivability.

2-3.4 Work Area.

A work area is the building space where occupants interact with information communications technology terminal equipment. In this UFC, consolidation points (CP), multi-user telecommunications outlet assemblies (MUTOA), and service outlets (SO) are included.

2-3.4.1 Outlets.

2-3.4.1.1 Wall-mounted Workstation Outlet Boxes.

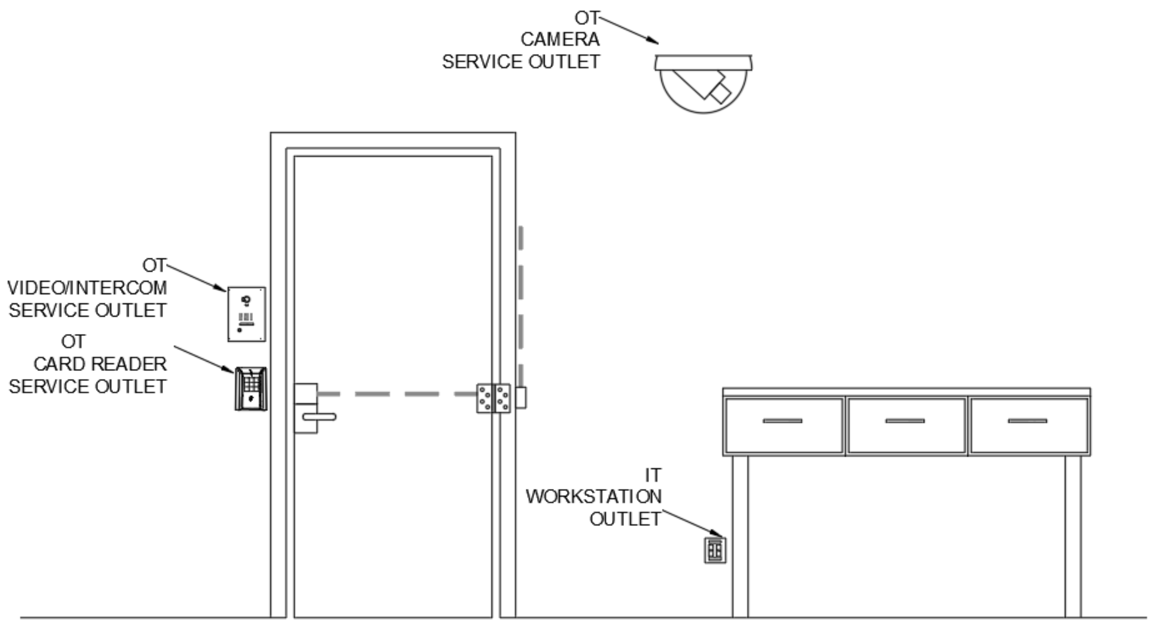
Use double gang electrical boxes, minimum standard size 4-11/16 inches (120 millimeters) square and 2-1/8 inches (54 millimeters) deep with plaster ring for connection of single gang faceplate. Design outlet boxes for recessed mounting with the faceplate flush with the wall surface, at the same height as the electrical outlets. Locate a quadruplex electrical outlet within 6 inches (152 millimeters) of all work area outlets to serve information communications technology loads associated with that outlet.

For the power outlet circuits, assume that each location of two duplex receptacles will power one personal computer with a monitor along with typical office appurtenances such as task lights, and assume that there will be no diversification of this load.

2-3.4.1.2 Service Outlet Boxes.

ANSI/BICSI 007-2020 defines a service outlet (SO) as an outlet that connects equipment to ICT infrastructure. Service outlets are typically used by FRCSs and are not subject to frequent disconnections or relocations. Service outlets need to be aligned with the operational technology (OT) equipment that they serve for mounting heights and box sizes.

Figure 2-9 Service Outlet



2-3.4.1.3 In-floor Outlet Boxes.

Use in-floor outlet boxes only if no other alternative exists for feeding systems furniture, classroom desks, lecterns in lecture halls, and other free-standing furniture. In some instances, an in-floor grid type system may be required to provide necessary flexibility. Account for environmental conditions and the maintenance of floor outlet boxes in the design.

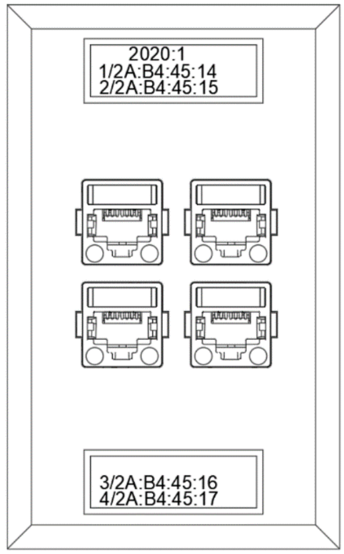
2-3.4.2 Faceplates.

2-3.4.2.1 Outlet Faceplate.

Use a single gang, four position, modular faceplate for each work area outlet. Standard configuration is two RJ-45 modular jacks and two blanks for future applications as shown in Figure 2-10. Provide other copper and fiber optic configurations to support special or legacy telecommunications systems when required.

Figure 2-10 represents a single gang faceplate with four CAT6A modules and sample labeling.

Figure 2-10 Typical Faceplate Configuration



2-3.4.2.2 Wall-Mounted Faceplate.

Use a single gang, single position modular faceplate with one wired modular jack and mounting lugs for each wall-mounted phone.

2-3.4.2.3 Coaxial Faceplate.

Use a single gang**,** single position modular faceplate with one F-type coaxial adapter or a faceplate with four modules with an F-type connector and three blanks.

2-3.4.3 Modular Jacks, Connectors, and Adapters.

Requirements in paragraphs 2-3.4.3.1 through 2-3.4.3.3 pertain to copper, fiber optic and coaxial cable jacks, connectors, and adapters. For copper systems, use the same category rating for cable, jacks, and patch panels throughout the entire system.

2-3.4.3.1 Copper Modular Jack.

Provide unkeyed Category 6A modular jacks in accordance with ANSI/TIA-568, terminated per T568A configuration. Information Communications Technology Manager approval is required for:

- use of T568B configuration to maintain existing system uniformity.
- use of keyed modular jacks where required to maintain system uniformity, security, or other user-specified reasons.

2-3.4.3.2 Fiber Optic Connectors and Adapters.

Provide unkeyed duplex LC connectors and adapters in accordance with ANSI/TIA-568. Terminate fiber optic cabling at both ends using duplex LC connectors, and use adapters at faceplates and patch panels to align and connect fiber optic cables. Consider using 12 or 24 fiber MPT assemblies with breakout cassettes to improve installation times and standardize quality with factory terminated and tested assemblies.

Information Communications Technology Manager approval is required for:

- use of other types of connectors and adapters such as SC, ST, and MT-RJ that are required to support existing systems.
- use of keyed fiber connectors with color coding where required to maintain system uniformity, security, or other user specified reasons.
- high fiber count with high density patch panels.

2-3.4.3.3 Coaxial Connectors and Adapters.

Provide F-type adapters and crimp on connectors in accordance with ANSI/TIA-568.

Terminate coaxial cabling at both ends using threaded, crimp-on connectors for CATV or other systems. Use of any other connectors, such as Bayonet Neill Concelman (BNC), requires Information Communications Technology Manager approval. Coordinate with the cable service provider where franchise agreements are in place.

2-3.4.4 Outlet Types and Density.

The number of work area outlets per square area (outlet density) required in a building varies greatly depending on the type of facility. Table 2-11 lists facility space categories, work area outlet types, and densities commonly used in military construction projects. The outlet configuration options in Table 2-11 must be selected by the proponent and the Information Communications Technology Manager. These outlet types do not address all possible user-required configurations. Provide user-defined outlets that have a corresponding valid requirement, such as multiple levels of classification or dedicated systems. Provide outlet configurations that comply with this UFC and the current versions of ANSI/TIA-568 and TIA-569. Outlet densities are provided for planning purposes when actual outlet locations are not known and cannot be determined with available information. Actual designs must include outlets in work areas, office automation outlets, private office outlets, conference rooms, and wall or access phones as necessary.

Outlet densities are based on gross area (overall building footprint without deducting for areas such as hallways, equipment rooms, and restrooms). Outlet configurations, densities, and locations for all special-purpose spaces not identified in Table 2-11 must be determined by the user and the Information Communications Technology Manager. These can be modified if it is validated (documented in writing, signed, and dated by the Information Communications Technology Manager) that mission operations require a quantity, configuration, or design other than specified in this UFC.

Table 2-11 Outlet Types

Facility Space Category	Outlet Configuration	Planning Area (ft^2(m^2)) per Outlet
Administrative space, to include private offices, conference rooms, classrooms, medical/ clinics, headquarters and special users	Two 8-pin modular (RJ45 type) outlet/connector OR One 8-pin modular and one duplex fiber optic connector OR Two duplex fiber optic connectors in a single gang outlet faceplate.	80(7.5) with a minimum of two (2) dual outlets on different walls for private offices
Open office	Two 8-pin modular (RJ45 type) outlet/connector OR One 8-pin modular and one duplex fiber optic connector OR Two duplex fiber optic connectors in a modular furniture outlet faceplate with outlet box extender	See paragraph 2-3.4.4.1.
Non-admin spaces (CDCs, chapels, recreation centers)	Two 8-pin modular (RJ45 type) outlet/connector OR One 8-pin modular and one duplex fiber optic connector OR Two duplex fiber optic connectors in a single gang outlet faceplate	500(46.5)
Barracks or dormitory space/Bachelors Quarters	Refer to paragraph 2-3.4.4.2.	
Warehouse space	Two 8-pin modular (RJ45 type) outlet/connector OR One 8-pin modular and one duplex fiber optic connector OR Two duplex fiber optic connectors in a single gang outlet faceplate	5000(465)
Wall outlet	One 8-pin modular (RJ45 type) connector in a single gang stainless outlet faceplate with mounting lugs.	As needed
Family Housing units	Refer to paragraph 2-3.3.4.3.	

2-3.4.4.1 Systems Furniture.

Provide a minimum of one systems furniture work area outlet per single occupancy cubicle and a minimum of two systems furniture outlets per cubicle designated for additional scanners, printers, copiers, or fax machines.

Coordinate with the furniture manufacturer to determine the workstation area outlets required for the furniture selected. Calculate cabling to the farthest point of each office furniture set, plus 10 feet (3 meters)

2-3.4.4.2 Barracks, Dormitory, Bachelor Quarters.

Provide one CAT6 modular jack (RJ-45 type) in each bedroom and common area (living room) of the suite configured per TIA-570.

2-3.4.4.3 Family Housing Units.

Provide a complete structured information communications technology system throughout housing unit in accordance with TIA-570. Provide Grade 1 wiring outlets (one telephone outlet and one CATV outlet) as required by TIA-570 and any other appropriate location, including attached garages. UTP cabling and modular jacks must be a minimum CAT6.

2-3.4.4.4 Utility Rooms.

Provide at least one wall-mounted information communications technology outlet in each utility room (e.g., electrical, mechanical, and telecommunications spaces) to accommodate energy management systems.

2-3.4.4.5 Elevators.

Provide a minimum of one work area outlet to the elevator machine room for each elevator. Coordinate the location with the elevator manufacturer.

2-3.4.4.6 Safety, Courtesy, and Convenience.

Provide wall-mounted telephone outlets at all logical locations to support safety, courtesy, and convenience. Examples include:

- Safety: barracks hall, laundry room
- Courtesy: building lobby/entrance
- Convenience: break rooms, rear (unmanned) entrances

2-3.4.4.7 Multi-user Telecommunications Outlet Assembly (MUTOA).

A MUTOA is a grouping in one location of several telecommunications' outlet/connectors. ANSI/TIA-568 allows MUTOAs in an open office environment. This option provides greater flexibility in an office that is frequently reconfigured. A MUTOA facilitates termination of single or multiple horizontal cables in a common location within a furniture cluster or similar open area. Cables from MUTOAs to workstations in system furniture or open offices are supported by the systems furniture raceway and the length must be calculated in accordance with ANSI/TIA-568 when establishing the total channel length. MUTOAs do not include an additional connection and are limited to terminating a maximum of 12 users. Locate MUTOAs and route cables within systems furniture in accordance with ANSI/TIA-568.

2-3.4.4.8 Consolidation Point.

A consolidation point (CP) is an interconnection point within the horizontal cabling using ANSI/TIA-568- or ANSI/TIA-568-compliant connecting hardware. It differs from the MUTOA in that it requires an additional connection for each horizontal cable run. A CP may be useful when reconfiguration is frequent, but not so frequent as to require the flexibility of the MUTOA. CPs are limited to terminating a maximum of 12 users. Locate CPs in accordance with; ANSI/TIA-568.

2-3.5 Other System Requirements.

2-3.5.1 CCTV System.

Where closed-circuit television is required, provide either a 75-ohm broadband quad-shield coaxial cable, single-mode fiber optic cable, or a category rated cable system. Coordinate with the system owner to design an RF or digital solution (such as internet protocol television [IPTV]) based upon system requirements. Ensure the correct cable is used in CCTV systems. Provide plenum cables in accordance with NFPA 70®, UFC 3-600-01, or when directed by the facility technical reviewing authority. CCTV cable distances are affected by multiple variables such as signal strength at the source, signal loss of cable, and CCTV components.

For CCTV security systems or video security systems (VSS), consult UFC 4-021-02.

2-3.5.2 CATV System.

Community antenna television systems are typically referred to as cable TV. Provide a complete system consisting of backboards or cabinets, cable, conduit, and outlets with jacks in all offices and other user required locations. Coordinate with the local CATV service provider.

Include amplifiers, splitters, combiners, line taps, cables, outlets, tilt compensators and all other parts, components, and equipment necessary to provide a complete and usable system. Include the head end amplifier as part of the system when required by the local provider. Passive CATV devices must support 1 GHz bandwidth.

Provide an ANSI/TIA-568- and NFPA 70®-compliant system. Use a star topology distribution system with each CATV outlet connected to a TR with a feeder cable or a drop cable, and each TR connected to the head end equipment with a trunk cable. Provide a high-quality signal to all outlets with a return path for interactive television and cable modem access. The system must operate within the 5- to 1000-MHz bandwidth using 1000 MHz passive devices and a minimum of 750 MHz active devices. Provide a minimum signal level of 0 decibel millivolts (dBmV) (1000 microvolts) and a maximum of 15 dBmV at 55 and 750 MHz at each outlet.

a. Cabling. Use a combination of 75-ohm broadband quad-shield coaxial cable, hard line, or single-mode fiber optic cable system. For fiber optic cables, follow horizontal and backbone cabling requirements. For coaxial systems less than 295 feet (90 meters) from head end equipment to the TR, or from TR to TR, provide RG-11 coaxial trunk cable as a minimum, and calculate the loss budget. For systems exceeding 295 feet from the head end equipment to the TR, or from TR to TR, consider using 625 series cable to reduce system losses and calculate the loss budget. Use RG-6 coaxial cables for drops from the TR (or head end) to the wall outlet. Do not use RG-59 for CATV projects.

The Telecommunications Manager and service provider may require a category cable system in lieu of an RF distribution system. Coordinate with each and provide a complete operable system.

b. HDBaseT™. HDBaseT™ is a trademark of the HDBaseT Alliance. This standard allows the transport of uncompressed ultra-high definition video, digital audio, power, Ethernet, USB 2.0 and other AV control over a single category cable up to 328 feet (100 meters) in length. Support for High Definition Copy Protocol (HDCP) high-bandwidth digital content protection is embedded in the standard to support the ability to use protected content without the 7ms violation breaking the link.

100 watts of power is supported by sending 25 watts over each of the four pairs in a horizontal cable. Power over HDBaseT™ is abbreviated as POH. HDBaseT™ 3.0 includes aggregate data rates of 16 Gb/s. Cat6A screened must be specified in the design. Consider specifying cabling with 22 AWG and screened conductors.

Supporting uncompressed video at 18 Gb/s over High Definition Multimedia Interface (HDMI) can be challenging to design due to cable distance limitations and cable size. Use of horizontal cabling as supported by HDBaseT™ offers flexibility to deliver AV solutions using standard 8P8C connectors and cabling.

2-3.5.3 WAP.

When a wireless local area network (WLAN) system or a wireless intrusion detection system (WIDS) is required, design in accordance with TIA Telecommunications Systems Bulletin 162-A (TSB-162-A) and ANSI/BICSI 008-2018. Give careful consideration to:

- building type
- availability requirements
- uses of the system RTLS
- bandwidth requirements

- coordination of systems, FRCS, IOT, and guest Wi-Fi
- system manufacturer recommendations
- facility type and use

2-3.5.3.1 Existing Facilities,

Once the needs assessment has been completed and the type of service determined, the next step is to create a layout of expected locations for access points. This will be followed up by a site survey. Based upon the output of the site survey, placement of access points in the design follows.

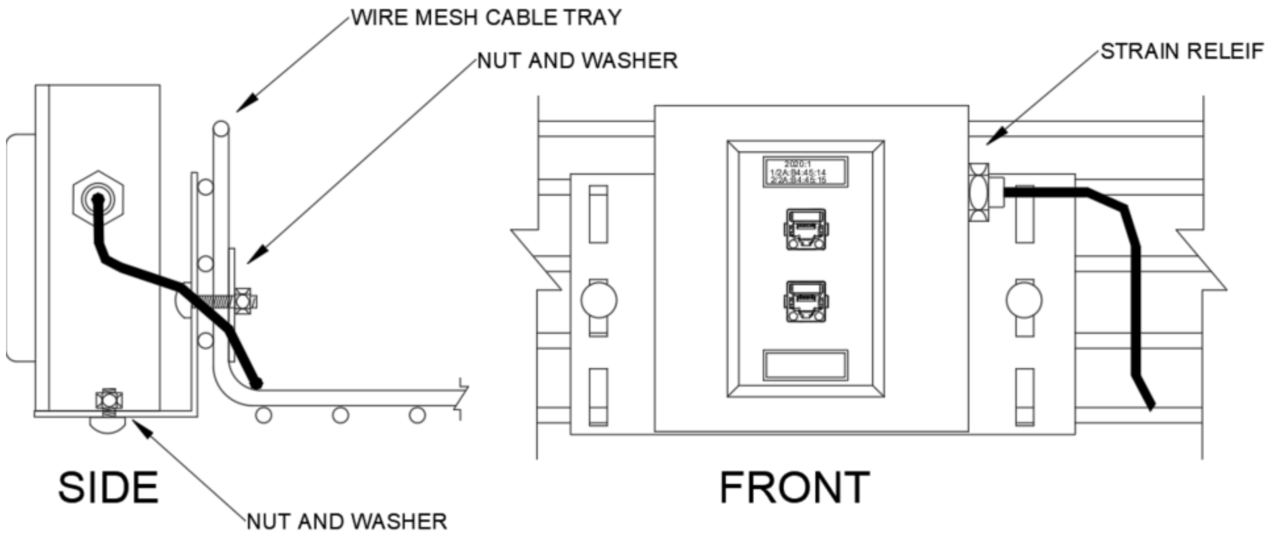
The IEEE 802.11ax, WiFi 6 by the Wi-Fi Alliance, is a 10 Gps application necessitating a Category 6A cable for 328 foot reach. The current best practice and compliance with TIA TSB-162-A recommends use of two category 6A (or higher) horizontal cables or OM3 (or higher) optical fiber cabling. This offers flexibility to use one of the horizontal cables to connect to additional WAPs when commissioning structures when data rates per WAP are less than 10 Gps. IEEE 802.11be uses connectivity greater than 10 Gps, requiring two category 6A cables per WAP.

a. Interior Layout. Work with the network architect to understand density requirements for number of users and use cases potentially including RTLS or other applications. Signal propagation best practice will require use of predictive RF design software to produce heat maps to determine the best layout. The commissioning signal survey may require adjustment in positions and quantities of WAPs that the designer must consider. If predictive RF design software is not available, the radius of the coverage area should not exceed 43 feet (13 meters) (based upon a standard radio in an office environment). Use hexagonal shapes to determine needed overages. Coordinate with the facility to provide TIA-606 compliant administration including location of above ceiling infrastructure.

b. PoE Wireless. NFPA 70®, the NEC®, requires that cables not be allowed to exceed their temperature ratings. The *Telecommunications Distribution Methods Manual*, 14th edition, gives guidance that bundles should not exceed 24 cables. Cables laid loosely in wire mesh cable trays and similar installations improve air flow around cables and reduce heat dissipation. Refer to additional PoE information in this chapter.

c. Horizontal Connection Points. It is advantageous to allow for maximum flexibility of final placement of WAPs. When designing an HCP, allow for a minimum of two permanent link connections for each WAP that is anticipated to be 802.11ax or higher.

Figure 2-11 WAP Outlet Detail



Provide two twisted-pair cables, Category 6A terminated on standard 8-pin modular connectors or two fiber multimode optical fiber strands, OM3 or higher for each wireless access point. Install the WAP cabling infrastructure in the same manner as other information communications technology outlets required in this UFC. Include the cable tray and conduit or J-hooks to support the cable connected to the WAP. Use of “J” hooks, flexible cable tray(s), and alternative support systems specifically certified for the cable used is permissible to support the WAPs from the cable tray. Do not exceed a 50 percent fill ratio for the “J” hooks. Support horizontal cabling to distribution areas in cable trays. Patch cables must match the cable rating.

Confirm power with the Telecommunications Manager if the WAP appliances will not be PoE-powered.

2-3.5.4 Emergency Radio and Cellular Distributed Antenna System (DAS).

2-3.5.4.1 Emergency Radio Codes and Standards.

- NFPA 1221
- NFPA 72® 24.9

2-3.5.4.2 Approval.

These radio systems are operating on frequencies assigned by a licensing authority to a jurisdiction, and coordination with the license holder and approval by the frequency manager or the FCC are required prior to installation. Coordination with the license holder should include a written approval.

The AHJ may require a permit be issued that is renewable after successful testing. This permit may be a condition precedent to an occupancy permit.

2-3.5.4.3 Cabling.

Cabling must be plenum-rated. Backbone cables are required to route through a 2-hour rated pathway from the donor antenna to the equipment enclosure matching the building's fire rating. Coordinate with the Fire Protection engineer for satisfaction of this requirement. Mount to the bottom of the communication tray where room is available or in a divided cable tray.

Connection between the backbone cables and the antenna cables must be made within an enclosure that matches the building's fire rating. Provide a 2-hour rated room to house the equipment.

In facilities where emergency responder radio coverage is required and such systems, components, or required equipment could have a negative impact on the normal operations of that facility, the fire code official has the authority to accept an automatically activated emergency responder radio coverage system. Reference NFPA 1221.

2-3.5.4.4 Coverage Area.

a. Design coverage and testing in accordance with NFPA 1221, Chapter 9. Predictive modeling software is recommended for design.

b. NFPA 1221 divides coverage into two categories. Critical areas are areas considered critical by the Fire Protection engineer. Examples include fire command centers, fire pump rooms, exit stairs, exit passageways, elevator lobbies, standpipe cabinets, and sprinkler sectional valve locations. These areas are required to have 99 percent floor area radio coverage. General building areas must be provided with 90 percent floor area radio coverage.

c. NFPA 1221 defines the requirement to have minimum inbound signal strength sufficient to provide usable voice communications. As this is difficult to quantify for design, the 2021 International Fire Code® (IFC®), Section 510 (a) 510.4.1.1 minimum signal strength of -95 dBm is recommended for use. The building is considered to have acceptable emergency responder radio coverage when signal strength measurements in 95 percent of all areas on each floor of the building meet the signal strength requirements of -95 dBm receivable and the agency's radio system can receive a signal strength of -95 dBm from transmissions inside the building.

d. Buildings may be well-served from existing terrestrial sources and not require radio communications enhancement systems. A survey of the signal strength outside the building combined with RF predictive software can go a long way in determining any need for enhancement. Equip buildings and structures that cannot support the required level of radio coverage with a system that includes RF-emitting devices certified by the radio licensing authority to achieve the required adequate radio coverage.

e. Design radio enhancement systems to support two portable radios simultaneously transmitting on different talk paths or channels, where the facility owner has required the radio enhancement system to support more than one channel or talk path.

f. In addition to quantitative signal strength requirements, qualitative requirements mandate that the signal have a delivered audio quality (DAQ) of 3.0 for either analog or digital systems, meaning that speech is understandable with slight effort, only requiring occasional repetition due to noise or distortion.

g. Consider spaces for pathway to a donor antenna and spaces for enhancement equipment during the design phase unless sure that enhancements will not be required. Drywall and glass must be installed in a building before preliminary functionality testing can be effective. This sometimes occurs late enough in the project that adding an enhanced system affects building occupancy dates.

2-3.5.4.5 Design Personnel Licenses and Certifications.

- general radio operator's license issued by the Federal Communications Commission (FCC)
- manufacturer certificate or nationally recognized organization certification

2-3.5.4.6 Isolation.

When a two-way radio communications enhancement system is installed, isolation between the donor antenna and all interior antennas must be a minimum of 20 dB under all operating conditions. Predictive RF design software should assist with proper placement of antennas near windows to maintain proper isolation.

2-3.5.4.7 Enclosures.

Equipment enclosures must be NEMA 4 or NEMA 4X, except for battery enclosures that require ventilation, and those must be NEMA 3R.

2-3.5.4.8 Interfaces with Facility Fire Alarm Control Panel.

When a two-way radio communications enhancement system is installed, numerous supervisory and trouble notifications must be reported to the Facility Fire Alarm Control Panel (FACP).

2-3.5.4.9 Testing.

Test in accordance with NFPA 1221, Chapter 11. The building floor is divided into 20 equal size test areas and a calibrated portable radio of the model used by the agency is used to talk through the agency's radio communications system. A test is conducted in the center of each test area as a pass/fail. Quantitative and qualitative readings are gathered, and a report produced. A spectrum analyzer must be used to ensure oscillations are not being generated by the amplified signal. The report must include the amplifier gain values and the results and is kept on file with the building owner.

2-3.5.4.10 Power Supply.

a. Provide at least two independent and reliable power supplies for all components, one primary and one secondary. The primary must be from a dedicated branch circuit and comply with NFPA 72®. The secondary power source must supply 12 hours of 100 percent system operation and be arranged in accordance with NFPA 10.6.10, or a battery system with 2 hours of 100 percent system operation and an automatic-starting generator service with a dedicated branch circuit arranged in accordance with NFPA 72®.

b. NFPA 1221 requires power supplies to be monitored by the system the same as for a fire alarm system.

c. Provide a dedicated annunciator within the fire command center to annunciate the status of all RF emitting devices and active system component locations. This device must provide visual and labeled indications of the following for each system component and RF-emitting device:

- normal AC power
- loss of normal AC power
- battery charger failure
- low-battery capacity (to 70% depletion)
- donor antenna malfunction
- active RF-emitting device malfunction
- active system component malfunction

d. The communications link between the annunciator and the two-way radio communications enhancement system must be monitored for integrity.

e. An emergency power off (EPO) switch may be required by the Fire Protection engineer to kill both the normal and redundant power supplies simultaneously.

2-3.5.4.11 Types of Systems.

Work with the building owner to determine the appropriate type of distribution system for the facility. Options are summarized in Table 2-12.

Table 2-12 Facility Distribution System Design Options

	System		
	Passive	**Active**	**Hybrid**
Distance	Limited	Extended	Extended in backbone
Horizontal Cable	Coax	Fiber or copper	Coax
Backbone Cable	Coax	Fiber	Fiber
Cost	Low	High	Medium
Advantages	• Lower cost, electronics for digital conversion not required • Power not required at the antennas	• Longest reach • Shares common building system infrastructure	• Extended backbone distances • Less expensive than active
Disadvantages	• Link budget calculations add to design complexity • Limited distance	• Dedicated power required at access points and antennas • Most expensive	• Installation complexity with multiple media types

2-3.5.4.12 Passive DAS Topology.

Passive DAS are typically used in spaces smaller than 80,000 square feet. They use coaxial cable, splitters, repeaters or bi-directional amplifiers and antennas to distribute the signal.

Passive systems can be single or multi-carrier and are cost-effective solutions. More extensive design adds to the complexity of the system.

2-3.5.4.13 Hybrid DAS Topology.

Hybrid systems combine use of active fiber backbone cable to intermediate nodes and distribute signals to passive antennas via coaxial cable.

2-3.5.4.14 Active DAS Topology.

Active DAS systems are often deployed in high-rise buildings and stadiums where distances between the source and antennas are long. They use a fiber optic head-end distribution to the intermediate nodes, and fiber or copper structured cabling for distribution to the antennas. The fiber is an APC solution, and the designer will need to work the selected solution vendors to design the system. Power is required for the access points and other equipment.

2-3.5.4.15 Cellular Coverage.

Work with the system owner to determine how the signal will enter the facility. The most common methods include:

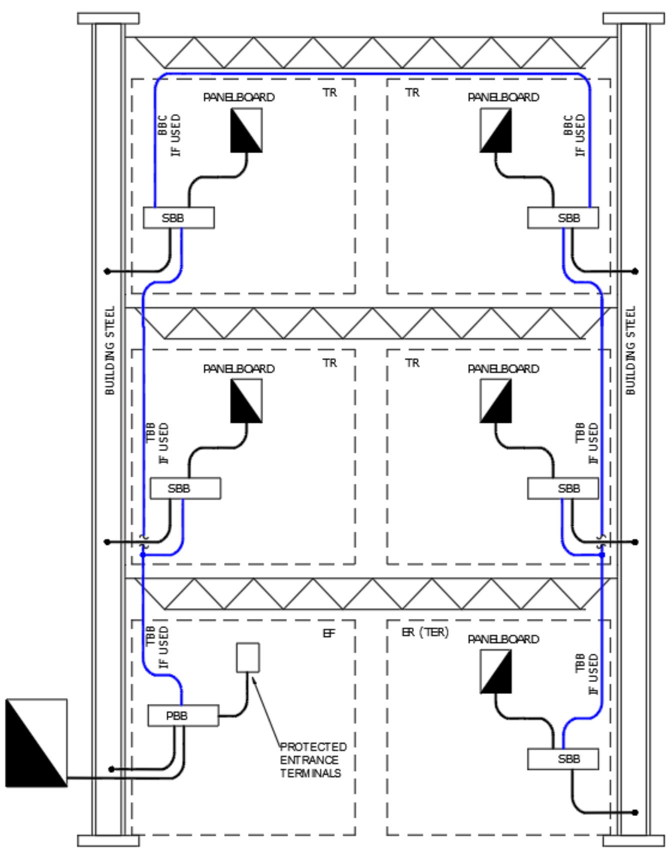
- Off air: The DAS uses an external donor antenna to capture cellular signals from local cell towers.
- Base Transceiver System (BTS): The DAS draws signals directly from the provider via optical fiber cables.
- Small cell: The DAS uses an internet connection to create a secure link to the carrier's network.

Coordinate and get approval for any devices that will amplify or distribute a licensed carrier's signals. If a multicarrier system is possible, all vendors are required to provide written approval of the design.

2-4 GROUNDING, BONDING, AND STATIC PROTECTION.

Comply with NFPA 70® for grounding and bonding requirements. Provide a telecommunications bonding and grounding system in accordance with TIA-607. Refer to Figure 2-12. Building grounding systems are covered in UFC 3-520-01.

Figure 2-12 Telecommunications Grounding and Bonding Infrastructure



BBC	Backbone Bonding Conductor
EF	Entrance Facility
ER	Equipment Room
GEC	Grounding Electrode Conductor
PBB	Primary Bonding Busbar
SBB	Secondary Bonding Busbar
TBB	Telecommunications Bonding Backbone
TBC	Telecommunications Bonding Conductor
TR	Telecommunications Room
TEBC	Telecommunications Equipment Bonding Conductor
RBB	Rack Bonding Busbar

Note: TIA-607 identifies a bonding conductor known as the telecommunications bonding backbone (TBB) which is intended to equalize potentials between TRs. The impedance of the TBB increases with length, thereby reducing its ability to equalize potentials between TRs. The ICT designer must consider that the TBB for a large site may be very costly to achieve. As an alternative, the SBB in each TR and PBB can be bonded to the electrical panel board in the space and to structural steel where applicable. Install bonding conductors in the shortest and most direct paths feasible.

Table 2-13 Grounding Terminology

TIA-607-B Term	TIA-607-C Term
Grounding equalizer (GE)	Backbone bonding conductor (BBC)
Telecommunications main grounding busbar (TMGB)	Primary bonding busbar (PBB)
Rack grounding busbar (RGB)	Rack bonding busbar (RBB)
Telecommunications grounding busbar (TGB)	Secondary bonding busbar (SBB)
Bonding conductor for telecommunications (BCT)	Telecommunications bonding conductor (TBC)

2-4.1 Cable Entrance Grounding.

Connect all metallic shields and strength members for outside plant cable entering a building to the electrical service grounding electrode system in accordance with NFPA 70®, Article 800. Bond the OSP cable shield, armor, and metallic strength member to the main building ground as close as possible to the building point of entrance with a No. 6 AWG or larger ground wire. When possible, preference is OSP cabling straight to the PET and not splice case. Use a non-bonded splice case for the transition from OSP-rated cable to interior-rated cable where a splice case is required by the AHJ. If the OSP cable extends past 50 feet (15 meters), bond the metallic strength member to the TBB with a No. 6 AWG or larger copper ground wire, as close to the conduit egress point as possible.

2-4.1.1 Protected Entrance Terminals.

Terminate all incoming OSP copper cables on UL-listed primary protector blocks located within the building entrance terminal cabinet. Provide protector blocks equipped with 5-pin solid state, gas, or hybrid protector modules for the number of pairs terminated plus 25 percent. Bond the protector blocks to the main electrical service ground via the PBB or SBB with a No. 6 AWG or larger copper ground wire.

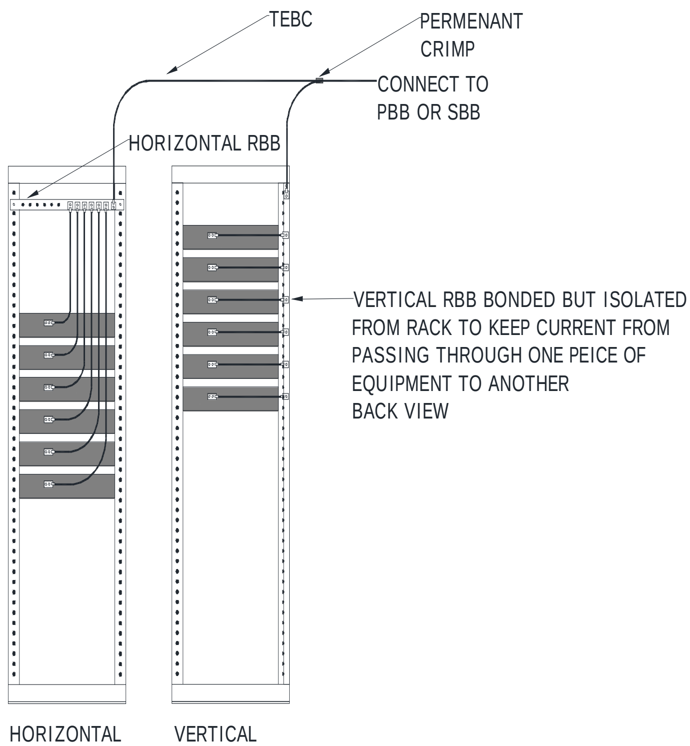
2-4.2 Telecommunications Spaces Bonding and Grounding.

Bond all telecommunications spaces and infrastructure in accordance with TIA 607 where applicable. When building steel is used as a grounding (earthing) electrode, the ICT distribution designer must specify that the telecommunications busbars be installed as close as practicable to a structural steel member within the ER, TR, or EF.

2-4.3 Telecommunications Rack and Supporting Structure.

Bond all telecommunications racks and supporting metallic structures (cable trays, ladders, conduits and baskets) in accordance with TIA-607and NFPA 70®. Non-continuous distribution systems (stub-ups, J-hooks) do not require bonding. Unless otherwise requested by the Telecommunications Manager, do not design rack bonding per Example C in TIA-607. See Figure 2-13 for allowable rack bonding methods. Only bond appliances that have manufacturer bonding connections available.

Figure 2-13 Rack Grounding and Bonding



2-5 TELECOMMUNICATIONS SYSTEM ADMINISTRATION.

Provide administration for the complete telecommunications system in accordance with TIA-606. Determine the minimum class of administration by evaluating the size and complexity of the premise infrastructure. Ensure the format for identifiers is backwards-compatible with TIA-606 for installations in existing facilities or per ISO/IEC TR4763-1 for new facilities unless otherwise directed by the Telecommunications Manager. Consult Appendix A and coordinate with the Telecommunications Manager for any additional service-specific labeling or administration requirements. Color-coding of telecommunications infrastructure and components is recommended, but not required. The DOR must identify the class of system in design documents.

CLASS 1 – Single equipment room (ER)

- the only telecommunications space (TS) administered
- no telecommunication rooms (TRs) and no cabling subsystem 2 and 3 cabling or outside plant cabling systems to administer

CLASS 2 – Single building served by multiple TRs

Identifiers included in Class 1 administration plus:

- one or more TRs within a single building
- cabling subsystem 2 and 3 cabling, multi-element bonding and grounding systems and fire stopping

CLASS 3 – Campus environment

Identifiers included in Class 2 administration plus:

- multiple buildings and building pathways, spaces, and outside plant elements

CLASS 4 – Multi-site (multi-campus)

Identifiers included in Class 3 administration plus:

- campus or site identifier

Labeling must be mechanically printed, except those requiring signatures, and must be legible.

2-6 TELECOMMUNICATIONS SYSTEM TESTING.

Installed backbone and horizontal telecommunications cabling and connecting hardware must meet minimum performance requirements and be tested in accordance with ANSI/TIA-568. Provide reports of all test results and certifications to the proponent and Telecommunications Manager upon completion.

2-6.1 Unshielded Twisted Pair Cabling and Connecting Hardware.

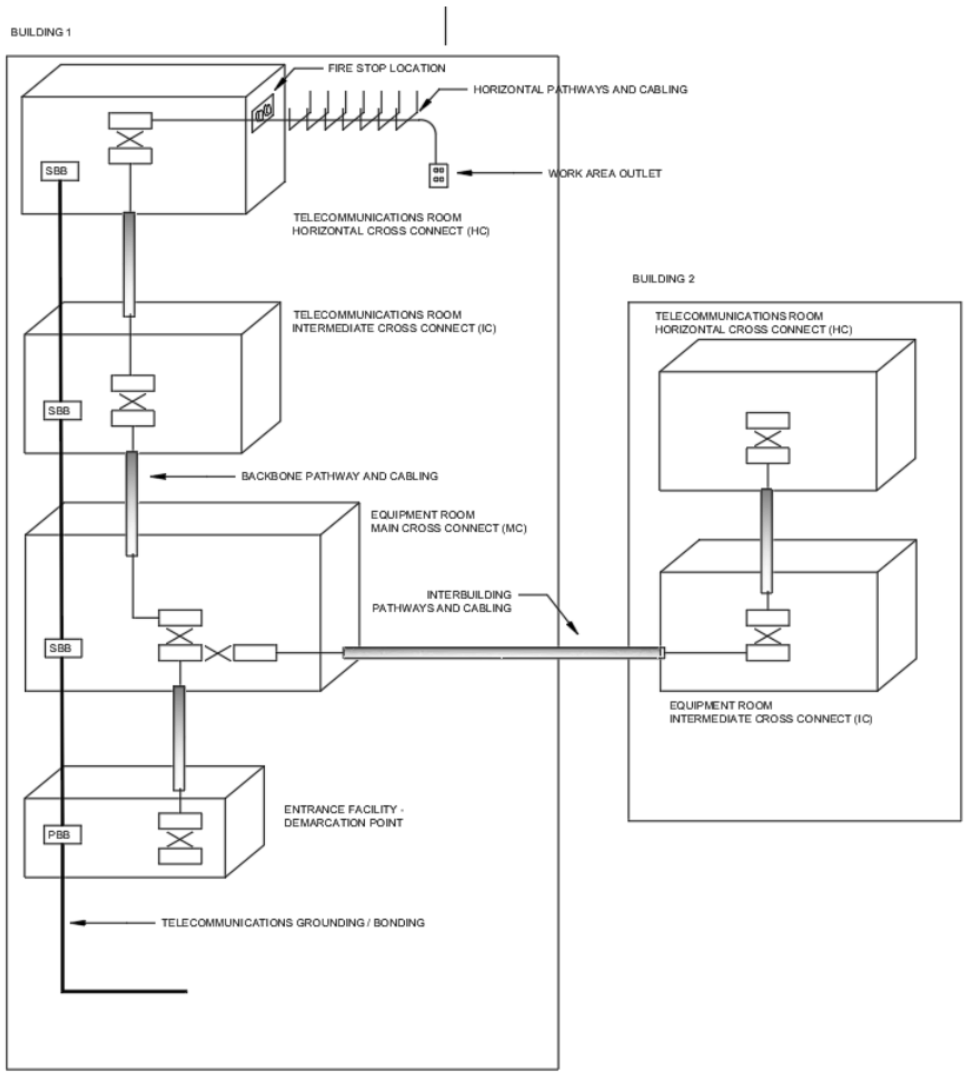
Perform all required testing to ensure minimum performance requirements are met in accordance with ANSI/TIA-568. There are different levels of certification test equipment for field testing and the correct level must be used to certify cabling plant.

Table 2-14 Certification Test Equipment Levels

Level	Frequency	Cable Category
IIe	100 MHz	5e and class D
III	250 MHz	6 and class E
IIIe	500 MHz	6A and class EA
IV	1000 MHz	8 and class F/FA*

*Currently, field tester accuracy to cover Class F cabling to 1000 MHz is not defined.

Figure 2-14 Telecommunications Labeling



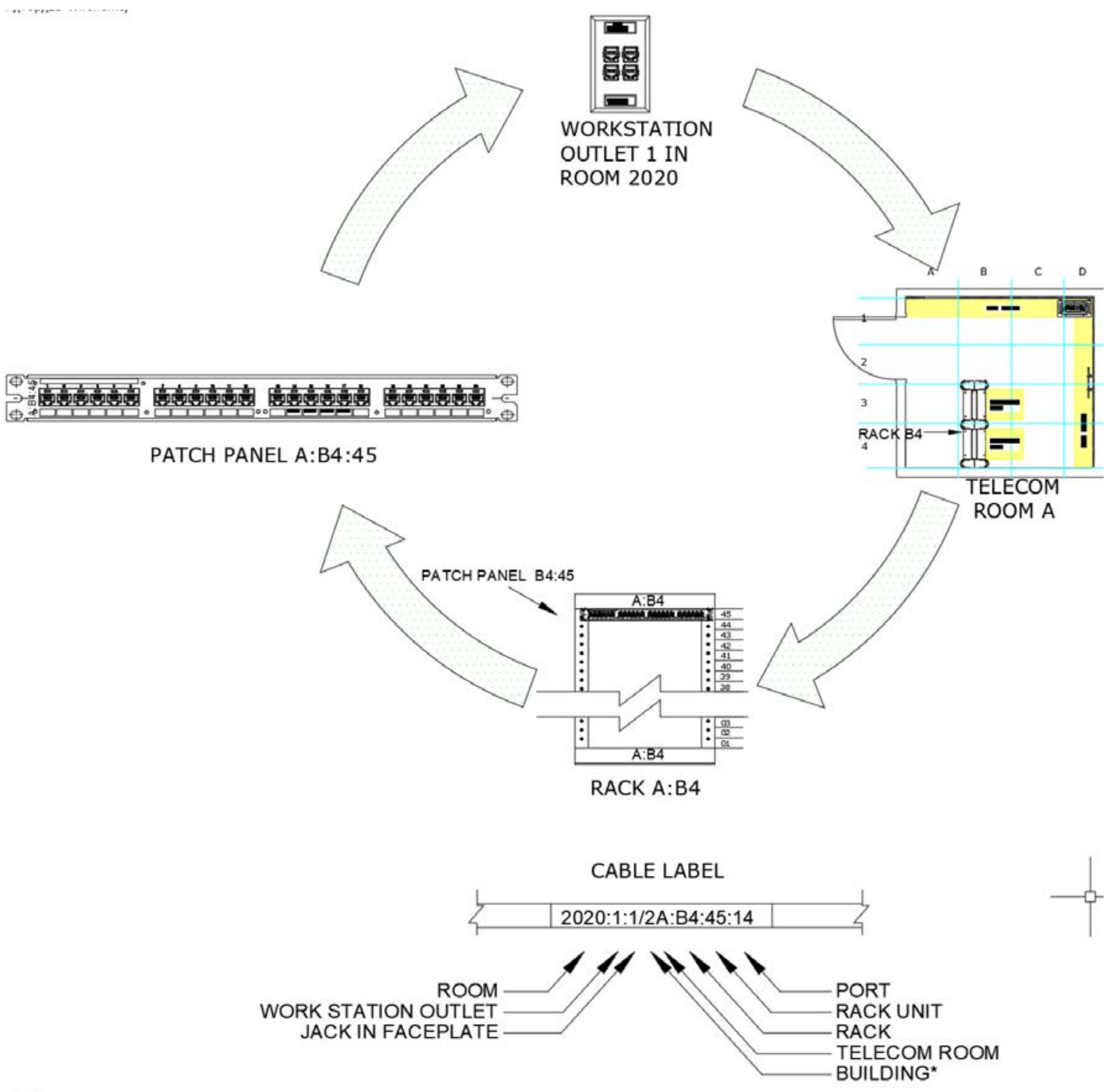
TELECOMMUNICATIONS INFRASTRUCTURE REQUIRED LABELING

Telecommunications spaces
• Entrance (where telecom networks enter the building)
• Telecommunications room
• Equipment room with switches, servers and routers

Pathways & Cabling
• Horizontal pathways
• Backbone pathways
• Interbuilding pathways

Fire Stopping Locations
Bonding Locations
Grounding Locations

Figure 2-15 Sample Labeling System



2-6.2 Fiber Optic Cabling and Connecting Hardware.

Perform all required testing in accordance with ANSI/TIA-568 on the link. Test the link at both standard frequencies bidirectionally for multimode and single mode. The testing method must comply with TIA 526-7A using the single jumper method.

An optical time domain reflectometer (OTDR) is required for all OSP and inside plant lengths in excess of 500 feet (152 meters) and when requested by the Telecommunications Manager using the launch cables and exit cables of the required length for the fiber type.

2-6.3 PON Testing and Certification.

Bidirectional loss at both 1310 nanometers and 155 nanometers must be conducted between the OLT and every cable in every ONT connected through the splitter.

2-6.4 Coaxial Cabling and Connecting Hardware.

Perform all required testing to ensure minimum performance requirements are met in accordance with ANSI/TIA-568.

2-6.5 Test Plan.

The contractor must submit for USG review a test plan of all proposed cabling and equipment being installed under the project. After the contractor has completed the installation and testing of the information technology system, the contractor must submit a test report for all fiber and copper cabling. The contractor's Registered Communications Distribution Designer (RCDD) must approve both the test plan and the test report before submitting to the USG.

Note: Test plans for small scale projects (less than 5,000 square feet (464.5 square meters)) described in paragraph 2-1.2 do not require RCDD approval.

The test plan must include, along with all testing system reports, a complete project test summary spreadsheet with indexed room numbers, outlet labels, jack labels, and the pass/fail status, and causes for failures along with a total number of outlets installed, jacks/cable runs installed and the total number of jacks/cable runs that passed and failed the tests. Failed tests require the contractor to correct the failures prior to turnover of the system. Testing, data, and analysis is required by the USG at the contractor's expense if original testing does not prove adequate for identifying causes of failures, and if the USG is responsible for paying for any repairs not within the original scope of contract.

The test plan will include subsequent testing of 5% of the cabling plant with the USGs quality assurance (QA) representative to verify that the contractor's quality control (QC) program is functioning correctly. Unsatisfactory results of the QA verification will require additional remediation of the QC plan.

2-7 COMMISSIONING.

Commissioning (Cx) of the telecommunications system must be accomplished for projects where more than passive equipment is provided. Cx must begin in the design phases and may extend beyond the building occupancy date. The designer must edit applicable Unified Facilities Guide Specifications (UFGS). They must include requirements for pre-functional checklists and submission of prefunctional testing, submittals reviewed and approved by the Cx Agent (CxA), development of functional checklists by the Commissioning Manager (CxM), establishment of roles and responsibilities, and test reports similar to those provided for mechanical and electrical systems. Commissioning activities must include required cybersecurity activities for FRCS systems in accordance with UFC 4-010-06.

Performance testing and operation of systems is required to ensure systems work in a coordinated manner and according to manufacturers' specifications, codes, rules, and standards. Commissioning also provides testing of failure modes and operational procedures in all modes, under all electrical conditions, both isolated and integrated with other systems. Commissioning a building system must clearly identify real and potential issues with the building system and the affiliated subsystems during all phases of the project.

2-8 NETWORK EQUIPMENT.

Active network equipment has unique requirements and considerations beyond the scope of this UFC. Any active equipment (controllers, IP switches, radios, IP-based components) must be designed in accordance with UFC 4-010-06, and may require a corresponding 25 05 11 specification.

CHAPTER 3 OUTSIDE PLANT CRITERIA

3-1 INTRODUCTION.

3-1.1 Scope.

This UFC provides a consolidated source of USG-approved standards and practices to facilitate the planning, design, construction, and installation of exterior unclassified OSP information communications technology infrastructure. This includes the minimum requirements for OSP spaces, pathways, cabling, and distribution systems. Special considerations may be given to unique circumstances that dictate a need to exceed the minimum criteria defined herein.

Standards and practices for planning, design, construction, and installation of classified information infrastructure must be coordinated with a Certified TEMPEST Technical Authority (CTTA) and Designated Accreditation Authority (DAA) responsible within that area. Hardened Carrier Distribution Systems (HCDS) are not within in the scope of this UFC and are expected to be fully compliant with CNSSI 7003.

3-1.2 Applicability.

Criteria and standards within this UFC are the minimum to provide DoD base/post/camps/stations (B/P/C/S) with efficient, economic, sustainable, scalable, maintainable, and reliable OSP information communications technology infrastructure. They apply to new work and upgrades and are not intended to be retroactively mandatory to existing, in-place infrastructure.

All construction performed outside the contiguous United States (OCONUS) is also governed by additional mandates that include SOFA, HNFA, and in some instances, BIA. Therefore, the team performing any planning, design, construction, and installation must ensure compliance with the most stringent requirements of any of these agreements that are in place.

3-1.3 Special Considerations.

Special considerations may apply in some locations involving aesthetics, historical preservation, archeological sites, environmental conditions, restricted areas, and wildlife preservation areas. These may include considerations such as use of underground pathways versus aerial; the type of building entrance; mounting of terminals; placement of pedestals; or routing of cables. Consultation is required prior to and throughout planning, design, construction, and installation of all OSP information communications technology infrastructure to ensure all special considerations are captured.

3-2 SPACE REQUIREMENTS.

3-2.1 Types of Outside Plant Supporting Structures.

3-2.2 Cable Vault.

A cable vault (CV) is an enclosed, unmanned information communications technology structure constructed of precast or cast-in-place reinforced concrete, is structurally solid, and installed underground to accommodate cables, splice enclosures, racking systems, low-voltage electronic equipment, lighting, and ventilation. Cable vaults are typically provided at core node and area distribution node (ADN) locations that require copper cable plant distribution to end user buildings (EUB) for voice services and/or support large concentrations of fiber optic cable (FOC). Cable vaults must not be shared with high or low voltage electrical equipment installations other than whatever low voltage equipment is required to support low-voltage electronic equipment and infrastructure within the space.

3-2.2.1 Size.

The cable vault must to future growth of 25 percent. At a minimum, the cable vault must extend the entire length of the main distribution frame (MDF) and have a minimum ceiling height of 7 feet (2.1 meters) above the finished floor (AFF). The cable vault must be designed to provide ample space for installation and splicing of all new and future cabling requirements.

3-2.2.2 Layout.

New cable vaults must be constructed to extend beyond the building’s external wall and provide one interior and one exterior personnel entrance with either a ladder or stairs to access the space. Each entrance hatch must be a minimum of 36 inches (914 millimeters) wide by 36 inches (914 millimeters) long to allow rescue personnel to safely enter the confined space in the event of an emergency while using a self-contained breathing apparatus. The interior and exterior walls of the cable vault must be properly sealed and waterproofed to protect the interior space from pests and environmental damage. Protected cage-style industrial lighting must be installed inside the cable vault to provide a minimum horizontal illumination of 50 foot-candles (fc) (500 lux) at 36 inches (914 millimeters) AFF within the space to support routine work operations and the passage of employees in a safe and healthful manner. The cable vault must be provided with adequate ventilation using an exhaust fan with a high-level exhaust stack and a low-level air intake to maintain safe oxygen levels and avoid harmful buildup of combustible gases as defined by the Occupational Safety and Health Administration (OSHA). The cable vault floor must be designed with a constant 1.0% slope elevation to a sump pit equipped with an electric sump pump for the removal of water that may enter the cable vault. The sump pit must be a minimum of 18 inches (457 millimeters) long by 18 inches (457 millimeters) wide by 18 inches (457 millimeters) deep with a grating cover of sufficient strength to support expected loads. The sump pump must be connected to a drainage line and stubbed out through the cable vault wall to the nearest storm drainage structure for sump pump discharge. An SBB must be installed in the cable vault to bond all metallic structures in accordance with the requirements of TIA-758. All vault electrical receptacles must be installed on a ground fault circuit interrupter (GFCI) circuit for the protection of personnel in accordance with NFPA 70®. Cable racking must be installed in the cable vault to support the splice enclosures required to splice the tip cables to the OSP cables. The center of the cable vault is preferred for the installation of cable racking; however, if required, cable racking may also be installed on the cable vault wall. Angled pulling tubes must be placed in the opposite wall in-line with the conduit entrance to facilitate installation of new and future cabling within the cable vault.

3-2.2.3 Maintenance Holes.

MHs are used to facilitate placement and splicing of OSP cables. The MH accommodates cables, splice enclosures, racking systems, and low-voltage electronic equipment. Telecommunications MHs must not be shared with high or low voltage electrical equipment installations other than whatever low voltage equipment is required to support low-voltage electronic equipment and infrastructure within the space. Measurements between MHs are from MH cover to MH cover, center-to-center (C-C), unless otherwise indicated. Measurements from MHs to buildings, pedestals, riser poles, and other structures are from the center of the MH cover to the outside wall, pedestal base, bottom of riser pole (center-to-point).

MHs are either precast or cast-in-place reinforced concrete structures provided with a removable lid that permits internal access to the housed components. All MHs must have an American Association of State Highway and Transportation Officials (AASHTO) working stress design minimum load rating is HS-20 for heavy vehicular traffic. Splayed MHs should be provided at main feed and distribution points where copper cables and high cable counts are planned.

A typical large MH interior size is 12 feet by 6 feet by 7 feet (3.7 meters [length] by 1.8 meters [width] by 2 meters [height]). A typical medium-sized MH is approximately 8 feet by 6 feet by 7 feet (2.4 meters by 1.8 meters by 2 meters). Other sizes and configurations may be used with approval from the COR for contract designs or the Government design lead for in-house designs.

3-2.2.3.1 Maintenance Hole Precast.

The preferred MH structure is precast reinforced concrete. Precast MH types are splayed, non-splayed, or multi-directional with cast-in single or multiple plastic duct terminators to accept the conduits. Splayed MHs are the preferred type when a precast MH structure is used. Suppliers of precast MH structures must have a National Precast Concrete Association (NPCA) certified manufacturing facility that implements and maintains a NPCA certified quality control program. MHs must be H-20 rated for continuous heavy vehicle traffic.

3-2.2.3.2 Maintenance Hole Cast-in-Place.

Cast-in-place MHs may be used where precast structures are not suitable (e.g., overbuild, unique shapes, and limited areas for hole placement). Cast-in-place MH structures must be constructed in accordance with Rural Utilities Service (RUS) Bulletins 1751F-643 and 1751F-644, using Class 1D concrete with high early strength Portland cement consolidated by mechanical vibration. RUS Bulletin 1751F-643,

Table 5, defines the reinforcement bar spacing for each category of structure. If the category of a cast-in-place MH structure is not explicitly stated in the design criteria, the minimum category for the precast MH structure must be 10.0. Conduit window locations and attachment points must be designed so core drilling is eliminated and drilling for anchors is minimized to the greatest extent possible. Drawings for all proposed cast-in-place MH structures must be submitted for approval prior to construction. Drawings must depict the conduit locations, size, and placement of structural reinforcement bars.

3-2.2.4 Hand Holes.

Hand Holes (HH) are reinforced concrete units provided with a removable cover that permits internal access to the housed components. The acceptable pull-point HH size is 4 feet by 4 feet by 4 feet (1.2 meters by 1.2 meters by 1.2 meters) and should be placed only as the last structure before a EUB and where there is no possibility that the conduit system will be extended. The acceptable splice-point HH size is 6 feet by 4 feet by 4 feet (1.8 meters by 1.2 meters by 1.2 meters). HHs with larger dimensions are considered to be MHs. An HH should not be used in place of an MH in a main conduit system. HHs should not contain more than four, 4-inch conduits per wall. Telecommunications HHs must not be shared with high or low voltage electrical equipment installations other than whatever low voltage equipment is required to support low-voltage electronic equipment and infrastructure within the space. All HHs must have an AASHTO working stress design minimum load rating of HS-20 for heavy vehicular traffic, or the Tier 22 rating.

3-3 SUPPORTING STRUCTURE REQUIREMENTS.

3-3.1 Common Installation Practices.

New OSP supporting structures must be installed and placed to support the locations of junction points, offsets, load points, and curvatures within the conduit run. Spacing of OSP supporting structures is determined by the environment (e.g., cantonment or range area); cable type (e.g., copper cables only; fiber optic cables only, or copper and fiber optic cables); number of changes in direction (e.g., bends); cable reel length; proximity to cable origination and termination points; and allowable pulling tension of the cable. Subparagraphs (a) through (k) list a few required common installation practices:

a. Additional MHs or HHs are required once the total number of changes within the planned route exceed 180°.

b. MHs and HHs that contain copper cables of 600 pairs or greater must not be spaced more than 600 feet (180 meters) apart, provided the restriction noted in subparagraph (a) is not exceeded.

c. MHs and HHs that contain both fiber optic and copper cables of less than 600 pairs can be spaced in excess of 600 feet (180 meters), provided the restriction noted in subparagraph (a) is not exceeded.

d. MHs and HHs used as splice points in direct buried applications can be placed as required within the planned route.

e. OSP supporting structures must be installed on a leveled, crushed, washed gravel base of sufficient depth, not less than 6 inches (150 millimeters) in thickness under the entire OSP supporting structure, to allow for proper drainage and stability. The gravel base must extend 1 foot (300 millimeters) beyond the entire perimeter of the OSP supporting structure. Refer to Figure A-19 to show placement of gravel base.

f. Installation of OSP supporting structures must comply with the American Society for Testing and Materials (ASTM) C891-19.

g. Precast concrete supporting structures must be manufactured in accordance with ASTM C858-19.

h. Flowable fill (slurry) must be used to fill in the voids up to the base of the paved areas around all OSP supporting structures. Refer to Figure A-16.

i. In geographical areas with a high-water table, OSP supporting structures must be designed to mitigate the risk of buoyancy (floating) in accordance with the American Concrete Pipe Association (ACPA), *Design Data (DD) 41 - Maintenance Hole Flotation*. Any deviations from these guidelines require approval of the USG. A spreadsheet calculator can be found at https://www.concretepipe.org/wp-content/uploads/2014/09/DD_41-Manhole-Flotation-Analysis.xls to determine if the MH installation is stable with respect to buoyancy. Additional buoyancy design criteria can be found on the NPCA web site at: https://precast.org/wp-content/uploads/2018/11/BuoyancyWhite-Paper2018.pdf.

j. The annular area, which is the space between the walls of the OSP supporting structure and the conduits, must be sealed to prevent infiltration of water, debris, rodents, insects, and other foreign matter.

k. Some OSP supporting structures may require alarm systems to be installed and must be validated with the authorizing official or the PDS owner.

3-3.2 Common Maintenance Hole/Hand Hole Structural Components.

Each new MH/HH must be equipped with an egress frame and cover, grade ring, physical security, exterior attachment hardware (secure and non-secure applications), sump, and interior hardware (e.g., pulling irons, cable racks/hooks). All components must be designed for use within the MH/HH structural space.

3-3.2.1 Egress Frame and Cover.

The MH/HH structure must include a frame and cover to provide a point of egress for maintenance personnel. Egress frame and cover design criteria are defined based upon the area of installation; traffic areas or non-traffic areas. MH/HH structures placed in or near traffic areas must meet the following criteria:

- The frame and cover must be circular and not less than 30 inches (765 millimeters) in diameter and must meet or exceed the AASHTO working stress design minimum load rating of HS-20 for heavy vehicular traffic of the MH/HH structure.
- The cover must fit into a steel frame and, at a minimum, be at grade level, unless otherwise dictated by project installation design.

Oversized frames and covers and/or additional covers may be used for MH/HH structures with special requirements (e.g., supporting structures containing carrier or loading equipment, or supporting structures in congested areas). Steel double hatched cover sidewalk doors are preferred for shallow MH/HH structures with an interior working height of less than six feet (1.8 meters) AFF and placed in non-traffic areas.

3-3.2.2 Grade Rings.

The MH/HH structure must include a grade ring that meets the following minimum design criteria:

- Grade rings must be precast concrete and meet all requirements of ASTM C478/C478M-20. Grade rings must be a minimum of 6 inches (150 millimeters) in height.
- Grade rings must incorporate slots or holes to accommodate 0.75-inch (20-millimeter) diameter frame anchor bolts, unless otherwise specified by the structural engineer.
- When grade ring sections are stacked, grade ring sections must be precisely matched with each other and contain no overhangs to prevent injury to personnel and/or equipment entering or exiting the MH/HH.
- Grade rings installed with cracks or fractures passing through the height of the grade ring, or any continuous crack extending for a length of 3 inches (75 millimeters) or more is unacceptable and will be rejected.
- Grade rings installed with damaged edges which prevent completing a satisfactory joint are unacceptable and will be rejected.
- Installation without a grade ring must be approved by the civil engineer. **Note:** Installation without a grade ring would provide only 10 inches (250 millimeters) of cover (height of egress frame and cover) over the MH.

3-3.2.3 Physical Security.

Lockable cover(s) must be provided for the MH/HH structure when required by the project documentation and/or the site owner. When required, the lockable cover uses a lever and clamp mechanism placed into a receiver installed within the cover. The mechanism should allow the cover to be replaced without indexing the cover to the frame. When in a locked position, the mechanism must be flush with the frame surface, minimizing the potential for the cover to be dislodged. The bolt used to secure the cover must be accessible only by using a special adapter that can be turned only with a socket provided by the manufacturer. The securing bolt design for the cover is available in several different manufacturer's configurations. The desired manufacturer and bolt configuration will be determined by the site owner. A disposable tamper-evident plastic cap that snaps into the locking body mechanism's covering housing the recessed bolt must be installed to help keep dirt and other debris out of the bolt area.

3-3.2.4 Exterior Attachment Hardware.

3-3.2.4.1 Attaching Hardware for Non-Secure Applications.

Two anchoring methods may be used when attaching frames and frames with grade ring(s) to non-secure MH/HH structures:

- Drop-in Anchors: If drop-in anchors are used, each anchor must be a minimum of 0.7 inches (20 millimeters) in diameter. Drop-in anchors must be installed in accordance with the manufacturer's recommendations using the manufacturer's recommended concrete adhesive best suited for the environmental conditions at the installation site. Prior to setting the drop-in anchor, the anchor hole must be brushed and blown out thoroughly to remove all foreign contaminants that could affect proper adhesion.
- Wedge Anchors: Wedge Anchors are acceptable for non-secure applications. When using wedge anchors, the drill bit and anchor diameters are equal. Concrete adhesive cannot be used for wedge anchors, as there is insufficient space between the anchor and concrete for the adhesive to bond.

Anchoring components used for attaching frames and frames with grade ring(s) to non-secure MH/HH structures must satisfy the testing conditions defined in ASTM E488/E488M-18 or equivalent standard. The USG reserves the right to randomly select and test anchoring components for compliance.

3-3.2.4.2 Attaching Hardware for Secure Applications.

Attachment of frames and frames with grade ring(s) to secure MH/HH structures can be accomplished by mechanical methods, non-mechanical methods, or by a combination of both. To attain maximum physical security of the MH/HH structure, a combination of the methods must be used. Levels of security for each method or combination of methods are shown in Table 3-1.

The mechanical method of attachment uses drop-in anchors installed in accordance with the manufacturer's recommendations using the manufacturer's recommended concrete adhesive as described in paragraph 3-3.2.4.1. Additional physical security is attained by replacing the anchors' standard fasteners with tamper-proof fasteners.

The alternative non-mechanical method of attaching frames and frames with grade ring(s) to the MH/HH structure is to use a Type 1, epoxy-resin-base bonding system that satisfies the requirements of ASTM C881/C881M-20a. The epoxy-resin-base bonding system must be applied in accordance with the manufacturer's recommendations and procedures.

Table 3-1 MH/HH Physical Security Levels

Method	Description	Security
1	Mechanical: Tamper proof fasteners	Low
2	Non-mechanical: Type 1 epoxy	Medium
1 & 2	Combination of mechanical and non-mechanical	High

3-3.2.5 Sump.

A sump must be cast into the floor of the MH/HH structure. Design the floor of the MH/HH structure with a constant 1.0% slope to a sump located in the center for the removal and proper drainage of water that may enter the MH/HH. The sump must be a minimum 13-inch by 13-inch (330-millimeter by 330-millimeter) square or a 13-inch (330 millimeter) diameter circle. Either choice must be a minimum of 4 inches (100 millimeters) in depth and covered with a removable grated or perforated cover of sufficient strength to support expected loads.

3-3.2.6 Interior Hardware.

Interior hardware typical for most common MH/HH structure sizes is listed in the Table on Figure A-5. Interior hardware, to include cable pulling irons, cable racks, cable rack supports, and any other interior hardware accessories required, must be corrosion resistant. Size and location of MH/HH structure interior hardware must conform to RUS Bulletin 1751F-643 and RUS Bulletin 1753F-151 to support the weight of the cable(s) and splice case(s). Provide corner racks at the in-line end of the MH/HH structure. A device or method to lock the hooks to the cable rack (step locks) must be provided for all hooks that will be installed to support splice cases.

3-3.3 Water Resistance.

Reasonable efforts must be made to prevent water from infiltrating all OSP supporting structures. At a minimum, apply the following guidelines as long as they do not violate the manufacturer’s recommendations or product warranty.

- Place water-resistant gaskets or seals between the sections of pre-cast OSP supporting structures.
- Place water-resistant gaskets or seals between the cover(s), frame(s), grade ring(s), and OSP supporting structure top(s).

3-3.4 Stenciling.

Stencil new OSP supporting structures inside the structure with an identifier designated by the site owner. Place the stencil near the top of the OSP supporting structure so that it is visible when the cover is open. In addition, conduit windows in both new and reutilized OSP supporting structures must be stenciled (if not already) to denote where conduits are connected.

3-3.5 Grounding.

New supporting structures, regardless of size, must have an integrated ground system, and be clearly identified by the manufacturer, either on drawings or inside the supporting structure. A bonding ribbon must be installed around the interior of each supporting structure so that splice cases and rack anchors can be bonded. Install a bonding ribbon in each half of two-part MHs. Permanently bond the top and bottom ribbons to the integrated ground system.

New splice cases and cases that are reopened and contain conductive elements (e.g., conductors, metallic sheaths, armor, and strength members) must be bonded to the grounding straps system or the existing grounding system. Never open an underground cable sheath for the sole purpose of bonding it to ground.

3-3.5.1 Ground Rod.

For existing underground supporting structures not equipped with an integrated ground system, or older structures requiring supplemental ground rods, ground rods must be steel that is copper-clad and a minimum of 0.75 inches (20 millimeters) in diameter and a minimum of 10 feet (2.75 meters) long. Ground rods must meet requirements and be installed in accordance with NEMA GR 1. Four inches (100 millimeters) of the rod, plus or minus 0.5 inches (13 millimeters), must extend above the finished floor level, if installed in the existing MH. The rod must not enter the supporting structure more than 3 inches (80 millimeters) or less than 2 inches (50 millimeters) from the vertical surface of the adjacent wall. Ground rod electrodes must be permanently and legibly marked with the manufacturer’s identification, and the catalog or equivalent designation within 12 inches (300 millimeters) of the driving end of the ground rod electrode.

3-3.5.2 Ground System Inspection.

Grounding system connections must be verified for mechanical tightness. Tighten loose connections to the manufacturer’s specifications. Inspect grounding electrode system terminations for evidence of corrosion. Clean areas of corrosion and treat with corrosion inhibitor. For in-building grounds, accomplish two-point bonding resistance measurements to verify resistance less than 100 milliohms (0.1Ω) between any two points. For alternating current (AC) and direct current (DC) measurements, amperage measurements should be taken on all accessible grounding electrode conductors to verify less than one AC ampere (1A) and less than five hundred milliamperes (500 mA).

3-3.5.3 Bonding Ribbon.

Bonding ribbon placed around the inside perimeter of the CVs, MHs, and HHs (halos) is not required if they are equipped with an integrated ground system.

3-4 EXTERIOR PATHWAYS.

OSP telecommunications infrastructure projects include several general requirements that must be accomplished prior to the start of any work. These include, but are not limited to, determination of rights-of-way, utility locates, digging permits, traffic closure procedures, crossing obstructions, rock excavation, and unstable soil excavation. These requirements and conditions must be captured, documented, and reviewed with the local government zoning authority to determine proper local procedures.

3-4.1 Utility Easement/Rights-of-Way.

A utility easement/rights-of-way is written permission established to allow aboveground or underground physical infrastructure to be placed along a specific route through a property that belongs to another landowner or federal, state, or local municipality. Some projects may require OSP telecommunications infrastructure to pass through these utility easements/rights-of-way requiring a documented utility easement/rights-of-way to be established. Approval must be established and obtained within a timely manner with the AHJ prior to the start of any work to ensure compliance and to ensure use of new and existing utility easements/rights-of-way is maximized.

3-4.2 Existing Utility Location.

Utility location is the process of identifying and marking existing underground utilities such as telecommunications, electrical distribution, natural gas, storm drainage, water mains, wastewater pipes, and is required to be done prior to the start of any excavation work. The site owner is responsible for the processes and procedures for performing utility locates. Coordination with the Directorate of Public Works (DPW) to ensure strict adherence with these processes and procedures are followed, and to ensure the required lead times to completion are captured. - The utility marking paint must adhere to the American Public Works Association (APWA) Uniform Color Code, be clearly visible, and chalk based not permanent. The utility location marks at the work location must be maintained until the work is completed and they are no longer required.

3-4.3 Existing Utility Verification.

Utility verification is required to positively determine the exact location and depth of the marked utilities and obstructions within the excavation area to avoid damage and safety risks to personnel. The exact location of existing utilities can be determined only by physically seeing the utility. The preferred method for utility verification at each work location must be coordinated with the site owner. Acceptable methods for utility verification are described in paragraphs 3-4.3.1 and 3-4.3.2.

3-4.3.1 Pot holing.

Pot holing is the practice of digging a test hole to provide visual confirmation of underground utilities or obstructions within 24 inches (600 millimeters) of a proposed excavation site to avoid potential damage. When pot holing in road surfaces, the initial hole must be no larger than 12 inches by 12 inches (300 millimeters by 300 millimeters). There are several pot holing methods:

- Hand digging. Hand digging is the safest method of pot holing where digging is accomplished manually with handheld equipment such as a spade shovel.

- Machine digging. Machine digging is the method of digging by mechanical means with heavy equipment such as a backhoe. Powered excavation equipment is not allowed within 24 inches (60 millimeters) of either side of a utility location marking. Clearance restrictions may vary depending on the site owner.

- Vacuum excavation (e.g., slot trenching). Vacuum excavation uses either air or water pressure to break up the soil and a vacuum device to collect the spoils. This technique may be used within congested areas having poorly marked underground utilities and obstructions that cannot be avoided.

3-4.3.2 Ground Penetrating Radar.

Ground penetrating radar (GPR) is a technology that uses radar pulses to image the subsurface area of the earth. This technology can be used to non-destructively locate subsurface objects and structures in various materials such as soil, rock, concrete, asphalt, wood, and water. In historical locations or areas where the existing utility infrastructure is over 35 years old, GPR must be employed to the greatest extent possible to ensure that planned routes are clear of undocumented obstacles.

3-4.4 Digging and Excavation Permits.

Digging and excavation permits complying with all local codes, ordinances, and regulations must be obtained from the site owner prior to starting any excavation and/or construction work. It is highly recommended that all involved parties carefully plan and execute this portion of the project in unison to avoid unexpected problems.

3-4.5 Traffic Closures.

Roadways and parking lots must be closed only for as long as is necessary to complete the project work. Traffic closures must be coordinated with the site safety office. Construction signs, flag personnel, rerouting of traffic, cutting restrictions, and steel plates may be required.

3-4.6 Crossing Obstructions.

3-4.6.1 Paved Surface Crossing.

Pavement crossings must be constructed using one of the following methods: cutting or sawing perpendicularly across the pavement (commonly known as a “T” cut); trenching perpendicularly across the pavement; horizontal directional drilling (HDD) under the pavement; or jack and bore under the pavement.

The preferred method for crossing a paved surface is cutting or sawing perpendicularly across the pavement. When this method is used, concrete encasement is required. The concrete encasement must extend a minimum of 6 feet (1.8 meters) beyond the road bed on each side. If concrete encasement is not practical, then an alternative method that meets the required loading conditions is permitted (e.g., galvanized steel rigid metallic conduit (RMC)). Depending on the location, single step or double step “T” cuts may be required by the site owner. Cutting and restoration of paved crossings must be coordinated with the site owner.

Note: Jack and bore and/or directional drilling must be used only for special circumstances. If additional sections of pipe are required to be welded during the process, local Fire and Safety personnel must be notified.

3-4.6.2 Paved Areas.

OSP supporting structures placed within paved areas must be backfilled with flowable fill (slurry).

3-4.6.3 Range Road Crossing.

For road crossings on installation ranges, concrete encasement must be extended a minimum of 6 feet (1.8 meters) beyond the edges of the road bed on each side. If concrete encasement is not practical, then an alternative method that meets the required loading conditions is permitted (e.g., galvanized steel RMC).

3-4.6.4 Railroad Crossing (Underground).

Push and bore with steel casings is the preferred method for railroad crossings unless otherwise dictated by the commercial railroad owner. Where multiple conduit formations are placed, a minimum of a 12-inch (300-millimeter) diameter steel casing, with a minimum wall thickness of 3/16 inch (5 millimeters) must be used. The casing must extend no less 12 feet (3.7 meters) beyond the centerline of the track or the outermost track if multiple tracks are crossed. The casing must be located no less than 50 inches (1.27 meters) below the top of the rails in accordance with the National Electrical Safety Code® (NESC®). In addition, the casing must be no less than 36 inches (900 millimeters) below the bottom of any crossed drainage ditch adjacent to the railroad bed.

HDD must not be used to place conduits below commercial railroad beds. HDD is not the preferred method of placing conduits below USG railroad beds; however, if HDD is used, the conduit must be placed a minimum of 15 feet (4.6 meters) below the railroad bed in typical soil. The conduit must be placed at such a depth so that standard E-80 live and impact loads of 80,000 lb/ft (119,500 kg/m) must not produce more than five percent deflection in the proposed conduit formation.

3-4.6.5 Pier and Bridge Crossings.

Coordinate design and installation for crossing military, commercial, and privately owned piers and bridges and accomplish in accordance with the requirements and procedures dictated by the state and local bridge authorities, and USG bridge authorities.

Conduit systems installed on all piers or bridges must employ either polyvinyl chloride (PVC) coated steel RMC or red-threaded fiberglass conduit (RTFC), which is the preferred choice. Either conduit type used must be installed using only manufacturer-approved hardware (e.g., hangers).

Place pull boxes at all critical points within the conduit run. Critical points include where the structure has a change in direction, where access for a ship berth is required, and at 90-degree bends. Conduit expansion joints are required at each pier or bridge expansion joint and within approximately 5 feet (1.5 meters) of where the conduit enters a distribution point.

Place expansion joints in the raceway system to coincide with the expansion joints in the structures that are supporting the raceways.

3-4.7 Rock.

Excavate rock from all areas where OSP supporting infrastructure will be placed. Rock excavation is excavation of all hard, compacted, or cemented materials that require use of ripping and excavating equipment larger than defined for common excavation.

Unclassified excavation is excavation of all materials encountered, including rock materials, regardless of their nature or the manner in which they are removed.

3-4.7.1 Classifications.

Refer to the United States Department of Agriculture (USDA) Natural Resources Conservation Service “National Engineering Handbook” Part 631, dated January 2012, for classifications of rock and excavation.

Rock is defined as limestone, sandstone, granite, or similar aggregate found in solid beds or masses in the original or stratified position which can be removed only by continuous drilling, blasting, or use of pneumatic tools. Pavement is not to be considered rock.

Rock which cannot be moved without systematic drilling, blasting, or use of a rock saw includes:

- boulders measuring 0.5 cubic yard (yd^3) (0.382 cubic meter [m^3]) or larger
- other material such as rock in ledges, bedded deposits, un-stratified masses, and conglomerate deposits
- below-grade concrete masonry structures

Table 3-2 Excavation Characteristics of Rock[1]

Classification Elements	Class I	Class II	Class iii
	Very hard ripping to blasting	Hard ripping	Easy ripping
	Rock material requires drilling and explosives or impact procedures for excavation may classify as rock excavation	Rock material requires ripping techniques for excavation may classify as rock excavation	Rock material can be excavated as common material by earth-moving or ripping equipment may classify as common excavation
Head cut erodibility index, k_h [1]	$k_h \geq 100$	$10 < k_h < 100$	$k_h < 10$
Seismic velocity, approximate	> 8,000 ft/s (> 2,450 m/s)	7,000–8,000 ft/s (2,150–2,450 m/s)	(< 7,000 ft/s (< 2,150 m/s)
Minimum equipment size (flywheel power) required to excavate rock. Machines assumed to be heavy-duty, track-type back-hoes or tractors equipped with a single tine, rear-mounted ripper.	260 kW (350 hp), for $k_h < 1,000$ 375 kW (500 hp), for $k_h < 10,000$ Blasting, for $k_h > 10,000$	185 kW (250 hp)	110 kW (150 hp)

3-4.7.2 Excavation.

Excavate rock to a minimum of 6 inches (15 millimeters) below the excavation depth required for placement of conduit formation or cable. Prior to placing the conduit or cable, the contractor must backfill the rock excavation and all excess trench excavation with a cushion of sand at least 6 inches deep. Refer to Figure A-23 for additional excavation details.

[1] **National Engineering Handbook Part 628 Dams**, Chapter 52 Field "Procedure Guide for the Headcut Erodibility Index", Section 52-1, "The head cut erodibility index, k_h, represents a measure of the resistance of the earth material to erosion. The index is the scalar product of the indices for its constituent parameters. The index takes the general form:

$$k_h = M_s \times K_b \times K_d \times J_s$$

Where:

M_s = material strength number of the earth material
K_b = block or particle size number
K_d = discontinuity or interparticle bond shear strength number
J_s = relative ground structure number"

3-4.8 Soil Types.

Soil classification is defined in OSHA Standard 29 CFR 1926 Subpart P, Appendix A. The soil classification system identified in this subpart provides a method of categorizing soil and rock deposits based upon a hierarchy of their stability in decreasing order -- Type A, Type B, and Type C. The categories are determined based on an analysis of the properties and performance characteristics of the soil and rock deposits and the environmental conditions. Type C consists of mostly unstable soil and rock deposits and is considered the most dangerous of the soil types. Unstable soil and rock deposits are defined as soil and rock that by physical characteristics will not stay in place on its own and therefore will require the use of shoring and/or sloping to hold in place. In locations where unstable soil and rock deposits are identified, the unstable soil and rock deposits must be removed to establish a sound base capable of properly supporting the OSP supporting infrastructure.

3-5 SPECIAL CONDITIONS.

Most DoD locations contain areas that may be affected by special conditions. These special conditions must be discussed and documented with the site owner. All procedures from the AHJ must be followed.

3-5.1 Building and Landscape Aesthetics.

Building and landscape aesthetic standards establish an appropriate theme within an area of development without jeopardizing the historical, cultural, and environmental fabric of an installation and its surrounding community. The goal is to maximize the visual and environmental assets and to minimize liabilities, while enhancing the ability of the installation to continue to perform its mission requirements. Assets are visual or natural elements that enhance the image, environmental quality, or sustainability of the installation and must be preserved, enhanced, replicated, and incorporated into the overall OSP supporting infrastructure design. Visual and natural elements include architecture, roads and paths, parking areas, landscape, signage, site furnishings, lighting, utilities, and security. Liabilities are elements or features that detract from the visual image, environmental quality, or sustainability of the installation. Liabilities must be identified so they can be eliminated and avoided. Strict coordination must be accomplished with any local building and installation design requirements and procedures to ensure that visual and environmental assets are incorporated into the OSP, supporting infrastructure design, mitigating liabilities, and preserving the historical, cultural, and environmental character of the installation.

3-5.2 Historical and Cultural Preservation.

Military installations contain an abundance of historical and cultural locations that must be considered when planning for the installation of OSP supporting infrastructure. Historical and cultural locations include historical buildings, structures, objects, districts, landscapes (e.g., battlefields), and archaeological sites that are eligible for or listed in the National Register of Historic Places, as well as sites sacred to federally recognized Native American tribes. During planning, detailed coordination must be conducted with the local historical and cultural resource managers to ensure strict adherence to any local building and installation design requirements and procedures for these locations. Early identification and planning in these locations will help to avoid project delays and additional required funding resulting from inadvertent discovery of historical and cultural resources within the proposed project areas. In addition, any federal, state, and local environmental laws, requirements, and policies must be considered and prioritized throughout this process.

3-5.3 Natural Resource Preservation.

Military installations contain an abundance of natural resources that must also be considered when planning for the installation of OSP supporting infrastructure. Natural resources include threatened and endangered species, wetlands, wildlife preservation areas, forests, undisturbed land, and viewsheds. During planning, detailed coordination must be accomplished with the local natural resource manager to ensure strict adherence to any local installation design requirements and procedures for these locations. Early identification and planning in these locations will help to avoid project delays and additional required funding resulting from inadvertent discovery of impacted natural resources within the proposed project areas. In addition, any federal, state, and local environmental laws, requirements, and policies must be considered and prioritized throughout this process.

3-5.4 Restricted Areas.

Restricted areas on an installation must be avoided during planning and execution of OSP supporting infrastructure installations. Restricted areas include, but are not limited to, areas that contain unexploded ordinance (UXO), hazardous soils, human remains, biological hazards, and landfills. During planning, if it is determined that work within a restricted area cannot be avoided, detailed coordination must accomplished with the site owner to ensure strict adherence to any local installation design requirements and procedures for these locations. In addition, restricted areas of work that contain contaminated soils must comply with the local requirements and procedures for proper removal and disposal of these contaminated soils and/or waste materials. Early identification and planning in locations that contain potential restricted areas will help to avoid project delays and additional funding.

3-6 UNDERGROUND PATHWAYS.

Underground pathways consist of conduit structures used for installation of OSP cable plant between different points of access. Employ practices described this section for design and installation of underground pathways.

3-6.1 Trenching.

Trench width and depth must be determined by the minimum requirements to support the size of the conduit formations, spacing between the conduits, required embedment, and required soil cover. At a minimum, at least 24 inches (600 millimeters) of cover is required above the top of the conduit formation. At least 18 inches (450 millimeters) of cover is required under roads or sidewalks. For conduits installed in solid rock, the cover must consist of at least 6 inches (150 millimeters) of concrete. If rock is encountered below grade, the minimum cover above the concrete-encased conduit must be 12 inches (300 millimeters).

3-6.2 Frost Line.

Movement of underground pathways due to frost heaving can cause damage to OSP cabling. The 50-year frost line data must be used to determine the underground pathway depth requirements. The top of the underground pathway must be buried below the frost line. In areas where frost lines exist at excessive depths, determine the minimum depth requirements to support local frost line requirements.

3-6.3 Shoring and Benching.

The contractor must rigorously adhere to the OSHA, host nation, and local requirements for shoring or sloping. For CONUS projects, the contractor must follow the safety and trenching requirements in 29 CFR 1926, Subpart P. The contractor must follow the specification of Appendix B, 29 CFR 1926, Subpart P. The trench width for conduit must be wide enough to permit tamping of dirt on the sides of the conduit formation.

Excavations over 5 feet (1.5 meters) deep that a person must enter or work within must have walls shored or benched as approved by a competent person meeting the requirements of 29 CFR 1926, Subpart P.

3-6.4 Hand Digging.

Hand digging must be accomplished in all locations around all MHs, HHs, building entrance points, utility crossings, under curbs, and any other obstacles identified by the site owner.

3-6.5 Plowing.

Plowing must be used only in range environments or other areas where there are no significant obstacles and where cable runs typically exceed 1,000 feet (305 meters) between supporting structures. Plowing paths must be within designated zones that are based on specified distances from the centerline of the road. The zone width is based on minimum and maximum setback distances from the centerline of the road. Designated zones and setback distance criteria must be coordinated with the site owner.

3-6.6 Horizontal Directional Drilling.

HDD is a trenchless utility installation method for installing underground conduit that involves using a directional drilling machine to accurately drill along the chosen bore path and back ream the required conduit. The vertical profile of the bore alignment is typically in the shape of an inverted arc.

3-6.6.1 Methodology.

HDD is a multi-stage process that consists of drilling a pilot hole along a predetermined path and then pulling the desired conduit product back through the drilled space. Back reaming must be used when it is necessary to enlarge the pilot bore hole.

To minimize friction and provide a soil-stabilizing agent, a drilling fluid is introduced into the annular space created during the boring operation. The rotation of the bit in the soil wetted by the drilling fluid creates a slurry that acts as a stabilizer of the surrounding soil, preventing bore hole collapses and loss of lubrication.

3-6.6.2 Drilling Fluids.

Use a mixture of bentonite clay and fresh clean potable water of the proper phosphate (pH) level as the cutting and soil stabilization fluid. Viscosity must vary to best fit soil conditions. No other chemicals are to be used in the drilling fluid without written consent of the USG and after a determination is made that the chemical additives are environmentally safe. When drilling in suspected contaminated ground, the drilling fluid must be tested for contamination and disposed of appropriately in accordance with applicable federal, state, and local environmental regulations.

3-6.6.3 Pits.

Sump areas must be created at the drill entrance and exit locations to contain any escaping free-flowing slurry (drilling fluids) at the ground surface that might damage or be hazardous to the surrounding work area. Excavation for entry, recovery pits, slurry sump pits, or any other purpose must be accomplished in accordance with UFGS 31 23 00.00 20.

3-6.6.4 Tracking.

A method of locating and tracking the drill head during the pilot bore must be employed during the drilling process. Conduit must be installed so that conduit location can be readily determined by electronic designation after installation is complete. For non-conductive installations, this must be accomplished by attaching a continuous conductive material, such as a copper wire line or coated conductive tape, externally, internally, or integrally with the product.

3-6.6.5 Conduit Requirements.

Conduit materials for HDD must meet or exceed the standards defined in Table 3-2.

Table 3-3 Conduit Standards for Directional Boring

Material Type	Standard	Title
High-density polyethylene (HDPE)	ASTM D2239	Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
High-density polyethylene (HDPE) (SDR)	ASTM D3485	Standard Specification for Coilable High Density Polyethylene (HDPE) Cable in Conduit (CIC)
High-density polyethylene (HDPE)	ASTM F1962	Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings
High-density polyethylene (HDPE)	ASTM F2160	F2160 Standard Specification for Solid Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)

HDPE conduit must be manufactured for inside diameter control (manufactured based on the specified inside diameter). Four-inch (100-millimeter) HDPE conduit must have a minimum wall thickness standard internal dimension ratio (SIDR) of 11.5. When connecting HDPE conduits, the internal diameter of the adjoining HDPE conduits must be within 0.030 inches (0.75 millimeters). PVC conduit that uses mechanical-type connectors made for the purpose of horizontal directional drilling may be used in lieu of HDPE, with USG approval. All conduit used for HDD must be placed within soil-tight joints. Joint requirements are defined in paragraph 3.6.8.3.

3-6.6.6 Restrictions.

The HDD trenchless utility installation method may be used only in locations approved by the site owner. Conduits installed under roads by means of HDD must be of sufficient depth to clear existing utilities and meet the H-20 load ratings. The conduits placed by HDD must not directly enter an MH, but must be attached to conduit stub-outs that extend a minimum of 10 feet (3 meters) from the MH. The maximum radius curvature of a bore is limited to the maximum conduit diameter multiplied by 100 feet per inch (30.5 meters per 25 millimeters).

3-6.6.7 Environmental Restoration.

The work location must be restored to the pre-construction condition after installation is complete. The work location must be cleaned of all excess slurry or spoils and properly disposed of in accordance with applicable federal, state, and local environmental regulations as the conduit is introduced. Excavated areas must be restored in accordance with UFGS 31 23 00.00 20. Damage caused by heaving, settling, escaping drilling fluid (fracout), or the HDD operation to roads, parking lots, pavement, curbs, sidewalks, driveways, lawns, storm drains, landscapes, and other facilities must be restored by the installer performing the work.

3-6.7 Jack and Bore.

Jack and bore (auger boring) is a trenchless utility installation method where a horizontal auger is driven through a jacked steel casing into the soil. The steel casing is advanced simultaneously with the boring operation using a hydraulic jacking system. Jack and bore must be accomplished in accordance with UFGS 33 05 23 and conform to the following criteria:

- Materials. Galvanized RSC must be fabricated from weldable quality steel. Steel pipe casings must comply with Grade B requirements of ASTM A139/A139M-16 or ASTM A252/A252M-19.
- Grout. Conduits placed through casing pipe must be grouted with non-shrinking cement grout. Grout must conform to ASTM C1107/C1107M-20.
- Conduit Spacers. Plastic spacers must provide at least 1 inch (25 millimeters) of spacing between conduits as necessary to allow encasement material to fully surround each conduit. Use of bricks or wood as spacers is not permitted. Placement between spacers must be no greater than five feet (1.5 meters). Use bands to secure bore spacers and conduits together. Banding must follow the best practices of the latest issuance of NEMA TCB 2-2017.
- Steel Casing Size. Sizing of casing is determined by the total diameter of the conduit formation. See Table 3-3 for casing sizing guidelines per 4-inch (100-millimeter) conduit formation.

Table 3-4 Casing Size per Four-inch (100-milimeter) Conduit Formation

Casing Size	Wall Thickness inches (millimeters)		Inside Diameter inches (millimeters)		Measured	Number of conduits
	Protected	Non-protected	Protected	Non-protected		
14	0.219 (5.6)	0.311 (7.9)	13.562 (344.5)	13.376 (339.75)	O.D.	4
16	0.219 (5.6)	0.312 (7.9)	15.562 (395.3)	15.376 (390.55)	O.D.	5
18	0.281 (7.1)	0.344 (8.7)	17.500 (444.5)	17.312 (439.73)	O.D.	7
22	0.344 (8.7)	0.375 (9.5)	21.376 (542.9)	21.250 (539.75)	O.D.	9
30	0.438 (11.1)	0.469 (11.9)	29.188 (741.38)	29.062 (738.17)	O.D.	16

3-6.8 Conduit.

3-6.8.1 Types.

Underground pathways consist of conduit structures built using the following acceptable conduit types:

- rigid nonmetallic conduit Schedule 40 – for direct burial or encasement in concrete. Must meet the requirements of NEMA TC-2-2020
- rigid nonmetallic conduit Schedule 80 – for direct burial or encasement in concrete. Must meet the requirements of NEMA TC-2-2020
- metallic pedestal disconnect (MPD) – for direct burial or installation in conduit
- RMC – for direct burial or encasement in concrete
- intermediate metallic conduit (IMC) – for direct burial or encasement in concrete
- RTRC and fittings – for direct burial or encasement in concrete
- innerduct PE – for direct burial or installation in conduit
- innerduct PVC – for direct burial or installation in conduit
- microduct for air blown fiber (ABF) applications
- HDPE – for plowing and HDD

3-6.8.2 Innerduct/Textile Innerduct.

For underground installation, new fiber optic cable plant must be installed in either an innerduct, subduct, or textile fabric mesh solution. More than one fiber optic cable may occupy a multi-cell textile fabric mesh solution. When existing underground pathway conduits systems are reutilized, determine the preferred solution for the location in which the installation is being completed. Fiber optic cables must never be installed directly into a 4-inch (100-millimeter) duct.

3-6.8.3 Joints.

Conduits must be joined to be soil tight. Joints must form a sufficiently smooth interior surface between joining sections so that cables are not damaged during pulling. Joints between dissimilar types of conduits (e.g., PVC, HDPE) must use appropriate connectors designed to provide a seal between the conduit types and prevent damage to cables pulled through these joints. These joint connections must be rated at a minimum of 125 pounds per square inch (psi) (0.862 megapascal (MPa)). Prepare joint surfaces in accordance with the manufacturer's recommended practices. HDPE to HDPE connections can be made by heating using one of the following techniques: socket, butt, electrofusion, or mechanical coupling.

Accomplish heat fusion in accordance with procedures detailed in ASTM F2620 and the procedures established by the manufacturer of the equipment being used. Prior to installing and joining HDPE conduits with an internal diameter of greater than 3 inches (75 millimeters), the conduit must be re-rounded and all inner edges beveled.

3-6.8.3.1 Socket Fusion.

This technique requires use of specially-designed hot irons to simultaneously heat both the external surface of the pipe and the internal surface of the socket coupling. Socket fusion is designed for outside diameter controlled standard dimensional ratio (SDR) material. Although this fusion joining method does not create a bead on the inside of the conduit created by the fusion process, telecommunications application requires internal diameter controlled or SIDR material. If socket fusion fittings are available for SIDR conduit, this method will be acceptable for joining HDPE together. Fabricate socket fusion joints in accordance with the latest issuance of ASTM F2620.

3-6.8.3.2 Butt Fusion.

This technique uses specially developed machines that secure, face, and precisely align the PE conduit for the flat face hot iron fusion process.

The butt fusion process produces an internal bead of equal or larger size than the visible outer bead. This method is acceptable only if verification can be provided that either the internal bead will have a negligible impact on the cable installation, or it can be demonstrated that the internal bead can be removed and the conduit will successfully pass a mandrel test. Fabricate butt fusion joints in accordance with the latest issuance of ASTM F2620.

Electrofusion differs from the hot iron (socket) fusion method described in (a). The main difference is the method used to apply heat. Electrofusion employs a special electrofusion fitting with an embedded wire coil. Electrofusion coupling must be accomplished in accordance with the procedures established by the manufacturer of the equipment being used.

3-6.8.3.3 Mechanical Coupling.

There are various coupling devices available to connect conduits of like material and for conduits of differing materials. Mechanical joints may be entirely mechanical, or a combination of mechanical and heat fusion or solvent weld. Mechanical couplers must meet or exceed the minimum pressure rating of 125 psi (862 kPa) and provide a smooth transition to prevent damage to cables pulled through this type of joint. The coupling must be encased within concrete in all mechanically joined conduits.

Accomplish heat fusion in accordance with procedures detailed in ASTM F2620 and the procedures established by the manufacturer of the equipment being used. Prior to installing and joining HDPE conduits with an internal diameter of greater than 3 inches (75 millimeters), the conduit must be re-rounded and all inner edges beveled.

3-6.8.4 Bends and Sweeps.

No more than the equivalent of two 90 degree bends (180 degrees total) may be used between pull points, including offsets and kicks with a curvature radius of less than 100 feet (30 meters). Avoid back-to-back 90 degree bends. The following definitions apply:

- 90 degree bend: Any radius bend in a piece of conduit that changes the direction of the conduit by 90 degrees.
- Kick: A bend in a piece of conduit, usually less than 45 degrees, made to change the direction of the conduit.
- Offset: Two bends usually having the same degree of bend, made to avoid an obstruction blocking the run of the conduit.
- 90 degree sweep: A bend that exceeds the manufacturer’s standard size 90 degree bend (e.g., 24 inches (600 millimeters) is standard for a 4-inch (100-millimeter) conduit).
- Back-to-back 90 degree bend: Any two 90 degree bends placed closer together than 10 feet (3 meters) in a conduit run.

Use radius-manufactured bends to the maximum extent possible. Manufactured bends may be used on lateral conduits at the riser pole or building entrance. RTSC bends and sweeps may be used where there is a potential to burn through the conduit during cable pulling. Where a conduit enters a building and sweeps up through the floor’s slab, galvanized RSC must be used. Bends and sweeps must be concrete-encased to protect the conduit from the pressures developed while pulling cables.

3-6.8.5 Minimum Formation Sizing.

The orientation of the conduit arrangements must maintain integrity throughout the entire run. Determine the number and size of conduits within the pathway based on the number of cables, cable diameter, known future growth, and sparing. Follow cable manufacturer conduit sizing charts or recommendations, if available. Conduit formations include:

- Node conduits: Conduits between a core node and the first MH should be based upon the types of services, the size of cables, the number of outside cables (not just limited to FOC), and 100% future growth.
- Main conduits: A main conduit run includes the MHs and conduits from the first MH away from the node and in locations where the cable routes diverge into multiple directions providing the pathways for large feeder cables and/or core FOCs.
- Lateral conduits: Lateral conduits run from the sidewall of an MH to the supporting structure (HHs, cross-net cabinets, pedestals, poles).
- Subsidiary conduits: Subsidiary conduits extend from the end wall of an MH, run along the main conduit run for some distance, and then turn to feed a structure.

- Entrance conduits: Entrance conduits run from an MH, HH, or pole to the EUB.

Sizing requirements include:

- one four-inch (100 millimeter) conduit for every four-way two-inch (50 millimeter) conduit system
- a minimal conduit size of 2 inches (50 millimeters) for pathways between supporting structures and end-user facilities
- for large copper cables, conduit with a diameter at least 1.15 times greater than the diameter of the cable, or one-half trade size larger in diameter than the diameter of the cable to be installed

3-6.8.6 Spacing.

Spacers are required for all conduit formations (both encased and non-encased) to properly support the conduits and maintain their integrity of orientation and must be installed in accordance with the manufacturer's specifications. Plastic spacers must provide a minimum of 2 inches (50 millimeters) of spacing between conduits, with the only exception being where conduits are placed in rock, a minimum of 1 inch (25 millimeters) of spacing will be acceptable. Use of bricks or wood as spacers is not permitted. However, use of concrete cinder blocks as spacers (and tie-downs) is an acceptable alternative with the approval of the COR. Conduits and spacers must be securely banded together. Spacers must be installed at a minimum of one spacer every 5 feet (1.5 meters). Direct buried conduit formations must be installed with embedment material around and between the conduits.

3-6.8.7 Placement.

Sweep down new conduits and install in the lowest available conduit positions within the MH or CV. In node and main conduit runs, install new conduit formations at a depth where a duct formation of equal size could be placed above the existing formation while maintaining 24 inches of cover or below the frost line, whichever is greater. New lateral, subsidiary, and entrance conduit runs must allow for 24 inches of cover or be below the frost line, whichever is greater. New conduits must not prevent placement of future conduits in the upper conduit positions. Conduits must terminate in bell ends or conduit terminators at the point of entrance into the MHs and HHs to assist in pulling cable. Main conduits entering cast-in-place or precast MHs must be located in the lower portion of the end wall. Conduits leaving side walls must be located a minimum of 4 inches (100 millimeters) from the end walls located farthest from the central office or serving node. Clearances of 12 inches (300 millimeters) must be maintained between main conduit formations and the roofs or floors of MHs. Unless the construction drawings indicate otherwise, wall recesses must be provided at conduit entrances. Locate lateral conduits leaving the MH to provide clearances of 4 inches (100 millimeters) from roofs and adjacent walls.

Conduits entering the walls of the supporting structure must be perpendicular to the face of the exterior wall. Conduits must remain perpendicular for a minimum 5 feet (1.5 meters) away from the exterior wall.

3-6.8.7.1 Stub-outs.

Stub-outs are short pieces of conduit that extend beyond the wall of a building or supporting structure offering an interface for future expansion. Stub-outs must be capped at the soil end and plugged and tagged within the building or supporting structure. Stub-outs for buildings with under-slab entrances must be RMC (refer to Figure A-11). Stub-outs must extend past the wall at least 5 feet (1.5 meters).

3-6.8.7.2 Transition.

For conduits transitioning from the lower conduit window of an MH to the nominal trench depth, the transition must be accomplished in no less than 30 linear feet (9.1 meters) from the MH to reduce the radius of the bends.

3-6.8.7.3 Clearances.

Clearances of 12 inches (300 millimeters) must be maintained between conduit formations and the roofs or floors of the supporting structure. Subsidiary conduits entering MHs must be located to provide clearances of 4 inches (100 millimeters) from roofs and adjacent walls.

3-6.8.7.4 Maintenance Holes.

Conduits entering the end wall of an MH must be located in the lowest portion available and remain together. Alternatively, the contractor may divide the conduit window of a multidirectional MH in half, leaving the other half of the window for future conduit systems. Highest conduits in the formations are reserved for fiber. The contractor must present the conduit pattern and identify conduit locations to the COR for approval prior to construction.

3-6.8.7.5 Existing Conduits.

New conduits installed with an existing conduit system must be placed above the existing conduit formation if the minimum depth requirements can be maintained. If sufficient cover is not available to maintain the depth requirement, the new conduit must be placed beside the existing conduit formation.

3-6.8.7.6 Rerouting of Existing Conduits.

Existing conduits must be joined to new MHs (pre-cast or cast-in-place) by rerouting the designated conduits from the demolished or abandoned MH to the new MH. Rerouting must begin , at least 30 feet (9 meters) from the old MH to allow for standard bending radii and pulling tension. Continuity of operations on the affected cables must be maintained during the conduit rerouting actions.

3-6.8.7.7 Conduit Termination.

Conduits must terminate in bell ends or conduit terminators at the point of entrance into supporting structures (MHs, HHs, cable vaults and buildings).

3-6.8.8 Concrete Encasement.

3-6.8.8.1 Vehicle Traffic.

Nonmetallic conduits placed under paved roads by open cut must be protected by concrete-encasement. In addition, conduits placed under paved road surfaces and certain heavy traffic non-surfaced roads must be protected by one of the following methods: concrete-encased conduit; galvanized RSC; steel pipe casings; or HDD of HDPE conduits.

3-6.8.8.2 Concrete Type.

The concrete type must be a wet type mix and be placed to ensure the concrete completely surrounds all conduits. Concrete used to encase conduits must have a minimum compressive strength of 3,000 psi (20,700 kPa). Additional concrete mix requirements may be required by the local jurisdiction and will be furnished by COR. Portland type cement must conform to American Society for Testing and Materials ASTM C94/C94M. Flowable fill must not be used as a substitute for concrete encasement.

3-6.8.8.3 Encasement Requirements.

Concrete must flow around and encase all conduits. The top of the concrete encasement must be a uniform finish and must be consolidated by mechanical vibration to ensure no air or voids are trapped in the mix. Provide a minimum 3 inches (75 millimeters) on each side and top, and 1.5 inches (38 millimeters) between the bottom row of conduit and the trench bottom.

a. New conduit systems must be connected to all supporting structures with dowels (those with or without conduit windows). Refer to Figure A-17.

b. For existing supporting structures, both precast and cast in place, that require core drilling, reinforcement bars must be placed 3 inches (75 millimeters) away from the outside wall and tied to dowels. Secure dowels to supporting structure using ASTM C881-rated epoxy. Refer to FigureA-17.

c. For conduits that will be encased in concrete, the contractor must tie down the conduits to minimize movement during the placement of concrete. The conduits in a concrete-encased pathway must be tied down at least every 10 feet (3 meters) using an industry-recognized method such as metal rods/stakes and strapping. The metal rods must be a minimum of 1/4 inch (6 millimeters) thick. As an alternative, the contractor may use concrete cinder blocks as both spacers and tie downs, with approval from the COR.

d. Concrete forms must be used when encasing conduits to OSP supporting structures to limit blockage of empty conduit knock-outs or windows in the OSP supporting structure.

e. The contractor must contact the on-site USG representative of the time and location prior to pouring any concrete over the conduit formations. The onsite USG representative will inspect the spacers and tie-downs prior to encasing the conduit formation.

f. Concrete encasement of the conduits for a “core path” is required where no alternate paths are present. All conduits between core buildings and serving MHs must be concrete encased.

g. Concrete encasement must be used in stream/drainage areas subject to washing out; in major construction zones; and for all sweeps or bends.

h. New encasement must be doweled to the existing encasement.

3-6.9 Detection and Marking of Underground Pathways.

3-6.9.1 Warning Signs.

3-6.9.1.1 Cantonment Areas.

Warning signs or route markers must be placed along the cable route to denote the location of below ground building entrances, changes in cable route, and in congested utility crossing locations. The signage or route marker must be permanent.

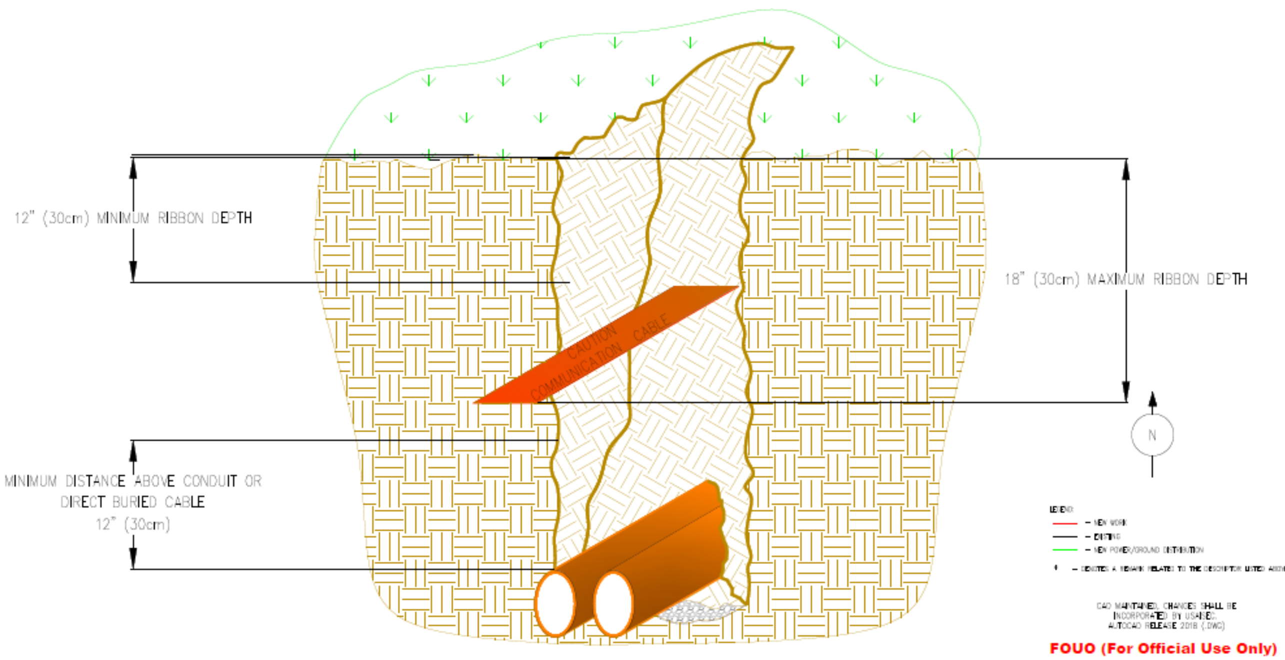
3-6.9.1.2 Non-Cantonment Areas.

Warning signs or route markers must be placed along the cable route at intervals of no greater than every 250 feet (75 meters), at each change in route, on both sides of each street crossing, over pipelines, and over buried power lines. The warning signs or route markers must be color-coded and orange in color.

3-6.9.2 Warning Tape.

Warning tape must meet the requirements of the latest version of UFGS 31 00 00. Warning tape must be installed at least 12 inches (300 millimeters) below the surface level and maintain a minimum separation of 6 inches (150 millimeters) between the warning tape and non-metallic conduit formations and DB cable installations (Figure 3.1). Warning tape must not exceed the manufacturer’s recommended depth below grade. For DB cable and non-metallic conduit formations placed by plowing, the warning tape should not be wider than the plow.

Figure 3-1 Warning Tape Placement



3-6.9.3 Detection Wire for Direct Buried Cable.

Detection wire for DB cable must be a minimum of #12 AWG insulated, single strand, solid copper wire, coated with a minimum 30-mil PE jacket designed specifically for buried use. Splices within the detection wire must be connected using a compression-type connector to ensure continuity. Wire nuts must not be used. After installation, the detection wire must be tested to verify end-to-end continuity and submitted in a report to the USG.

3-6.9.4 Detection Wire for Conduit Formations.

Detection wire must be installed within all new conduit formations. One detection wire must be installed per conduit formation. The detection wire must be placed as centrically as possible within the top of the conduit formation. When dielectric cable is installed in existing conduit formations that do not contain toneable cables, a detection wire must be installed along with the dielectric cable. Detection wire must be terminated on a terminal block and placed either within the MH near the opening, or in a “test well” so that the detection wire can be accessed without physically entering the MH confined space. Each detection wire and termination must be labeled to indicate the path of the detection wire (e.g., “TO MH-3”). Splices in the detection wire must be connected using a compression-type connector to ensure continuity. Wire nuts must not be used. After installation, the detection wire must be tested to verify end-to-end continuity and submitted in a report to the USG. No detection wires are required when the conduit formation contains an integrated detection wire (e.g., toneable conduit/textile innerduct).

3-6.9.5 Conduit Embedment.

Embedment is not required when the conduit formation is concrete-encased. Non-concrete encased conduit formations must be backfilled in accordance with NEMA TC2 and UFGS 31-00-00, using whichever is more stringent. Backing terminology includes:

- Bedding and initial backfill zone. The embedment zone of a conduit trench is that portion of the trench from approximately four inches (100 millimeters) below the bottom of the first row of conduits to approximately six inches (150 millimeters) above the top of the final row of conduits.

The external loading capacity of flexible conduits largely depends upon the type of embedment material chosen and the quality of the installation of the material in the embedment zone.

- Embedment material. The best materials for use in the embedment zone are coarse-grained materials such as crushed stone, sand, and pea gravel. Coarse-grained soils mixed with silts or clays can also be satisfactory, provided the mix is compactible and stable. Soils not recommended in the embedment zone are the highly organic materials and the highly plastic clays. The maximum particle size in the embedment zone should be limited to one inch (25 millimeters) in diameter.

- Final backfill zone. The final backfill zone of the conduit trench is that portion of the trench extending from the top of the embedment zone to the top of the trench.

- Final backfill materials. The final backfill is not critical for conduit performance, but can be important for providing a proper foundation for a road or other structure which may be constructed over the conduit trench. Selection of the final backfill materials is not critical for the conduit; all types of soils are acceptable, provided they do not contain particles that can damage the conduit. For conduit systems that will be under roads or parking lots, flowable fill is the preferred material.

3-6.9.6 Backfilling.

All excavated areas around new OSP supporting structures, conduits, and/or cables must be backfilled in accordance with the latest issuance of UFC 3-220-04FA.

Prior to placing any embedment or backfill, the pathway must be inspected by the onsite USG representative to verify the acceptability of the new supporting structures, pathway, and cables. In accordance with UFGS-31 00 00, all excavated areas around the new supporting structures, conduits, bore pits, and cables must be backfilled with approved materials.

3-6.9.6.1 Materials.

Material larger than 1 cubic foot (0.028 cubic meters) is not allowed in the backfill and must be removed. Materials must be free from hydrocarbons and other chemical contaminates. Approved materials can be a mixture of earth to include loam, sandy clay, sand, gravel, and soft shale. Backfill materials must be placed into the excavation and then tamped in 1-foot (300-millimeter) layers.

If native soil is of a suitable type, it may be used as embedment and backfill material. Blasted rock, large boulders, broken concrete, or pavement must not be used a backfill materials. Final backfill is a topsoil used that is conducive to growth of plants and grass. Material larger than 1 inch (25 millimeters) in diameter is not allowed in the final backfill.

3-6.9.7 Flowable Fill (Slurry).

Flowable fill, also known as slurry, must used for backfilling the portion of the trench above concrete-encased conduit systems under roads and parking lots. The flowable fill must meet the compressive strength requirements defined in Military Detail (MIL-DTL)-32537, and placed using the traditional (wet) method. Flowable fill must not be used as a substitute for concrete encasement. Backfilling the portion of the trench above concrete-encased conduit systems under roads and parking lots with clean backfill is acceptable only when approved by the COR. Reference paragraphs 3-6.9.6 and 3-6.10 for backfill and restoration requirements.

3-6.10 Restoration.

Restore disturbed areas to the same density, grade, and vegetation as adjacent undisturbed material. Grade the earth to a reasonable uniformity. Resurface paved areas with the same type of material and to the same thickness as the original surface. Paved surfaces must be restored in accordance with UFC 3-270-01. Restore road surface markings, including but not limited, to yellow lines, white lines, cross walks, and parking lot stripes, to the original location and condition. Clean the work site of debris and restore it to original condition.

3-6.11 Proof, Rod, and Clean Conduits.

Proof new conduits and existing vacant pathways prior to use. Proofing must be witnessed by the USG representative. Conduit with existing cable or that will not allow the passage of a mandrel must be rodded and cleaned.

3-6.11.1 Rodding.

Rodding entails inserting or pushing a rod through the conduit to determine the length, locate the other end, determine if the conduit is usable, and insert a pull string.

3-6.11.2 Cleaning.

When necessary, clean conduits using high pressure jetting, wire brushes, rubber conduit swabs, and leather washer conduit cleaners.

3-6.11.3 Proofing.

Proofing a conduit consists of pulling a test mandrel or slug through the duct to ensure the integrity and alignment of the ducts. New ducts in main and subsidiary duct runs must be mandrelled with a test mandrel (non-flexible) or slug that is approximately 12 inches (300 millimeters) in length and 0.25 inches (6 millimeters) less than the duct inside diameter. Use the test mandrel to verify the integrity of duct joints, to test for out-of-round duct, and to verify that sweeps are not so severe as to preclude placement of multiple cables or large diameter cables. A 6-inch (150-millimeter) length test mandrel may be used to test duct runs to buildings or riser poles. Pull the mandrel through all conduits to ensure proper alignment. Pulling the test mandrels through the conduits should be accomplished after backfilling, but prior to replacing any grass, sod, or repaving.

3-6.12 Pull String/Rope/Tape.

Place a pull string, pull rope, or pull tape, rated at not less than 200-pound (890-newton) tensile strength within each new conduit and innerduct. Provide a minimum of 5 feet (1.5 meters) of slack at each end of the conduit, tied and secured to the back of the conduit plug to prevent being accidently pulled back into the conduit. When installing new cable in existing conduit, place and secure a pull string, pull rope, or pull tape alongside the new cable so it cannot be accidently pulled back into the conduit.

3-6.13 Subdividing Conduit.

Subdividing conduit is the practice of using either innerduct or fabric-mesh to facilitate the initial and subsequent placement of multiple cables within a single conduit space.

The preferred count for fabric mesh in a 4-inch (100-millimeter) conduit is two, where each has three cells. Cut off fabric mesh at the end of each conduit run, leaving a minimum of 2 feet (600 millimeters) of spare slack. Roll up the spare slack and place it back inside the end of the conduit. Subdivision requirements of conduit can differ at each B/P/C/S and must be coordinated prior to installation with the AHJ.

3-6.14 Conduit Sealing.

3-6.14.1 Vacant New Conduit.

Seal new vacant conduits, multi-ducts, and innerducts using a mechanical reusable conduit plugs at each end. Conduit plugs must have a means of attaching pull strings. Cap stub-outs at the soil end, and plug and tag them within the building or OSP supporting structure.

3-6.14.2 Existing Occupied Conduit.

After placing new cables in existing conduit, seal the pathway at both ends. Sealant must be designed for use within telecommunication applications to block entry of water and debris and be removable without damage to the conduits or cables. Install sealant in accordance with the manufacturer recommendations and procedures. When using expandable foam, encapsulate only the first 6 inches (100 millimeters) of conduit by placing removable materials within the conduit to block any unnecessary expansion of the foam.

3-6.15 Conduit Rehabilitation.

The preferred method of installing new cables uses existing pathways. Rehabilitation of existing conduits is an alternative to installation of new conduit when the cost, location, or magnitude of new construction is prohibitive. Conduits intended as candidates must be surveyed to ensure that rehabilitation is feasible. The survey must include an inspection from the MH/HH or building entrance endpoints, either visually or by a conduit video system, from both ends of the conduit. If a pathway is found blocked or damaged, coordinate with the COR to discuss an acceptable solution. Collapsed or crushed conduit must not be used for rehabilitation. Several acceptable methods of rehabilitating conduit have been found, which include, but are not limited to, split conduit repair, resin-impregnated tube, conduit clamps, or conduit replacement. Accomplish conduit rehabilitation in accordance with the latest issuance of ASTM F1216, using ASTM-compliant products and processes. Completed rehabilitated conduit must be inspected by a conduit video system to verify it was restored to a usable system that meets the minimum requirements defined within this UFC.

3-7 DIRECT BURIED INSTALLATION.

DB is a type of installation where the infrastructure is in direct contact with the soil, without extra protection from the elements. DB solutions are implemented via trenching or plowing. Install DB cable in accordance with the latest issuance of RUS Bulletins 1751F-640, 641, and 642. Refer to Figure A-10 for typical pedestal measurements for DB.

3-7.1 Cable Type.

Rodent-protected (armored) cable must be used for DB applications.

3-7.2 Direct Buried Fiber Optic Cable.

DB FOC must be placed at a depth providing a minimum top cover of 48 inches (1200 millimeters) or below the frost line, whichever is greater. In solid rock, the minimum top cover must be 6 inches (150 millimeters).

3-7.3 Direct Buried Copper.

DB copper cable must be placed at a depth providing a minimum top cover of 24 inches (600 millimeters) in soil, 36 inches (900 millimeters) at ditch crossings, and 6 inches (150 millimeters) in solid rock (RUS Bulletin 1753-150/RUS Form 515A).

3-8 AERIAL INSTALLATION.

Aerial cable plant systems are not preferred. However, exceptions may include range cables or other long runs through undeveloped areas, locations where underground systems cannot be installed (e.g., wetlands), or locations where compliance with local mandates are required and require site owner approval. The desired or required reliability (99.999 percent) of some communications systems may preclude use of aerial pathways. Supporting documentation for aerial placement is available in RUS Bulletin 1751F-630 and 1751F-635.

3-8.1 Aerial Fiber.

Do not use aerial fiber splices without USG approval. Place fiber optic splices in a pedestal at the bottom of the pole. The cable alone must not support the aerial splice case. Fiber splice locations must include enough cable slack to allow the splice case to be moved into a splice trailer or tent for maintenance or service. Secure the cable slack to the existing messenger. Organize slack on aerial FOCs neatly, using aerial fiber optic storage loops ("snowshoes"). Base the snowshoe's size on the cable bend radius.

3-8.2 Aerial Copper.

Support all terminals and splice cases by direct attachment to the messenger strand, pole, building, or pedestal. The cable alone must not be used for support. Use pole-mounted and fixed-count terminals and place them so that no single drop exceeds 500 feet (150 meters) in length.

3-8.3 Messenger Strand.

The smallest messenger strand used for all new installations must be 6.6M. A 2.2M strand should be used only as an extension of existing 2.2M strands. FOC must be installed on its own messenger. Do not lash copper and fiber cables on the same messenger without site owner approval. A figure-eight type cable may be used; however, no additional cable must be lashed to it.

3-8.4 Guys and Anchors.

Place new guys and/or anchors for each new messenger strand at each applicable location (cable turns, wind loading, cable ends). The down guy must be sized to the next larger strand. Permission may be required to use an existing anchor.

3-8.5 Water Protection.

Weatherproof all outdoor connections by using weather boots or other approved methods. Form a rain-drip loop at all cable entrances into buildings at the point of ingress. Slant conduit sleeves placed through the entrance wall downward towards the outside a minimum of 0.5 inch (13 millimeters). Waterproof all building entrance points.

3-8.6 Horizontal Clearances for Poles/Aerial Cable.

Adhere to horizontal clearance standards in accordance with the latest issuance of the NESC®.

3-8.7 Vertical Clearances for Aerial Cable.

Communications cables must be no closer to power cables than 40 inches (1,000 millimeters) at the pole. At midspan, communication cables must be no closer than 75 percent of the separation distance at the pole. Adhere to vertical clearance standards in accordance with the latest issuance of the NESC®.

3-8.8 Aerial Cable Slack.

Slack on aerial cables must be neatly organized, using aerial fiber optic storage loops (“snowshoes”). Base the snowshoe’s size on the cable bend radius. Calculate the minimum amount of slack as follows:

- road crossings (aerial): 100 feet (30.5 meters)
- aerial per linear mile: three locations, each with 100 feet (30.5 meters)

3-9 EXTERIOR OUTSIDE PLANT CABLING.

Install cable plant to avoid kinks and other sheath deformities. Cables must be rated in accordance with the latest requirements of the National Electrical Code (NFPA 70®) for the environment in which they will be installed.

3-9.1 Cable Pulling Tension.

When pulling cable into ducts, inner ducts, or sub-ducts, do not exceed the manufacturer’s recommended pulling tension. Use of properly rated breakaway swivels is recommended. Various commercial cable lubricants compatible with different types of cable sheathing materials are available for pulling cables. During installation, a cable lubricant should be used in the proper amount specified by the lubricant manufacturer. Environmental conditions such as temperature can affect the overall performance of the pulling lubricant and must be conveyed to the manufacturer when making the proper selection. Pulling must comply with all manufacturer’s recommendations.

3-9.2 Evaluating Existing Cable Plant.

When installation includes work on existing cable plant (e.g., copper cable and fiber optic cable) that is to be re-used, test all affected pairs and/or strands before performing any splice work or cable throws. Test results must be compiled, to include any defective pairs and/or strands identified, and submitted to the COR to be addressed by the USG prior to proceeding with installation.

3-9.3 Cable Transfers, Cuts, and Throws.

Cable transfers, cuts, and throws must maximize use of existing resources. Cables and terminals affected by cable count transfers must be retagged in the field to reflect all new changes. Coordinate cable transfers, cuts, and throws with the site owner.

3-9.4 Service Loops.

For supporting structures with fiber optic splice cases, install a 75-foot (25-meter) splice loop on each side of the fiber optic splice case. In addition, 75-foot (25-meter) service loops are required at the last MH prior to building entrances. The service loop should be properly labeled and securely supported by two cable hooks. Position cable hooks so the highest one supports the underside of the top of the coil and the bottom hook supports the underside of the bottom of the coil.

3-9.5 Copper Cable.

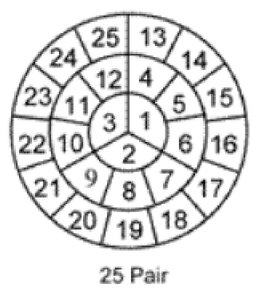
Copper cabling in outside plant implementation is diminishing rapidly with fiber centric backbones, but smaller copper counts may still be needed for legacy systems. Size all copper cables to provide a minimum of six copper pairs to each building.

3-9.5.1 North American Telephone Copper Cable Specifications.

North American telephone copper cable must be UL-listed and meet the specifications of Telcordia, GR-421-CORE. The conductors within the copper cable must be color coded using a basic color coding scheme to provide different color combinations on the insulation of each cable pair. The North American standard is based on a 25-pair binder group (see Figure 3-2) defined by Telcordia, GR-421-CORE, with the following colors:

- Tip: white (pairs 1-5), red (pairs 6-10), black (pairs 11-15), yellow (pairs 16-20), violet (pairs 21-25)
- Ring: blue (pairs 1, 6, 11, 16, 21), orange (pairs 2, 7, 12, 17, 22), green (pairs 3, 8, 13, 18, 23), brown (pairs 4, 9, 14, 19, 24), grey (pairs 5, 10, 15, 20, 25)

Figure 3-2 GR-421-CORE, 25 Pair Binder Group Structure



3-9.5.2 European Telephone Copper Cable Specifications.

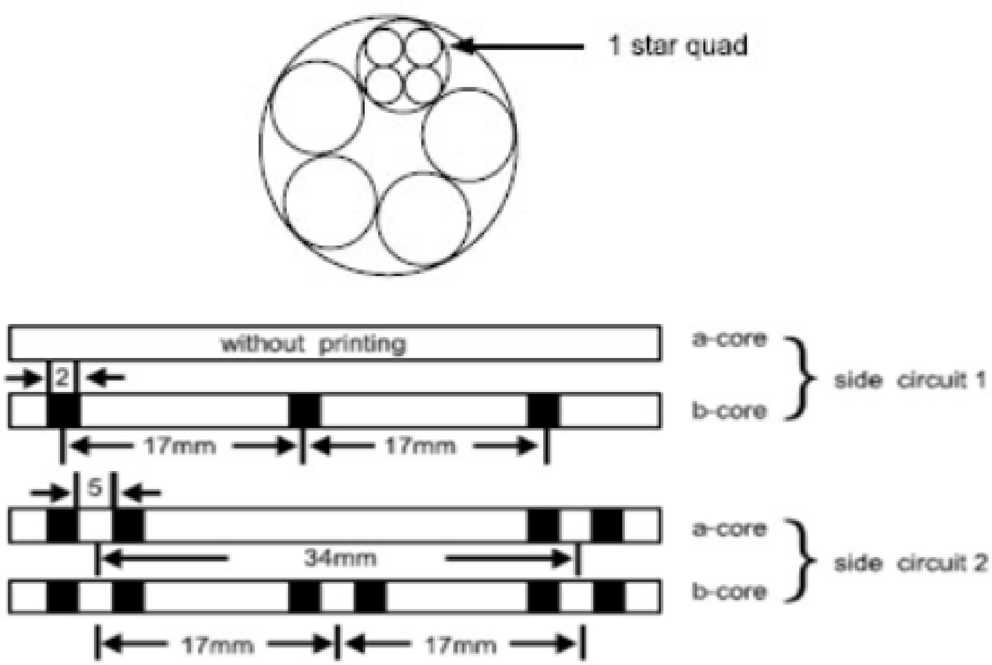
European telephone copper cable must meet the specifications of DIN VDE 0815/A1:1988-05 and DIN VDE 0816-1:1988-02. Commercially available, industry standard cables must be type A-02YSOF (L) 2Y …x2x0.6 ST III BD. The ellipsis (…) represents the required pair count. The conductors within the copper cable must be color-coded using a basic color-coding scheme to provide different color combinations on the insulation of each cable pair. The European standard is based on a 10-pair (five star-quads) sub-unit (Figure 3-3) defined by DIN VDE 0816-1:1988-02 with the following characteristics:

- Each star-quad of the sub-unit is defined by a unique insulation color. The first star-quad is red, the second star-quad is green, the third star-quad is grey, the fourth star-quad is yellow, and the fifth star-quad is white.
- The first or pilot sub-unit is marked by an open helix of red plastic tape.
- Remaining sub-units are marked with open helix of white or transparent plastic tape.
- Insulation of single conductors within a star-quad is marked with black rings.

3-9.5.3 Gauge and Resistance.

The cable gauge (copper conductor size) must be #24 American Wire Gauge (AWG) in North America and 0.6 millimeters in Europe.

Figure 3-3 DIN VDE 0816-1:1988-02, 10 Pair Sub-Unit Structure



3-9.5.4 Loading.

Analog telephone sets or circuits must not exceed 18,000 feet (5,490 meters) unless approved by the USG. If approved, these telephone sets or circuits must be loaded. When loading copper cables, use H88, loading 3,000 feet (914 meters) from the telephone switch or digital loop carrier for the first load (includes calculations for tip cables, jumper wires,) and every 6,000 feet (1,830 meters) thereafter. End sections, to include all drops and station wire, must be greater than 3,000 feet (914 meters) and less than 12,000 feet (3,660 meters). Proprietary digital or Integrated Services Digital Network (ISDN) telephone sets used with the telephone switch must not be loaded. Design build-out capacitors on trunk circuits for placement between telephone switches and load points shorter than 6,000 feet (1,830 meters) or between loads and end sections. Cable pairs used for data circuits must not be loaded.

3-9.5.5 Splicing.

Splice copper cable in accordance with the latest issuance of RUS Bulletin 1753F-401. Splice cable as one continuous length using one of two common modular splicing techniques: the inline or the fold-back technique. The inline technique places the conductor in a straight-across arrangement, providing for little slack within the conductor. The fold-back technique allows the conductors to be folded into the splice, facilitating future work within the splice. The fold-back technique is preferred. Completed splices must meet performance and mechanical specifications similar to those for a single copper cable of the same overall length.

3-9.5.5.1 Connectors and Caps.

Use self-piercing, electrical, filled connectors when plastic-insulated conductors are spliced. Connectors must be placed and installed using a tool specifically designed to place them. In North America, a 25-pair splicing module 3M-type MS2, or equivalent, must be used. In Europe, a 10-pair splicing module must be used. The same modules must be used throughout each project and must be consistent with previously installed connectors to preclude the requirement for a variety of installation tools. The integrity of all binder groups within the splice must be maintained. All dead pairs in a copper cable must be spliced through if the size of the continuing cable allows a clear and cap at the end. Use only UL-listed material for capping cable pairs.

3-9.5.5.2 Splice Cases.

Use encapsulant-fillable closures on underground and buried splice cases and fill with encapsulant upon the completion of the splice(s) in accordance with RUS Bulletin 345-72. Use of non-encapsulated, re-enterable splice cases in aerial or underground non-pressurized networks is permitted for non-direct buried applications. Do not install splice cases allowing their weight to be supported by the cables on the cable hooks in the MH. Installed splice cases must not interfere with ingress and egress into the OSP supporting structure space for technicians entering to perform maintenance. The preferred method for installing splice cases is to hang them from an overhead support structure (e.g., pipe supported by a set of cable hooks above the splice case). Do not place splice cases near or on the floor of the OSP supporting structure. To ensure continuity, bond new splice cases, existing splice cases that are reopened, and their associated components that contain conductive elements (e.g., conductors, metallic sheaths, armor) to the grounding electrode system of the OSP supporting structure in accordance with the requirements of this UFC.

3-9.5.6 Bend Radius.

The minimum bend radius for non-gopher-resistant OSP twisted-pair cable during installation must not be less than ten times the cable diameter, and after installation must not be less than eight times the cable diameter, as specified in ANSI/TIA-758.

The minimum bend radius for gopher-resistant OSP twisted-pair cable during installation must not be less than fifteen times the cable diameter, and after installation must not be less than ten times the cable diameter, as specified in ANSI/TIA-758. If the manufacturer's recommended installation and post installation bend radius requirements are more stringent, then follow the manufacturer's specifications.

3-9.5.7 Count Assignment.

When assigning new copper cable counts, the center of the cable must be the last pairs assigned on a cable route. The higher pair counts within the cable must be used first. The highest pair count in the cable must be located nearest to the telephone switch, and the lowest pair count must be farthest away. Per the requirements of 6-pair and/or 12-pair terminals, Pair 13 (of a binder group) rather than Pair 1 must be spared. If existing cable plant is reused and the cable pair count assignment differs from this layout, coordinate updated cable count assignments with the site owner.

3-9.5.8 Building Terminations.

3-9.5.8.1 Protected Entrance Terminal.

A PET is a device that provides electrical protection and a demarcation termination point where the OSP cabling transitions to the inside plant (ISP) cabling within an EUB.

PETs must be UL-listed and must be of flame-retardant construction and equipped with a build-in splice chamber; either 5-pin solid state or gas protector modules; locking cover; and output onto either 110 blocks or RJ21 connectors. PETs used for European projects must be equipped with protected, line-sharing adapter plus (LSA+) terminal blocks. Connect PETs to the building's lightning protection grounding system as required in NFPA 780. Terminate OSP copper cable pairs on the primary protector blocks of the PET, equipped with either 5-pin solid state or gas protector modules.

3-9.5.8.2 Main Distribution Frame.

The MDF serves as the intermediate interface between the OSP cable and the telephone switch cables at core node and ADN locations. The iron framework of the MDF supports the horizontal blocks and vertical connectors. Equip the MDF with guard rails and end rails. When re-using an existing MDF, install additional horizontal blocks and/or new vertical connector sections to support new cable plant if none are available. A minimum of 36 inches (900 millimeters) of clearance around the guard and end rails of the MDF is required for safety.

a. Horizontal Blocks. The horizontal blocks are mounted on the horizontal side of the MDF and terminate the telephone switch cables between the telephone switch and the MDF. The type and number of horizontal blocks on the frame are based upon the telephone switch solution and must be determined prior to installation. Stencil horizontal blocks to show the termination identification information.

b. Vertical Connectors. Vertical connector blocks are mounted on the vertical side of the MDF. Each vertical protector block must protect either 100 or 200 OSP cable pairs. Equip each vertical connector block with tip cables that are pre-terminated. The tip cables are routed either from the MDF through the floor to the cable vault, or over the MDF to the wall, where they are spliced to the OSP cable plant. Provide connectors for the tip cables as either stub-up or stub-down, as required by the type of installation. Vertical connectors protect the electronics within the telephone switch room by providing lightning and surge protection. Each termination corresponds to a pair of the OSP cables. All OSP cable pairs must be terminated on connectors. Stencil each vertical connector block to show the cable number and the pair counts for all connectors on that particular vertical connector block. Connectors must show the count terminated. A schematic of the vertical side of the MDF is shown in Figure A-11. Use space-saver type MDF connectors unless directed otherwise by the USG.

c. Cross-Connects. Install cross-connects between the OSP terminations on the vertical connectors and the switch terminations on the horizontal blocks. This process connects an OSP pair to a telephone number or other analog circuit. Leave approximately 8 inches (200 millimeters) of slack in the cross-connect wire to allow re-termination for future moves, additions, or changes.

d. Special Circuits. Special circuits, such as data circuits, T-1s, or alarms, are non-switched and must be treated differently than voice circuits. Various colors of protector modules are available to help with differentiation. Coordinate the specific color and marking for each special circuit type with the site owner. Cross-connect special circuits to designated blocks on the horizontal side and not to telephone switch horizontal blocks that provide telephone numbers.

3-9.5.9 Acceptance Testing.

Conduct end-to-end testing to ensure every cable pair installed, spliced, and terminated is installed in accordance with applicable USG and industry standards. Complete end-to-end tests in accordance with RUS Bulletin 1753F-201, IEEE Standard 743-1995, and other applicable documents referenced within. End-to-end tests that must be completed, include, but are not limited to, the following:

- direct current (DC) insulation resistance
- short/crosses
- grounds
- opens
- reversals
- splits
- transpositions
- shield continuity
- loop resistance

- insertion loss
- capacitance

Document and compile test results into an official test report format, to include raw data files, for submission to the USG. One hundred percent (100%) of all pairs within a cable must past initial acceptance testing prior to installation. After installation, 99 percent (99%) of all cable pairs must pass final acceptance testing unless the failed percentage of defective cable pairs are deemed by the USG not economical to recover. All defective cable pairs must be identified by their location and the type of fault(s). Any faults caused by defective cable pair splices must be corrected.

Existing copper cable being rehomed and re-terminated must be tested end-to-end following the testing protocols in this section for new cable to recertify the newly completed permanent link. If existing cable pairs are damaged during rehoming and re-termination, they must be properly repaired.

3-9.6 Fiber Optic Cable.

3-9.6.1 Cable Types.

There are two types of fiber optic cable used in OSP; single-mode (SM), and multi-mode (MM). New OSP fiber optic cable must be SM; however, designers may use MM to mate with existing plant in coordination with all stakeholders. Loose tube cable construction is better suited for the OSP environment. Tight-buffered cables are not recommended for use above the frost line except to edge devices that may not readily accept loose tube connections because they may be subject to damage from freezing water or moisture.

3-9.6.1.1 Multi-mode Fiber Optic Cable.

Fiber strands must have a nominal core/cladding diameter of 50/125 microns. All cabled MM fibers must have the characteristics in Table 3-6 over the entire specified temperature range.

Table 3-5 Multi-mode Dual-Windowed Fiber Optic Cable Characteristics

Function	Parameters for 50 Microns	Parameters for 62.5 Microns LEGACY ONLY
Core/cladding diameter (microns)	50/125	62.5/125
Coating diameter (microns)	250	250
Core eccentricity maximum	6%	6%
Core ovality	6%	6%
Refractive index delta	1%	2%
Core diameter (microns)	50 (+/- 3)	62.5 (+/- 3)

Function	Parameters for 50 Microns	Parameters for 62.5 Microns LEGACY ONLY
Cladding diameter (microns)	125 (+/- 3)	125 (+/- 3)
Numerical aperture	0.20 (+/- 0.015)	0.275 (+/- 0.015)
850 nm		
Maximum attenuation dB/km	3.5	3.75
Minimum bandwidth MHz-km	500*	160
1,300 nm		
Maximum attenuation dB/km	1.5	1.0
Minimum bandwidth MHz-km	600*	500
Cable tensile load rating	2,670 N (600 lb)**	
Cable minimum bending radius	15 x cable diameter under no load 0-800 N (0-180 lb)** 20 x cable diameter under load 800-2,700 N (181-600 lb)**	
*Building/breakout cables (tight buffer). Minimum bandwidths do not apply to tight buffered or breakout type cables. Minimum bandwidths for tight-buffered cable are 400 MHz-km at both 850 nm and 1,300 nm. The index of refraction profile of MM fiber must be near-parabolic graded index. **Building/breakout cables (tight buffer). Tensile load rating and minimum bending radius do not apply to tight-buffered breakout-type cables.		

dB=decibel; km=kilometer; MHz=megahertz; nm=nanometer

3-9.6.1.2 Single-mode Fiber Optic Cable.

Use SM FOC as defined in ANSI/TIA-568, TIA-758, and International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) G.652 through ITU-T G.657 documents. All cabled SM fibers must have a maximum attenuation value of 0.5 dB/km for high grade at 1,310 nanommeters over the entire specified temperature range.

Table 3-6 Single-mode Dual-Windowed Fiber Optic Cable Characteristics

Function	Parameters
Maximum attenuation dB/km @ 1,310 nm	0.5*
Maximum attenuation dB/km @ 1,550 nm	0.4*
Zero dispersion range	1,310 nm (+/- 10)
Maximum dispersion range	3.2 ps/nm-km (range 1,285 to 1,330 nm) 19 ps/nm-km (range 1,550 nm)

Function	Parameters
Cable minimum bending radius	15 x cable diameter under no load. 0-800 N (0-180 lb)** 20 x cable diameter under load 800-2,700 N (181-600 lb)
*Building/breakout cables (tight buffer). Minimum attenuations do not apply to tight-buffered or breakout type cables. The maximum attenuation for tight-buffered cable is 1.00 dB/km @ 1,310 nm and 1.0 dB/km @ 1,550 nm. **Building/breakout cables (tight buffer). Tensile load rating and minimum bending radius do not apply to tight-buffered breakout-type cables.	

ps=picosecond

3-9.6.1.3 Non-zero Dispersion-shifted Fiber.

Fiber optic cables installed to high bandwidth optical transport equipment (e.g., Dense Wave Division Multiplexing (DWDM), Optical Transport Node (OTN), PON) must employ non-zero dispersion-shifted fiber (NZDSF) FOC when cable distances exceed 25 miles (40 kilometers). NZDSF FOC must meet or exceed the recommendations of ITU-T Recommendation G.655, Table 1/G.655.C and Table 2/G.655.D. Table 3-6 presents an extract from the ITU-T G.655 recommendation. If use of standard fiber versus NZDSF for the distance is in question, determine which fiber optic cable type will support the channel capacity for the distance at which the cable will be installed.

Table 3-7 Non-zero Dispersion-shifted Fiber Single-mode Fiber Optic Cable Characteristics

Fiber Attributes		
Attribute	**Detail**	**Value**
Mode field diameter	Wavelength	1,550 nm
	Range of nominal values	8-11 µm
	Tolerance	+/- 0.7 µm
	Number of turns	100
	Maximum at 1,625 nm	0.50 dB
Chromatic dispersion coefficient wavelength range: 1,530-1,565 nm	λ_{min} and λ_{max}	1,510 nm and 1,565 nm
	Minimum value of D_{min}	1.0 ps/nm-km
	Minimum value of D_{max}	10.0 ps/nm-km
	Sign	positive or negative
	D_{max} - D_{min}*	≤ 5.0 ps/nm-km*
	Maximum PMD_Q	0.20 ps/ √ km

λ=wavelength; µm=micrometer; D=chromatic dispersion coefficient; M=cable sections

3-9.6.2 Bend Radius.

The minimum bend radius for FOC during and after installation must conform to the latest issuance of ANSI/TIA-568. If the manufacturer's requirements are more stringent, follow the manufacturer's installation practices.

3-9.6.3 Cable Count.

Assign new fiber optic cable strand counts in a similar manner to copper counts. Drop the highest number strands within the cable count first; Strand 1 will be the farthest from the serving core node or ADN. Fiber counts must be split, handled, and/or terminated in groups or bundles of 12 strands. Drop groups or bundles designated as spares (dark fibers) in the nearest OSP supporting structure (e.g., MH, HH, or cable vault) stipulated by the site owner to position them for future growth. If the existing cable plant is reused and the strand count assignment differs from this layout, coordinate the updated strand count assignments with the site owner.

3-9.6.4 Splicing.

Fiber optic cable splicing permanently joins two fiber strands together and must be accomplished in accordance with TIA 609A000. There are two fiber splicing methods: mechanical splicing and fusion splicing. Mechanical splicing doesn't physically fuse two optical fibers together; rather, two fibers are held end-to-end mechanically. In fusion splicing, two fiber strands are fused together with an electric arc. Use the fusion method when splicing FOC into one continuous length. Fusion splices must have an insertion loss of <0.05 dB and return loss of >55 dB for loose tube fiber, or must have an insertion loss of <0.10 dB and return loss of >55 dB for ribbon fiber. FOC splice cases must meet requirements of TIA/EIA 515B000 and be tested using the manufacturer's recommended testing procedures to validate the integrity of the splice case seal. FOC splice cases must be installed within OSP supporting structures (e.g., MH, HH, or cable vault) in accordance with RUS Bulletin 1751F-642. Direct-buried splices may be used only in emergency situations (restoration of communications) and must be locatable through the installation of a permanent in-ground marker. Loop-through splicing must be used in lieu of dedicated cables (home runs) to the serving location. In loop-through splicing, only the fiber strands branching off from the main cable run to enter an EUB are cut and spliced, and the remaining fiber strands are not. The remaining fiber strands are folded back within the splice case and routed on to the next branch point. Binder group integrity must be maintained during this process. Splice unused spare fibers (dark fibers) through if the size of the FOC allows for the installation of a clear and cap at the end. Prepare unused spare fibers (dark fibers) for future splicing requirements. All splicing must be fusion spliced except for instances of emergency restoration when fusion splicing is not available.

3-9.6.5 Building Terminations.

3-9.6.5.1 Devices.

Strands of OSP FOC plant entering an EUB, ADN, or core node from an exterior pathway must be properly terminated within each facility on fiber optic patch panels (FOPP). Extend the OSP fiber optic cabling from the building's entrance facility to the main telecommunications room in accordance with NFPA 70® requirements. The main telecommunications room will house the FOPPs and serve as the facilities demarcation point where the OSP cabling transitions to ISP cabling. All FOPPs must be stenciled with the panel number, cable identification, and cable count.

3-9.6.5.2 Methods.

Accomplish new FOC terminations using the physical contact (PC) family of small form fit connectors and adapters. PC connectors and adapters, also referred to as polished connectors, are designed to support network devices with connection rates of 10 Gbps or higher. PC connectors and adapters that can be used include ultra PC (UPC), super PC (SPC), and angle PC (APC). APC connectors are typically used in video and RF signal transport where UPC are more suited for data networks. Use duplex LC connectors for new installation. If existing FOC plant and FOPPs are being reworked, subscriber connector (SC) or straight tip (ST) (ST™ compatible) connectors and adapters may be used to mate to existing plant with the approval of the site owner. All connectors and adapters must meet the requirements defined in TIA 604. OSP FOC strands must be fusion spliced to factory produced and compatible pigtails for FOPP termination.

3-9.7 Design Criteria.

The DoD currently employs a number of architectural topologies for OSP at each B/P/C/S. The intent is to provide voice and data services at the lowest possible cost, to include the total cost of ownership. Each B/P/C/S and project-specific criterion must be individually analyzed to determine the best technical solution based on available funding. One of the most important guiding principles for design and implementation of OSP infrastructure is to ensure single points of failure that would impact the user populace are eliminated in accordance with the Uniform Capabilities Requirements (UCR).

Paragraph 3-9.7.1 provides minimum criteria when specific guidance is not provided in project documentation.

3-9.7.1 New Cable Installation Minimum Requirements.

If the design requires installation of new cable, the requirements in Table 3-8 apply to all buildings unless the facility is designated as a special case. Special case buildings must meet the minimum requirements defined in Table 3.9.

Table 3-8 Standard Fiber Cable Sizing Between Buildings

From	To	Minimum Existing Fiber Strands	Minimum Fiber Strands if Installing New Cable	Notes
Core node	Core node	144	288	1, 2, 4
Server farm IPN/ISN	Core node	72	144	1, 2, 4
ADN	ADN/ core node	72	144	1, 2, 4
ADN	EUB	12	12	3, 5

IPN=Installation Processing Node; ISN=Installation Servicing Node; ADN=Area Distribution Node; EUB=End User Building

Notes:
1. The physical path of the cable from a physical ADN location to each adjacent core node/ADN should be direct to the connected core node/ADN without routing through or patching through any other building, with the exception of stand-alone cable huts or vaults.
2. The physical pathway between building locations must be dual-homed where two connections are run over two physically diverse paths or over a single concrete encased path.
3. Single physical pathway between building locations where a single connection is established.
4. Designs for new FOC must include at least 25-percent spare, unused strands, with cables designed in multiples of 12-strand groups.
5. Designs for new FOC must include at least 50-percent spare, unused strands, with cables designed in multiples of 12-strand groups.

Table 3-9 Special Case Fiber Cable Sizing between Buildings

COMMAND AND CONTROL USERS	
User Classification	**Description**
Special C2 users	• President of the United States of America • Secretary of Defense • Chairman of the Joint Chiefs of Staff • Commanders of the united commands • RED Switch subscribers

COMMAND AND CONTROL USERS	
User Classification	**Description**
C2 users	• Users that have the requirement for C2 communication, but do not meet the criteria of special C2 users. • Includes any person (regardless of position in the chain of command) who issues guidance or orders that direct, control, or coordinate any military forces, regardless of the nature of the military mission, whether said guidance or order is issued or effected during peace or war time.
Other Users	• Do not meet the criteria for special C2 users and C2 users. • May also be denied access during national emergencies.

Note: User classifications pertain to Defense Switched Network (DSN) access. Originally defined and applied to voice services, their use has been extended to data services by implication.

Table 3-10 Infrastructure Requirements for Buildings Requiring Connections to Multiple Nodes

User Classification	Building Entrance Requirements	Standards Document
Special C2 users	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1] Entrance conduits at a minimum will be concrete encased.	NFPA 1221, 8.4.3.2[2] Specific requirements defined as the mission dictates Requirements listed here are the absolute minimum for design purposes.
C2 users	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1]	NFPA 1221, 8.4.3.2[2] Requirements listed here are the absolute minimum for design purposes.
Main data facilities	Diverse entrance facilities with a minimum separation of 66 feet (20meters) The building entrance or the serving conduits will be below ground.	NFPA 1221, 8.4.3.2[2] Latest issuance of ANSI/TIA 942 ANSI TIA/942 does not state if the entrance facility is above or below ground.

User Classification	Building Entrance Requirements	Standards Document
Hospitals	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1] The building entrance or the serving conduits will be below ground.	NFPA 1221, 8.4.3.2[2] NFPA 99
Emergency Operation Centers	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1] The building entrance or the serving conduits will be below ground.	NFPA 1221, 8.4.3.2[2]
Fire stations (as mission dictates)	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1] The building entrance or the serving conduits will be below ground.	NFPA 1221, 8.4.3.2[2]
Garrison headquarters	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1] The building entrance or the serving conduits will be below ground.	NFPA 1221, 8.4.3.2[2]
Military Police (if not co-located with EOC)	Diverse dual entrance facilities with a minimum separation of 20 feet (6 meters)[1] The building entrance or the serving conduits will be below ground.	NFPA 1221, 8.4.3.2[2]

[1]Minimum separation is the same minimum separation for medical facilities.
[2]NFPA 1221, 8.4.3.2: Where multiple communications centers that serve a jurisdiction are not located in a common facility, at least two circuits with diverse routes, arranged so that no singular incident interrupts both routes, must be provided between communications centers.

Note 1: Non-concrete encased underground conduits and direct buried cables are considered diverse if the minimum separation between them is greater than 20 feet (66 meters).

Note 2: Except for Special C2 uses, node connections can share the same conduit system if the shared pathway is concrete-encased.

3-9.7.2 Passive Optical Networks in the Outside Plant Architecture.

The designer must obtain approval from the technical authority before designing a PON architecture. The way in which a PON influences the OSP design depends on whether the PON solution serves an individual building, multiple buildings, or an entire campus. PON is a point to multi-point architecture where signals from the headend or central office are divided by a passive optical splitter and fed downstream to many end users. In a single building PON solution the feeder fiber from the central node would traverse through the MH and duct system and the splitter would typically be located in the building. A PON serving multiple buildings or an entire campus would involve placing a splitter or series of splitters in the OSP section of the architecture (e.g., MH, HH, enclosure).

3-9.7.3 Air Blown Fiber in the Outside Plant Architecture.

ABF systems are an alternative to traditional optical fiber and innerduct solutions. ABF systems push FOC through preinstalled micro-ducts or tubes utilizing compressed air. ABF systems can be useful in scenarios where frequent moves, adds, and changes to the infrastructure are necessary or where it is not realistic to break ground to install new OSP infrastructure (e.g., airports, runways, training campuses). It is important to note that ABF systems often require proprietary equipment such as blowers, micro-ducts/tubes, fiber cable, and manufacturer’s accessories. The maximum distance most vendors will support without advanced blowing techniques is just over a half mile (3280 feet or 1 kilometer). The designer must obtain approval from the technical authority before implementing an ABF system. All blown fibers must be installed in new or existing micro-duct and manufacturers couplers must be used as required.

3-9.7.3.1 Fiber Optic Cable Testing.

Testing must be completed on all FOCs (OSP cable, premise distribution, patch cords), cable connections, splices, and terminations. Test using Tier 1 and Tier 2 test equipment, or a combination of both. Both a light source and power meter (LSPM) and optical loss test set (OLTS) are used for Tier 1 testing. An OTDR is used for Tier 2 testing. Tier 1 and Tier 2 testing must be accomplished in accordance with ANSI/TIA-568 and TIA-526 Series, SM fiber optic cable must be tested at wavelengths 1310 nanometers and 1550 nanometers for both Tier 1 and 2 testing. MM fiber optic cable must be tested at wavelengths 850 nanometers and 1300 nanometers for both Tier 1 and 2 testing. All connectors and bulkheads must be thoroughly cleaned prior to performing any testing. The following tests must be done at minimum for each tier:

- Tier 1 Testing:
  - Optical power
  - Optical loss (insertion loss) single reference jumper
- Tier 2 Testing:
  - Unidirectional (pre-installation)
  - Bidirectional (post-installation) with minimum 0.63 mile (1 kilometer) long launch and receive cables.

– Fiber characterization (chromatic dispersion (CD), polarization mode dispersion (PMD))

a. For new fiber optic cable installations, end-to-end testing using Tier 1 and Tier 2 test equipment must be performed on every fiber strand installed, spliced and/or terminated as follows. Prior to installation, Tier 2 testing (unidirectional) must be performed on all strands per bundle of new fiber optic cable while the cable is still on the manufactures cable reel. This test will verify the cable functionality is free from defects or damage from the manufacturer before installation. Factory test results are not acceptable, as damage may have occurred during shipment to the project location. Any fiber optic cable strands that fail pre-installation testing must be documented and reported to the USG prior to moving forward with installation.

b. Following completion of fiber optic cable installation, to include permanent placement, splicing and connector termination, both Tier 1 and Tier 2 (bidirectional) testing must be performed on all new strands per bundle of fiber optic cable.

c. For existing fiber optic cable that is being rehomed and reterminated, Tier 2 testing (unidirectional) must be performed from the originating or unaffected end prior to the start of work to identify existing defects or anomalies that need to be corrected. Once work has been completed on the existing fiber optic cable as part of the rehoming/retermination effort, Tier 1 testing must be completed from the end of the new work completed. Upon completion of Tier 1 testing, Tier 2 testing (bidirectional) must be completed to recertify the completed permanent link. Any existing fiber optic cable strands damaged during the rehoming/retermination effort must be repaired and restored to working order.

d. A test report must be developed that contains a strip chart for each fiber strand tested, to include the cable ID, strand ID, source location, test set location, dB loss at each wavelength and fiber length, and whether a strand has passed or failed. The test report must also include all raw data files collected from the test equipment used. All strands that passed testing prior to installation must pass testing after installation is complete.

3-9.8 OSP Cable Labeling.

3-9.8.1 Cable Identification/Cable Tags.

Cable Identification/cable tags must be installed at all termination points (terminals) and splices, including house cables. In all OSP supporting structures, all new and existing cables that are part of the project must be tagged and/or retagged between the splice and the wall and on both sides of a splice loop or maintenance loop. When a cable is rehomed to a new location all existing cable tags and terminal labels on the rehomed cable must be re-tagged and re-labeled to reflect the new information. One tag is required for a copper cable pull-through, and two tags are required for an FOC pull-through if there is no service loop. Labels in MHs and HHs must be machine-produced on a durable material suitable for the environment. Handwritten labels are not acceptable.

3-9.8.2 Cable Label Schemes.

The unique identifier for each cable will include an indicator of the originating location of the cable unless directed otherwise by unique project requirements. For a copper cable, it can be as simple as a local policy; e.g., cables 1 through 15 originate from Building xxx; cables 16 through 25 originate from Building yyy. For fiber optic cable, the originating number could be included as part of the identifier. Use the following cable label schemas:

- To identify a copper cable, size + type and cable identification + count are needed. Cable sizes must be identified with an abbreviation. For example, a 1,200 pair cable must be identified as “P12-24PF.” The “24” represents the AWG. PF (plastic insulated cable (PIC) fill) refers to the cable type (fluorinated ethylene propylene). All cables with fewer than 25 pairs must include an “X.” (Refer to the examples.)

Note: Only an existing cable is identified with a “CA” prefix.

  - 6-pair = P6X-24PF
  - 12-pair = P12X-24PF
  - 18-pair = P18X-24PF

- To identify a 900-pair, 24 AWG copper cable:
  - P9-24PF = cable size and type
  - 03, 1-900 = cable number and pair count

- To identify two different copper cables under the same sheath:
  - P18-24PF
  - 07, 1-1,500 + T1, 1-300

- To identify a 10-pair, 0.6 mm European copper cable:
  - 10x2x0.6 = size and type
  - 01, 1-10 = cable number and count

- To identify an 800 pair, 0.6 mm European copper cable:
  - 800x2x0.6 = size and type
  - 05, 1-800 = cable number and count

- To identify a fiber optic cable, use the cable identification + strand count and then the cable size + type.
  - FOC 01, 1-72 = cable identification and strand count
  - 172 SM = type of cable

- To identify a ribbon type fiber optic cable, use the cable identification + strand count and then the cable size + R (for ribbon) + type.
  - FOC 01R, SM, 1-72 = cable identification and strand count
  - 172 SM = type of cable

3-9.8.3 Identification of Core Network, Distribution Backbone, and Other Unique Cables.

The following requirement does not apply to cables to end user buildings. New cables placed to support core networks, the distribution backbone, and other unique cables must have at a minimum the cable name applied to the cable sheath during the manufacture of the cable. Refer to the site unique requirements for other characters that may need to be applied during the manufacturing process. The number of additional characters that can be applied to the cable sheath varies from 28 to 120 characters by cable manufacturer. Cable tagging is still required for these cables.

Note: Cable naming schemas should not include building numbers, as cable may be rehomed.

3-9.8.4 Existing Cable Labeling.

When an existing cable is rehomed to a location, the new location identifier should apply to all of the rehomed cable, to include laterals. Therefore, all the existing cable tags, the labels on the building terminals, and associated cable records must be changed to reflect the new information. This requirement is not to be construed as a requirement to place labels on cables that do not have existing tags unless the identification of the cable is easy to determine with minimal or no impact on the project's cost or schedule. An example of this is when there is only one cable in the MH, and the identifier and count were verified in the previous MH.

3-9.8.5 Tamper Evident Labeling.

Tamper evident labels must be affixed to all splice cases opened or installed as part of a project and any other major warranted components of the OSP infrastructure. Label components include the following and must be documented:

- type of component
- location of component
- date label was applied to the component
- photograph(s) that show the component and the location where the label was applied

Documentation of components must be provided to the COR at the conclusion of all work.

3-9.9 Demarcation Point Requirements.

The demarcation point is the point where OSP cabling transitions to ISP cabling and where termination and testing can take place.

- A PET is a device that provides electrical protection and a termination point for outside plant cable and indoor house wiring.
- Fiber optic patch panels are devices that provide a termination point for OSP FOC and ISP FOC.

3-9.9.1 Building Entries.

The standard method for entering buildings is through RMC. Refer to Figure A-10 for building entrance details. Use of above-ground entries in lieu of underground entries is permissible with USG approval. The preferred method for creating above ground cable entrance is to use el-shaped rigid conduit bodies (LL, LB, and LR). The riser conduits to must be RMC. Refer to Figure A-21 for above ground building entrances.

Typical foundation types include slab-on-grade, crawl space, full basement, and deep drilling on piles. Refer to Figure A-10 for duct assignment details. Footers encountered may be continuous or non-continuous. The footer portion of the foundation must not be cut. Entrance conduits must pass below footers or through the building foundation wall. RMC must be placed where the entrance conduits pass through foundation walls. Annular spaces between the conduits and floors and walls must be sealed to prevent water intrusion and must be fire stopped in accordance with UFGS 07 84 00, the NEC®, and local codes. The most stringent code applies. Conduits must extend between four to six inches (100 to 150 millimeters) above the finished floor or below the ceiling with bell ends to aid in pulling cables. Entrance conduits must be plugged or sealed to prevent water intrusion. Where conduits entering through the floor cannot be placed within 3 inches (75 millimeters) of a wall, as shown in Figure A-10, the conduits must enter a pull box within the building.

3-9.9.2 Above Ground Entrances.

Entrance conduits must not be mounted on the exteriors of buildings unless previously approved by the USG. Annular spaces between the conduits and floors and walls must be sealed to prevent water intrusion and must be fire stopped in accordance with UFGS 07 84 00, the NEC®, and local codes. The location of existing main telephone terminal rooms on floors above the ground level is insufficient cause to justify mounting entrance conduits on the exteriors of buildings. Where approved by the USG, the number of conduits mounted on the external walls of buildings must be minimized.

3-9.9.3 Pull Boxes and Conduit Bodies.

Pull boxes and conduit bodies must be sized in accordance with the cable manufacturer's recommended cable bending radius to accommodate the fiber optic and copper cables sized for the building. Conduit bodies are preferred for use where conduits enter the exterior walls. The contractor must obtain approval from the COR to install external pull boxes in lieu of installing conduit bodies. Conduit bodies are more robust and have a smaller footprint than pull boxes. The contractor must coordinate the location and finish of the above ground building entrances with the COR.

3-9.9.4 Transition.

The transition from plastic to RMC for entrance conduits must take place at the bottom of the trench prior to sweeps or bends to the building.

3-9.9.5 Building Telecommunications Grounding.

The contractor must ensure that the various grounding electrode systems, electrical grounding system, lightning protection grounding systems, telecommunications grounding system, and cable grounding system are bonded together. Unclassified TRs must be connected to the building's earth electrode subsystem in accordance with the latest issuance of ANSI/TIA 607. An acceptable grounding system encompasses fault protection grounds, lightning protection grounds, signal grounds, and DC power grounds (when applicable). Refer to UFC 3-575-01 for proper lightning protection and to NFPA 70® for proper fault protection grounding. The contractor must review applicable project drawing(s) to ensure that the lightning and fault protection grounds are addressed by the appropriate disciplines.

3-9.9.6 Building Ground.

The contractor must bond all edge and core network devices to the building earth electrode system (EES) in accordance with the latest issuance of ANSI/TIA 607. The contractor must be conscious of the proposed use of the facility; international, national, or local codes; DoD and Service standards; and/or manufacturers' equipment specifications, and should plan accordingly.

3-9.9.7 Cable Entrance Grounding.

The contractor must ensure that lightning protection complies with UFC 3-575-01 and ensure all grounding electrode systems are bonded together. All metallic shields and strength members for OSP cable entering a building must be bonded to the lightning protection ground system.

3-9.9.8 Copper Cable Entrance.

The designer must use a non-bonded splice case for the transition from OSP-rated cable to interior-rated cable or must indicate that the implementer must not install the splice case carry-through bonding conductor. The OSP copper cable shield, armor, and metallic strength member must be bonded to the lightning protection ground as close to the building point of entrance as possible with a No. 6 AWG bonding conductor in accordance with the latest issuance of ANSI/TIA 607. If the contractor extends the OSP copper cable past 50 feet (15 meters), in accordance with NFPA 70®, the metallic strength member must be bonded to the lightning protection ground as close to the conduit egress point as possible with a No. 6 AWG copper bonding conductor.

3-9.9.9 Surge Protector.

The contractor must terminate all OSP copper cables using surge protectors. Surge protectors are primary protector blocks equipped with 5-pin solid state or gas protector modules. The guidance on surge protection and proper bonding to the grounding system is found in IEEE C62.43. The protector blocks must be bonded to the building ground system with a No. 6 AWG bonding conductor. Terminals, surge protection modules, and hardware must be UL-listed. The PET for European projects must be equipped with protected, LSA+ terminal blocks.

3-9.9.10 FOC Entrance.

The designer must use a non-bonded splice case for the transition from OSP-rated cable to interior-rated cable or must indicate that the implementer must not install the splice case carry-through bonding conductor. The OSP FOC armor and metallic strength member must be bonded to the lightning protection ground as close to the building point of entrance as possible with a No. 6 AWG bonding conductor. If the contractor extends the OSP FOC armor past 50 feet (15 meters), in accordance with NFPA 70®, the metallic strength member must be bonded to the lightning protection ground as close to the conduit egress point as possible with a No. 6 AWG copper bonding conductor.

CHAPTER 4 AIR FORCE SPECIFIC REQUIREMENTS

4-1 REDUCE COSTS, ENHANCE SAFETY.

Follow industry trends of roll pipe and air-assisted cable pathway utilization to reduce the real property cost and complexity of traditionally designed MH and ducting systems from the Bell System era.

Retirement of high pair count, large diameter copper-cabling-based plain old telephone and time domain multiplexing (TDM) equipment has greatly reduced the need for expensive large capacity MHs and ducting. New conduit and cabling system installation technologies have the potential for significant cost avoidance because installations can be designed with longer uninterrupted spans, and do not adhere to the same requirements for maximum number of degrees of direction change before MH installation is needed for traditional “pulled installation” cable. This results in far fewer, if any, MHs within the design, reducing cost and number of additional dangerous confined spaces to an installation’s infrastructure baseline.

4-1.1 Copper Cable.

Install new copper cable only when the end equipment cannot be updated to fiber optic transmission.

4-1.2 High-Density Polyethylene Microduct Bundles.

a. Where there is no existing and available MH and ducting, directly bury HDPE-jacketed microduct bundles using methods described in this UFC.

b. HDPE microduct bundles between main communication nodes (MCN) must include no fewer than seven individual micro-ducts.

c. HDPE microduct bundles between EUBs must include no fewer than four individual microducts.

d. HDPE microduct bundles must not exceed 2000 feet (610 meters) in length without MH/HH or above-ground enclosure access to the span.

4-1.3 Conduit Access Points.

To reduce the number of confined spaces on Air Force installations and in areas of rocky terrain, use above-ground enclosures for conduit access points whenever possible.

4-1.4 Cable Sizing.

Adhere to Table 3.8, “Standard Fiber Cable Sizing Between Buildings,” with the following modifications:

- Column 3 heading: Originally Installed Fiber Strands Shall Not Exceed
- Column 4 heading: Do Not Exceed Strand Count if Installing New Cable

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CHAPTER 5 ARMY SPECIFIC REQUIREMENTS

5-1 INTRODUCTION.

5-1.1 Purpose.

This chapter provides additional requirements and guidance for Department of Army projects.

5-1.2 Army Technical Authority.

The Army's technical authority for this UFC is an Army employee regularly engaged in the design of information and communication technology. The Army Technical Authority should also have a BICSI RCDD certification. The delegated role of the Authority Having Jurisdiction (AHJ) does not change.

5-2 SPECIFIC REQUIREMENTS.

5-2.1 USG-Designed Projects.

Refer to Chapters 2 and 3.

5-2.2 Classified Infrastructure.

Use the following documents for projects that include SIPRNET requirements:

- *SIPRNET Technical Implementation Criteria*, U.S. Army Information Systems Engineering Command (AKO login required). https://www.us.army.mil/suite/files/5744948

- UFGS 27 05 29.00 10
  https://www.wbdg.org/ffc/dod

5-2.3 Telecommunications Spaces.

5-2.3.1 Collocation of Other Telecommunication Systems.

CATV, CCTV, fire alarm and electronic security systems (ESS) may be collocated inside the TR.

5-2.3.2 Multi-Story Buildings.

Refer to Chapter 2.

5-2.3.3 Barracks, Dormitory, and Bachelor Quarter Telecommunications Room Sizing Considerations.

Standard TIA-569 TRs are typically too large for these types of facilities. Provide an 8-foot by 10-foot (2.4-meter by 3.0-meter) main TR on the first floor and provide a minimum of one 6-foot by 8-foot (1.8-meter by 2.4-meter) TR on subsequent floors.

Provision the TRs in these facilities in accordance with TIA-569. Telecommunication enclosures are acceptable in barracks with non-linear designs..

5-2.4 Telecommunications Pathways.

Refer to Chapter 2.

5-2.5 Fiber Optic Backbone Cable.

The Defense Information System Network (DISN) Enterprise Network Installation and Campus Area Network (ICAN) design and implementation standards and specifications dictate use of single mode fiber cables for building backbones on Army projects.

5-2.6 Work Area.

5-2.6.1 Outlet Types and Density for Barracks, Dormitories, and Bachelor Quarters.

Use outlets with a minimum of a “F” type jack and a category CAT6A jack. Locate outlets in the kitchen, living room, family room, and all bedrooms adjacent to a duplex electrical receptacle.

5-2.6.2 General Range Information Infrastructure Design.

With the advent of digital ranges, the preferred infrastructure to ranges is an underground infrastructure, consisting of a two-way conduit system. Direct-buried cable may be used when directed by the USG.

The minimum conduit size for ranges must be no less 1.5-inch (40-millimeter) trade size conduits. The minimum depth for conduit or cable placement is 48 inches (1200 milimeters). Coordinate with the mission owner to determine the required depth.

a. Splices must be placed in underground concrete supporting structures with an HS-20 load rating. Use of buried composite concrete fiberglass is not permitted. Support structures must be large enough to accommodate cable service loops and splice cases.

b. Concrete encasement or galvanized RMC must be used in range projects under road crossings, heavy equipment (tank) crossings, and high-traffic areas. The contractor must plan for a minimum of two, 1.5-inch (40-millimeter) conduits under road crossings. For heavy equipment traffic loads (e.g., tank crossings), the contractor must design and install a pathway based on the maximum expected wheel load. The encasement and/or galvanized RMC must be extended a minimum of 6 feet (1800 millimeters) beyond the road bed for all road crossings.

c. The contractor must also specify a minimum of 12 strands of SM FOC to the individual ranges or range buildings.

5-2.6.4 Inter-Building and Outside Plant Requirements.

Follow Chapter 3 of this UFC.

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CHAPTER 6 NAVY SPECIFIC REQUIREMENTS

6-1 INTRODUCTION.

6-1.1 Purpose.

This chapter provides additional guidance and planning information for Department of the Navy (DoN) projects that will require Navy and Marine Corps Internet (NMCI) network connections. Navy medical facilities must comply with the Defense Medical Facilities Office (DMFO) criteria, including UFC 4-510-01, and are not normally part of NMCI.

Note: For this UFC, the term “NMCI” references the network provided for use by the Navy and Marine Corps; Next Generation Enterprise Network (NGEN) references the contract between the USG and the contractor providing the NMCI network service.

All Naval Facilities Engineering Systems Command (NAVFAC), Facilities Engineering Commands (FEC), Public Works Departments (PWD), Resident Officer in Charge of Construction (ROICC) offices, BCO, and other concerned parties must refer to this UFC when designing, planning, or preparing documentation for new projects that will require operational NMCI support.

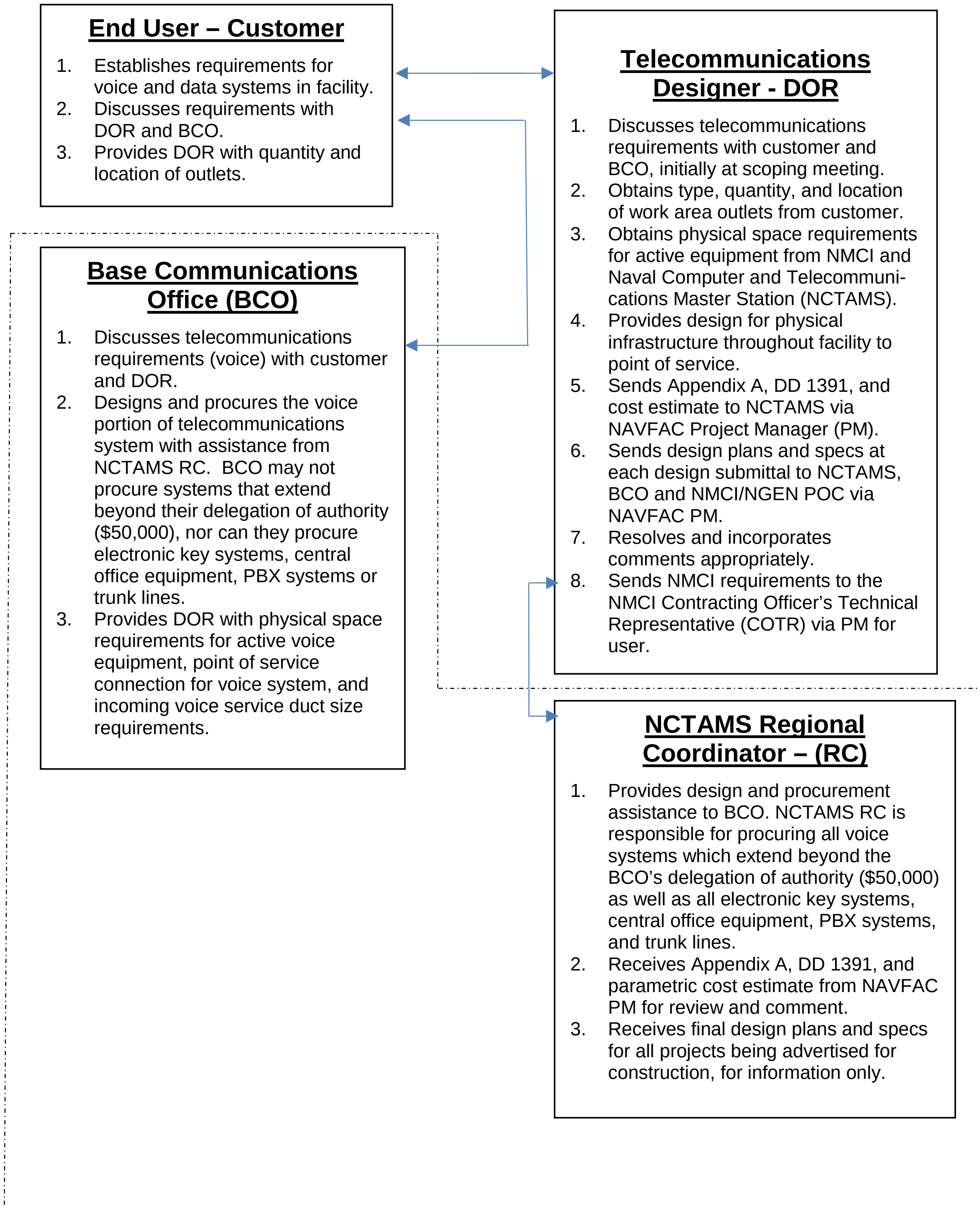
6-1.2 Order of Precedence.

If conflicts arise between this UFC and the NGEN contract, the NGEN contract governs.

6-1.3 Coordination.

Although this UFC was written to be as inclusive as possible, IT installations may vary greatly from building to building. It is therefore imperative that the USG facilities team (Naval Enterprise Networks (NEN) Program Office, Commander Navy Installations Command (CNIC), and NAVFAC components), facility design team, and construction contractor coordinate closely at each stage of planning, design, and construction. The telecommunications system DOR must coordinate their efforts for each design with the applicable entities identified in Figure 6-1.

Figure 6-1 Navy Telecommunications Coordination Chart for Typical Design/Bid/Build for Non-National Capital Region Projects



6-2 SPECIFIC REQUIREMENTS FOR NAVY INTRANET CONSTRUCTION.

6-2.1 Collocating Various Systems.

Provide adequate space in TRs to facilitate tenant-owned telecommunications systems and other low-voltage systems such as fire alarm, CATV, CCTV, and ESS.

6-2.2 Bachelor Quarters Considerations.

Standard TIA-569 TRs are normally too large for these types of facilities. For multi-story quarters, provide a minimum of one 8 feet (2.4 meters) by 10 feet (3 meters) main TR on the first floor and a minimum of one 6 feet (1.8 meters) by 8 feet (2.4 meters) TR on subsequent floors. Provide additional TRs on the main and subsequent floors as required to meet system limitations.

6-2.3 Fiber Optic Backbone Cabling.

Provide single mode fiber optic cabling (OS1) on all projects for building backbones to future proof the network and standardize the backbone. Additionally, this permits the option of flattening the network via direct connection to switches in TRs other than the main TR. In existing Navy facilities with multimode cables and switches, coordinate with the activity and the NMCI/NGEN contractor to determine whether the switch optics will be changed to use the single mode backbone, or if multimode cable must also be provided in addition to the single mode. If using multimode, OM3 (which permits data rates up to 10 Gigabits) is first choice. OM2 and OM1 should be used only to supplement existing systems.

6-2.4 Navy-Specific Technical Authorities.

For the purposes of implementing fiber to the desktop, the DOR must have justification in writing from the end user certifying that the 1391 supports this requirement, and from the NMCI/NGEN POC certifying that this requirement is included in their planned system.

6-2.5 Barracks, Dormitory, Bachelor Quarters.

Provide a minimum of one standard telecommunications outlet in each bedroom and common area (living room) of the suite. Comply with FC 4-721-10N.

6-2.6 Utility Rooms.

Coordinate with other disciplines and the Activity to determine if a voice or data outlet is needed in mechanical or electrical utility spaces (for smart metering or automated building control systems).

6-3 OUTSIDE CABLE PLANT.

See Chapter 3.

6-3.1 Pathways.

Coordinate with the NMCI contractor to determine if the NMCI pathways can be routed in the same duct bank with other telecommunication conduits. If so, conduits beyond the 5-foot (1.5-meter) line and manholes are MILCON funded to the closest manhole where service exists. The location of underground structures and the necessary interconnecting ducts must be explicitly described and identified in the contract documents.

For new buildings, provide a minimum of one, 4-inch (103 millimeter) conduit for NMCI service. Provide a minimum of two conduits for multi-story buildings. Use three innerducts (two, 1.5-inch (41-millimeter) and one, 1-inch (27-millimeter)) or three fabric mesh innerducts in each conduit. Install a pull wire inside each of the innerducts. This is in addition to the conduits required for other telecommunications services (telephone, cable television, fire alarm and intrusion detection).

6-3.2 Detection.

Provide electronic detection for each pathway in accordance with the following:

- Use detectable warning tape or tracer wire above the duct back for new installations.
- Use tracer wire when pulling new cable in existing duct systems.
- Terminate all tracer wire in test stations for utility locating personnel with a cover/lid marked “Test Station.”

6-3.3 Cabling.

Standard NMCI practice employs SM FOC with a minimum core size of 8 microns as the transport medium between building EFs.

- Install fiber underground in conduit.
- A minimum of 12 strands of SM fiber is required. Coordinate with the NMCI contractor for additional requirements. Provide fiber with facility contract.
- If classified seats are supported and unencrypted classified communication occurs over the outside plant cabling, conduits are required and normally must be encased in concrete. Comply with applicable PDS requirements, including IA PUB 5239-22.

CHAPTER 7 MARINE CORPS SPECIFIC REQUIREMENTS

7-1 INTRODUCTION.

7-1.1 Purpose.

This chapter will be used by the Marine Corps to provide additional guidance and planning information for USMC projects that will require telecommunications or IT network connections.

Marine Corps projects must use an optical solution as the first course of action when planning and designing new projects. Exceptions to this can be granted only by the Marine Corps installation's advocate or where life safety is concerned due to local building codes. Refer to Chapter 2 of this UFC for non-optical solutions.

Naval Facilities Engineering Systems Command (NAVFAC), Facilities Engineering Commands (FEC), Public Works Departments (PWD), Resident Officer in Charge of Construction (ROICC) offices, installations' G/S-6, and other concerned parties in the process must refer to this UFC when designing, planning, or preparing documentation for new projects.

7-1.2 Marine Corps-Technical Authority.

Telecommunications infrastructure must meet the needs of the activity and supporting facilities in accordance with this UFC. Architect/Engineer (A/E) contractor-generated final drawings and specifications for Design-Bid-Build and Design-Build projects must be stamped by a BICSI RCDD. Design and construction may be concurrent efforts in Design-Build projects, and multiple phases may be approved. Therefore, each phase and/or project must be stamped.

Modernization of telecommunications systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required.

7-1.3 Coordination.

Although this UFC was written to be as inclusive as possible, cable plant electronics installations may vary greatly from building to building. It is therefore imperative that the USG facilities team as stated above, facility designer, and construction contractor coordinate closely at each stage of planning, design and construction. The DOR must coordinate their efforts for each design with the applicable entities identified in Figure 7-1.

Figure 7-1 Marine Corps Telecommunications Coordination Chart for Typical Design-Build and Design-Bid-Build Projects

Note: Solid lines represent customer coordination requirements within installation staff and their tenants. Dashed lines represent contractor-to-installation communication.

7-2 SPECIFIC REQUIREMENTS FOR MARINE CORPS PROJECTS.

7-2.1 USG-Designed Projects.

USG-designed (in-house) projects require the approval of the Service-appointed telecommunications agent, prior to bid, in accordance with regulations, policies, memorandums, and guidance.

7-2.2 Classified Infrastructure.

Classified work areas, rooms and facilities must comply with MCO 5530.14A.

7-2.3 Collocation of Other Telecommunication Systems.

CATV, CCTV, control systems, fire alarm and electronic security systems (ESS) may be collocated inside the TR. Tenant owned systems that are not considered part of the facility are not accorded space within a TR. Planning for an equipment room will be considered as required if there are no other hosting capabilities available. Final decision authority is the site owner.

7-2.4 Telecommunications Rooms.

Follow the general requirements of Chapter 2 with the following additional requirements. Minimum dimensions are 10 feet, 8 inches (3.25 meters) by 12 feet (3.6 meters), meeting all TIA-569 standards with the following exceptions.

- Base sizing of room on the additional systems requirements of the service space such as Building Management System (BMS), Automated Control Management System (ACMS), Intrusion Detection System (IDS), fire-alarm panels, and A/V equipment.
- Provide a minimum of two standard 19-inch (0.5-meter) cabinets per TR. Equipment racks will be used by exception due to physical security requirements and other specific facility requirements.
- In facilities or structures that require only the minimum infrastructure to the EF, one cabinet may be used, and the room resized appropriately. FRCS substations and remote locations may be served by a splitter or other passive connection in a pedestal.
- Mount all cabinets to the permanent floor, centered in the TR to meet Americans with Disabilities Act (ADA) access requirements.
- Colocation support agreements will be established at local level being first Flag Officer (FO)/General Officer (GO).

Treat floors, walls, and ceilings to eliminate dust by providing eggshell or semi-gloss paint finish, light in color, to enhance room lighting. Provide one wall outlet installed at or near the entry door for emergency or primary voice communications.

7-2.5 Cabinet Layout.

Existing TR cabinet layout will include ONTs and optical splitters. Future layouts will have splitter/patch panel in cabinets and ONT at work stations. Locate OLTs at the area distribution node.

7-2.6 Facility Optical Network Terminal Placement.

Do not place rack-mounted ONTs with more than 120 Gigabit Ethernet (GbE) interfaces per PON port off of the OLT. Current ONTs configured with 24-ports are grouped in multiples of five onto a 1:8 or 2:8 (for pathway redundancy) passive optical splitter.

7-2.7 Optical Splitters.

Locate splitters at a central aggregation point or EF when feeding a single ONT at a remote location, EUB, or hybrid A/V rack area. This is the demarcation point of an EUB. Place the optical splitter at the ADN if the facility will house four to five ONTs and will require only a single (or two for redundancy) strand(s) of OSP fiber to the OLT. The minimum strand count for OSP run to remote location is 24 strands. However, if this EUB requires dual homing or special redundancy, locate a secondary 2:1 splitter to connect the ONT and allow for two OLTs to be interfaced into the EUB 2:1 splitter.

It is important to ensure that the optical loss budget is taken into account. As the common point of load (PoL) budget is from -8 to -28dB, there may be a requirement to attenuate the optical signal via a splitter or attenuator to allow for proper ONT operation.

7-2.8 Patch Panels and Patch Cords.

Provide patch panels to support locking or keyed patch cords for improved physical security and the ability to meet fixed emergency communication location requirements. Code or key patch cords in accordance with the type of service they are providing – primary voice, data, video, or Supervisory Control and Data Acquisition (SCADA). Provide a reference color code and naming convention for baseline consistency.

Provide bend-insensitive, pre-terminated patch cords capable of being locked into place to avoid accidental disruption of services or tampering. For OLT to fiber optic patch panel (FOPP) connections, provide SC-UPC to SC-APC patch cords. Provide all other patch cords to match the patch panel they are connecting. LC-APC connectors and patch panel adapter bulkheads are acceptable for increased density; however, they are not permissible at the information outlet faceplate.

7-2.9 Telecommunications Pathways Interior Conduit.

Provide wall-mounted work area outlets with rigid metal conduit stubbed up from the outlet to the horizontal cable distribution system. Use cable trays or non-continuous supports (J-hooks) to support the cable from the TR to the top of the wall containing the work area outlet, then route the cable in the wall cavity to a low-voltage mounting bracket.

7-2.10 Work Area Outlets.

Connect work area outlet face plates to a double-gang, 4-inch by 4 inch (100 millimeter by 100 millimeter) outlet box, at least 3.5 inches (90 millimeters) deep to accommodate fiber inserts, slack management, and potential in-wall signal converters.

7-2.10.1 Type 1 Outlet.

Terminate Type I horizontal fibers in a traditional face plate. Because ONTs typically allow multiple Ethernet interfaces, a single fiber interface per workstation/classification is typically all that is required. This consists of a traditional wall plate equipped with two single-port SC-APC connectors. This scenario provides flexibility in that any ONT type can be used in the design, along with other traditional duplex send and receive fiber pair technologies that may be required under special circumstances.

When using fiber outlets for desktop or surface mounted ONTs, the outlet connectors for the horizontal fiber drop must be an individual snap-in style and fit securely into the face plate housing. The connector must be compatible with single-mode SC-APC fiber. SC-APC is recommended throughout the installation to ensure compatibility with RF video service and future 10G-PON applications employing the 1577 nanometer wavelengths. Angled connectors or inserts with hinged dust covers are recommended to minimize fiber end face contamination.

7-2.10.1.1 Optical Network Terminal Copper Ethernet Interfaces.

For ONTs equipped with Ethernet interfaces, provide a minimum of one (1) 10/100/1000 RJ-45 interface conforming to IEEE 802.3 standards. A quantity of two or four 1000 Base-T interfaces are recommended to comply with current industry best practices. 10/100 Base-T interfaces and those not supporting PoE or PoE+ are not permissible except in scenarios where RF video or plain ordinary telephone services (POTS) are being provided.

7-2.10.1.2 Optical Network Terminal Copper Analog Interfaces.

ONTs equipped with analog POTS provide various quantities (2, 4, or 24 depending on the model) of RJ-11 or RJ-21 telephone jacks for connection of analog devices (telephones, faxes, modems). These interfaces may provide 600 or 900 ohm terminations and adhere to typical analog voice wire length specifications.

7-2.10.1.3 Optical Network Terminal Coaxial Outlet/Connector.

ONTs equipped with RF video interfaces can provide broadcast television service or any RF frequency up to 1 GHz. The coaxial outlet/connector integrated within the ONT is a standard, male 75-ohm “F” type connector. The designer must coordinate with the cable service provider where franchise agreements are in place and additional head-end components such as an RF combiner, laser modulator, and erbium-doped fiber amplifier (EDFA) will be required for PoL distribution of RF services.

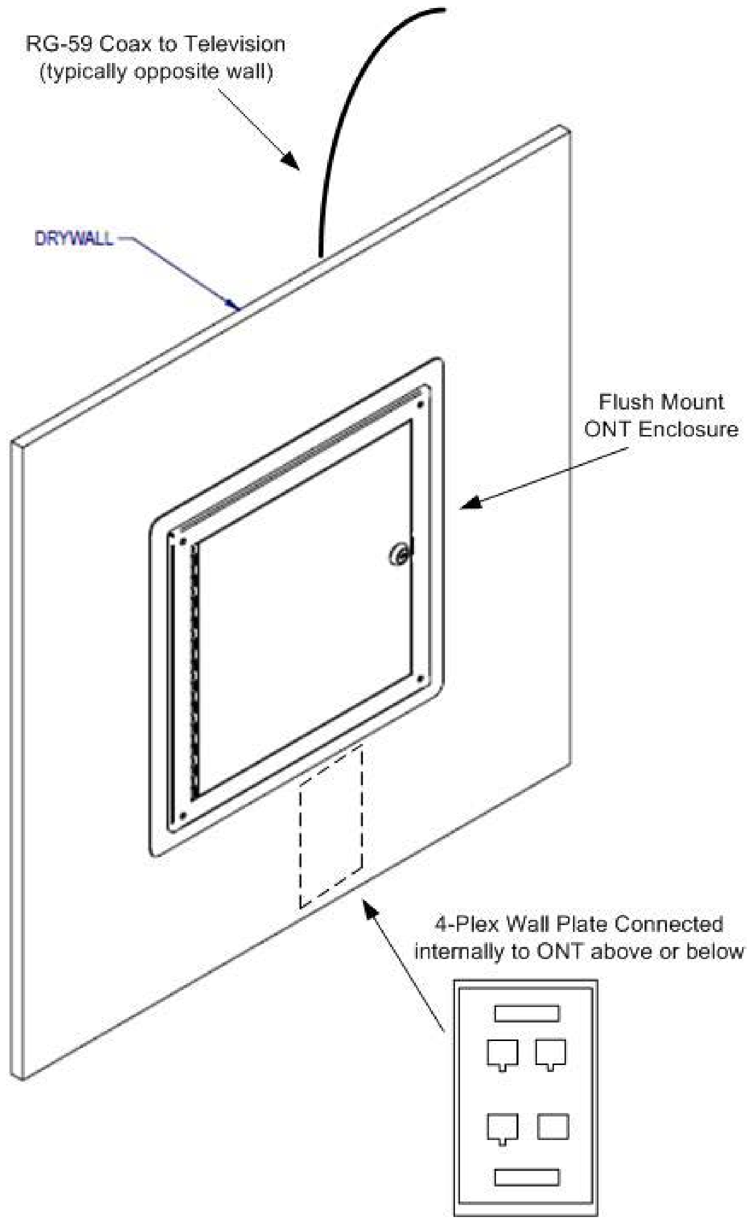
7-2.10.1.4 Optical Network Terminal Density (Port Sharing).

Consider end user requirements for the number of information outlets at a workstation when designing a POL system layout. While some IP endpoints (including printer locations, IP surveillance, access control entry points, and building automation systems) may require multiple ports for connectivity to various Ethernet devices or multiple networks, there are many instances where a workstation or IP endpoint need only connect to perhaps one or two network interfaces. In this scenario, it is acceptable to allow for port sharing between ONTs to increase the operational and financial savings associated with the POL deployment. In the port sharing deployment, adjacent cubicles or modular workstations can share the ports of a single ONT by distributing copper Ethernet patch cords between the cubicles. The quantity depends upon the number of required interfaces for each workstation and/or the forecasted growth of the end user's network requirements. In many cases, an IP telephone can be installed in tandem with a user's PC or workstation eliminating the need for a duplex Ethernet jack per user. This allows for as many as four users to share a single, four-port ONT, for example. Another scenario provides two jacks per workstation so that the ONTs are shared at a 2:1 ratio. Regardless of port sharing, the designer must provide a single work area outlet (WAO) at each workstation for future growth and flexibility.

7-2.10.2 Type 2 Outlet.

The Type 2 outlet mirrors the approach of a Type 1 deployment with the exception of the termination of the ONT at the end user workstation or IP endpoint. The Type II deployment will provide protection of the ONT from tampering, disruption of service, and environmental anomalies such as liquid spills, dust, or even vandalism. Enclosures are also recommended in medical facilities, conference rooms, or common areas to conceal cabling and ensure continuity of operation. All connectivity to the ONT (power, fiber port, Ethernet, analog voice, and RF video) may be contained within the enclosure and end user information outlets can either extend externally from the enclosure to a face plate apparatus, or exit the enclosure via pass-through devices. The location of the information outlets is dependent upon end user requirements and whether the enclosure is surface-mounted or flush-mounted. See Figure 7-2.

Figure 7-2 Flush-mounted ONT Enclosure



7-2.10.3 Type 3 Outlet.

Type 3 deployments allow for a hybrid approach to passive optical LATB infrastructures. Type 3 deployments are appropriate where TRs exist and are not planned to be re-purposed after installation of the PON. Type 3 deployments are also appropriate where a viable copper cabling infrastructure exists and is not in need of a technology refresh. Type 3 systems use high-density ONTs (typically 24 Ethernet ports) which are then patched to the horizontal copper cabling drops as does a legacy system using workgroup switches. Type 3 deployments allow for a migration strategy to fiber-to-the-desktop architectures and can readily accommodate technology refreshes where the legacy work group switches must be replaced.

The workstation outlet used in a Type 3 architecture consists of standard category rated copper cabling per Chapter 2 of this UFC. The WAOs in this architecture are commonly in place prior to the upgrade or replacement of the active electronics to POL. A new copper plant is recommended, but not required, to provide flexibility in the types of networks patched into the POL or for special sources.

Note: Refer to Chapter 2 of this UFC for additional outlet types and design standards for copper or optical-based interior telecommunication wiring.

7-2.11 Installations Communications Grid (ICG) or Backbone Cabling.

Provide a minimum telecommunications service to all new facilities consisting of one 25pr copper cable and one 24 strand, single mode (OS1) fiber optic cable through a minimum of two, 4-inch (100-millimeter) ducts. Provide additional cable count in accordance with maximum population and workspace requirements per facility type.

APPENDIX A STANDARD DRAWINGS

Figure A-1 Drawing Symbols and Legend

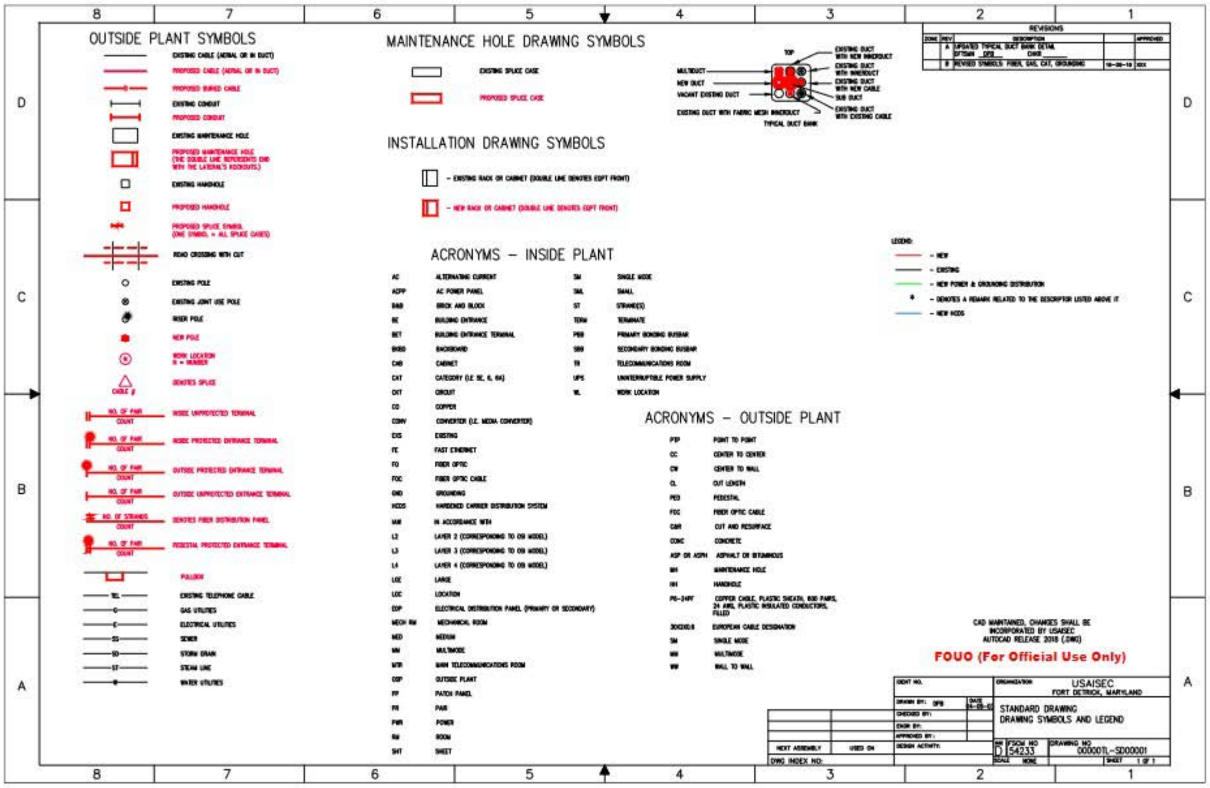


Figure A-2 Conduit Placement and Cut and Resurface

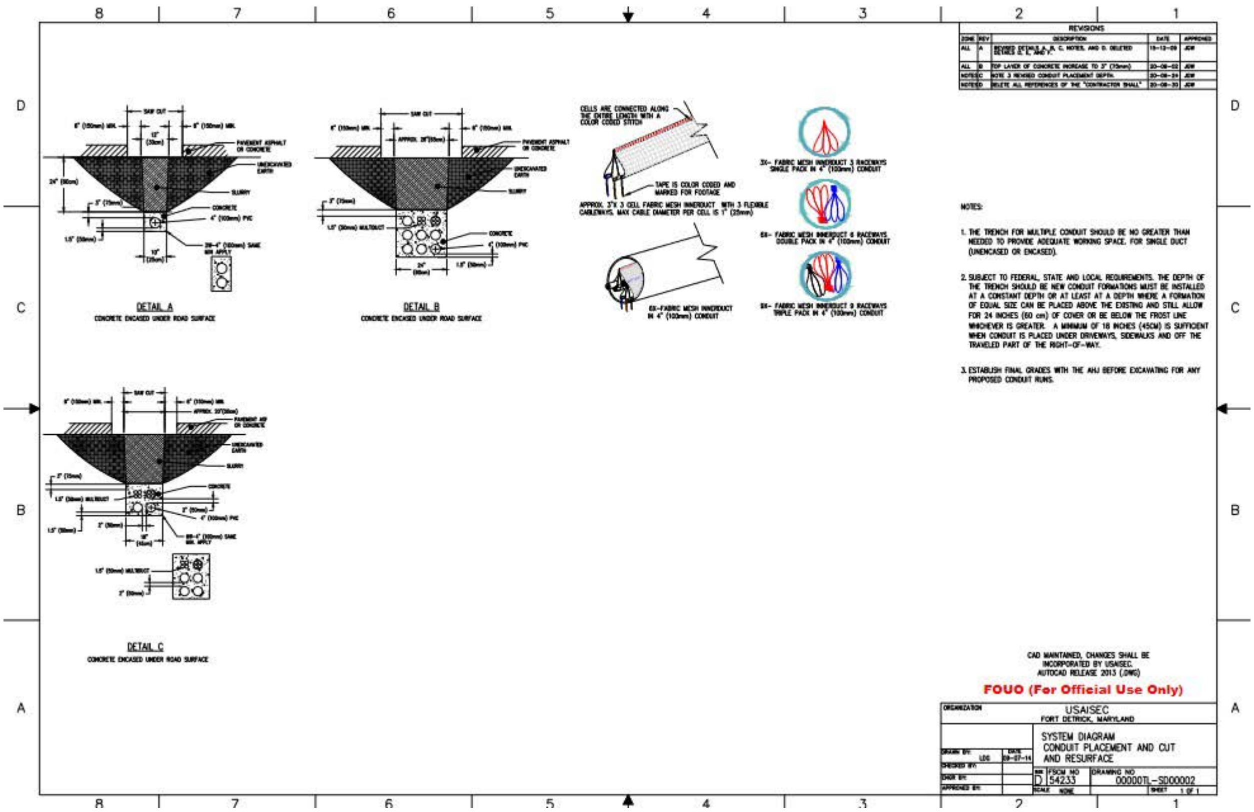


Figure A-3 Conduit in Casing Placement

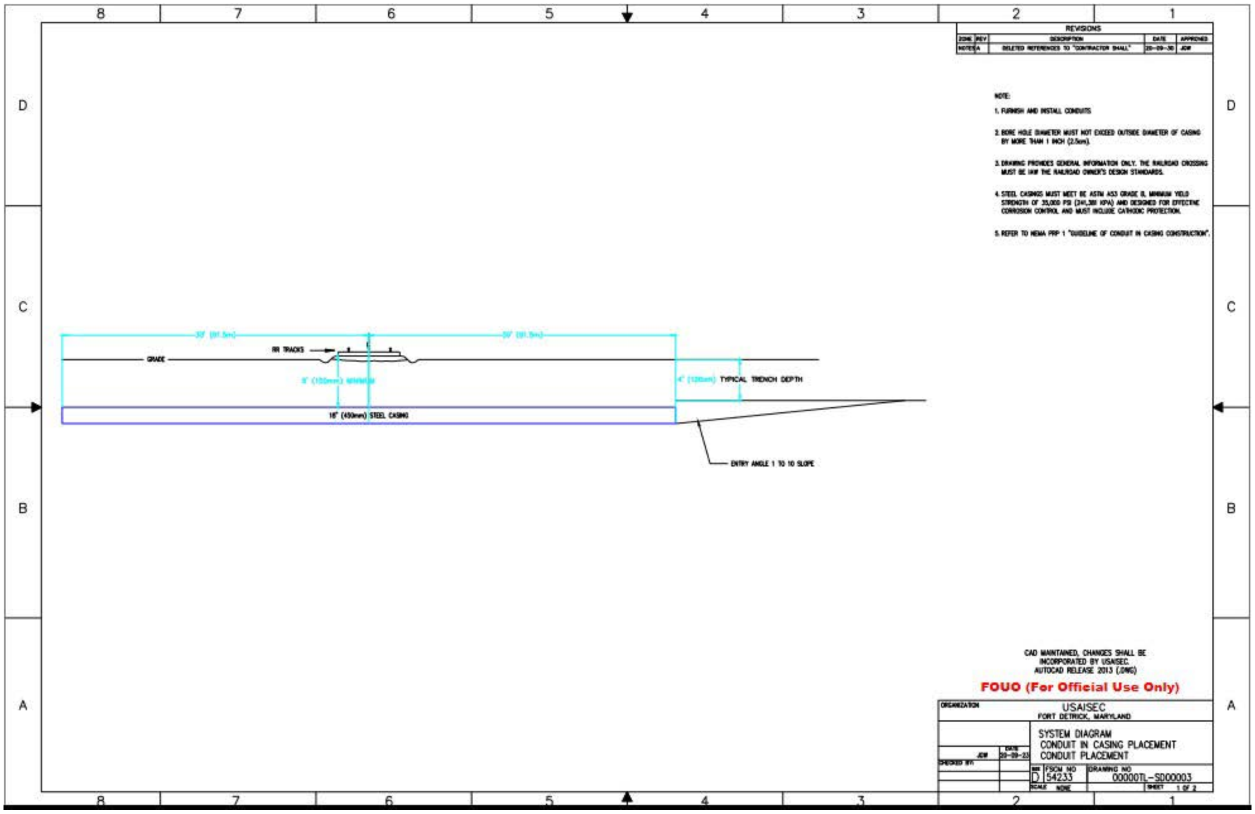


Figure A-4 Double Stepped Tee-Cut and Resurface Details

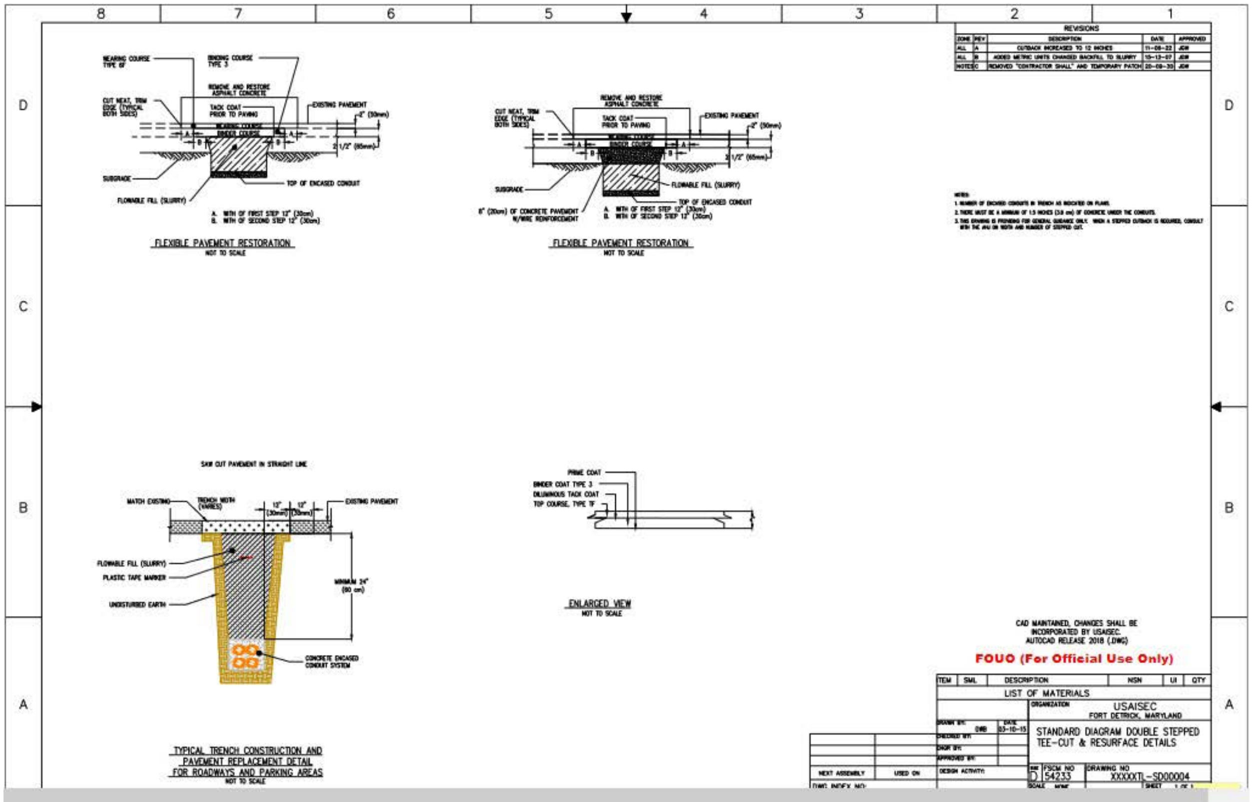


Figure A-5 Large Maintenance Hole Detail - Typical

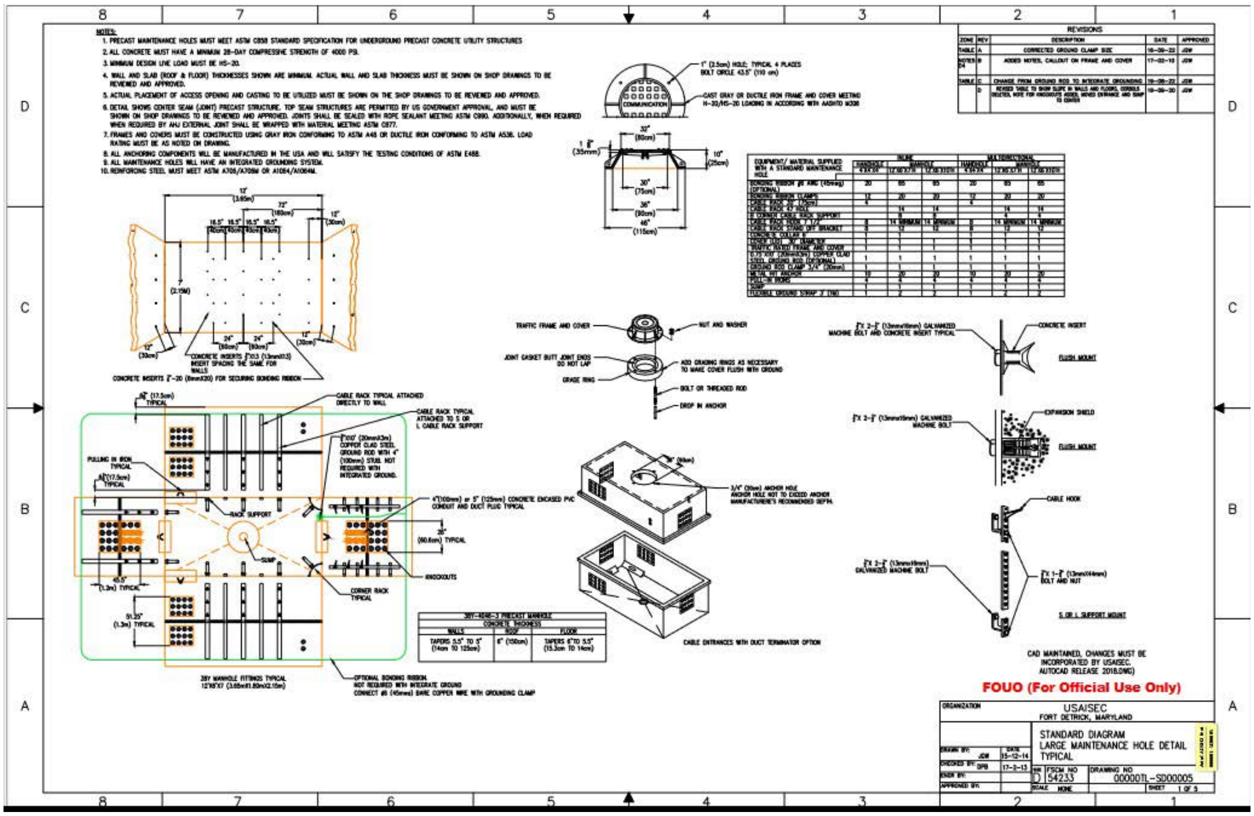


Figure A-6 Splay Maintenance Hole Detail - Typical

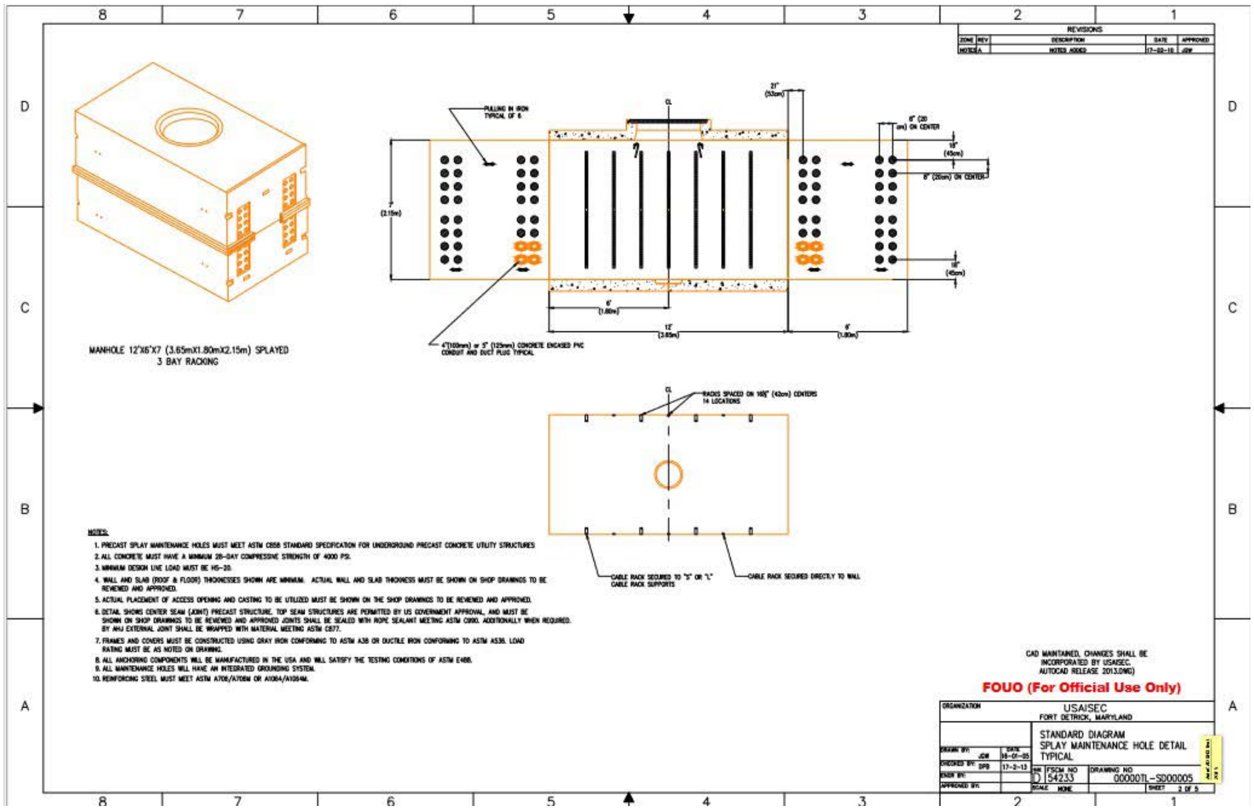


Figure A-7 E80 Rated Maintenance Hole Detail – Large Typical

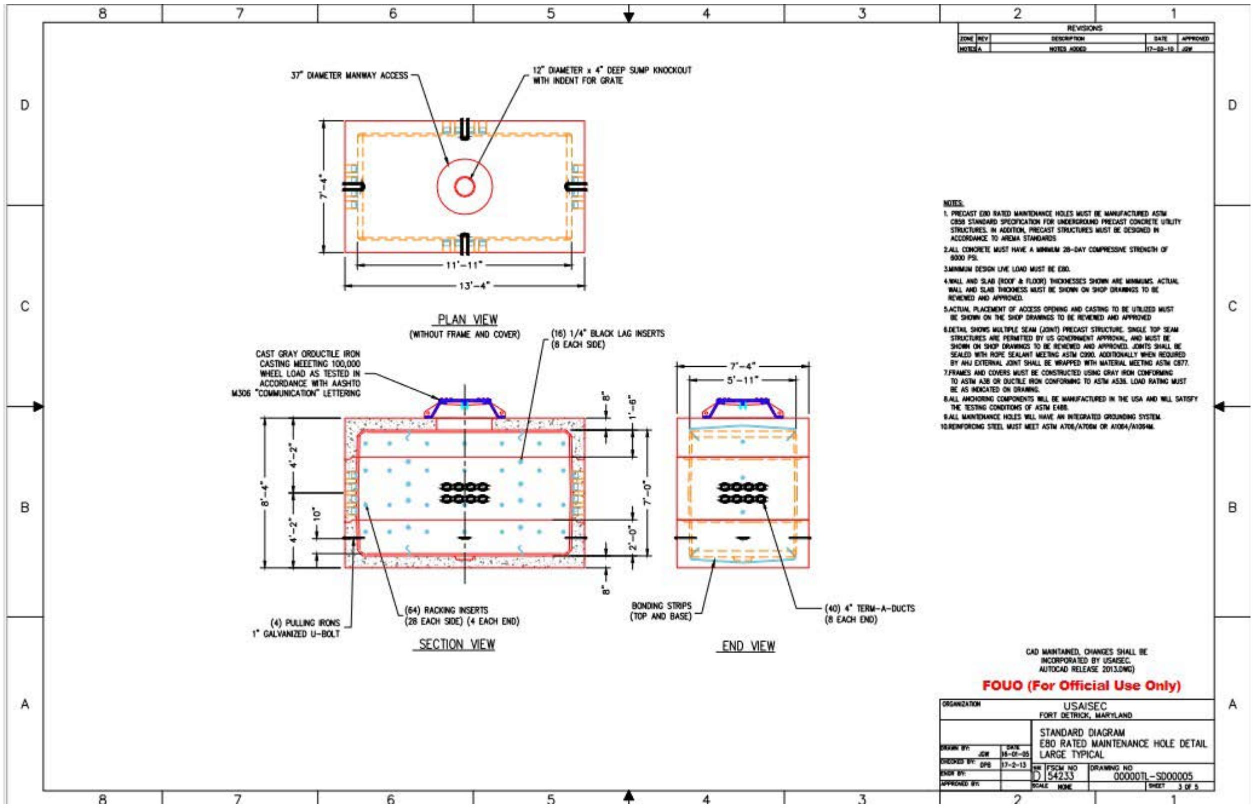


Figure A-8 E80 Rated Maintenance Hole Detail – Medium Typical

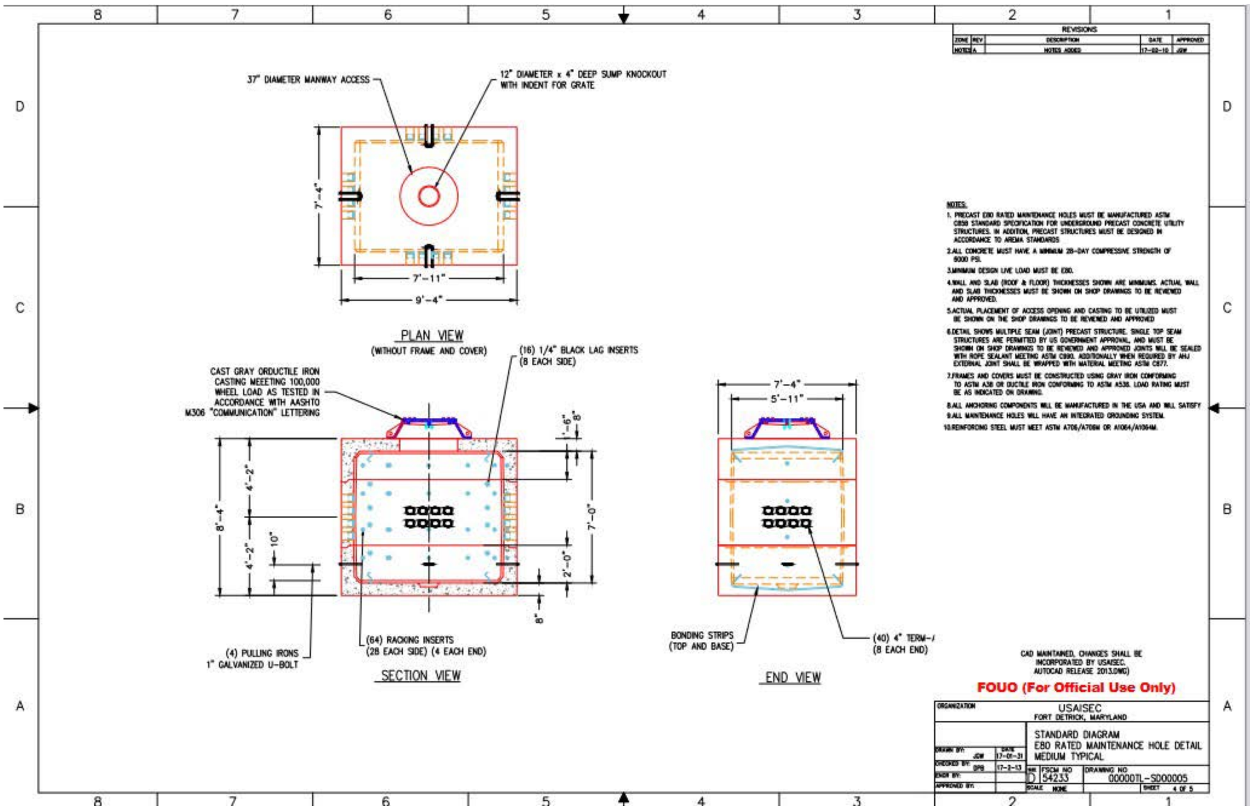


Figure A-9 Type V-1 Maintenance Hole

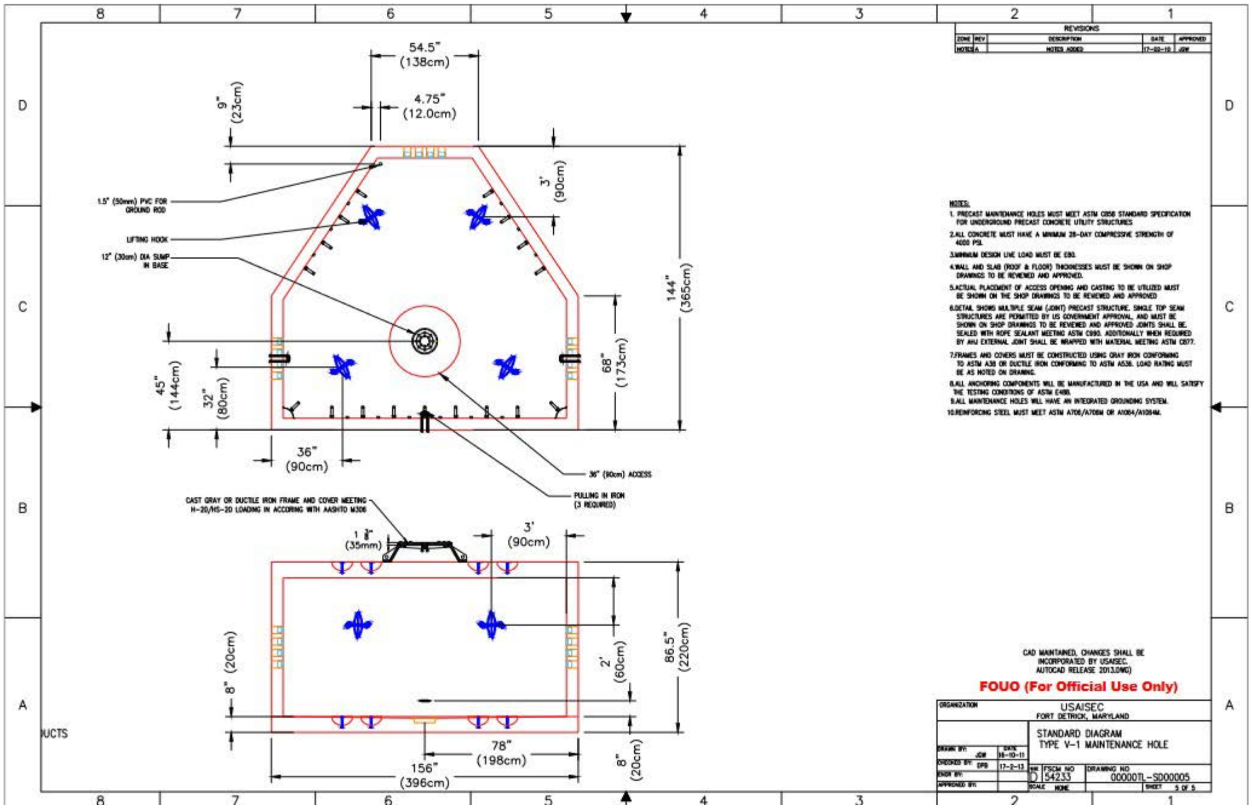


Figure A-10 Pedestals and Building Entrance Details (Sheet 1 of 3)

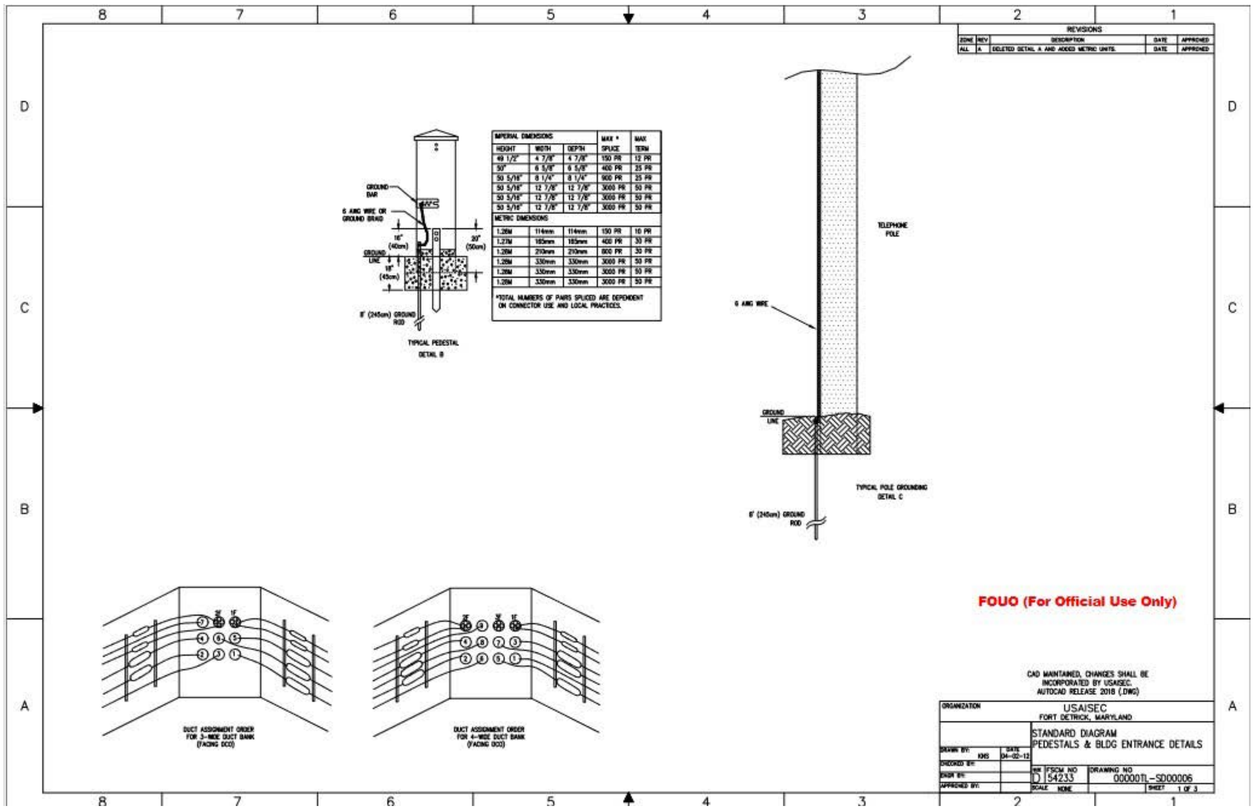


Figure A-10 Pedestals and Building Entrance Details (Sheet 2 of 3)

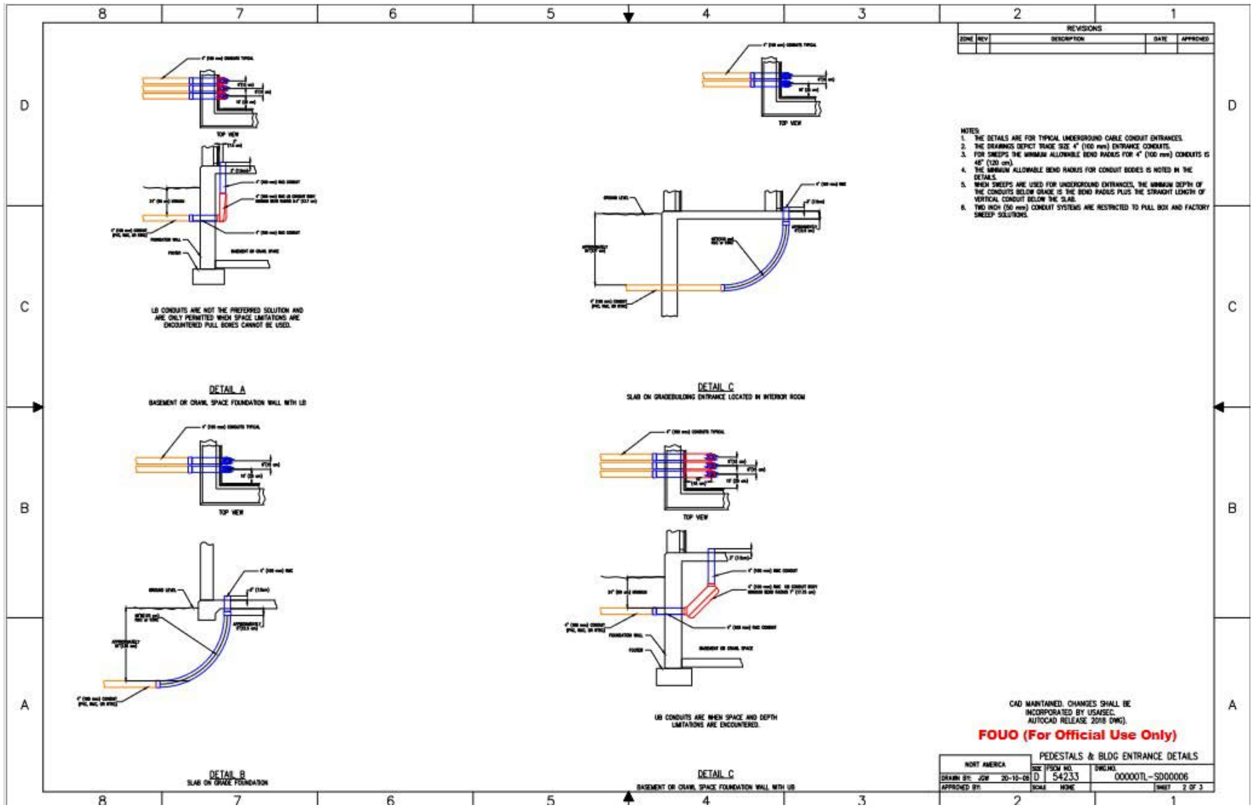


Figure A-10 Pedestals and Building Entrance Details (Sheet 3 of 3)

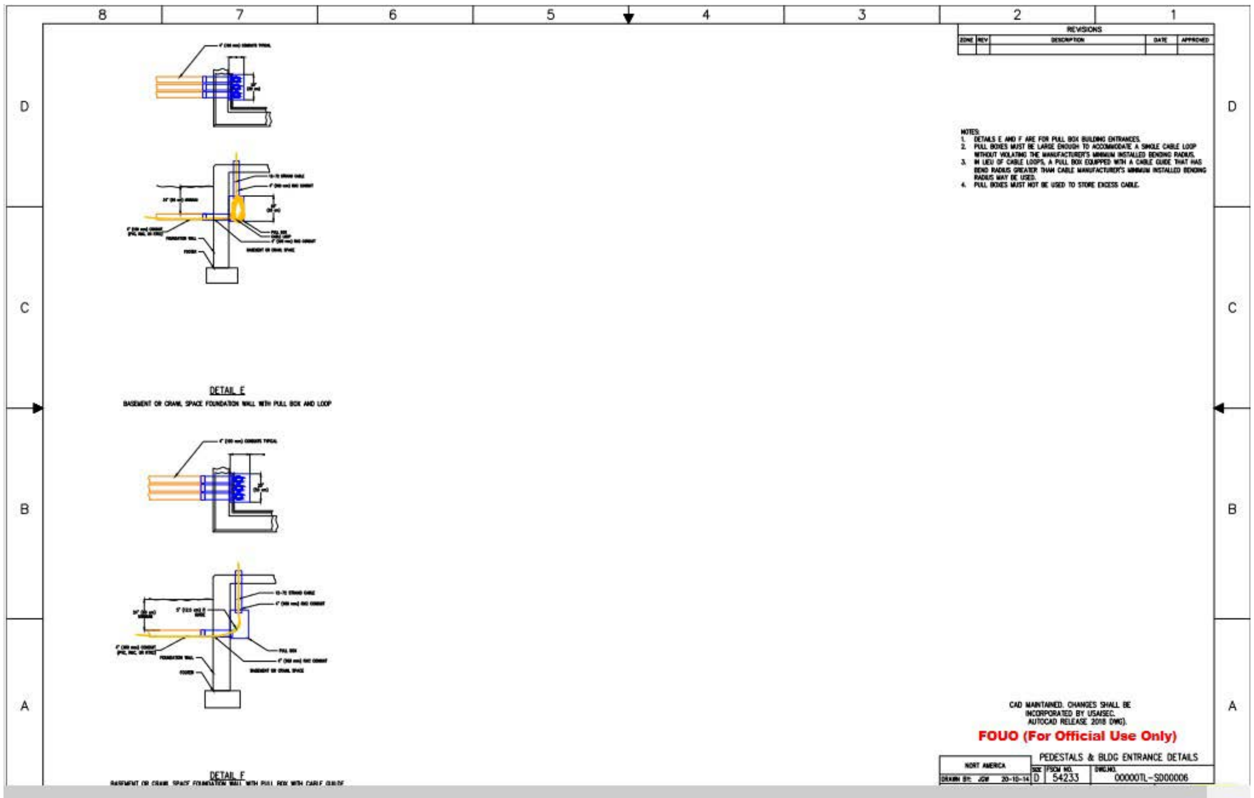


Figure A-11 Main Frame Drawing MDF and Cable Vault Schematic

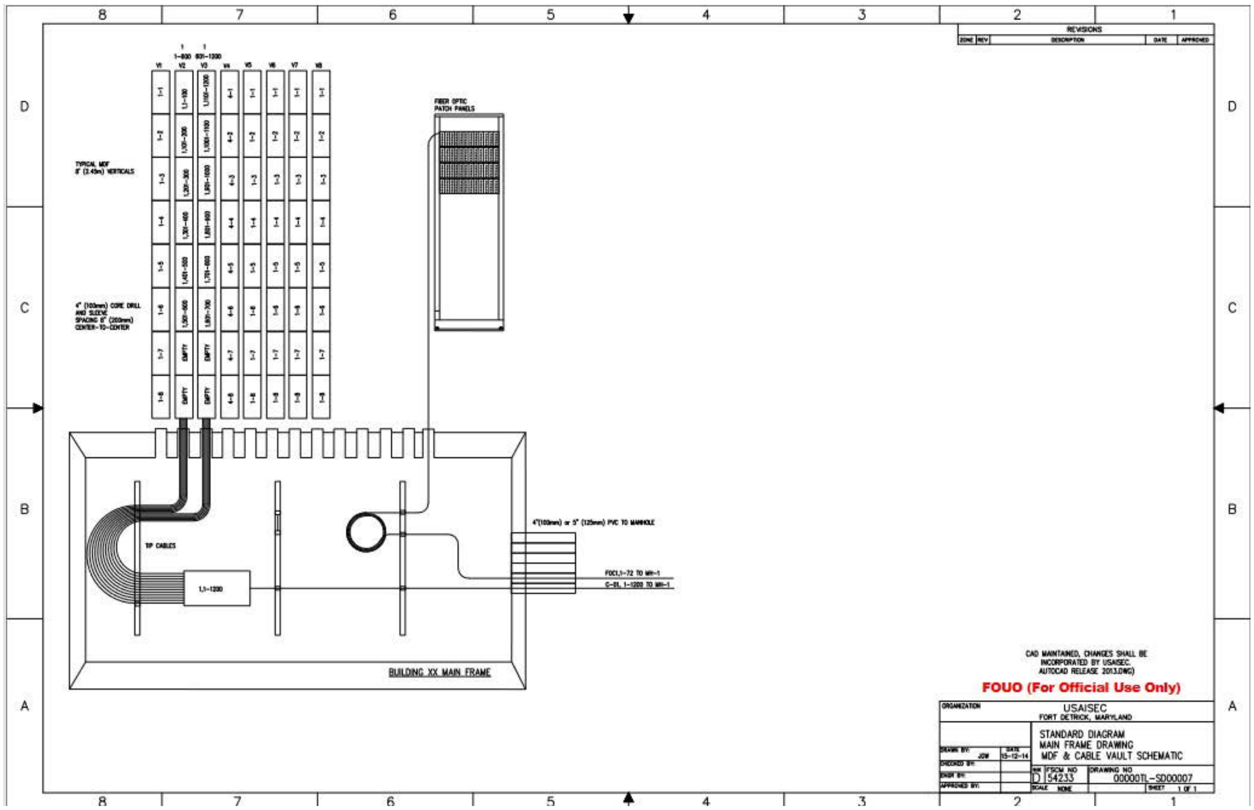


Figure A-12 Pipe Bollard Construction Detail

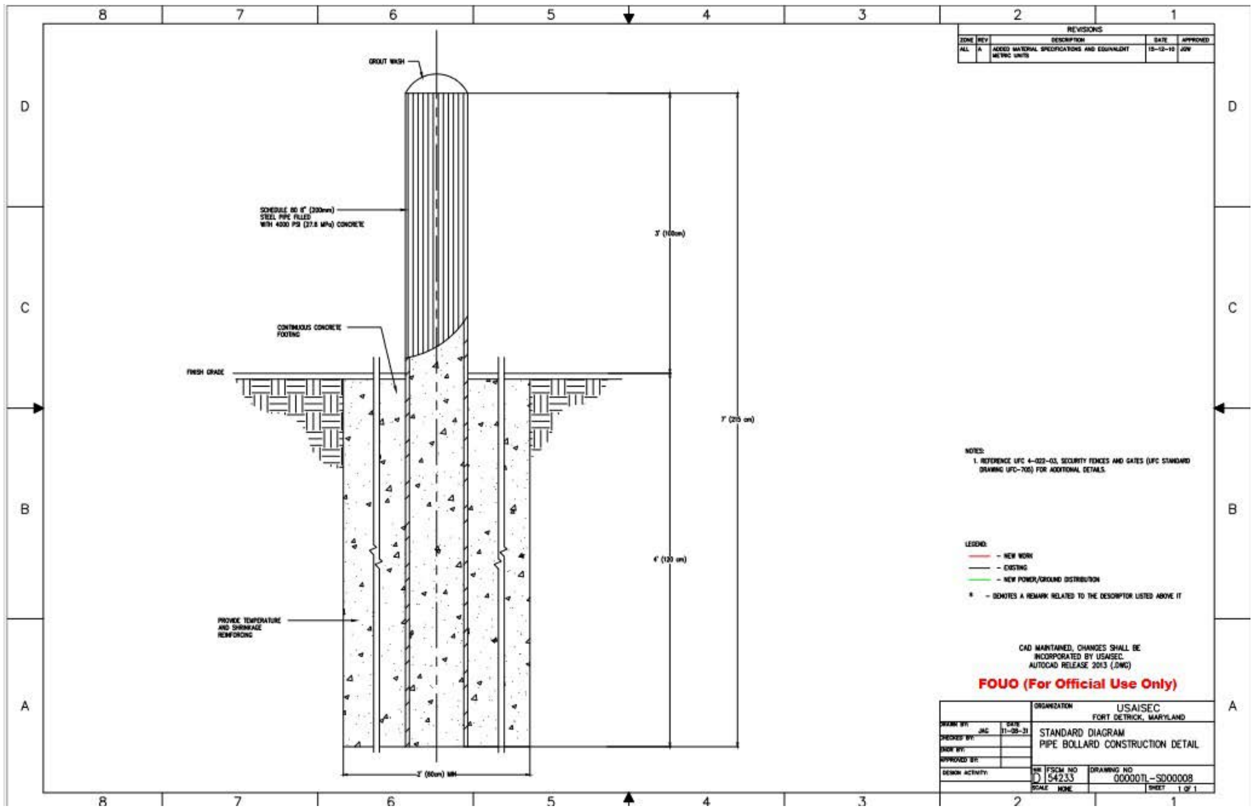
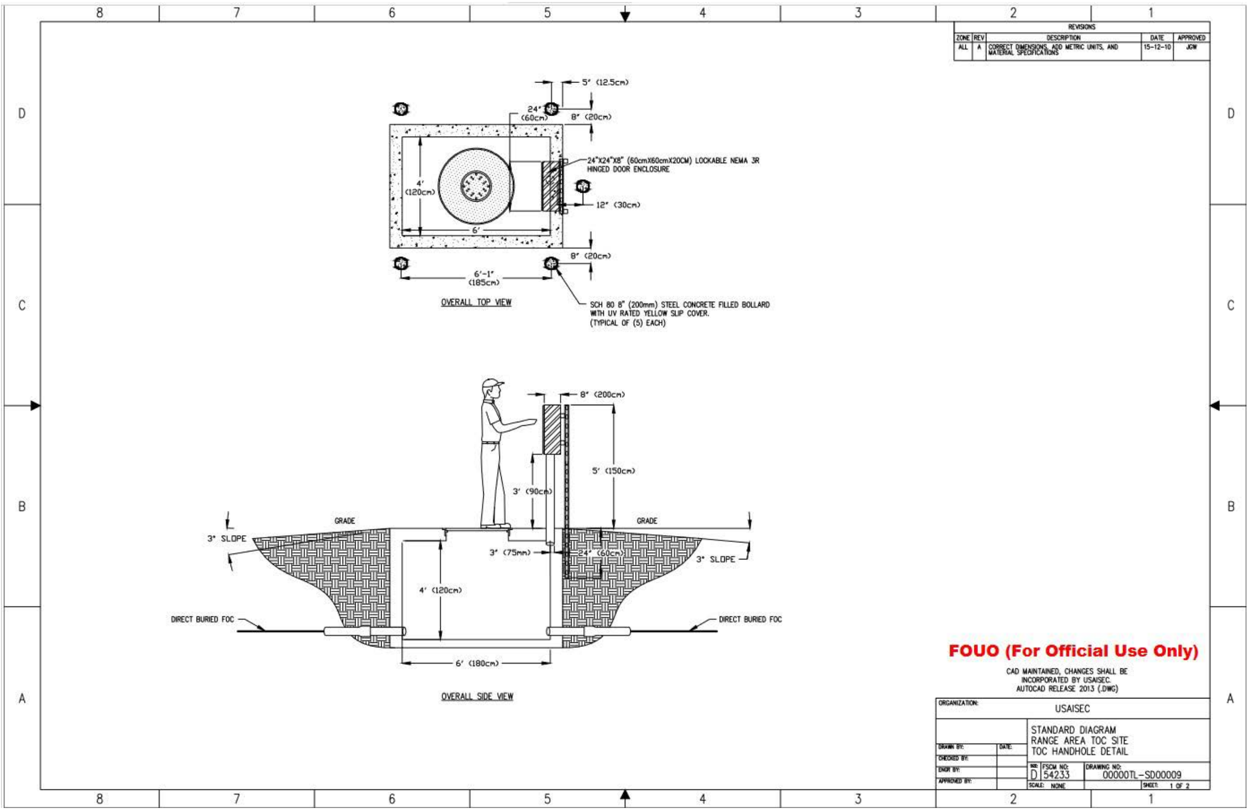


Figure A-13 Range Area TOC Site – TOC Handhole Detail



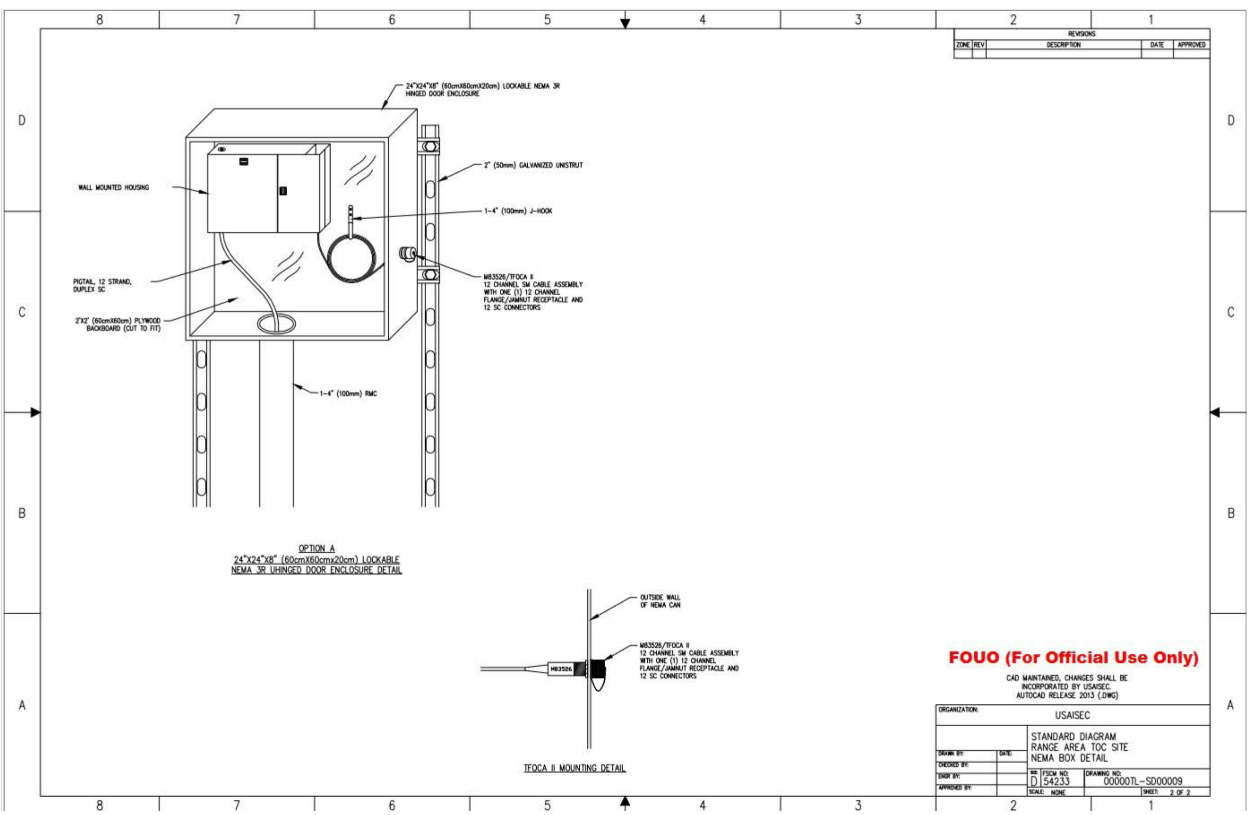


Figure A-14 Range Area TOC Site NEMA Box Detail

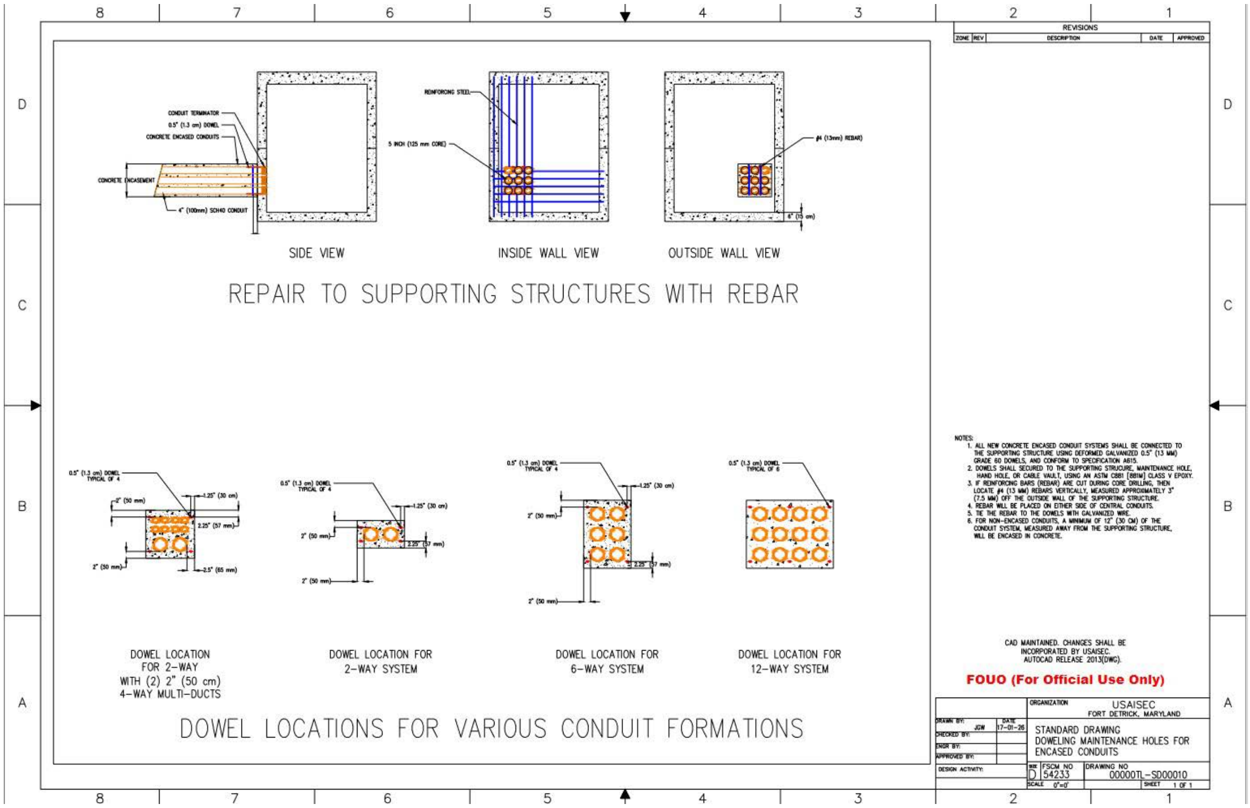


Figure A-15 Doweling Maintenance Holes for Encased Conduits

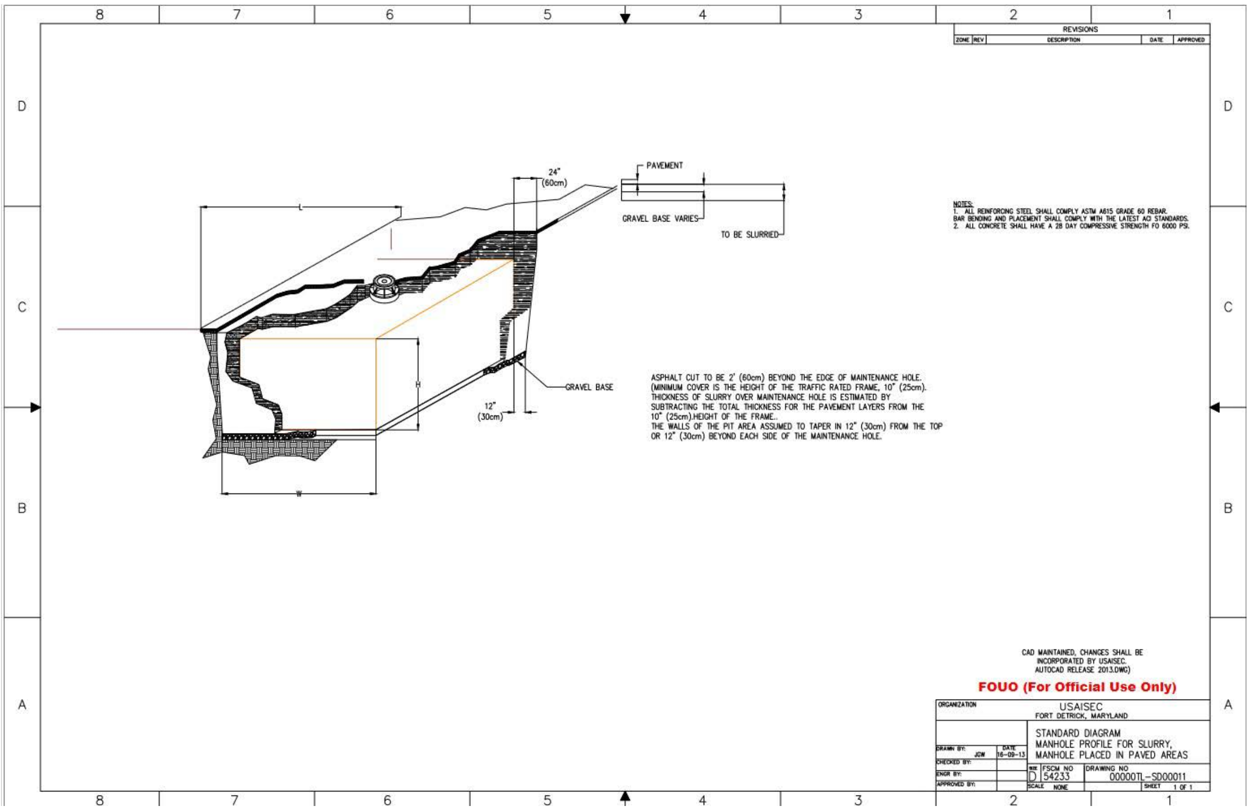


Figure A-16 Maintenance Hole Profile for Slurry, MH Placed in Paved Areas

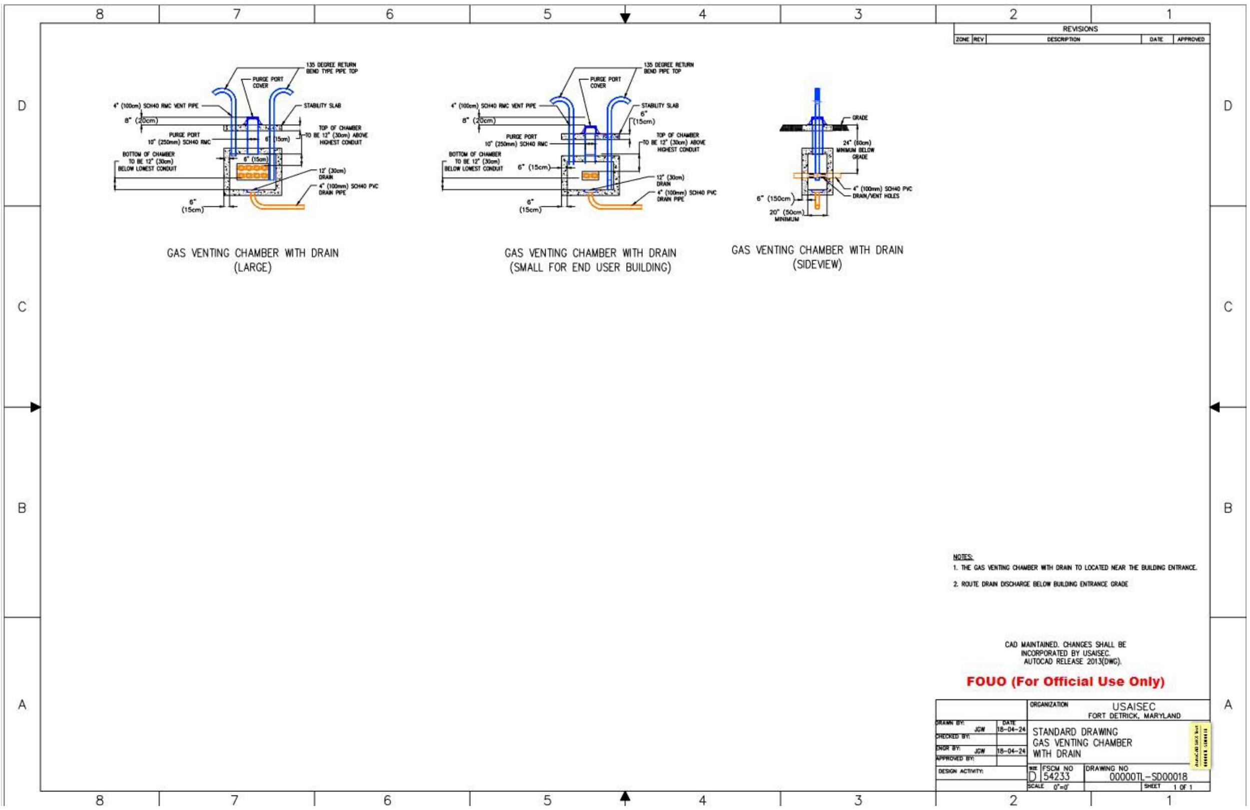


Figure A-17 Gas Venting Chamber with Drain

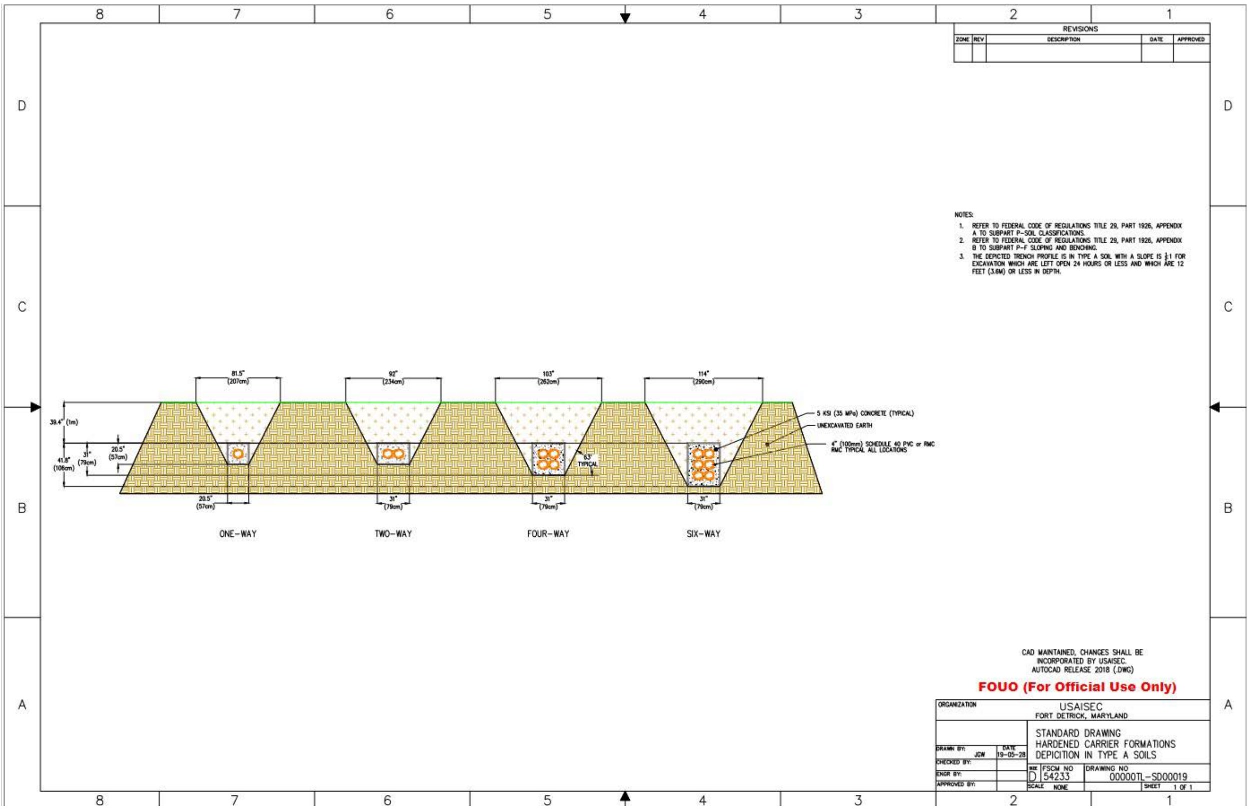
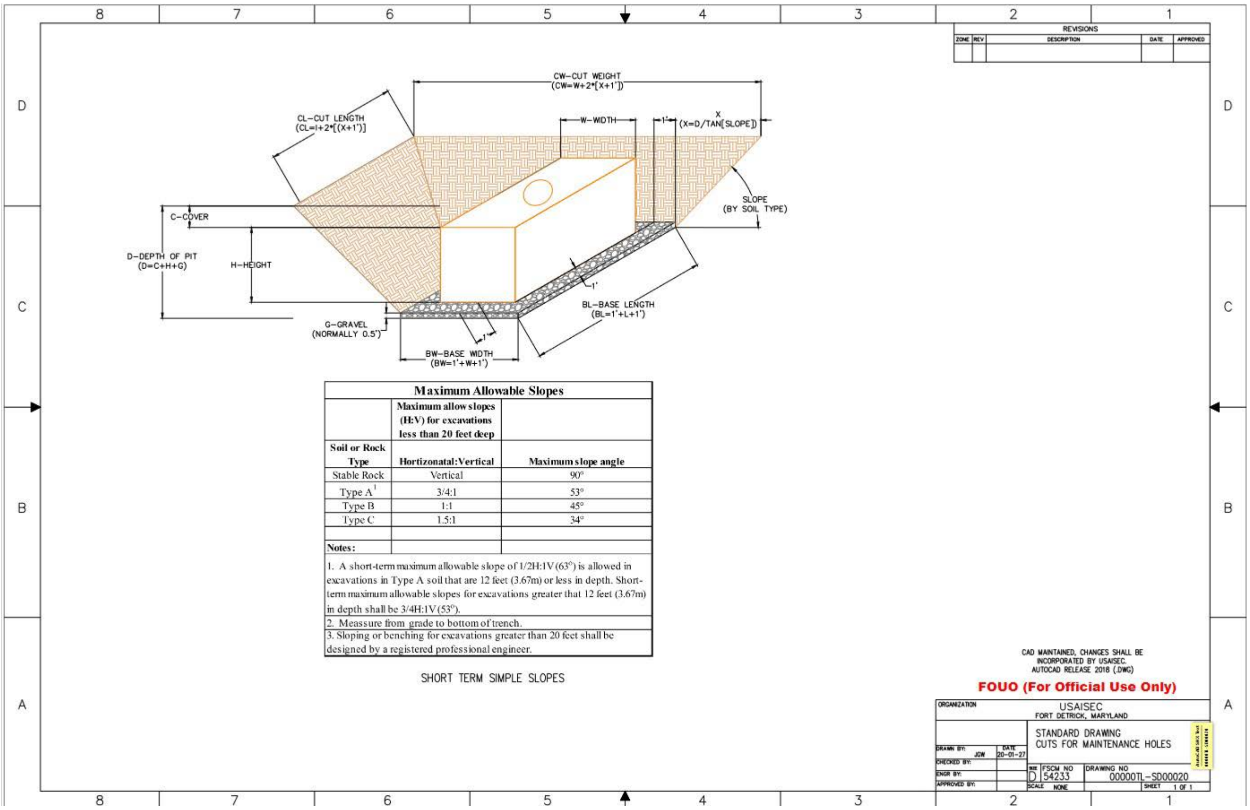


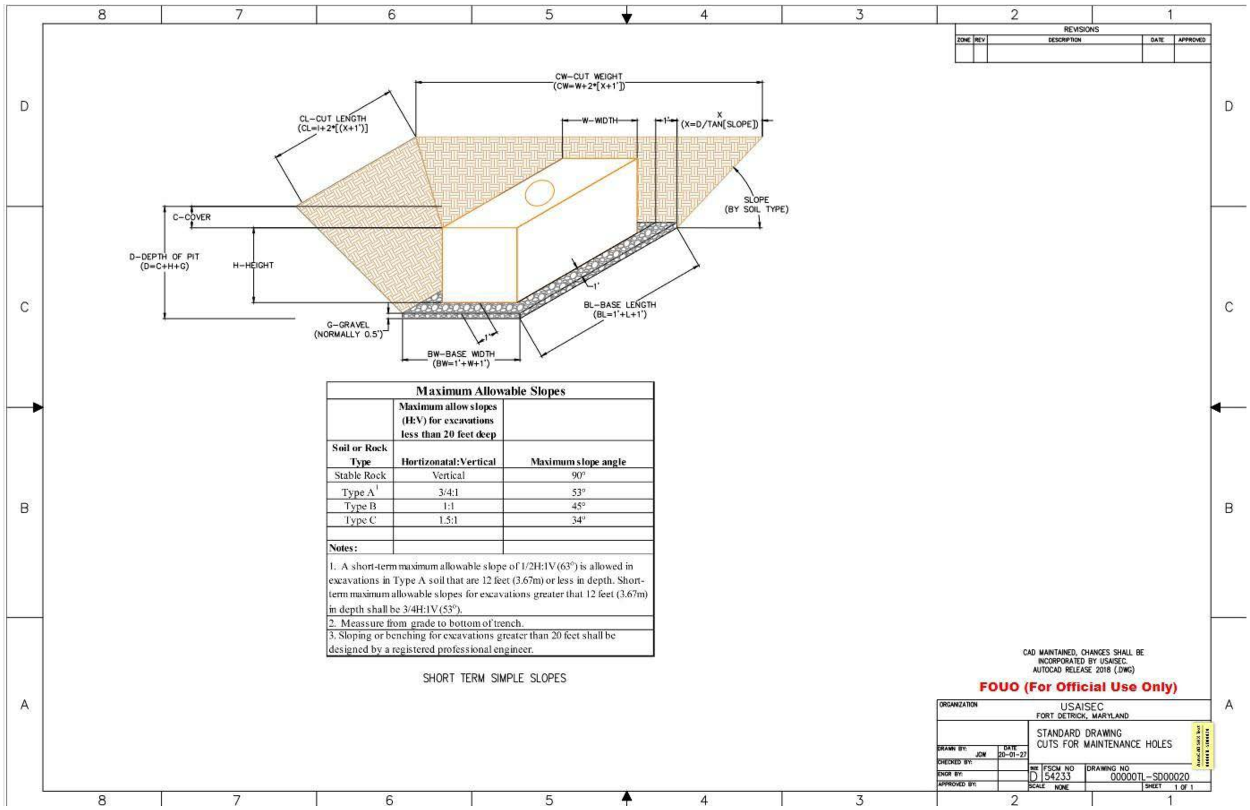
Figure A-18 Hardened Carrier Formations, Depiction in Type A Soils



Maximum Allowable Slopes		
	Maximum allow slopes (H:V) for excavations less than 20 feet deep	
Soil or Rock Type	Hortizonatal:Vertical	Maximum slope angle
Stable Rock	Vertical	90°
Type A[1]	3/4:1	53°
Type B	1:1	45°
Type C	1.5:1	34°
Notes:		

1. A short-term maximum allowable slope of 1/2H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67m) or less in depth. Short-term maximum allowable slopes for excavations greater that 12 feet (3.67m) in depth shall be 3/4H:1V (53°).
2. Meassure from grade to bottom of trench.
3. Sloping or benching for excavations greater than 20 feet shall be designed by a registered professional engineer.

Figure A-19 Cuts for Maintenance Holes



Maximum Allowable Slopes		
	Maximum allow slopes (H:V) for excavations less than 20 feet deep	
Soil or Rock Type	Hortizonatal:Vertical	Maximum slope angle
Stable Rock	Vertical	90°
Type A[1]	3/4:1	53°
Type B	1:1	45°
Type C	1.5:1	34°
Notes:		

1. A short-term maximum allowable slope of 1/2H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67m) or less in depth. Short-term maximum allowable slopes for excavations greater that 12 feet (3.67m) in depth shall be 3/4H:1V (53°).
2. Meassure from grade to bottom of trench.
3. Sloping or benching for excavations greater than 20 feet shall be designed by a registered professional engineer.

Figure A-20 Installation Details – Warning Tape

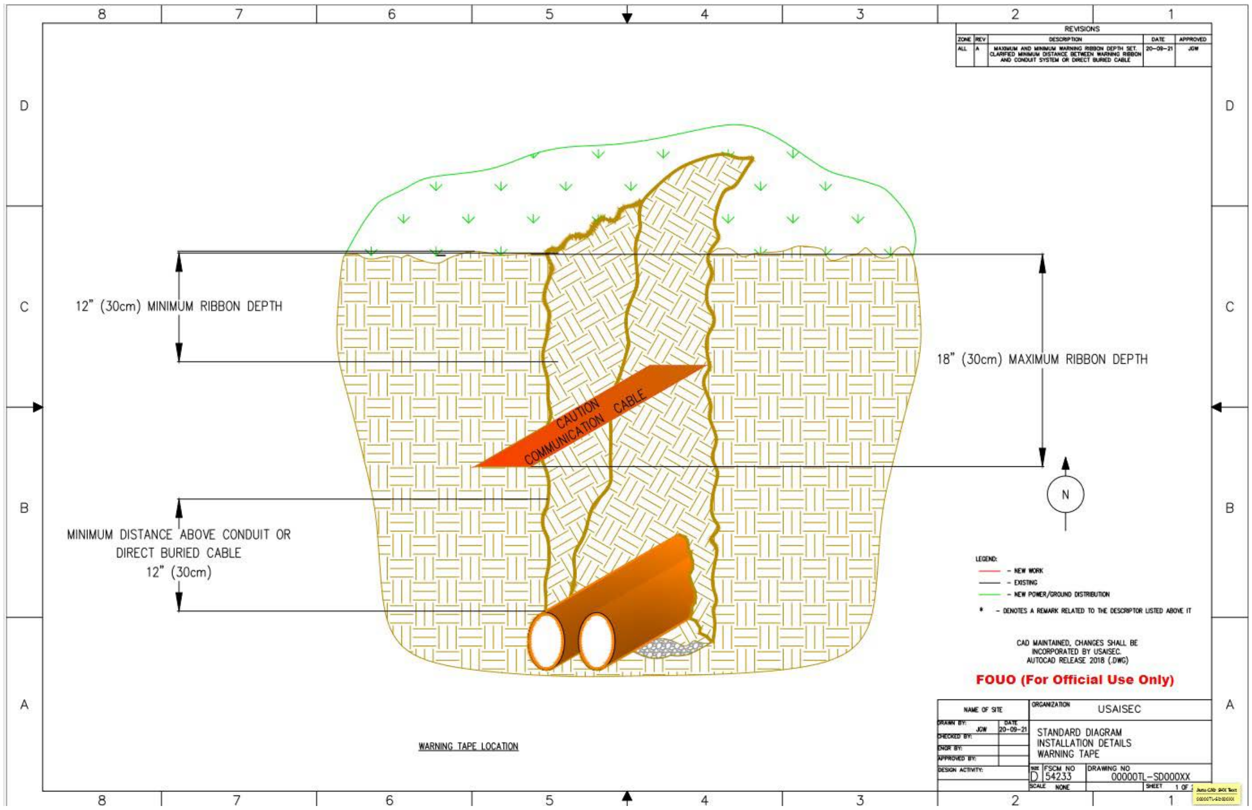


Figure A-21 Above Ground Building Entrances, Pullbox, and Conduit Bodies

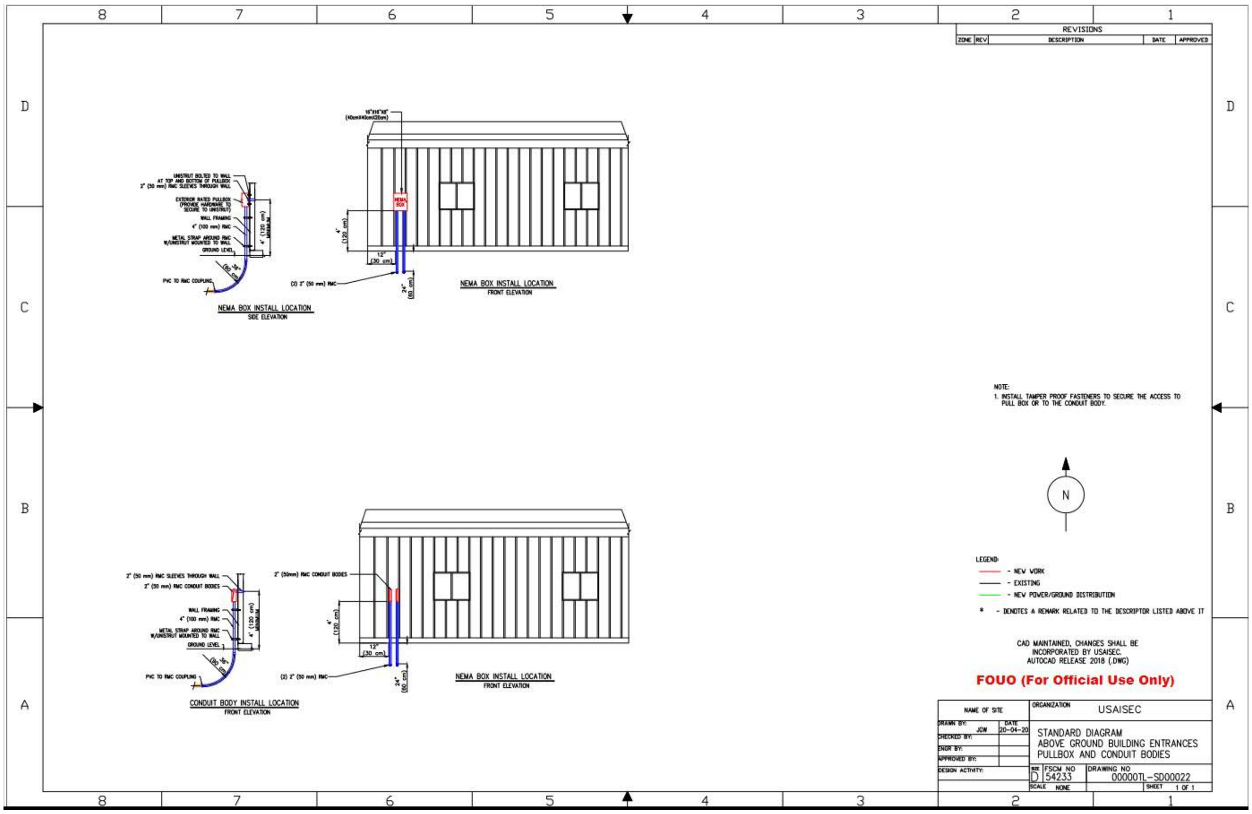


Figure A-22 Doweling to Repair Concrete Encased Conduit Systems

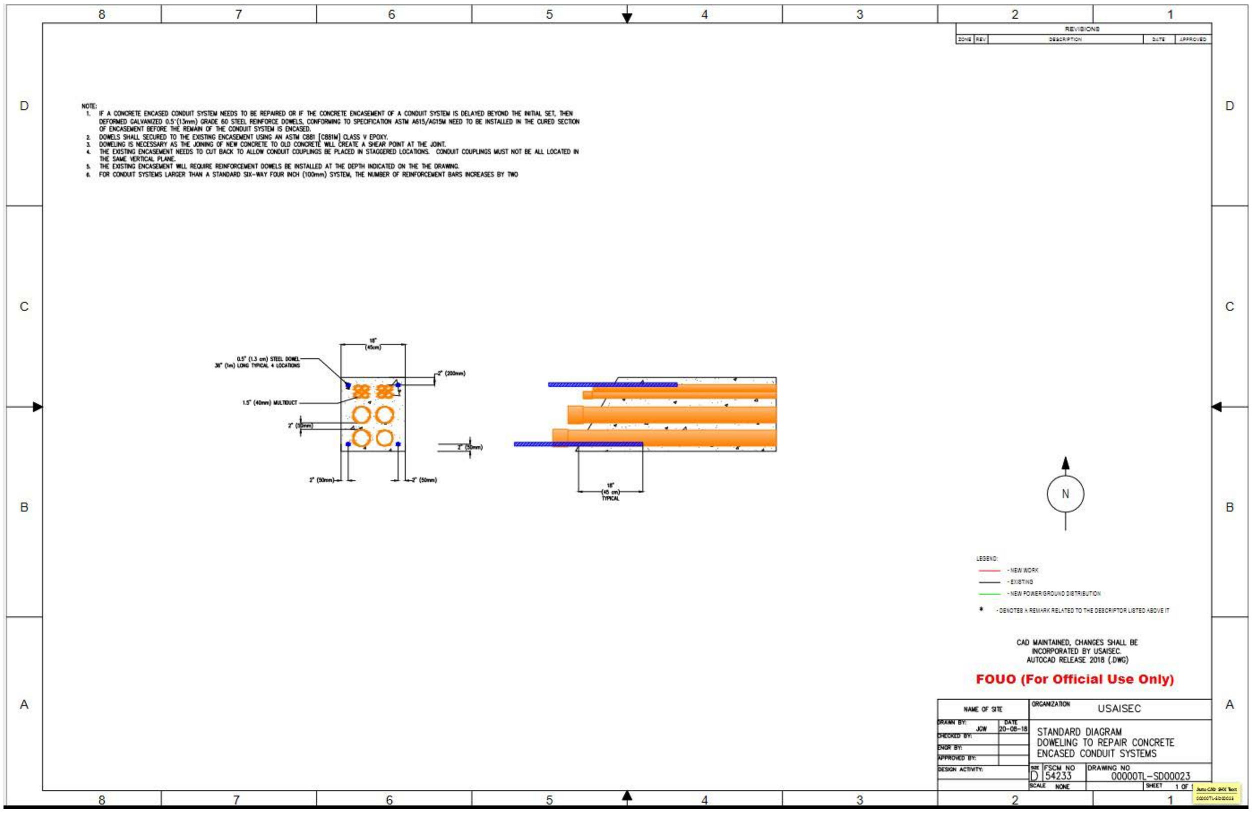


Figure A-23 Minimum Trench Depth for New Conduit Placement

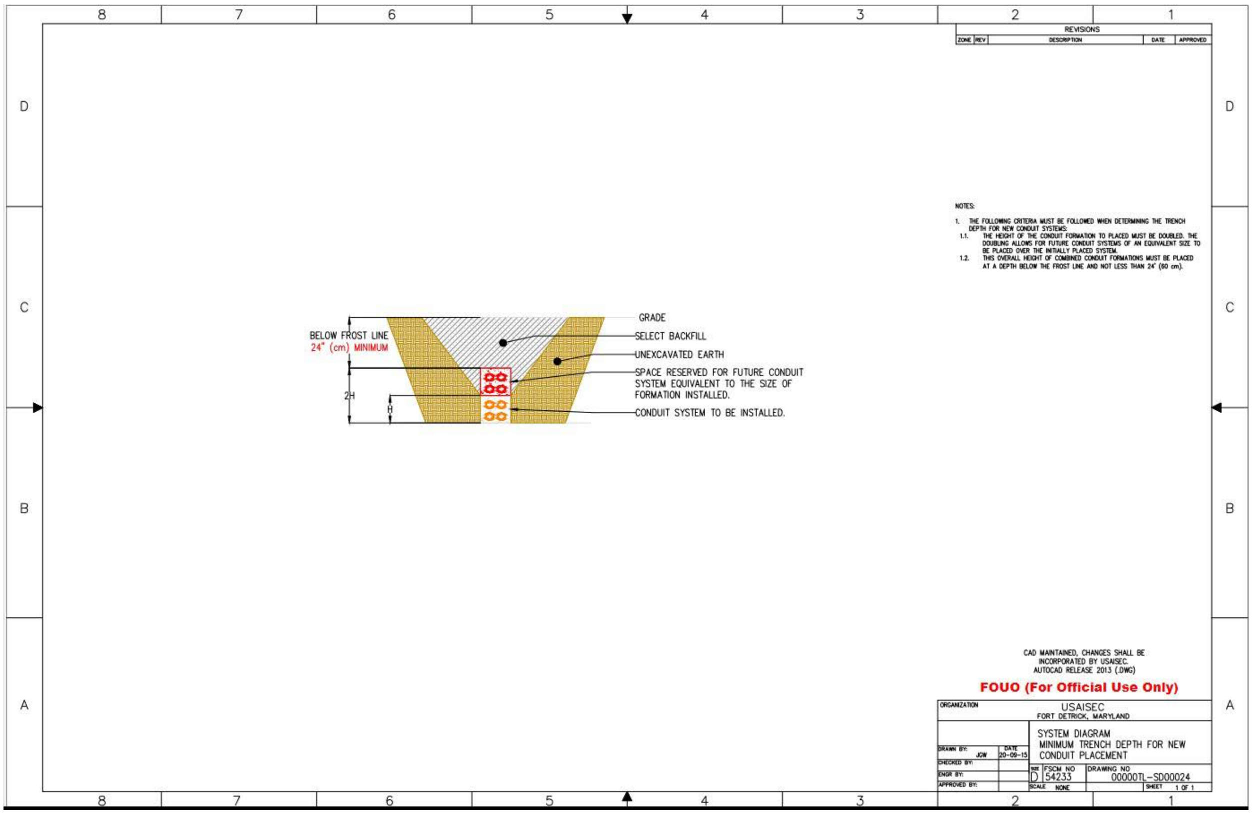
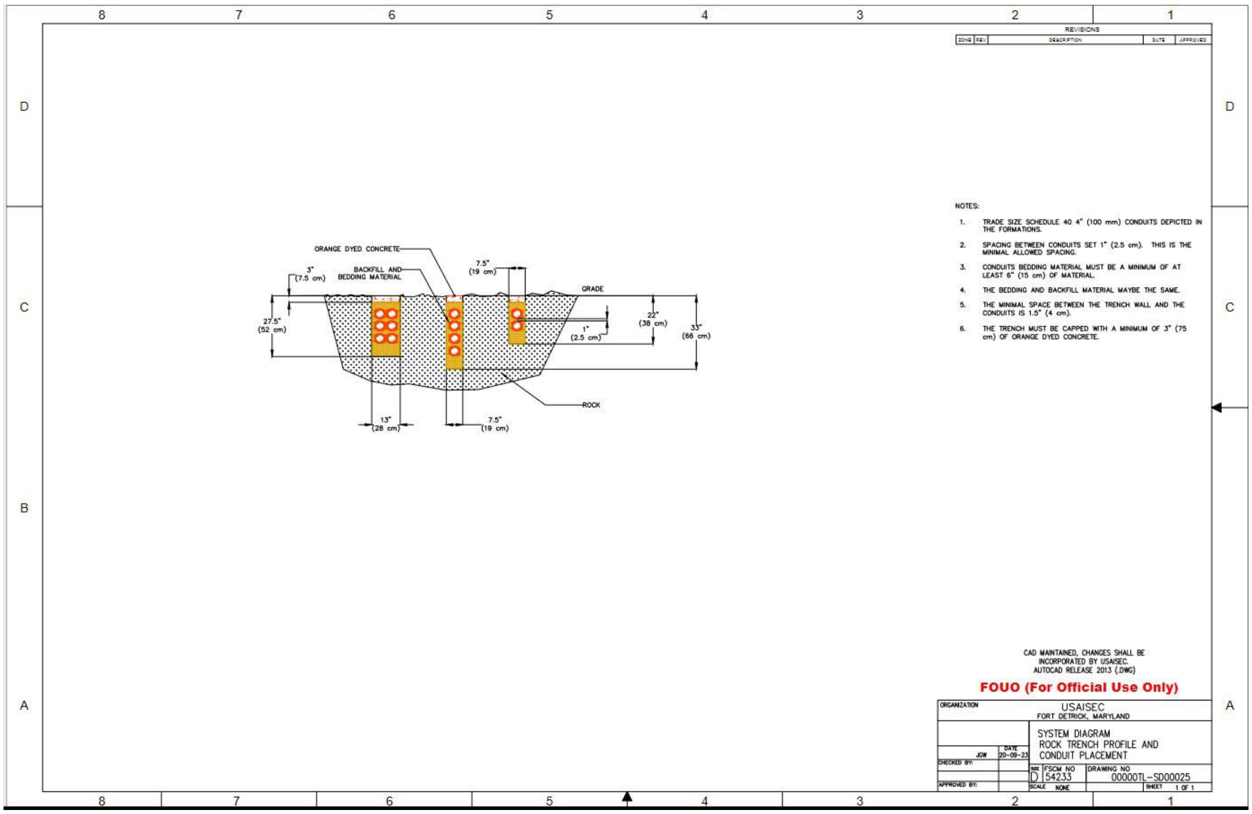


Figure A-24 Rock Trench Profile and Conduit Placement



APPENDIX B GLOSSARY

B-1 ABBREVIATIONS AND ACRONYMS.

µm	micrometer
10G-EPON	10 Gigabit per second Ethernet passive optical network
10G-PON	10 Gigabit per second passive optical network
8P8C	8-position, 8-contact
A	ampere
A/C	air conditioning
A/E	architect/engineer
A/V	audio visual
AASHTO	American Association of State Highway and Transportation Officials
ABF	air blown fiber
AC	alternating current
ACMS	Automated Control Management Sytem
ACPA	American Concrete Pipe Association
ADA	Americans with Disabilities Act
ADNCon	area distribution node
AFCEC	Air Force Civil Engineer Center
AFF	above the finished floor
AFH	Army Family Housing
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
APC	angle polished connector
APWA	American Public Works Association
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers

ASTM	American Society for Testing and Materials
AV	audio visual
AWG	American Wire Gauge
B/P/C/S	base/post/camps/stations
BAS	building automation systems
BATB	base area transport boundary
BBC	backbone bonding conductor
BCO	Base Communications Officer
BCT	bonding conductor for telecommunications
BD	building distributor
BEQ	Bachelor Enlisted Quarters
BET	building entrance terminals
BIA	Bilateral Infrastructure Agreements
BICSI	Building Industry Consulting Service, International, Inc.
BIM	Building Information Modeling
BMS	Building Management System
BNC	bayonet navy connector
BOQ	Bachelor Officers Quarters
BTS	base transceiver system
BTU/hr	British thermal units per hour
C4I	Command, Control, Communications, Computers, and Intelligence
CAT6A	Category 6A
CATV	community antenna or cable television
C-C	center-to-center
CCTV	closed-circuit television

CD	chromatic dispersion
CE	compromising emanations
CIC	cable in conduit
CNIC	Commander Navy Installations Command
CNSSAM	Committee on National Security Systems Advisory Memorandum
CNSSI	Committee on National Security Systems Instruction
CONUS	Continental United States
CP	consolidation point
CTTA	Certified TEMPEST Technical Authority
CV	cable vault
Cx	commissioning
CXA	Commissioning Agent
CXM	Commissioning Manager
DA	Department of the Army
DAA	Designated Accreditation Authority
DAQ	delivered audio quality
DAS	distributed antenna system
dB	decibel
DB	direct buried
dBmV	decibel millivolt
DC	direct current
DCO	Dial/Digital Central Office
DDC	direct digital controller
DIN	Deutsche Industrie-Normen
DISN	Defense Information System Network

DMFO	Defense Medical Facilities Office
DODIN	Department of Defense Information Network
DoN	Department of Navy
DOR	Designer of Record
DPW	Directorate of Public Works
DSN	Defense Switched Network
DWDM	dense wave division multiplexing
ED	edge device
EDFA	erbium-doped fiber amplifier
EES	earth electrode subsystem
EF	entrance facility
EIA	Electronic Industries Alliance
EOC	Emergency Operations Center
EPO	emergency power off
EPON	Ethernet passive optical network
ER	equipment room
ESS	enterprise survivable server
EUB	end user building
FACP	fire alarm control panel
fc	foot candle
FCC	Federal Communications Commission
FD	floor distributor
FEC	Facilities Engineering Command
FO	fiber-optic
FO/GO	Flag Officer/General Officer

FOC	fiber optic cable
FOCIS	Fiber Optic Connector Intermateability Standard
FOPP	fiber optic patch panel
FOUO	For Official Use Only
FRCS	Facility Related Control System
ft/s	feet per second
Gb	gigabit
GbE	gigabit Ethernet
Gbps	gigabit per second
GE	grounding equalizer
GEC	grounding electrode conductor
GFCI	ground fault circuit interrupter
GHz	gigahertz
GPON	gigabit passive optical network
GPR	ground penetrating radar
GSA	General Services Administration
HC	horizontal crossconnect
HCDS	hardened carrier distribution systems
HCP	horizontal connection point
HDCP	high definition copy protocol
HDD	horizontal directional drilling
HDMI	high definition multimedia interface
HDPE	high density polyethylene
HNFA	Host Nation Funded Construction Agreements
hp	horsepower

HVAC	heating, ventilation, and air conditioning
I3A	Installation Information Infrastructure Architecture
IC	integrated circuit
IC	intermediate crossconnect
ICAN	Installation and Campus Area Network
ICD	Intelligence Community Directive
ICDS	installation communications distribution system(s)
ICG	installation communications grid
ICS	industrial control system
ICT	information and communications technology
IDC	insulation displacement connector
IDF	intermediate distribution frame
IDS	intrusion detection system
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFC®	International Fire Code®
IMA	Information Mission Area
IMC	intermediate metallic conduit
IoT	Internet of Things
IP	internet protocol
IPN	installation processing node
IPS	intrusion prevention system
IPTV	internet protocol television
IS	information system
ISDN	Integrated Services Digital Network

ISN	installation servicing node
ISO	International Organization for Standardization
ISP	inside plant wiring
IT	information technology
ITE	information technology equipment
ITS	information transport system
ITU	International Telecommunications Union
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
JWICS	Joint Worldwide Intelligence Communications System
Km	kilometer
kPa	kilopascal
LAN	local area network
LATB	local area transport boundary
lb	pound
LC	lucent connector
LPS	limited power source
LSA	line-sharing adapter
LSA+	line-sharing adapter plus
LSPM	light source and power meter
LVDC	low voltage direct current
m/s	meters per second
mA	milliampere
MAC	moves, adds, and changes
MB	megabyte
Mb/s	megabit per second

MC	main crossconnect
MCEN	Marine Corps Enterprise Network
MCN	main communications node
MDF	main distribution frame
MH	maintenance holes
MHz	megahertz
MILCON	Military Construction
MIL-DTL	Military Detail
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
MM	multi-mode
MPa	megapascal
MPD	metallic pedestal disconnect
MPTL	male plug terminated link
MTP®	Multi-fiber Termination Push-on
MT-RJ	mechanical transfer registered jack
MUTOA	multi-user telecommunication outlet assembly
N	Newton
NAVFAC	Naval Facilities Engineering Command
NCTAMS	Naval Computer and Telecommunications Area Master Station
NEC®	National Electrical Code®
NEC	network enterprise center
NEMA	National Electrical Manufacturers Association
NEN	Naval Enterprise Network
NESC®	National Electrical Safety Code®

NETCOM	U.S. Army Network Enterprise Technology Command
NFPA	National Fire Protection Association
NGEN	Next Generation Enterprise Network
nm	nanometer
NMCI	Navy and Marine Corps Intranet
NPCA	National Precast Concrete Association
NRTL	Nationally Recognized Testing Laboratory
NSANet	National Security Agency Intranet
NSC	network service center
NSI	National Security Information
NZDSF	non-zero dispersion-shifted fiber
OCONUS	outside of the continental United States
OLT	optical line terminal
OLTS	optical loss test sets
ONT	optical network terminal
OSHA	Occupational Safety and Health Administration
OSP	outside plant
OT	operational technology
OTDR	optical time domain reflectometer
OTN	optical transport node
P2P	peer-to-peer
PBB	primary bonding busbar
PBX	private branch exchange
PC	physical contact
PDS	protected distribution system

PE	polyethylene
PET	protected entrance terminal
PF	fluorinated ethylene propylene
PIC	plastic insulated cable
PM	Program Manager
PMD	polarization mode dispersion
POC	point of contact
PoDL	power over data line
PoE	power over Ethernet
POH	Power over HDBaseT
POL	passive optical local area network
PON	passive optical network
POTS	plain old telephone service
pr	pair
ps	picosecond
PSI	physical site identifier
psi	pounds per square inch
psi	pounds per square inch
PVC	polyvinyl chloride
PWD	Public Works Department
PWO	Public Works Office
QA	quality assurance
QC	quality control
RBB	rack bonding busbar
RC	Regional Coordinator

RCDD	Registered Communications Distribution Designer
RF	radio frequency
RGB	rack grounding busbar
RMC	rigid metallic conduit
ROICC	Resident Officer in Charge of Construction
RSC	rigid steel conduit
RTRC	red threaded fiberglass conduit/reinforced thermosetting resin conduit
RU	rack unit
RUS	Rural Utilities Service
SAPF	Special Access Program Facility
SBB	secondary bonding busbar
SC	standard connector
SCADA	Supervisory Control and Data Acquisition
SCIF	Sensitive Compartmented Information Facility
ScTP	screened twisted pair
SDAN	software defined access network
SDR	standard dimensional ratio
SEBQ	Senior Enlisted Bachelor Quarters
SFP	small form pluggable
SIDR	standard internal dimension ratio
SIPRNET	Secret Internet Protocol Router Network
SM	single-mode
SMF	single mode fiber
SOFA	Status of Forces Agreements
SPC	super personal computer

ST	subscriber terminal
STP	shielded twisted pair
TBB	telecommunications bonding backbone
TBC	telecommunications bonding conductor
TDM	time domain multiplexing
TDMM	Telecommunications Distribution Methods Manual
TE	telecommunications enclosure
TEBC	Telecommunications Equipment Bonding Conductor
TEF	telecommunications entrance facility
TEMPEST	Telecommunications Electronics Material Protected from Emanating Spurious Transmissions
TGB	telecommunications grounding busbar
TIA	Telecommunications Industry Association
TMGB	telecommunications main grounding busbar
TR	telecommunications room
TS	telecommunications space
TSB	Telecommunications Systems Bulletin
UCR	Unified Capabilities Requirements
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriters Laboratory
UPC	ultra physical contact
UPS	uninterruptable power systems
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USG	U.S. Government

UTP unshielded twisted pair

UXO unexploded ordnance

VA volt-amp

VAC volts alternating current

VDC volts direct current

VDE Verband Deutscher Elektrotechniker

VTC video teleconference

WAO work area outlet

WAP wireless access point

WIDS wireless intrusion detection system

WLAN wireless local area network

B-2 DEFINITION OF TERMS.

core node: On an installation (B/P/C/S), a core node (also referred to as a main communications node or area distribution node) is a physical location that typically hosts the commercial point of presence and serves as the aggregation point for the area distribution nodes.

intra-building backbone: Connectivity for the voice, video, and data networks between the entrance facility or equipment room, to a telecommunications room.

inter-building backbone: Connectivity between buildings, also referred to as part of outside plant (OSP).

ps: chromatic dispersion coefficient (Table 3-5)

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APPENDIX C REFERENCES

AMERICAN CONCRETE PIPE ASSOCIATION

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ACPA Design Data (DD) 41, *Maintenance Hole Flotation*

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RUS Bulletin 1753F-201, *Acceptance Tests and Measurements of Telecommunications Plant*

RUS Bulletin 1753F-401, *Standards for Splicing Copper and Fiber Optic Cable (PC-2)*

DEUTSCHE INDUSTRIE-NORMEN VERBAND DEUTSCHER ELEKTROTECHNIKER

https://www.vde-verlag.de/

DIN VDE 0816-1:1988-02, *External cables for telecommunication and data processing systems; cables insulated and sheathed with polyethylene, unit stranded*

DIN VDE 0815/A1:1988-05, *Wiring cables for telecommunication and data processing systems*

INTERNATIONAL CODE COUNCIL

https://codes.iccsafe.org/content/IFC2021P2

2021 International Fire Code® (IFC)®

INTERNATIONAL ELECTROTECHNICAL COMMMISSION

https://webstore.iec.ch/

IEC 63171-1, *Connectors for electrical and electronic equipment - Part 1: Detail specification for two-way, shielded or unshielded, free and fixed connectors - Mechanical mating information, pin assignment and additional requirements for Type 1 copper LC style*

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS

https://www.ieee.org

IEEE 743, *Equipment Requirements and Measurement Techniques for Analog Transmission Parameters for Telecommunications*

IEEE 802.3, *IEEE Standard for Ethernet*

IEEE 802.3ah, *IEEE Standard for Information technology-- Local and metropolitan area networks-- Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks*

IEEE 802.3av, *IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks*

IEEE 802.3cg, *IEEE Standard for Ethernet - Amendment 5: Physical Layer Specifications and Management Parameters for 10 Mb/s Operation and Associated Power Delivery over a Single Balanced Pair of Conductors*

IEEE 802.11ax, *IEEE Standard for Information Technology--Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks-- Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 1: Enhancements for High-Efficiency WLAN*

IEEE 802.11be, *Extremely High Throughput (EHT)*

IEEE C2-2023, *2023 National Electrical Safety Code® (NESC®)*

IEEE C62.43*, IEEE Guide for the Application of Surge Protectors Used in Low-Voltage (Equal to or Less Than 1000 V, RMS, Or 1200 V, DC) Data, Communications, and Signaling Circuits*

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION/INTERNATIONAL ELECTROTECHNICAL COMMISSION

https://ww.iso.org

ISO/IEC 11801, *Information Technology – Generic Cabling for Customer Premises*

ISO/IEC 14763-1, *Information Technology – Implementation and Operation of Customer Premises Cabling, Part 1: Administration*

ISO/IEC 14763-2, *Information Technology – Implementation and Operation of Customer Premises Cabling, Part 2: Planning and Installation*

ISO/IEC 14763-3, *Information Technology – Implementation and Operation of Customer Premises Cabling, Part 3: Testing of Optical Fiber Cabling*

INTERNATIONAL TELECOMMUNICATION UNION

https://www.ito.int

ITU-T G.984: *Gigabit Passive Optical Networks*

ITU-T G.987: *10-Gigabit-capable passive optical networks (XG-PON): General requirements*

ITU-T G.652: *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*

ITU-T G.655: Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable; Recommendation

ITU-T G.657: Characteristics of a bending-loss insensitive single-mode optical fibre and cable

NATIONAL COUNTERINTELLIGENCE AND SECURITY CENTER

https://www.dni.gov/files/NCSC/documents/Regulations/IC_Technical_Specifications_for_Construction_and_Management_of_Sensitive_Compartmented_Information_Facilities_v151_PDF.pdf

Technical Specifications for Construction and Management of Sensitive Compartmented Information Facilities: IC Tech Spec – for ICD/ICS 705

NATIONAL FIRE PROTECTION ASSOCIATION

https://catalog.nfpa.org

NFPA 70®: *National Electrical Code®(NEC®)*

NFPA 72®: *National Fire Alarm and Signaling Code®*

NFPA 99, *Health Care Facilities Code*

NFPA 101®: *Life Safety Code®*

NFPA 780, *Standard for the Installation of Lightning Protection Systems*

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

https://www.nema.org/standards

NEMA GR 1-2017, *Ground Rod Electrodes and Ground Rod Electrode Couplings*

NEMA TCB 2-2017, *Guidelines for the Selection and Installation of Underground Nonmetallic Raceways*

NEMA TC-2-2020, *Electrical Polyvinyl Chloride (PVC) Conduit*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926SubpartPAppA
https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926SubpartPAppB

1926 Subpart P App A - *Soil Classification*

1926 Subpart P App B - *Sloping and Benching*

TELECOMMUNICATIONS INDUSTRY ASSOCIATION

https://global.ihs.com/csf_home.cfm?&csf=TIA

TIA/EIA-515B000, *Sectional Specification for Splice Closures for Pressurized Aerial, Buried and Underground Fiber Optic Cables*

TIA-526 Series, *Standard Test Procedures for Fiber Optic Systems* (includes all current TIA/EIA-526 and TIA-526 standards)

TIA-568.0, *Generic Telecommunications Cabling for Customer Premises*

TIA-569, *Telecommunications Pathways and Spaces*

TIA-570, *Residential Telecommunications Infrastructure Standard*

TIA-598, *Optical Fiber Cable Color Coding*

TIA-604, *FOCIS 4 Fiber Optic Connector Intermateability Standard- Type FC and FC-APC*

TIA-606, *Administration Standard for Telecommunications Infrastructure*

TIA-607, *Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises*

TIA 6090000, *Sectional Specification for Conventional, Permanent, Optical Fiber Splices*

TIA-758, *Customer-Owned Outside Plant Telecommunications Infrastructure Standard*

TIA 942, *Telecommunications Infrastructure Standards for Data Centers*

TIA TSB-162~~-A~~, *Telecommunications Cabling Guidelines for Wireless Access Points*

FEDERAL SPECIFICATIONS

FF-L-2740, *Locks, Combination, Electromechanical*
http://everyspec.com/FED_SPECS/F/FF-L-2740A_7413/

FF-P-110-J, *Padlock, Changeable Combination (Resistant to Opening by Manipulation and Surreptitious Attack)*
http://everyspec.com/FED_SPECS/F/FF-P-110J_NOTICE-1_35918/

DEPARTMENT OF DEFENSE

MCO 5530.14A, *Marine Corps Physical Security Program Manual*

MIL-DTL-32537, *Detail Specification: Flowable Fill Backfill Material, Rapid Setting*

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

FC 4-721-10N, *Navy and Marine Corps Unaccompanied Housing*

UFC 1-200-01, *DoD Building Code*

UFC 3-220-04FA, *Backfill for Subsurface Structures*

UFC 3-270-01, *O&M Manual: Asphalt and Concrete Pavement Maintenance and Repair*

UFC 3-501-01, *Electrical Engineering*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*

UFC 3-530-01, *Interior and Exterior Lighting Systems*

UFC 3-580-10, *Navy and Marine Corps Intranet (NMCI) Standard Construction Practices* (cancelled)

UFC 3-580-02, *Telecommunications. Systems Outside Plant Cabling System* (Draft; never issued)

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 4-010-05, *SCIF/SAPF Planning, Design, and Construction*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UFC 4-021-02, *Electronic Security Systems*

UFC 4-510-01, *Design: Military Medical Facilities*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs

UFGS 07 84 00, *Firestopping*

UFGS 27 05 29.00 10, *Protective Distribution System (PDS) for SIPRNET Communication Systems*

UFGS 31 00 00, *Earthwork*

UFGS 31 23 00.00 20, *Excavation and Fill*

UFGS 33 05 23, *Trenchless Utility Installation*

ADDITIONAL REFERENCES

SIPRNET Technical Implementation Criteria
https://www.us.army.mil/suite/files/5744948

Telcordia, GR-421-CORE, *Generic Requirements for Metallic Telecommunications Cables*
https://telecom-info.njdepot.ericsson.net/site-cgi/ido/docs.cgi?ID=SEARCH&DOCUMENT=GR-421&

UFC 3-600-01
8 August 2016
Change 6, 6 May 2021

UNIFIED FACILITIES CRITERIA (UFC)

FIRE PROTECTION ENGINEERING FOR FACILITIES

UNIFIED FACILITIES CRITERIA (UFC)

FIRE PROTECTION ENGINEERING FOR FACILITIES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	28 Nov 2016	Change to definition of '*AHJ*' (paragraph 2-1.3) required modifications to paragraphs 1-7.2.2, 1-9, 9-16.1, and 9-18.5.1. Change to paragraph 9-13.1.3 was a technical change.
2	25 Mar 2018	Clarification to definitions *Fire Water Demand* (2-1.11) and *Multi-Family Housing* (2-1.26), in addition to many clarifications of requirements. Paragraphs added for Hydroelectric Generating Plants(4-20) and Navigation Locks" (4-31). Change in requirements for Liquid Oxygen (4.3-33). Army eliminated the requirement for two water storage tanks. DLA requires redundant fire pump for large risk facilities. Dry pipe systems require nitrogen.
3	10 May 2019	Added Paragraph 1-2.1.3.1 referring to new Appendix G Change Paragraph 4-14.1 to apply to all family housing. Added Paragraph 4-46 for wildland-urban interface. Moved Paragraph 9-2.2.2 to where it should have been located.

		Clarified Paragraph 9-5.3.2 to follow NFPA 20 for run time. Changed Paragraph 9-6.3.5 friction loss requirements. Added Paragraph 9-19.2.3, CO detection for large spaces. Added Appendix G, requirements for Host Nation projects in Japan. Some changes made to clarify requirements.
4	3 Feb 2020	Added/changed requirements (9-9.3 and 9-17) to comply with 2020 NDAA. Added 4-38.2 to allow FEMA approved Tank and Pump Systems. Other changes added clarity.
5	24 Sep 2020	Added section 4-2, Additive Manufacturing to address 3-D printing. Added section 4-39, Privacy Pods or Privacy Enclosures Included Lake Projects to section 4-32, Navigation Locks. Added a requirement in section 4-32 to protect hydraulic reservoir and pumping equipment. Added section 10-5, Communicating Space to provide clarity to the code allowances. Made changes to Chapter 34 to simplify requirements. Other changes were made to provide coordination, clarification, or correct formatting.
6	6 May 2021	Added the following sections: 4-7, Animal Housing Facilities; 4-8, Battery Energy Storage Systems – Lithium; and, Section 10-7 Accessible Means of Egress Updated section 4-6, Anechoic Chambers, Updated and renamed the Ordnance section (4-33) to Ammunition and Explosives (4-5) Update section 9-3.6, Pressure Regulating Valves Changed “Authority Having Jurisdiction” to “Component Fire Protection Engineer”

This UFC supersedes UFC 3-600-01, dated 26 September 2006, Change 3 and all preceding changes.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force \2\ Civil Engineer Center (AFCEC) /2/ are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)

REVISION SUMMARY SHEET

Document: UFC 3-600-01, *Fire Protection Engineering for Facilities*

Superseding: This UFC supersedes UFC 3-600-01, dated 26 September 2006, Change 3 and all preceding changes.

Description of Changes: This update to UFC 3-600-01 clarifies many of the requirements in the 26 September 2006, Change 3, 1 March 2013 version, as well as updates references, and further coordinates the Services' requirements. This update also coordinated requirements with consensus standards and reorganized the document to match the organization of the IBC to make it easier to use for the Architectural-Engineering Firms. New criteria for the following were added:

- Planning Section
- Definitions
- Facilities Housing Unmanned Aerial Vehicles (UAV) or Remotely Piloted Aircraft (RPA)
- Military Operations on Urban Terrain (MOUT) Trainers
- Sensitive Compartmented Information Facility (SCIF)

Reasons for Changes:

- Planning Section is to help scope projects properly and assist in ensuring the proper funding is requested
- Definitions are to help clarify requirements
- Requirements were added for UAVs to ensure the UAVs and the facility are properly protected
- Information was added for MOUTs to ensure they have the proper protection and are not provided with unnecessary requirements.
- Requirements were added for SCIFs to ensure coordination with the security requirements.

Unification Issues:

Some criteria are Service specific as it will reference a Service UFC, FC, Instruction, or Manual.

Navy Unification Issues:

- Paragraph 7-2 – The spacing allowed by the IBC for the identification of the rated wall is too large and will not be easily seen by trade personnel performing work.

Air Force Unification Issues:

- Paragraph 9-5.4.3 – This paragraph is an option allowed by code. This choice only adds a single engine driven generator and associated maintenance burden, rather than add multiple engine driven drivers and the associated maintenance burden.
- Paragraph 34-10.1.1 – There are many existing Air Force Lodging and Billeting Facilities without sprinkler protection. Requirements are different and exceed those found in minimum criteria, including NFPA 101. The requirements are unique to the Air Force and this section is needed to prevent change to Air Force facilities simply because it is different.

Army Unification Issues:

- Paragraph 4-3.4.8 – Provides additional requirements for facilities that support UAV or UAS.\4\
- /4/Paragraphs 9-6.3.2 and 9-18.2 – Requires fire protection shop drawings prepared under the immediate supervision of and sealed by a professional engineer, who must certify in writing that the system was installed as designed.

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CHAPTER 1 INTRODUCTION

1-1 SCOPE AND ADMINISTRATION.

This UFC establishes fire protection engineering policy and criteria for Department of Defense Components (*DoD Components)*. These criteria are based on commercial requirements set forth by national insurance underwriters and may exceed minimum national code requirements. The requirements in this UFC reflect the need for the protection of life, mission continuity, and property (building or contents) while taking into account the costs of implementing the criterion and risks associated with the *Facility*. These criteria have been established in the best interest of DoD.

1-2 APPLICABILITY.

1-2.1 General.

1-2.1.1 The provisions of this UFC are applicable to all new and existing DoD *Facilities* located on or outside of DoD *Installation*s, within the United States and its territories and possessions or outside the United States and its territories and possessions, whether owned or leased, by appropriated or non-appropriated funds, or third party financed and constructed.

1-2.1.2 The provisions of this UFC are applicable to all types of *Facilities* and their contents, structures, whether considered permanent, semi-permanent or temporary construction, mobile and stationary equipment, civil works or military facilities, hydroelectric plants, waterfront facilities, outside storage, and shore protection for ships and aircraft. \5\As required by DoDI 4165.56, these provisions are applicable to any structure that is used to provide the same capabilities as real property acquired facilities and structures./5/

1-2.1.3 Projects outside the United States and its territories and possessions must comply with provisions of this UFC and the host nation fire protection requirements. For conflicts between this UFC and the host nation fire protection requirements, the \6\ *DFPE* /6/ must be consulted.

1-2.1.3.1 \3\For projects in Japan, see specific mandatory requirements in Appendix G: "Criteria for Projects in Japan"./3/

1-2.2 Acronyms, Abbreviations, Defined Terms, and Referenced Criteria.

Acronyms and abbreviations used within this UFC are defined in Appendix F. The full name of referenced criteria, codes or standards can be found in Appendix A. Terms defined in Chapter 2 are italicized in this UFC.

1-2.3 Fire Department Operations.

Matters relating to fire department operations, staffing and firefighting equipment are outside the scope of this UFC.

1-3 PURPOSE.

This UFC must be used as the minimum standard for the planning and development of projects and, design, construction and commissioning documentation used for the procurement of Facilities. Examples include, but are not limited to, the development of scopes of work, DD1391 documentation, drawings, specification and request for proposals. It is the primary fire protection criteria reference document for services provided by architectural and engineering (A&E) firms and consultants in the development of both design-bid-build and design-build contracts. It is not intended to be used in lieu of detailed design documents in the procurement of *Facility* construction.

1-4 CRITERIA.

1-4.1 Federal Laws.

This UFC complies with all applicable Federal laws, including but not limited to:

UNITED STATES CODE http://uscode.house.gov/.

a. USC Title 10, Chapter 8, Subchapter II, Military Child Care.

b. USC Title 15, Section 272 Utilization of Consensus Technical Standards by Federal Agencies.

c. USC Title 15, Section 2225 Hotel-Motel Fire Safety.

d. USC Title 15, Section 2227 Fire Administration Authorization Act (also referred to as the Fire Safety Act).

e. USC Title 42, Section 4151 Architectural Barriers Act of 1968.

1-4.2 DoD Criteria.

1-4.2.1 UFC 3-600-01 supplements the requirements listed in UFC 1-200-01. UFC 3-600-01 supersedes NFPA and other industry standards, except where not specifically addressed by this UFC.

1-4.2.2 Features in excess of the requirements in this UFC must be approved by the \6\ *Component Fire Protection Engineer (CFPE)* /6/.

1-4.2.3 Where the IBC references the International Fire Code (IFC), the IFC must be replaced with NFPA 1, except where superseded by this UFC.

1-4.2.4 For leased *Facilities*, the criteria in this UFC must apply, unless it is determined by the *DFPE* it is not in the best interest of DoD. For conflicts between this UFC and the local municipal jurisdiction, the *DFPE* must be consulted.

1-4.2.5 \6\ /6/ *DoD Component*s issue specific technical guidance that expands the requirements of this UFC. For example, \6\ the Army issues engineering construction bulletins (ECB); the Navy issues interim technical guidance (ITG); and the Air Force issues guidance memorandums (AFGM) /6/.

a. For Army, Air Force, and Navy, see http://dod.wbdg.org/.

b. For Washington Headquarters Service (WHS), see WHS Building Code, http://www.wbdg.org/ccb

1-4.2.6 Where criteria are not included in this UFC, fire protection criteria must conform to the requirements of the latest editions of the National Fire Codes. Where criteria are not available from the National Fire Codes, a fire protection design analysis must be submitted to the *DFPE* for approval.

1-4.3 Standards, Codes and Guides.

Fire protection criteria must conform to the requirements of standards, codes and guides as modified or referenced in this UFC. The primary references include, but are not limited to, the most recent editions of the following:

a. National Fire Codes, published by the National Fire Protection Association (NFPA).

b. FM Global (http://www.fmglobal.com/) Property Loss Prevention Data Sheets, as referenced by this UFC.

Note: NFPA 5000, state or local building or fire codes must not be used.

1-4.4 Antiterrorism and Security Standards.

Antiterrorism and security requirements noted in UFC 4-010-01, UFC 4-020-01 and other 4 series UFCs must not preclude any fire protection requirements. This UFC will be in coordination with the ATFP sections as noted in the other 4 series UFCs.

1-5 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, general building requirements. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-6 REFERENCES AND DATES OF PUBLICATION.

1-6.1 General.

Appendix A contains a list of references used in this document. The publication date of codes or standards are not included in this document. Unless modified by UFC 1-200-01, this document or the applicable contract, the latest available issuance of a reference must be used.

1-6.2 Project Delays.

For projects that have a delay, as defined in UFC 1-200-01, the *DFPE* has the responsibility to determine if design revisions are required based on an analysis performed by the *Qualified Fire Protection Engineer (QFPE)*.

1-7 FIRE PROTECTION ENGINEERING SERVICES.

1-7.1 General.

1-7.1.1 *Major Projects* require the design, review and oversight services of a *QFPE*. A *QFPE* must be involved in every aspect of the design, construction and testing/commissioning as it relates to fire protection and life safety. This includes, but is not limited to, building code analysis, life safety code analysis, design of automatic fire alarm, detection and suppression systems, water supply analysis, a multi-discipline review of the entire project, construction inspections and witnessing of fire protection acceptance testing/commissioning.

Note: Utilization of multiple *QFPEs* on the same project is permitted, but not preferred.

1-7.1.2 This requirement is applicable to engineering services for design-bid-build projects as well as all phases of design-build projects including RFP development, design development, and construction.

1-7.1.3 For the purpose of this UFC, the *QFPE* must submit, upon request, a written copy of their resume indicating education, professional registration and work experience, along with a letter attesting to their compliance with the requirements of this Section. The letter must include an imprint of their professional engineering stamp with signature.

1-7.2 Fire Protection Design Analysis and Life Safety Plans.

1-7.2.1 A fire protection design analysis and life safety plans must be provided for all *Major Projects* and must address the fire protection requirements of the project as required by this UFC. The fire protection design analysis and life safety plans must be submitted with the initial design submission, separate from other disciplines. The final design analysis and life safety plans must be signed and sealed by the *QFPE.*

Note: When directed by the *DFPE*, projects with little or no fire protection considerations may not require a fire protection design analysis or life safety plans.

1-7.2.2 Fire Protection Design Analysis.

Where applicable, discuss the following minimum fire protection provisions (include required vs. provided):

a. Identification of all fire protection and life safety related codes and standards applicable to the project, including the edition. This includes Host Nation requirements.

b. Building code analysis (e.g., type of construction, height and area limitations, building separation, exposure protection, etc.).

c. Classification of occupancy (both IBC and NFPA 101).

d. Requirements for fire walls, fire barriers, fire partitions, smoke barriers and smoke partitions, compartmentation and special hazard protection (both horizontal and vertical). Include the associated fire resistance rating.

e. Requirements for protection of horizontal and vertical penetrations and openings as well as the associated fire resistance rating.

f. Separation from hazards per NFPA 101.

g. Interior finish ratings.

h. Means of egress provisions and components (occupant load, exit capacity, exit width, travel distance, common path of travel, dead-end corridors, use of suites, etc.).

i. Water supplies, water distribution, location of fire hydrants, Fire Flow calculations.

j. Location of fire department connections (FDCs).

k. Location of post indicator valves (PIVs) and other control or isolation valves.

l. Analysis of automatic sprinkler and suppression systems and protected areas. Include supporting calculations used to establish system performance requirements such as hydraulic analysis of water demand or agent concentration and quantity.

m. Standpipe systems.

n. Portable fire extinguishers.

o. Fire detection (the type of detection and type/location of detectors).

p. Fire alarm system (the type of alarm system, location of the fire alarm equipment and mass notification).

q. Smoke management or control methods.

r. Connection to and description of base Fire Alarm Reporting System.

s. Coordination with security and antiterrorism requirements, including connection to Installation-wide Mass Notification System.

t. Fire department access.

u. \6\ *CFPE* /6/ approved equivalencies \1\/1/ (see the paragraph entitled "Equivalencies" below).

v. For projects not within the United States or its territories, identify code/criteria conflicts and \6\ *CFPE* /6/ approved design solutions\1\ or/1/ equivalencies \1\/1/to DoD or Host Nation criteria necessary to resolve. The analysis must also identify the associated impact on project cost.

w. Initial, or draft, integrated performance verification and testing plan(s) where multiple systems across multiple trades rely on an integrated operation to perform the desired result.

1-7.2.3 Life Safety.

Where applicable, the following minimum fire protection provisions must be included on the life safety plans:

a. All minimum fire protection provisions listed above, on a separate code summary sheet.

b. Capacity and number of occupants using each major means of egress component (e.g., stairs, stair doors, exterior doors, assembly exit doors).

c. Maximum travel distance, dead-end corridor, common path of travel, accessible means of egress and exit components for each floor and occupancy classification. When suites are used, indicate type, location, area and arrangement.

d. IBC and NFPA occupancy classification of each room, area or compartment (on the drawings or in tabular form). Include occupant load of each room, area or compartment. Similar occupancies can be grouped together for occupant load calculations.

e. Location and rating of all fire walls, fire barriers, fire partitions, smoke barriers and smoke partitions (both horizontal and vertical). Barriers requiring fire resistance rated supporting construction must be specifically identified for coordination with the structural design.

f. Location of hazardous materials storage, handling and use that exceed the maximum allowable quantities.

g. Structural fireproofing locations and associated ratings.

1-7.2.4 Code Compliance Plans.

1-7.2.4.1 Code Compliance Summary Sheet.

Provide the building code and life safety code analyses included in the \4\ fire protection design analysis/4/. Specifically call out any approved criteria exemptions. For projects outside the United States and its territories and possessions, identify code/criteria conflicts and proposed design solutions to resolve.

1-7.2.4.2 Code Compliance Site Plan.

Where applicable, the following minimum fire protection provisions must be included on the Code Compliance Site Plan:

a. Line of encroachment identifying assumed property lines and minimum separation distances from adjacent buildings.

b. Building perimeter used for frontage increases.

c. Fire department access.

d. Fire lane width, marking and locations, approach roads and turn radius and location.

e. Type and quantity of antiterrorism secure access.

f. Intended fire department main entrance to facility.

g. Location of fire department connections.

h. Fire hydrants, post indicator valve or valves and their connected water distribution mains serving facility.

i. Fire pump room.

j. Water storage tanks.

k. Hazardous material spill containment\6\ /6/.

l. Backflow prevention assembly or assemblies serving water-based fire protection systems (if located outside of building).

1-7.2.5 Preliminary Hydraulic Analysis.

1-7.2.5.1 Prepare a preliminary hydraulic analysis to demonstrate that the anticipated water demand(s), including those for fire, domestic, and industrial needs, will be satisfied by the available water supply. This analysis must include an estimate for the minimum required capacity of water, along with minimum volumetric waterflow rate and water pressure, with all assumptions clearly defined and referenced and must demonstrate that the available water supply is capable of meeting the required water demands in any project. Include a graphical analysis of the relationship between the *Fire Water Demand* and the available water supply.

1-7.2.5.2 For design-build projects, prepare the preliminary hydraulic analysis prior to advertisement of the request for proposal.

1-7.3 Final Design Submission.

The *QFPE* must review the complete 100 percent design drawings and specification submission (all disciplines) and document in writing that the design is in compliance with this UFC and all applicable fire protection and life safety design criteria. The review must provide verification that all items listed in the design analysis are correctly shown on the drawings and in the specification and list any approved equivalencies or deviations from this UFC. This design compliance document must be submitted with the final design submission as part of the design analysis and must bear the signature and professional seal of the *QFPE*.

1-7.4 Host Nation.

For projects outside the United States and its territories and possessions, a Host Nation Code Compliance certification must be performed by a Host Nation fire protection consultant. For each item of conflict or nonconformance with the Host Nation codes, the certification must include the following:

a. Item of conflict.

b. Translation of Host Nation requirement to the English language.

c. Recommended resolution.

d. Additional costs, both engineering effort to prepare the design modification and estimated construction costs.

1-8 EQUIVALENCIES.

Alternative design approaches proposed as equivalencies to established criteria must be approved by the \6\ *CFPE* /6/. Requests for approval must include written justification for the deviation from established criteria and demonstrate how the proposed alternative solution provides an equivalent level of fire protection and life safety. Requests must also include hazard analysis, compensatory features, comparative cost analyses (first cost and life cycle cost), criteria used, and other pertinent data. Lack of funds is not considered sufficient justification for an equivalency to established criteria. Approved equivalencies and alternatives apply only to the specific *Facility* or project involved, and do not constitute blanket approval for similar cases.

1-9 EXEMPTIONS.

Exemptions to established criteria must be submitted to the \1\Service Signature Authority/1/ for determination. The *exemption* must demonstrate that the criteria cannot be technically executed, or execution of the criteria will increase a hazard or create a new hazard and no technical alternatives exist. Written request for exemptions must include justification, hazard analysis, cost comparison, alternatives considered, and other pertinent data. Lack of funds or cost savings are not considered sufficient justification for deviation from established criteria. *Exemptions* will only apply to the specific *Facility* or project involved and do not constitute blanket approval for similar cases. *Exemptions* must follow the process outlined in MIL-STD-3007.

1-10 PERFORMANCE-BASED FIRE SAFETY DESIGN.

1-10.1 General.

1-10.1.1 The use of performance-based fire safety design methods may only be permitted upon authorization by the \6\ *CFPE* /6/.

1-10.1.2 Performance-based fire safety design must comply with the procedures, provisions and applicable requirements of Appendix C.

Note: Appendix C is in accordance with the performance-based option of NFPA 101 and the performance-based fire safety design approach of the Society of Fire Protection Engineers (SFPE), Introduction to Performance-Base Fire Safety.

1-10.1.3 A *QFPE* must perform the performance-based fire safety design.

1-10.2 Application.

1-10.2.1 Performance-based fire safety design methods may not be used to eliminate required exiting requirements of NFPA 101, nor may it be used to eliminate automatic sprinkler systems required by DoD criteria.

1-10.2.2 The use of performance-based fire safety design will only be considered for the following:

1-10.2.2.1 Existing facilities where it is not feasible to meet prescriptive requirements of this UFC.

1-10.2.2.2 New facilities for which established prescriptive criteria does not exist.

1-11 FIRE PROTECTION DURING CONSTRUCTION.

Contract specifications must reference the USACE Engineering Manual (EM), EM-385-1-1 and NFPA 241 and must contain the requirement that the *Installation's* fire regulations be followed.

1-12 PLANNING\2\ (CONTRACT DOCUMENT DEVELOPMENT)/2/.

1-12.1 General.

1-12.1.1 The criteria in this UFC must be used in project planning or the development of projects \2\and contract documents/2/. The information in this section must be reviewed during the planning phase to verify that adequate *Installation* infrastructure exists.

1-12.1.1.1 It is DoD's responsibility to determine whether or not the *Installation* infrastructure is adequate to support the project.

Note: Examples of infrastructure include water supply and fire department access.

1-12.1.2 The requirement for a *QFPE* must be included in the statement of work for design services as well as design/build services.

1-12.2 *Installation* Water Supply.

1-12.2.1 The quantity of water required is equal to the greater of the largest *Fire Water Demand* or *Fire Flow* for the required duration. This quantity represents fire water supply requirements only, that must be available at all times. Water supply for domestic, industrial, and other demands must be added to these requirements to determine the total amount of water required at an *Installation*.

1-12.2.2 The water supply analysis must include an analysis of the domestic water quantity using diurnal curves if time of day water curves are not available The analysis must include historical data to address seasonal water supply fluctuations, peak water demand and average daily demand and its effect on fire suppression water availability.

1-12.3 *Installation* Water Distribution.

Note: The requirements of this section apply to the *Installation*, as defined in Chapter 2, not the individual *Facility*.

1-12.3.1 Except as modified below, water distribution mains, service mains and service laterals must be designed in accordance with AWWA M31, NFPA 24 and UFC 3-230-01.

1-12.3.2 \2\For *service laterals* \6\ /6/, the velocity must not exceed 10 feet per second (3 m/s).

1-12.3.3 /2/One or more of the following reliable means must provide fire protection water to an *Installation*:

1-12.3.3.1 Multiple connections to looped or gridded public *Service Main*(s) arranged so that during any single-point failure, at least 50 percent of the maximum required *Fire Flow* plus 100 percent of domestic demand can still be supplied to the *Installation*.

1-12.3.3.2 A single connection to a public *Service Main(s)*, plus on-site storage sized in accordance with UFC 3-230-01, in the event the connection to the public system is lost.

1-12.3.3.3 One or more on-site sources, such as wells or open bodies of water, with treated water storage capacity sized in accordance with UFC 3-230-01.

1-12.3.4 For a small *Installation*, such as a Reserve Training Center, a single connection to a looped or gridded public water *Service Main*, capable of providing concurrent domestic demand and *Fire Flow* to the *Installation*, is acceptable.

1-12.3.5 For service mains served by fire pumps or service laterals serving fire pumps, velocities must be calculated using 150 percent of the rated capacity of the fire pump.

1-12.4 *Installation* On-Site \2\Water/2/ Storage.

\2\/2/

1-12.4.1 Water level must be remotely monitored in accordance with NFPA 22 and NFPA 72 at a constantly attended location, preferably at the *Installation*'s remote supervising station.

1-12.4.2 In geographic locations having a 99.6% dry bulb temperature less than 32°F (0°C) per UFC 3-400-02 Engineering Weather Data, water temperature of aboveground storage tanks must likewise be monitored at a constantly attended location.

1-12.4.3 Provide an external visual water-level gauge on each non-elevated or below ground tank.

1-12.5 Waterflow Testing.

1-12.5.1 Conduct waterflow tests, in accordance with the procedures contained in NFPA 291, to determine available water supply for the water-based fire extinguishing systems. The flow test must be performed under the direction of the *DFPE*. Advertisement of the project must not occur without obtaining water supply information.

1-12.6 *Fire Flow.*

1-12.6.1 *Fire Flow* for any proposed *Facility* must be calculated to determine if upgrades to the *Installation* water supply is required. *Fire Flow* must be calculated in accordance with Chapter 9.

1-12.6.1.1 Where the *Fire Flow* cannot be met, the *DFPE* is permitted to approve a reduction in *Fire Flow*.

1-12.6.2 When the required *Fire Flow* cannot be provided by the existing infrastructure, a cost and benefit analysis must be conducted by the *DFPE*, or their representative, to determine if additional fire protection systems, features, or design changes that provide more favorable factors, such as type of construction or sprinkler protection, are more cost effective than providing the required *Fire Flow*.

1-12.7 Fire Pumps.

1-12.7.1 The *DFPE* must determine the need for a fire pump in the planning stages of a project in order to ensure adequate space is available at the *Facility*.

1-12.7.2 The *DFPE* must determine if a *Reliable Power Source* is available to the *Installation* or *Facility* in the planning stages of the project in order to ensure that the cost and space associated with secondary power is considered and included in the project.

1-12.7.3 \2\Where a fire pump is needed, a single pump is satisfactory for ordinary value and ordinary use structures. For structures with critical missions or very high values, the \6\ *CFPE* /6/ may require redundancy in fire pump capacity such, as two pumps at 100% capacity or three pumps at 50% capacity. /2/

1-12.8 Automatic Sprinkler Systems.

1-12.8.1 \2\For facilities that do not require sprinkler protection as required in the "Special Detailed Requirements Based On Use" or "Fire Protection Systems" chapters of this UFC,/2/ the *DFPE* must determine if an automatic sprinkler or other fire suppression system is required for the *Facility* based on mission, hazard of contents, value of contents or other criteria. This determination must be included in the contract documents for design services or design-build services.

1-12.8.2 Prior to the installation of backflow preventers in an existing fire suppression system, a thorough hydraulic analysis, including hydraulic calculations and flow test, must be performed to ensure that the water supply is still adequate for the system with the backflow preventer. If the backflow preventer causes the demand to exceed the water supply, the backflow preventer must not be installed until the water supply is corrected to support the new demand.

1-12.9 Clean Agent Fire Extinguishing Systems.

The DFPE must determine if a connected reserve supply should be provided.

Note: A reserve supply should only be considered if replacement cannot be delivered to the site within 24 hours. This would typically apply to locations outside the United States and its territories and possessions.

1-12.10 Rural, Remote, \3\and Range/3/ Locations.

Fire protection water supplies supporting rural, remote, \3\or range/3/ *Facility* locations without water distribution systems must be in accordance with NFPA 1141 and NFPA 1142.

1-12.11 Military Operations on Urban Terrain (MOUT) Trainers.

1-12.11.1 See the paragraph entitled "MOUT" in the “Special Detailed Requirements Based on Use” Chapter in this UFC.

1-12.12 Warehouses and Storage *Facilities.*

1-12.12.1 The DFPE must determine if sprinkler protection must be provided for *facilities* less than 5,000 ft^2 containing materials, equipment and supplies that are critical to operations, pose a severe fire hazard, are of high monetary value, pose a safety or environmental health risk, or expose an important structure.

1-12.12.2 The DFPE must determine the commodity classification and maximum storage height and include this information in the contract documents when this information differs from the minimum noted in the section on "Warehouse and Storage *Facilities*" in this UFC.

1-12.12.3 \2\Information such as the storage configuration (racks, shelves, palletized, bin box, and solid-piled), aisle width, clearance to ceiling, and ceiling sprinkler temperature rating must be evaluated prior to developing contract documents in order to provide the proper sprinkler protection./2/

1-12.12.4 See the section on "Warehouse and Storage *Facilities*" in this UFC for additional requirements.

1-12.13 Existing *Facilities*.

1-12.13.1 When planning any \5\ work /5/ to existing facilities, determine if the facility has any existing or outstanding fire protection or life safety deficiencies and include them into the work being planned.

1-12.13.2 If work is being phased, the total floor area of all the phased work must be used to determine if the facility needs to be brought into compliance with new criteria in lieu of just the work being performed. See the section for "Phased Projects" in this UFC.

1-12.13.3 See the "Existing Facilities" Chapter in this UFC for additional requirements.

1-13 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

CHAPTER 2 DEFINITIONS

2-1 GENERAL.

The definitions contained in this chapter apply to the terms used in this UFC. Where terms are not defined in this chapter or within another chapter, they are defined in the referenced UFC, code or standard applicable to the context in which they are used. Plural terms must have the same definition as singular terms.

2-1.1 Addition.

An increase in the building area, aggregate floor area, building height, or number of stories of a structure. [NFPA 101]

2-1.2 \6\ Ammunition and Explosives.

Includes, but is not limited to, all items of U.S.-titled (i.e., owned by the U.S. Government through the DoD Components) ammunition; primers, propellants, liquid and solid; pyrotechnics; high explosives; guided missiles; warheads; devices; and chemical agent substances, devices, and components presenting real or potential hazards to life, property, and the environment. Excluded are wholly inert items and nuclear warheads and devices, except for considerations of storage and stowage compatibility, blast, fire, and nonnuclear fragment hazards associated with the explosives. [DESR 6055.09] /6/

2-1.3 /1/Bin Storage.

Bin storage consists of five-sided, open from top or side storage containers, stacked in rack structures. They are commonly used in automatic storage and retrieval systems.

Note: Bin storage requires unique considerations for fire protection. Bin storage configurations do not limit oxygen supply. Horizontal flame spread can be rapid. The narrower the aisles and the higher the storage, the less ceiling sprinkler water penetration is delivered to control the fire.

2-1.4 \5\/5/ \6\ Component Fire Protection Engineer (CFPE).

The term "*CFPE*" as used in this UFC means the Fire Protection Engineer assigned to the Military Department or Defense Agency office of responsibility listed below. Where the codes and standards referenced in this UFC refer to an individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure will be interpreted to mean the *CFPE*. The exercise of *CFPE* is contingent upon maintaining the qualifications required of the Fire Protection Engineer. For the Defense Departments or Defense Agencies not listed, and where a listed Defense Component is unable to maintain the qualifications of the Fire Protection Engineer, *CFPE* falls to the Military Service with jurisdiction of the *Installation* on which the facility is located. /6/

\6\ *CFPE* /6/ offices are as follows/1/:

a. U.S. Army - HQ USACE/CECW-CE.

b. U.S. Navy - NAVFACENGSYSCOM HQ, \6\ Chief Fire Protection Engineer /6/.

c. U.S. Marine Corps - HQMC Code LF.

d. U.S. Air Force - AFCEC/CO.

e. \1\Defense Logistics Agency (DLA), DS-IE./1/

f. National Geospatial-Intelligence Agency (NGA) - Security and Installations.

g. National Reconnaissance Office (NRO) - MS&O/ESO.

h. Washington Headquarters Services (WHS) - Office of the Pentagon Fire Marshal.

i. National Security Agency/Central Security Service - Office of Occupational Health, Environmental and Safety Services (NSA/CSS OHESS).\1\

2-1.5 Distribution Main.

Any pipe in a water distribution system other than a *Service Main* or *Service Lateral*. A distribution main carries water from the original source (i.e. tank or underground water source) to the *Service Main*. A distribution main can be connected to the source, *Service Main* or another distribution main. A distribution main cannot connect to a *Service Lateral*.

2-1.6 DoD Component.

The specific DoD branch or subunit of a branch or service. For the purpose of this UFC, this includes, but is not limited to, Army, Navy, Marines, Air Force, NRO, WHS, NGA and NSA.

2-1.7 Dwelling Unit.

One or more rooms arranged for complete, independent housekeeping purposes, with space for eating, living, and sleeping; facilities for cooking; and provisions for sanitation. [NFPA 101]

2-1.8 Electronic Equipment Area.

Areas of a *Facility* that include, but are not limited to data centers, communication centers, and command and control systems. Electronic equipment areas are also areas containing telecommunication equipment that serves more than one *Facility*, a portion of an *Installation* or the entire *Installation*. This section does not apply to the room in a *Facility* that contains the incoming telecommunications service for that specific *Facility* or *Incidental Electronic Equipment* rooms.

2-1.9 Exemption.

The authority to deviate from a UFC requirement indefinitely. See MIL-STD-3007.

2-1.10 \6\ Exposed Explosives.

Explosives that are open to the atmosphere (such as unpackaged bulk explosives, or disassembled or open components) and that are susceptible to initiation directly by static or mechanical spark, or create (or accidentally create) explosive dust, or give off vapors, fumes, or gases in explosives concentrations. This also includes exudation and explosives exposed from damaged munitions such as gun powder or rocket motors. [DESR 6055.09_and AFMAN91-201] /6/

2-1.11 Facility.

This includes all types of buildings and their contents, structures, mobile and stationary equipment, civil works or military buildings, hydroelectric plants, waterfront structures, outside storage, and shore protection for ships and aircraft. A facility can be either of temporary or permanent construction.

2-1.12 Fire Alarm Reporting System.

Fire alarm reporting systems are the *Installation*-wide reporting systems that connect the *Facility* fire alarm control panel(s) to a constantly attended location staffed with qualified operators for the receipt and processing of emergency communications. Consider compatibility of extensions of fire reporting systems with existing equipment.

2-1.13 Fire Area.

The aggregate floor area enclosed and bounded by fire walls, fire barriers, exterior walls or horizontal assemblies of a *Facility*. Areas of the *Facility* not provided with surrounding walls must be included in the *Fire Area* if such areas are included within the horizontal projection of the roof or floor above. [IBC]

2-1.14 Fire Flow.

The flow rate of a water supply, measured at 20 psi (138 kPa) residual pressure that is available for firefighting. [NFPA 1]

2-1.15 Fire Water Demand.

The fire water demand is the water flow required for the fire suppression system plus \2\interior/exterior hose stream demands./2/

2-1.16 Fire Protection Engineer.

2-1.16.1 Designated (or Service) Fire Protection Engineer (DFPE).

The DoD fire protection engineer that oversees that Area of Responsibility for that project. This is sometimes referred to as the "cognizant" fire protection engineer.

Note 1: For USACE, this is usually the District or Center FPE.

Note 2: For NAVFAC, this is usually the Facilities Engineering Command (FEC) FPE.

2-1.16.2 Qualified Fire Protection Engineer (QFPE).

\2\An individual who is a registered professional engineer (P.E.) who has passed the fire protection engineering \6\ /6/ examination administered by the National Council of Examiners for Engineering and Surveying (NCEES) and has relevant fire protection engineering experience./2/

[C] 2-1.16.2

The QFPE can act as the designer of record and/or quality control representative for fire protection matters.

2-1.17 Incidental Electronic Equipment.

Word processing stations, printers, and systems; desk top computers; office automation systems; individual data output stations (i.e. printers, etc.); individual computer work stations; telephones; communication equipment; video conference centers; administrative telephone rooms; reproduction equipment; and similar equipment. Incidental Electronic Equipment includes building only or building-wide communication/telephone/LAN equipment typically found in communication, data or telephone rooms that do not serve an essential mission or purpose for National Defense. This includes the room in a *Facility* that contains the incoming telecommunications service for that specific *Facility*.

2-1.18 \5\/5/Installation.

As used in this document, the Installation is the DoD base, post, camp, fort, station, airfield or other similar complex that shelters military equipment or personnel or facilitates training and operation. An Installation includes one or more DoD *Facilities*.

2-1.19 Life Safety System.

Those systems that enhance or facilitate evacuation, smoke control, compartmentalization or isolation. [NFPA Glossary of Terms]

2-1.20 Major Project.

A project that includes any one of the following:

a. \5\ Adding /5/ to an existing *Facility*.

b. \5\Work to a facility that consists /5/ of 50 percent or more of the total floor area of an existing *Facility*.

c. Design or construction of a new *Facility*.

d. New installation or \5\ work to /5/ an area of construction greater than 5,000 ft^2 of floor area that involves existing or new fire barriers or fire-rated construction; *Life Safety Systems*; \6\ modifying, moving, adding 20 or more sprinklers; /6/ fire alarm or detection systems; fire suppression systems.

e. New installation or \5\ work to an /5/ existing HVAC systems that removes or installs the duct work passing through fire-rated or smoke partitions/barriers or interconnected plenum areas serving an area greater than 5,000 ft^2 of floor area.

2-1.21 Mass Notification System.

Refer to UFC 4-021-01.

2-1.22 \2\/2/Medical Facilities.

Also referenced as Medical Treatment Facilities (MTFs), includes medical and dental treatment facilities, medical training facilities, medical research facilities, and veterinary facilities in the Military Health System (MHS)

2-1.23 Missile Alert Facilities (MAF).

The aboveground *Facilities* that support underground ballistic missile launch control centers.

2-1.24 Missile Assemblies.

Missile assemblies are considered to be large rocket type, cruise missiles without their ordnance, intercontinental ballistic missiles, or Poseidon missiles.

2-1.25 \5\/5/Multi-Family Housing.

More than two *Dwelling Unit*s under one roof intended for occupancy by spouses or dependents of DoD personnel. \2*Multi-Family Housing* does not include multiple single-family dwellings, i.e., townhouses./2/

2-1.26 Noncombustible Material.

A material that, in the form in which it is used and under the conditions anticipated will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat. Materials that are reported as passing ASTM E136 must be considered noncombustible materials. [NFPA 102]

2-1.27 Ordnance Facility.

A *Facility* or area used for the manufacturing, storage, maintenance or demilitarization of ordnance including, but not limited to, munitions, weapons, missile assemblies.

2-1.28 \5\/5/Reliable Power Source.

2-1.28.1 For a *Facility* located on an *Installation*, reliability is determined at the power source serving the *Installation*. For a *Facility* not located on an *Installation*, reliability is determined at the power source to the *Facility*.

Note: For example, if the building in question is located on a Navy Base, Army Post or similar, reliability is determined by when power is lost to the entire Base, Post or similar, not the actual building. If the building is located away from a Base, Post or similar, reliability is determined by when power is lost to the building itself.

2-1.28.2 Unless otherwise noted, a reliable power source is a power source having forced down time, excluding scheduled repairs, that does not exceed 8 consecutive hours for any one incident within the last 3 years, or more than 24 hours cumulatively over the last 3 years.

2-1.29 \5\ /5/Review Stamp.

A stamp certifying that the *QFPE* has reviewed the document and finds that it meets all contractual requirements. A Review Stamp is not a professional engineer stamp or seal.

2-1.30 Sensitive Compartmented Information Facility (SCIF).

Accredited areas, room(s), or building(s) where Sensitive Compartmented Information (SCI), is stored, used, processed or discussed. SCIF are only required for SCI and not necessarily required for Secret or Top Secret information. [UFC 4-010-05]

2-1.31 Service Lateral.

A pipe that connects to the *Service Main* and terminates at a fire hydrant or a *Facility*. A service lateral to a *Facility* is permitted to have no more than two fire hydrants. A service lateral does not connect from one *Service Main* to a second *Service Main*. \4\/4/.

2-1.32 Service Main.

A pipe that transports water from the *Distribution Main* to the *Service Lateral*. A service main can be connected to a *Distribution Main*, *Service Lateral* or another service main. A main with three or more fire hydrants connected to it is a service main. A main from a fire pump to more than one building is a service main.

2-1.33 Stakeholders.

A group of identified individuals or representatives, typically having authoritative control or input, having a share or interest in the successful completion of a project. A project's identified stakeholders must include the building's design and construction team members, security, the \6\ *CFPE* /6/, accreditation agencies, tenants, supported commands and emergency responders.

2-1.34 Telecommunications Equipment Areas.

See “Electronic Equipment Areas”.

2-1.35 Tension Membrane Structure.

A membrane structure incorporating a membrane and a structural support system such as arches, columns, and cables, or beams wherein the stresses developed in the tension membrane interact with those in the structural support so that the entire assembly acts together to resist the applied loads. [NFPA 102]

2-1.36 Very Early Warning Smoke Detection.

Detection that is listed as being capable of providing the level of protection as defined in NFPA 76 for Very Early Warning Fire Detection. Aspirating smoke detection installed in Europe must comply with Class A requirements as specified in EN54 (Fire Detection and Fire Alarm Systems), Part 20 (Aspirating Smoke Detection) (EN54-20).

The maximum area of coverage per detector, or sampling point, is 200 ft^2 (18.5 m^2) for one level of detectors. A minimum of one alert and one alarm level are provided.

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CHAPTER 3 USE AND OCCUPANCY CLASSIFICATION

3-1 GENERAL

This UFC utilizes criteria from both IBC and NFPA 101. Care must be exercised when using this UFC to ensure proper use of IBC and NFPA 101.

3-2 INTERNATIONAL BUILDING CODE (IBC).

3-2.1 General.

3-2.1.1 The IBC must be used where dictated by UFC 1-200-01 except where noted in this UFC.

3-2.1.2 The IBC must be utilized to determine the occupancy classification as it relates to allowable construction type, building height, building area, building separation distance, occupancy separation and associated requirements.

3-2.1.3 Medical funded projects, including but not limited to, healthcare, ambulatory healthcare and all facilities required to comply with The Joint Commission standards must comply with NFPA 101 in its entirety.

3-3 NFPA 101.

3-3.1 General.

3-3.1.1 NFPA 101 must be utilized to determine the occupancy classification as it relates to fire/smoke resistance rating of interior non-load bearing partitions (other than occupancy separation), means of egress, interior finish, features of fire protection (including vertical openings) and associated requirements.

3-3.1.2 Where specific criteria is provided in NFPA 101 related to occupancy location within a building (i.e. story), conform to the requirements of NFPA 101 based on the equivalent construction type.

Note: Where IBC permits a particular occupancy classification on the third floor of a building of Type IIB construction and NFPA 101 only permits that occupancy classification on the second floor for Type II (000), the occupancy is only permitted on the second floor.

3-3.1.3 Appendix D provides a cross reference between the construction types referenced in NFPA 220 and the IBC.

3-4 HAZARDOUS MATERIALS.

For the purpose of occupancy classification, the maximum allowable quantities (exempt amounts) noted in NFPA 400 must be used \6\ with the exception of *ammunition and explosives*, for which the maximum allowable quantity noted in IBC Chapter titled

"Occupancy Classification and Use" must be used /6/. Where the maximum allowable quantities are exceeded in NFPA 400, the H occupancy classification (H-1, H-2, etc.) must be defined in accordance with IBC for High-Hazard Group H occupancies, except as modified by this UFC. IBC Chapter titled "Occupancy Classification and Use" must be utilized to determine the IBC occupancy type. IBC Chapter titled "Special Detailed Requirements Based on Use and Occupancy" is not to be utilized for hazardous materials requirements \6\ except as specifically noted herein. See Table 3-1. /6/

Table 3-1 Hazardous Materials Classification

HAZARDS	NFPA 400 & NFPA 1 CLASSIFICATION	NFPA 400 & NFPA1 PROTECTION LEVEL	IBC GROUP H CLASSIFICATION
Detonation Hazard	High Hazard Level 1	Protection Level 1	H-1
Deflagration Hazard	High Hazard Level 2	Protection Level 2	H-2
Physical Hazard	High Hazard Level 3	Protection Level 3	H-2 or H-3
Health Hazard	High Hazard Level 4	Protection Level 4	H-4
HPM Facility	Not Applicable	Not Applicable	H-5

CHAPTER 4 SPECIAL DETAILED REQUIREMENTS BASED ON USE

4-1 GENERAL.

This Chapter provides specific criteria for special or unique occupancies and hazards and supersedes IBC Chapter 4 in its entirety. For special or unique occupancies and hazards not addressed in this Chapter, comply with the requirements of NFPA 101. This Chapter either supersedes or is in addition to requirements in other Chapters of this UFC.

4-2 \5\ADDITIVE MANUFACTURING (3D PRINTING TECHNOLOGY AND COLD SPRAY MATERIAL-DEPOSITION PROCESS TECHNOLOGY).

4-2.1 General.

Additive manufacturing includes manufacturing process using polymer, glass, or ceramic powders including any material with minimum ignition energy greater than 10mJ (ASTM E2019 or EN 13821).

4-2.2 Additive manufacturing processing equipment.

Additive manufacturing process equipment using combustible powders with a maximum ignition energy of 10mJ or less, including metal powders such as stainless steel (any alloy mix), aluminum (any alloy mix), and titanium (any alloy mix) must comply with the following:

a. Must be located in a separate building, or:

b. Be located in a separate room with an exterior wall and separated by construction of not less than 2-hour fire rating, and,

c. Have explosion venting through the exterior wall. Explosion venting may comply with either FM Global or NFPA 68; or for European countries, VDI 3673 (Verein Deutscher Ingenieure).

Note: See NFPA 652, NFPA 68, and FM Global Loss Prevention Data Sheet 7-76 for additional information./5/

4-3 AIRCRAFT ACOUSTICAL ENCLOSURES.

4-3.1 Complete Enclosures (Hush House).

For Air Force, Aircraft Acoustical Enclosures are not classified facilities (real property); they are classified equipment and as such are managed by the Air Force Sustainment Center, Air Force Logistic Complex, Propulsion Support Equipment, Hush Houses/ Noise Suppressors (AFLCMC/WNZEC) Robins AFB, GA. The criterion of the UFCs does not apply to this equipment. These systems are centrally managed and are not constructed nor maintained as facilities under this UFC. The fire protection system controls in such enclosures are provided with connection to the installation fire alarm communication network by the installation.

4-3.1.1 Conform to the requirements listed in the paragraph entitled "Aircraft Facilities". Provide separate manual controls for actuation of each foam system.

4-3.2 Out of Airframe Acoustical Enclosures (Test Cells).

Fire protection system for Test Cells must consist of the following:

a. Overhead water deluge system having a density of 0.35 gpm/ft^2 (14.3 L/min/m^2) over the entire floor area.

b. Water spray system for the engine having a density of 0.50 gpm/ft^2 (20.4 L/min/m^2) of engine surface area.

c. Water spray system for the floor area beneath the engine having a density of 0.50 gpm/ft^2 (20.4 L/min/m^2) over the entire shadow area.

Note: The overhead deluge system need not extend into the area where the water spray systems for the engine and floor are present.

4-4 AIRCRAFT FACILITIES.

4-4.1 Aircraft Hangars.

For fixed wing and rotary wing aircraft fuel cell maintenance facilities, alert, storage, depot-level and general-purpose maintenance hangars comply with UFC 4-211-01. For corrosion control hangars, comply with UFC 4-211-02.

4-4.2 Tensioned-Membrane Hangars.

4-4.2.1 Construction type must conform to NFPA 409. Tension fabric hangars must utilize rigid-steel-frame structures.

4-4.2.2 The minimum separation between tensioned-membrane hangars and all other structures must be 100 feet (30.5 m), with a clear zone of 50 feet (15.3 m) immediately adjacent to the tension fabric structure. The clear zone cannot be used for storage and must be clear of vegetation (maintained lawn is permitted). The clear zone may be used as a street or driveway, but not for vehicle parking. The clear zone must be clearly striped to indicate no storage or parking.

Note: For Navy, see OPNAVINST 11010.33 for regulations and restrictions on the use of relocatable facilities.

4-4.3 Aircraft Weather Covering.

4-4.3.1 \6\ Weather coverings are structures that control the amount of direct sunlight on aircraft parked on the flight line, see Figure 4-1 and Figure 4-2. Weather coverings used for aircraft on the flight line must comply with all of the following:

a. Constructed of noncombustible materials,

b. If using fabric material, the fabric must meet the requirements of Test Method 2 contained in NFPA 701,

c. Open on all sides,

[C] 4-4.3.1

The weather covering being open on all sides allows for the dissipation of heat, dispersion of vapors from flammable or combustible liquids, and will not restrict firefighting operations from any side of the structure. The open sides maintain the current conditions on the flight line.

d. Any permanent electrical devices or equipment (receptacles, lighting, or other similar devices) installed on the aircraft weather covering (sunshade) must comply with the requirements of NFPA 70, Article entitled “Aircraft Hangars”, as well as the criteria for fuel servicing safety zone found in the individual DoD Service’s criteria (i.e. AF T.O. 00-25-172, NAVAIR 00-80R-14, NAVAIR 00-80T-109 or AR 420-90).

4-4.3.2 A fire detection or suppression system is not required. /6/

Figure 4-1 Examples of Weather Covering

Figure 4-2 Example of Weather Covering

4-4.4 *Facilities* Housing Unmanned Aerial Vehicles (UAV) or Remotely Piloted Aircraft (RPA).

4-4.4.1 \2\For this UFC, an Unmanned Aerial Vehicle (UAV) or Remotely Piloted Aircraft (RPA) consists of just the vehicle; and, an Unmanned Aerial System (UAS) consists of the vehicle, launcher, and any other associated equipment for that system./2/

4-4.4.2 *Facilities* designed to support \2\UAS,/2/ UAV, or RPA that have both of the following must be protected in accordance with the section for Aircraft Hangars in this UFC:

a. Combined fuel capacity of all \2\UAS,/2/ UAV, or RPA equal to or greater than 240 gallons (908.4 L) and

b. Access to a runway that supports manned aircraft.

4-4.4.3 *Facilities* designed to support \2\UAS,/2/ UAV, or RPA that have both of the following must be protected in accordance with the section for Aircraft Hangars in this UFC:

a. Has a door opening greater than \2\or equal to/2/ 20 feet (6.1m) in height and

b. Access to a runway that supports manned aircraft.

4-4.4.4 *Facilities* designed to support \2\UAS,/2/ UAV, or RPA that have both of the following must be \2\provided with sprinklers designed/2/ in accordance with NFPA 30, \2*Storage of Liquids in Containers – Storage Occupancies*/2/:

a. Combined fuel capacity of all \2\UAS,/2/ UAV, or RPA is equal to or greater than 240 gallons (908.4 L) and

b. No access to a runway that supports manned aircraft.

4-4.4.5 *Facilities* designed to support \2\UAS,/2/ UAV, or RPA that have both of the following must be \2\provided with sprinklers designed/2/ in accordance with NFPA 30, \2*Storage of Liquids in Containers – Storage Occupancies*/2/:

a. Has a door opening less than 20 feet (6.1m) in height and

b. Access to a runway that supports manned aircraft.

4-4.4.6 *Facilities* designed to support \2\UAS,/2/ UAV, or RPA that have both of the following must be protected with automatic sprinklers:

a. Combined fuel capacity of all \2\UAS,/2/ UAV, or RPA is \2\more/2/ than \2\120 gallons (454.2 L) and less than/2/ or equal to 240 gallons (908.4 L) and

b. No access to a runway that supports manned aircraft.

4-4.4.7 *Facilities* designed to support \2\UAS,/2/ UAV, or RPA that have all of the following do not require automatic sprinklers:

a. Combined fuel capacity of all \2\UAS,/2/ UAV, or RPA is less than 120 gallons (454.2 L) per control area (as defined by NFPA 30),

b. No access to a runway that supports manned aircraft,

c. Sprinkler protection is not required by the "Application Requirements" paragraph in the section for Automatic Sprinkler Systems in this UFC,

d. Supports small, human packable, portable UAV or RPA, and

e. The facility is separated from other structures by a minimum of 100 feet (30.5 m).

4-4.4.8 \2\For Army, in addition to the aforementioned paragraphs, *Facilities* designed to support UAS or UAV must be protected as follows. If there is a conflict between the aforementioned paragraph and this paragraph, follow the more stringent paragraph.

a. *Facilities* housing Group 4 UAS or UAV must be protected in accordance with the section for Aircraft Hangars in this UFC. Group 4 UAV weigh more than 1,320 LBS.

b. *Facilities* housing Group 3 UAS or UAV, where the fire area of the aircraft servicing or storage area exceeds 7,500 ft^2, must be protected in accordance with the section for Aircraft Hangars in this UFC. Group 3 UAV weigh more than 56 LBS but less than 1,320 LBS.

c. *Facilities* housing Group 3 UAS and UAV, where the fire area of the aircraft servicing or storage area does not exceed 7,500 ft^2, but is required by another section of the UFC to have sprinklers, must have the aircraft servicing or storage area protected in accordance with NFPA 30, Storage of Liquids in Containers – Storage Occupancies. All operations outside the UAV or UAS housing area must be isolated from the UAV or

UAS housing area by 1-hour fire barrier walls. Floor elevations must be arranged to prevent a spill within the UAV or UAS housing area from flowing into adjacent areas. Adjacent areas are not permitted to have their required egress through the UAV or UAS housing area, except for normally unoccupied rooms less than 100 ft^2.

d. *Facilities* housing Group 3 UAS and UAV, where the fire area of the aircraft servicing or storage area does not exceed 7,500 ft^2, and is not required by another section of the UFC to have sprinklers, is not required to have a suppression system. All operations outside the UAV or UAS housing area must be isolated from the UAV or UAS housing area by 1-hour fire barrier walls. Floor elevations must be arranged to prevent a spill within the UAV or UAS housing area from flowing into adjacent areas. Adjacent areas are not permitted to have their required egress through the UAV or UAS housing area, except for normally unoccupied rooms less than 100 ft^2./2/

Note: The reference to NFPA 30 in this section pertains to sprinkler requirements only and is not intended to follow all of the requirements in NFPA 30.

4-5 \6\ AMMUNITION AND EXPLOSIVES FACILITIES.

[C] 4-5

The section was titled Ordnance. The terminology was changed to better coordinate with the DoD explosive safety standards.

4-5.1 General.

This section includes Facilities that are used for the manufacturing, processing, dispensing, use, storage, maintenance, inspection or demilitarization of ammunition and explosives, primers, propellants, and oxidizers related to ammunition and explosives. This section addresses general fire protection and life safety criteria associated with Ammunition and Explosives (A/E) Facilities with the objective to minimize risk to life and protect property. Separate explosives safety criteria also apply to these types of facilities. Any equivalencies approved by the appropriate CFPE as defined in this document only apply to the fire protection and life safety requirements specified herein. This does not exempt the facilities from conformance with any applicable explosives safety requirement.

4-5.2 Criteria.

4-5.2.1 Compliance.

Comply with the requirements specified herein, and with the fire protection requirements in Defense Explosives Safety Regulation DESR 6055.09 and in the applicable service explosives safety regulation. In cases of conflict the most specific and stringent criteria will apply. Where it is not possible to meet all criteria, coordinate with the DFPE for guidance. The service explosives safety regulations include:

- For Navy projects, NAVSEA OP-5, Volume 1.
- For Army projects, AR 385-10 and DA PAM 385-64
- For Air Force projects, DESR 6055.09_AFMAN 91-201.

4-5.2.2 In the absence of specific guidance in this UFC, DESR 6055.09, or the service regulations follow the applicable requirements of the IBC for Group H occupancies, including applicable portions of IBC Chapter titled “Special Detailed Requirements Based on Occupancy and Use”, section titled “Hazardous Materials”, and section titled “Groups H-1, H-2, H-3, H-4 and H-5”.

4-5.3 Design Analysis.

The design analysis for ammunition and explosives facilities must include identifying the material being stored or processed, the hazard division, and the maximum expected quantities of ammunition and explosives to be stored or used and must address toxic and/or hazardous material types, classification categories and quantities. Where toxic or hazardous materials are also present in ammunition and explosives facilities, the more stringent of these and other applicable special detailed requirements based on use and occupancy defined elsewhere in the UFC must apply. Areas requiring electrical classification will also be identified. The methods of protection from hazards must be indicated in the design analysis. Separate floor plans must be submitted identifying the location of anticipated content and process. Information must be provided with the first design submittal and updated as the design is developed.

4-5.4 Building Code and Life Safety Criteria.

4-5.4.1 Egress requirements must meet the applicable NFPA 101 requirements for high hazard industrial or storage occupancies except as modified herein.

4-5.4.2 Control areas not exceeding the allowable quantities of explosives identified in IBC chapter 3 are permitted to prevent classification of the building as an H-1 or H-2 occupancy. Control areas must meet the requirements of IBC chapter 4. The number of control areas, the quantity in the control area and fire resistance of control areas must comply with the requirements of IBC Table 414.2.2, titled Design and Number of Control Areas. Supporting construction of control areas must be not less than the fire resistive rating of the control area.

4-5.4.3 *Ammunition and Explosives Facilities* classified as an H-1 or H-2 must be constructed as detached buildings from other occupancies. Supporting spaces necessary to provide direct support for the *ammunition and explosives* operation and the personnel that directly work with the explosives operations are permitted to be attached to the H-1 or H-2 structure. The supporting spaces must be separated with fire rated barriers or fire walls in accordance with IBC. The fire rated separation of H-1 occupancies from supporting spaces must not be less than the required separation of H-2 occupancies from other occupancies and must also comply with any fire rated requirements of DESR 6055.09 and service explosive safety regulations.

[C] 4-5.4.3

Supporting spaces permitted include control spaces; desk space for the workers whose duties require direct access to the ammunition and explosives as a part of their daily duties; small break rooms; required laboratory space; small conference rooms needed for safety briefings and similar activities; toilet rooms, showers, and locker rooms, as well as mechanical, electrical, and similar spaces. First line supervisors and quality control staff may be considered as requiring direct access as part of their daily duties. Desk space must not be provided for any personnel who do not require direct access to the ammunition and explosives in the facility as a part of their regular duties. Conference rooms and break rooms must be sized to only support explosives personnel regularly working in the building and must not be large enough to be considered an assembly occupancy. Individual toilet rooms do not require rated separation.

4-5.4.4 *Ammunition and Explosives Facilities* must be located on the property in accordance with DESR 6055.09, the service regulations, and this section. *Ammunition and Explosives Facilities* classified as an H-1 occupancy must be set back not less than 75 feet to lot lines, and facilities classified as H-2 must be set back not less than 50 feet to the lot line. Multiple H-1 facilities may be attached to each other with fire walls in accordance with IBC requirements. A minimum of 25% of the perimeter of each H-1 building must be an exterior wall.

4-5.4.5 The *CFPE* may approve increases in the allowable building area, height, and number of stories of Type IIB and better construction where buildings cannot be constructed within the allowable area limits of the IBC due to the size of the *ammunition and explosives* or due to special mission needs or production process requirements.

4-5.4.6 Reduced separation distance or attached buildings may be allowed by the *CFPE* when there is a decreased risk over separated *facilities* or where site constraints dictate reduced separation combined with protective construction. Where a reduction in the separation distance between *facilities* specified by IBC or an attached building is proposed an equivalency must be submitted to the *CFPE* defined in this document. The equivalency must document why the equivalency is needed, along with additional protective features being provided

[C] 4-5.4.6

Example: In chemical de-militarization processes a detached building might increase the risk that nerve agent is released to the environment when moving the munition from one part of the operation to another. A mitigation would be 4-hour fire rated concrete blast containment walls.

4-5.4.7 Exterior walls must be rated in accordance with IBC Chapter titled "Types of Construction".

4-5.5 Fire Suppression Systems.

4-5.5.1 Complete automatic sprinkler protection and/or water spray systems must be provided for all *Ammunition and Explosives Facilities*, except as modified herein or as modified by a service regulation. Water based automatic suppression systems are permitted to be omitted where application of water may intensify or spread the fire or increase the hazard of explosion. Where critical electronic process control equipment is required for continued safe operation and/or safe shutdown of hazardous operations, automatic clean-agent fire suppression systems may be provided in addition to water based automatic suppression systems in the control, electrical, and telecommunications rooms only.

[C] 4-5.5.1

Note that the cooling effects of water application during a fire of water sensitive materials may reduce propagation of the fire and of overall property damage.

4-5.5.2 Where testing involves the intentional ignition of energetic materials, the suppression system must be designed to prevent sprinkler discharge during testing, or sprinkler system may be omitted from the area with the approval of the *DFPE*.

4-5.5.3 Automatic sprinkler and water spray systems in *Ammunition and Explosives Facilities* must be protected from movement in accordance with NFPA 13 for protection of piping where subject to earthquakes, regardless of seismic design category. Where the applicable standard does not address seismic protection, NFPA 13 or ASCE 7 methodology must be followed. Contractor must use a minimum seismic coefficient (Cp) of 0.5.

4-5.5.4 Sprinkler systems protecting *Ammunition and Explosives Facilities* must be wet pipe or deluge systems. Automatic sprinkler systems must be designed and installed in accordance with NFPA 13, this UFC and as specified in the service regulations. Sprinkler water demand for areas containing *ammunition and explosives* must meet or exceed the design requirements for ordinary hazard as defined in this UFC. Service regulations, areas with special or *exposed explosives*, and special processes may require higher hazard classification or higher densities and larger areas to provide proper protection or provide cooling to prevent propagation of fires to other ammunition and explosives.

4-5.5.5 Water Spray Systems: Water spray systems, including high speed and ultra-high-speed deluge systems must be designed and installed in accordance with NFPA 15 unless otherwise noted herein or in the applicable DoD or Service explosives safety regulation.

4-5.5.5.1 High-Speed Deluge Systems: High-speed deluge systems will be provided where specified herein or in the applicable DoD or Service explosives safety regulation. High-speed deluge systems are required to have a response time of 500 ms or less.

4-5.5.5.2 Ultra-High-Speed Deluge Systems: Comply with the requirements of NFPA 15, except as noted herein or in the applicable DoD or service explosives safety regulation. NFPA 15 limits on use of ultra-high-speed deluges systems must not be used to eliminate DoD requirements for the system. Ultra-high-speed deluge systems must be designed to have a response time of not more than 100 ms, unless a risk assessment or other data indicates a need for a faster response time.

a. Timers.

   1. Timers or similar devices to stop water flow after a predetermined time are permitted if they are fail-safe (i.e., water continues to flow in the event of a timer failure).

   2. b. Timers or similar devices that shut off the water flow after a predetermined time (typically 1 to 2 minutes) when the optical fire detectors no longer detect a fire are permitted. In case of a failure, timers must be fail-safe (i.e., water continues to flow in the event of a timer failure).

b. Qualifications. Due to the sensitivity and complexity of ultra-high-speed deluge systems only designers, engineers, and installers who have at least two years' recent experience with ultra-high-speed deluge systems must design and install ultra-high-speed deluge systems.

c. Water Demand. Water supplies for ultra-high-speed deluge systems must be adequate to supply the largest total demand of the ultra-high-speed deluge system and the corresponding largest sprinkler demand in the fire area at the specific residual pressure required by the systems. The combined system must be deemed to operate for at least 90 minutes. Where the water supply to an ultra-high-speed is on a timer or there is a reliable means to shut the system down, the ultra-high-speed system must be designed to operate for a period of at least 15 minutes unless a hazard analysis indicates a longer flow time is needed.

4-5.5.6 Small Self-Contained Deluge Systems. Small self-contained deluge systems may be used in conjunction with the ultra-high-speed deluge systems discussed in this section, or alone if an adequate water supply is not available for the *Facility*, or as otherwise permitted by the DESR or applicable Service regulation. Self-Contained ultra-high-speed deluge systems may also be used for short term operations. These small self-contained deluge systems are primarily intended for personnel protection, although they provide limited building/equipment protection.

4-5.5.6.1 When used, self-contained deluge systems must be connected to the existing water supply.

4-5.5.6.2 Portable, self-contained ultra-high-speed deluge systems must meet the following:

- Multiple nozzles,
- Multiple optical fire detectors,
- Pressurized water tank (typically 100 gal (380 L) of water),
- Response time must not exceed 100 ms (detection to water at the nozzle).

4-5.5.6.3 Pressurized sphere ultra-high-speed deluge systems must meet the following:

- One or more optical fire detectors,
- At least one pressurized (typically 500 psi (3,447 kPa)) water sphere (typically 2.6 to 7.9 gal (10 to 30 L)) with a rupture disc and internal squib, and an electronic controller,
- Response time must be less than 10 ms (detection to water at the nozzle).

4-5.6 Fire Detection and Alarm Systems.

4-5.6.1 Fire detection and alarm systems must be provided in Ammunition and Explosives Facilities except as modified herein.

4-5.6.2 All fire protection systems protecting *Ammunition and Explosives Facilities* must have complete supervision so that any deficiency that develops that would affect the speed or reliability of sprinkler system operation will give a distinct signal in the facility.

4-5.6.3 Heat detection equipment of any type is acceptable if equipment meets the operating time limitations and is suitable in other respects, such as complying with explosion-proof requirements. When pneumatic-type detection equipment is used, not more than three detectors, and preferably only one, must be on a single circuit in the same heat influence area.

4-5.6.4 Detection systems for high-speed and ultra-high speed deluge systems must comply with the requirements of NFPA 15.

4-5.7 Requirements for Specific Types of Ammunition and Explosives Facilities.

4-5.7.1 Accessory Magazines and Armories. 4-5.7.1.1 Accessory magazines and armories containing limited quantities of *ammunition and explosives* for reasons of operational necessity at police stations, security *facilities* and similar type *facilities* are not required to comply with the *ammunition and explosives* section of this UFC. These facilities must comply with other requirements of this UFC and with UFC 4-215-01.

4-5.7.2 *Ammunition and Explosives* Storage *Facilities*.

4-5.7.2.1 *Ammunition and explosives* storage *facilities* are permitted to be either Earth Covered Magazines (ECM) or above ground storage facilities as defined by DESR 6055.09. An *ammunition and explosives* storage *facility* is used for *ammunition and explosives* storage only with the exception of minor activities incidental to storage. These activities and the equipment involved must be explicitly approved and consistent with the DoD principles of storage. Refer to explosives safety regulations for relevant policy.

4-5.7.2.2 Compliance with IBC or NFPA 101 is not required for eCMS.

4-5.7.2.3 Automatic sprinklers and hydrant protection are not required for ECMs or aboveground magazines. Provide sprinkler protection for all aboveground storage of missile assemblies. Consideration must be given to including appropriate fire protection systems in ammunition and explosives storage facilities used for the storage of critical assets. Hydrant protection should also be considered where needed to protect ammunition storage facilities from fires originating at other facilities.

[C] 4-5.7.2.3

Missile assemblies are considered to be large rocket type, Cruise missiles without warheads, Intercontinental Ballistic Missiles or Poseidon missiles.

4-5.7.2.4 Fire alarm and detection systems are not required for ECMs or above ground magazines except as noted herein. Fire alarm and detection systems must be provided in any ammunition and explosives storage facility with an automatic fire suppression system and must be considered in other aboveground storage facilities.

4-5.7.3 Explosives Operating *Facilities*.

4-5.7.3.1 Explosives operating *facilities* are those facilities where *explosives and ammunition* are present for operations to include production, manufacturing, maintenance, assembly, processing, inspection, demilitarization, testing, quality assurance, servicing, and other handling. This also includes facilities in which propellants and oxidizers or related devices containing these materials are present for operations.

4-5.7.3.2 Risk Assessment. A risk assessment will be performed in accordance with DESR 6055.09 and the applicable Service regulation to identify potential fire and thermal threats and to assess the level of risk. When a final risk assessment cannot be accomplished during the design, a preliminary risk assessment must be performed. The hazard(s) must be accurately defined. A potential fire or thermal hazard with an unacceptable risk requires personnel protection in accordance with explosives safety requirements. The risk assessment will consider factors such as:

- Initiation sensitivity,
- Quantity of material,
- Heat output,
- Rate of burn,
- Potential ignition and initiation sources,
- Protection capabilities of shields, types of clothing, and fire protection systems,
- Personnel exposure,
- Munitions configuration.
- Process equipment and layout,
- The building layout.

4-5.7.3.3 Fire Suppression. Provide complete automatic fire suppression throughout. Provide additional localized automatic fire suppression system(s) based on the Risk Assessment and as follows:

- Provide high-speed, pre-primed deluge systems wherever *exposed explosives*, pyrotechnics, or propellants are processed in *Ammunition and Explosives Facilities*. Complete protection of such locations is essential.
- Where the risk assessment shows that exposed thermally energetic materials are handled that have a high probability of ignition, a large thermal output and a high probability of causing personnel injury, operations must be protected using ultra-high-speed deluge systems.
- Ultra-high-speed deluge systems must be provided where mixing of explosives occurs.
- Consult special detailed requirements for hazardous materials herein where other than energetic materials (acids, corrosives, oxidizers, etc.) are present in or near explosives operating *facilities*. The more restrictive of the applicable requirements shall apply. Provide sprinkler protection for outdoor storage vessels.

4-5.7.4 Combat Related *Ammunition and Explosives Facilities*.

4-5.7.4.1 Combat related *Ammunition and Explosives Facilities* are those permanent *facilities* used for support of combat missions, such as alert aircraft *facilities*. This section does not apply to temporary combat related *facilities* in support of contingency operations.

4-5.7.4.2 Due to combat mission needs it may be necessary to construct combat related *Ammunition and Explosives Facilities* that do not comply with the detached building requirement of IBC for H-1 and H-2 occupancies. Where an H-1 building area is attached to a living or sleeping area, a minimum of a 4-hour fire wall must be provided between the areas.

4-5.7.5 *Facilities* Containing Chemical and Nuclear Warheads.

4-5.7.5.1 *Facilities* containing *ammunition and explosives* with chemical or nuclear warheads will comply with the requirements of this section for *Ammunition and Explosives* and all other DoD criteria applicable to chemical and nuclear weapons to include FC 4-420-07F and DA PAM 385-61. /6/

4-6 ANECHOIC CHAMBERS.

\6\ **[C] 4-6**

See FM Global Data Sheet 1-53, Anechoic Chambers, for additional information and guidance for installation of systems and other possible protection as each chamber may necessitate additional protection or features.

4-6.1 Protecting Contents and Anechoic Chamber.

4-6.1.1 Provide a FM Approved clean agent system in the anechoic chamber including the space created under raised floors and inside utility trenches.

[C] 4-6.1.1

Three clean agents have been tested by FM Global and are FM Approved for the use in anechoic chambers. As stated in FM Global Data Sheet 1-53, Anechoic Chambers, they are: Novec 1230 (6.1% concentration), Inergen (49% concentration), and FM200 (9% concentration).

4-6.1.2 Provide an equally sized reserve supply of gaseous suppression agent. The reserve supply must be physically connected to the system and controlled by a manually activated switch that is supervised by the releasing panel.

4-6.1.3 Sprinkler protection that complies with the following “Sprinkler Protection” paragraph in this section may be used in lieu of a clean agent system.

4-6.1.4 Use Air-Aspirated High Sensitivity Smoke Detection to activate the clean agent fire suppression system.

4-6.2 Safeguard of the Surrounding Occupancy and Building.

4-6.2.1 Separate the room or space containing the anechoic chamber from the remainder of the facility with 2-hour fire rated construction.

4-6.2.2 Provide sprinkler protection inside the anechoic chamber that complies with the following “Sprinkler Protection” paragraph in this section.

4-6.2.3 Provide sprinkler protection above and around the anechoic chamber, within the 2-hour fire rated construction, that meets the requirements for the occupancy hazard of that space.

4-6.2.4 Provide sprinkler protection above the anechoic chamber if there is at least three feet of clearance between the top of the anechoic chamber and the ceiling/floor above.

4-6.3 Sprinkler Protection.

4-6.3.1 Use either quick-response sprinklers with a minimum K-factor of 11.2 or control mode k-factor of 11.2 sprinklers.

4-6.3.2 Extended coverage sprinklers are prohibited.

4-6.3.3 Design the sprinklers to provide a minimum density of 0.6 gpm/ft2 (24.4 L/m/m2) over the most remote 2,000 ft2 (186 m2) of floor area or over the entire chamber floor area, whichever is less.

4-6.3.4 Limit the sprinkler coverage to a maximum of 80 ft2 (7.4 m2), with the maximum spacing between sprinklers or between branch lines not to exceed 9 ft (2.7 m).

4-6.3.5 Use upright sprinklers in the pendent position.

4-6.3.6 Where the anechoic chamber exceeds 15 ft (4.6 m) in height, install at least one level of sprinklers along the walls approximately one-half to two-thirds of the height above the floor

4-6.3.7 Where the anechoic chamber exceeds 25 ft (7.6 m) high, install one level of sprinklers at the 15 ft (4.6 m) height and an additional level every 10 ft (3 m) vertically.

4-6.3.8 Use upright sprinklers in the sidewall position for the sidewall protection.

4-6.3.9 Arrange sprinkler drops into chamber so that the sprinkler deflector extends at least 6 in. (150 mm) beyond the tip of the absorber liner material for pyramids up to 1 ft (0.3 m) long, and 12 in. (0.3 m) for pyramids exceeding 2 ft (0.6 m). The extension may be interpolated for intermediate pyramid lengths. /6/

4-7 \6\ ANIMAL HOUSING FACILITIES.

This section applies to all DoD facilities housing government-owned or -managed animals. These facilities must comply with NFPA 150 and the requirements of this UFC.

This section does not apply to retail kennels, riding stables, private or club stables, or similar facilities that are not included in DoD real property inventory, nor to shelters provided for either domesticated or feral animals that do not confine the animals.

4-7.1 Sprinkler Protection.

Provide automatic sprinkler protection throughout the facility.

4-7.2 Fire Alarm.

4-7.2.1 Provide smoke detection in the animal housing area.

4-7.2.2 Audible notification in the animal housing area must not disturb the animals. The use of chimes or other “soft” notification is acceptable. The use of private operating mode for the animal housing area is acceptable as determined by the *DFPE*.

4-7.2.3 Visual notification in the animal housing area may be omitted in order to avoid disturbing the animals.

4-7.3 Animal Housing Separation.

Provide a minimum one-hour fire rated construction to separate the animal housing area from the remainder of the facility.

4-7.4 Air Handling.

Provide a separate air handling system for the animal housing area that does not support any other part of the facility.

[C] 4-7.4

Providing a separate air handling system will prevent the spread of smoke and heat from the other areas of the facility into the animal housing area that could affect the working animals or research animals. This maybe more critical with research animals.

4-7.5 Smoke Control.

The DFPE will determine if a smoke control system will be required.

[C] 4-7.5

Animal housing or animal research facilities may require smoke control in order to ensure a clean atmosphere in the animal housing or research area is maintained in the event of a fire. If products of combustion enter the animal housing or research area, it could compromise the animals and impact the animals working ability or research to be terminated due contamination of the animals resulting in the loss of years of training or research.

4-7.6 Veterinary Care and Animal Research Facilities.

Comply with UFC 4-510-01. /6/

4-8 \6\ BATTERY ENERGY STORAGE SYSTEMS – LITHIUM

This section applies to battery energy storage systems that use any lithium chemistry (BESS-Li). Unoccupied structures housing BESS-Li must comply with NFPA 855, except where modified by this section.

[C] 4-8

There are no current commercially available lithium battery chemistries that provide a significantly different margin of fire safety over any other lithium battery chemistry. This includes lithium iron phosphate chemistry.

See NFPA 855 including Appendix A and NFPA 1 chapter entitled “Energy Storage Systems” for additional guidance related to energy storage systems.

4-8.1 BESS-Li in Unoccupied Structures.

The structure must be dedicated to the BESS-Li operation. BESS-Li structure may not be used for any other purpose other than the lithium batteries and required/approved switching.

[C] 4-8.1

In many cases these structures and the battery systems are not DoD real property or equipment, rather are owned by public and private utilities and other energy providers. The owner’s technical guidance may be used, provided it meets or exceeds the requirements of this UFC; however, it must not be used to reduce the minimum requirements of this UFC.

4-8.1.1 Location. Unoccupied Structures housing lithium battery must be located no closer than 100 feet (30 m) to an occupied structure or an identified outdoor use area.

A perimeter fence or wall in accordance with the installation's facility standards must be provided not less than 100 feet from the structure. An adjacent facility exterior wall maybe part of the perimeter separation.

[C] 4-8.1.1

For information pertaining to fire potential, see articles and fire report on the energy storage fire at the McMicken Energy Storage facility located in utility Arizona Public Service territory just outside of Phoenix on 19 April 2019.

4-8.1.1.1 Other electrical utility switching, transformers, and distribution equipment may be within the perimeter in accordance with the appropriate electrical safety requirements or specific utility technical requirements.

4-8.1.2 Doors. Each doorway leading into the structure housing lithium batteries must be equipped with locks and kept locked. Provision for emergency access for fire and security purposes in accordance with installation guidance is required.

4-8.1.2.1 A minimum of two separate doors must be provided. The doors must be spaced a minimum distance apart equal to the long dimension of the structure, or a minimum of 75% of the diagonal distance apart, whichever is greater. Door swing must be in the direction of egress travel.

4-8.1.3 Ventilation. General ventilation must comply with NFPA 855.

4-8.1.4 Explosion/Deflagration Venting. Explosion/deflagration venting must be provided for the BESS-Li room. See NFPA 855 for guidance on design of explosion/deflagration venting.

4-8.1.5 Signage. All sides of the structure and the doors to the structure must be provided with ANSI compliant signs indicating; “DANGER – In Emergency Call XXX-XXX-XXXX Before Any Entry”, where XXX-XXX-XXXX is the lithium energy storage system operator 24-hour emergency response center; “WARNING – LITHIUM Battery Energy Storage System”; and “DANGER – High Voltage”.

[C] 4-8.1.5

It is assumed any energy supplier has a 24-hour emergency response capability. In the absence of such a capability, sign should indicate in event of an emergency entry to the structure should not be attempted by anyone including DoD emergency responders or installation craftsmen.

4-8.2 BESS-Li in Occupied Structures.

The BESS-Li room must be dedicated to DoD owned and operated BESS-Li operation. BESS-Li rooms must not be used for any other purpose other than the lithium batteries and required/approved switching. Third party owned and operated BESS-Li that are supporting power generation equipment (photovoltaic panels, wind turbines, and other similar equipment) are not permitted in DoD facilities.

[C] 4-8.2

UFC 3-520-01 prohibits the use of any type of lithium energy storage system in an occupied facility. This UFC technical section does not exempt the use prohibition in UFC 3-520-01.

This section provides requirements for standalone BESS-Li structures and requirements for an occupied facility in the event an exemption is approved through the UFC exemption approval process in MIL-STD-3007G.

4-8.2.1 Location. BESS-Li rooms must have one exterior wall, i.e., located where the room can be ventilated to the outside air without using flues or ducts.

4-8.2.2 Size. BESS-Li rooms must not contain more than 600 kWh energy system.

4-8.2.3 Walls, Roofs, and Floors. The walls and roof of the BESS-Li room must be constructed of materials that have approved structural strength for the conditions with a minimum fire resistance of 3 hours.

4-8.2.3.1 A floor in contact with the earth must be of concrete that is not less than 4 in. (100 mm) thick. A floor that is constructed with a vacant space or other stories below it must have approved structural strength for the load imposed thereon and a minimum fire resistance of 3 hours.

4-8.2.3.2 For the purposes of this section, studs and wallboard construction is prohibited. Sturdy construction with impact resistance equivalent to reinforced concrete or concrete masonry units (CMU) is required.

4-8.2.4 BESS-Li Separation. The BESS-Li cabinets or open battery racks must be separated from other BESS-Li cabinets or open battery racks by a minimum of 3 feet (1 m) or by partitions extending from floor to ceiling/roof/floor above. The partitions must be constructed of masonry units. The partitions need to extend 6 inches (150 mm) beyond the cabinet or open battery rack. For cabinets that meet UL 9540A, the partitions can be constructed of one layer of 5/8-inch Type X gypsum board on both sides of noncombustible studs. Penetrations through the partition must be firestopped as a 1-hour assembly.

[C] 4-8.2.4

The partitions separating the battery cabinets or open battery racks will help limit the spread of a fire from one battery or battery system to another. The partitions need to be floor to ceiling/roof/floor above. Any penetrations need to be firestopped for an hour rating. The partitions are not going to be a true fire rated partition or fire wall. The partitions will help limit or prevent the spread of a fire from the high-energy battery system going through thermal runaway.

4-8.2.5 Doorways. Each doorway leading into an BESS-Li room from the building interior must be provided with a door that has a minimum fire rating of 3 hours. The DFPE may require such a door for an exterior wall opening where conditions warrant.

4-8.2.6 Doors. Doors must be equipped with locks and kept locked. Access is restricted to qualified persons. Doors must swing in the direction of egress travel and be equipped with listed panic hardware.

4-8.2.6.1 When two separate doors are required, the doors must be spaced a minimum distance apart equal to the long dimension of the room, or a minimum of 75% of the diagonal distance apart, whichever is greater.

4-8.2.6.2 Doors to the BESS-Li room must be provided with ANSI compliant signs indicating; “DANGER – In Emergency Call XXX-XXX-XXXX Before Any Entry”, where XXX-XXX-XXXX is the lithium energy storage system operator 24-hour emergency response center; “WARNING – LITHIUM Battery Energy Storage System”; and “DANGER – High Voltage”.

4-8.2.7 Exhaust Ventilation. Exhaust ventilation must comply with NFPA 855, section entitled “Exhaust Ventilation”. The exhaust system must be activated by the sprinkler system protecting the BESS-Li room or the room smoke detection.

4-8.2.8 Explosion/Deflagration Control. Provide explosion/deflagration venting for the BESS-Li room as required by NFPA 855, section entitled “Explosion Control”.

4-8.2.9 Sprinkler Protection. Design the sprinkler protection to provide a minimum density of 0.6 gpm/ft2 (24.4 L/m/m2) over the entire room. Water supply must be able to support 120 minutes of sprinkler flow plus not less than 500 gpm (1,900 l/min) hose stream allowance.

4-8.2.10 Smoke Detection. Design a smoke detection system for the entire BESS-Li room such that each fire area is identified separately.

4-8.2.11 Water Pipes, Conduits, and Accessories. Any pipe, conduit, or duct system foreign to the BESS-Li installation must not enter or pass through the BESS-Li room. Piping or other utilities provided for BESS-Li room fire protection or for cooling must not be considered foreign to the BESS-Li installation.

4-8.2.12 Storage in BESS-Li Rooms. Flammable and combustible materials must not be stored in BESS-Li rooms.

4-8.2.13 Use Group. For Building Code and Life Safety code purposes, BESS-Li rooms in occupied structures must be classified as occupancy Use Group H-3.

4-8.2.14 Battery Management System. Provide an approved battery management system for monitoring and balancing cell voltages, currents, and temperatures within the manufacturer's specifications. Transmit signals to an approved location if potentially hazardous temperatures or other conditions including short circuits, overvoltage (i.e., overcharge) or under voltage (i.e., over discharge) are detected. /6/

[C] 4-8.2.14

The battery management system should be monitored and send any abnormal conditions to a location that can dispatch qualified personnel to evaluate the situation and make any necessary corrections or request additional support.

4-9 CHILD DEVELOPMENT PROGRAMS.

4-9.1 Child Development Centers (CDC).

Comply with UFC 4-740-14. For Navy, comply with FC 4-740-14N.

4-9.2 Continuous Child Care Facilities (24/7).

Comply with UFC 4-740-15.

4-9.3 Other Child Development Programs.

Other child development programs include part-day, preschool, kindergarten, before and after school programs, school-age *Facilities*, etc. Comply with the provisions of educational occupancies in NFPA 101.

4-9.4 Youth Centers.

Youth centers must comply with UFC 4-740-06.

4-10 COAL.

4-10.1 General.

Coal storage and handling must comply with NFPA 850 and FM Loss Prevention Data Sheet 8-10.

4-10.2 Pulverizing Equipment.

Use components designed and constructed in accordance with requirements of NFPA 850.

4-11 COMMISSARIES AND EXCHANGES.

4-11.1 Mixed Occupancy.

Commissaries and Exchanges that are part of another facility (i.e., mixed occupancy) and the Commissary or Exchange area is greater than 8,000 ft2 (743.2 m2) gross floor area, the entire facility must meet the requirements of the sprinkler "Application Requirements" section of this UFC.

4-11.2 Standalone.

Commissaries and Exchanges that are a separate facility (i.e. standalone) and greater than 8,000 ft2 (743.2 m2) gross floor area must be provided with automatic sprinkler protection regardless of construction type.

4-12 COMPACT MOBILE SHELVING.

4-12.1 Reserved.

4-13 DEPARTMENT OF DEFENSE EDUCATION ACTIVITY (DODEA).

DoDEA *Facilities* must comply with the requirements in this UFC.

4-14 DETENTION AND CORRECTIONAL *FACILITIES*.

4-14.1 Requirements.

Comply with NFPA 101 and the following:

4-14.1.1 Individual *Fire Area*s must not exceed 50,000 ft^2 (4,647 m^2).

4-14.1.2 \6\ /6/Provide a minimum separation from other structures and public ways of 20 feet (6.1 m).

4-14.1.3 Provide complete automatic sprinkler protection. Design must utilize institutional (breakaway) type sprinklers in areas accessible to detainees or inmates. Sprinkler piping in detainee or inmate areas must be concealed.

4-14.1.4 Provide an automatic smoke control system in cell areas. In addition, provide manual system activation controls at a continuously manned position outside of the cell area. Design the smoke control system in accordance with NFPA 92.

4-14.1.5 Provide for constant visual supervision of cell areas. Central supervisory control area must be separated from cell areas by not less than one-hour fire-rated construction.

4-14.1.6 Fire alarm notification in cell areas must be at a constantly attended location, with detainees or inmates notified by the staff of fire events. Positive alarm sequence is permitted to be provided in accordance with NFPA 72.

4-14.1.7 Locking Devices.

Provide mechanical or electrical gang release, and individual release devices whenever 10 or more locks must be operated to release prisoners confined in cells. Require gang release devices to open doors necessary to evacuate prisoners to an area of refuge. Require heavy, identically keyed, prison-type locks for exit and corridor doors not requiring gang release devices that must be opened for evacuation in the event of fire.

Dormitory-style confinement facilities are not required to meet the above criteria.

4-14.1.8 Interior Finish.

Interior finish including padded cells must be Class A flame spread (i.e., 25 or less) and must have a smoke development rating not exceeding 50 when tested in accordance with ASTM E84.

4-14.1.9 Navy *Facilities* must also comply with the ACA's Planning and Design Guide for Secure Adult and Juvenile Facilities.

4-15 ELECTRONIC EQUIPMENT AREAS.

This section applies to *Electronic Equipment Areas* and telecommunications areas as defined in this UFC.

4-15.1 General.

4-15.1.1 Construct and protect *Electronic Equipment Areas* in accordance with NFPA 75, except as modified by this UFC.

4-15.1.2 For Air Force *Facilities*, \6\ it is recommended to follow TSFPEWG G 3-600-01.01-18 /6/ for fire protection criteria, in lieu of this section.

4-15.2 Telecommunication Equipment Areas.

This section applies to areas containing telecommunication equipment that serves more than one *Facility*, a portion of an *Installation* or the entire *Installation*. This section does not apply to the room in a *Facility* that contains the incoming telecommunications service for that specific *Facility*.

4-15.2.1 Telecommunication areas must comply with NFPA 76, in lieu of NFPA 75.

Buildings housing telecommunication areas must be of noncombustible construction.

4-15.2.2 Co-located *Facility*.

For *Facilities* that house telecommunication areas that have occupancies and uses other than telecommunication, the entire *Facility* must be provided with sprinkler protection, including the telecommunication area.

4-15.2.3 Stand-alone *Facilities*.

4-15.2.3.1 For stand-alone *Facilities* greater than 2,500 ft^2 (232 m^2), provide a fire extinguishing system in accordance with \2\either/2/ the paragraph entitled "Clean Agent Fire Extinguishing Systems" \2\or “Sprinkler Systems”/2/ below.

4-15.2.3.2 For stand-alone *Facilities* greater than 7,500 ft^2 (696 m^2), provide a sprinkler system in accordance with the paragraph entitled "Sprinkler Systems" below. A clean agent fire extinguishing system can be provided in addition to, but not in lieu of, the sprinkler system.

4-15.2.3.3 Single-story *Facilities* may be of Type II-B construction.

4-15.3 Smoke Detection.

4-15.3.1 *Electronic Equipment Areas* must be protected by Very Early Warning Smoke Detection systems.

4-15.3.2 Smoke detection must provide not less than two distinct alarm conditions (levels) indicating increasing smoke/combustion levels.

4-15.3.3 Smoke detection must notify equipment operators of all distinct threshold conditions/levels. Where operators are not in constant attendance, alarm signals must notify the constantly attended alarm receiving location.

4-15.4 Sprinkler Systems.

4-15.4.1 *Electronic Equipment Areas* must be located in *Facilities* protected by wet pipe automatic sprinklers, except those telecommunication areas identified above.

4-15.4.2 Provide complete wet pipe sprinkler protection throughout the *Electronic Equipment Area*.

4-15.4.3 The *Electronic Equipment Area* must be able to be isolated from other areas by a zone control valve assembly. The control valve assembly must include a control valve, \6\ check valve, /6/ waterflow switch, and inspector’s test connection.

Note: Consult with the DFPE to determine the extent, or boundary, of the *Electronic Equipment Area*.

4-15.4.4 For areas with finished ceilings, use concealed pendent or concealed sidewall sprinklers. For areas without finished ceilings, use upright sprinklers with listed sprinkler guards or concealed sidewall sprinklers.

4-15.4.5 Fire sprinklers must not be provided below raised floors.

4-15.5 Clean Agent Fire Extinguishing System.

Note: Consideration may be given to the use of a supplementary, \2\/2/clean agent fire extinguishing system inside the electronic equipment units or a total flooding system for the room and raised floor.

4-15.5.1 Clean agent fire extinguishing systems must not be utilized as a substitute for automatic sprinklers.

4-15.5.2 Where the requirements of the paragraph entitled “Power and Communication Cabling” are not met, the room and the effected space above the ceiling and below the floor in the room must be protected by a \2\/2/clean agent fire extinguishing system. Where only the below floor area is affected, it is acceptable to provide a \2\/2/clean agent fire extinguishing system below the floor only.

4-15.5.3 *Very Early Warning Smoke Detection* must be used to activate a clean agent fire extinguishing system.

4-15.6 Electronic Equipment Power Disconnect.

4-15.6.1 A means to disconnect power to critical electronic equipment must be provided as required by NFPA 70.

4-15.6.2 The power disconnect method may be by manual means for *Electronic Equipment Areas* with one of the following:

a. Areas that are constantly occupied (24 hours per day, 7 days a week) by personnel familiar with the electronic equipment, or

b. Areas located within a *Facility* that are constantly staffed by a trained response force having ready access to the *Installation* and trained in emergency shutdown procedures.

4-15.6.3 Where multiple rooms that utilize power disconnect simultaneous to water discharge are located in one area, coordinate with the customer on the shutdown requirements. If all adjacent areas may be considered as one, with power to all discontinued simultaneously, the entire area may be protected by one sprinkler system. However, if the customer requires each physically separated area to operate independently of the other, provide separate shutdown capabilities for the separated areas.

4-15.6.4 Electrical equipment must be protected by disconnecting the power upon activation of the fire sprinkler system in the electronic spaces, unless power disconnect is permitted by manual means indicated above.

4-15.6.4.1 The disconnect must be installed downstream of any UPS or similar equipment such that when the disconnect switch is activated, the UPS cannot supply power to the equipment.

4-15.6.4.2 Electrical power disconnect is not required when approved by the *DFPE*.

4-15.7 Power and Communication Cabling.

Power and communication (data) cabling installed in spaces above ceilings or below raised floors must be plenum rated or installed in non-combustible conduit in accordance with NFPA 70.

4-16 ELEVATORS.

4-16.1 General.

This section provides criteria for electric traction, machine room-less equipment and hydraulic elevators. Elevators must comply with the requirements of ASME A17.1 except as modified by this section.

4-16.2 \2\/2/Fire-Resistant Construction.

4-16.2.1 The machine room must have the same fire resistance rating of the elevator shaft it serves.

4-16.2.1.1 This requirement applies to the room containing the elevator controller for machine room-less elevator systems.

4-16.3 Detection.

4-16.3.1 Provide smoke detectors at all elevator lobbies not open or exposed to the exterior (i.e. open parking structures and similar elevator lobbies) and all elevator machine rooms, including where machine room-less controllers are located.

4-16.3.2 Provide smoke detectors at the top of elevator hoistway only when automatic sprinklers are provided in the hoistway.

4-16.3.3 Provide listed control relays within 3 feet (915 mm) of the elevator controller to provide a supervised interface between the fire alarm system and the elevator controller as required by NFPA 72. The wiring between the control relays and the fire alarm control unit must be monitored for integrity as required by NFPA 72.

4-16.3.4 Activation of any elevator machine room, hoistway, or lobby smoke detector must activate the *Facility* fire alarm system and send the affected elevators to the designated floor.

4-16.4 Sprinkler Protection.

4-16.4.1 Where sprinklers are provided in the *Facility*, provide sprinklers for the elevator as noted below.

4-16.4.2 Elevator Machine Room.

4-16.4.2.1 Provide sprinkler(s) with listed sprinkler guard(s) in the machine room(s).

4-16.4.2.2 Provide a supervised shut-off valve, check valve, waterflow switch, and test valve in the sprinkler line supplying the machine room(s). These items must be located outside of and adjacent to the machine room(s).

4-16.4.2.3 Actuation of the waterflow switch must remove power to the elevator(s) served by that machine room, by direct connection from the waterflow switch (i.e. DPDT switch) to the shunt trip breaker.

4-16.4.2.4 The waterflow switch must have no time delay capability.

4-16.4.2.5 Provide an inspector's test connection for each waterflow switch associated with the elevator machine room. Locate the test connection outside the machine room. Route test connection piping to a floor drain location that can accept full flow or where water may be discharged without property damage. Discharge to a floor drain may be permitted only if the drain is sized to accommodate full flow (minimum of 40 gpm). Discharge to service sinks or similar plumbing fixtures is not permitted.

4-16.4.3 Top of Hoistway.

4-16.4.3.1 Provide sprinklers at the top of the hoistway when elevator machinery is located within the shaft.

4-16.4.3.2 When sprinklers are provided at the top of the hoistway, a supervised shut-off valve, check valve, waterflow switch, and test valve must be provided in the sprinkler line supplying the top of hoistway.

4-16.4.3.3 Actuation of the waterflow switch must remove power to the elevator(s) served by that hoistway, by direct connection from the waterflow switch (i.e. DPDT switch) to the shunt trip breaker.

4-16.4.3.4 The waterflow switch must have no time delay capability.

4-16.4.3.5 Provide an inspector's test connection for each waterflow switch. Locate the test connection outside the hoistway. Route test connection piping to a floor drain location that can accept full flow or where water may be discharged without property damage. Discharge to a floor drain may be permitted only if the drain is sized to accommodate full flow (minimum of 40 gpm). Discharge to service sinks or similar plumbing fixtures is not permitted.

4-16.4.3.6 The top of the hoistway and machine room sprinklers may be served by the same control valve assembly and flow switch.

4-16.4.4 Hoistway Pit.

4-16.4.4.1 Provide sprinklers in elevator pits as required by NFPA 13.

4-16.4.4.2 Provide a supervised shut-off valve in the sprinkler line supplying the pit. Locate the valve outside of and adjacent to the pit. Actuation of the pit sprinkler must not disconnect power to the elevator.

4-16.5 Host Nation.

Comply with the requirements of \3\this section and Host Nation requirements. If requirements in this section violates host Nation laws, follow the Host Nation laws. For Host Nation projects in Japan, see Appendix "Criteria for Facility Projects in Japan" in this UFC./3/

Table 4-1 Electric Traction Elevator

ROOM / AREA	PROVIDE SPRINKLER (Not Applicable for Buildings Without Sprinkler Protection)	PROVIDE SMOKE DETECTOR to INITIATE ELEVATOR FIREFIGHTERS SERVICE and BUILDING FIRE ALARM SYSTEM
PENTHOUSE MACHINE ROOM	YES	YES
ELEVATOR LOBBIES	YES	YES
PIT AREA	NO	NO
TOP of HOISTWAY	NO	NO

Table 4-2 Direct Plunger Hydraulic Elevator

ROOM / AREA	PROVIDE SPRINKLER (Not Applicable for Buildings Without Sprinkler Protection)	PROVIDE SMOKE DETECTOR to INITIATE ELEVATOR FIREFIGHTERS SERVICE and BUILDING FIRE ALARM SYSTEM
MACHINE ROOM	YES	YES
ELEVATOR LOBBIES	YES	YES
PIT AREA	YES	NO
TOP of HOISTWAY	NO	NO

Table 4-3 Holeless Hydraulic and Roped Hydraulic Elevator

ROOM / AREA	PROVIDE SPRINKLER (Not Applicable for Buildings Without Sprinkler Protection)	PROVIDE SMOKE DETECTOR to INITIATE ELEVATOR FIREFIGHTERS SERVICE and BUILDING FIRE ALARM SYSTEM
MACHINE ROOM	YES	YES
ELEVATOR LOBBIES	YES	YES
PIT AREA	YES	NO
TOP of HOISTWAY	NO	NO

Figure 4-2 Electric Traction Elevator

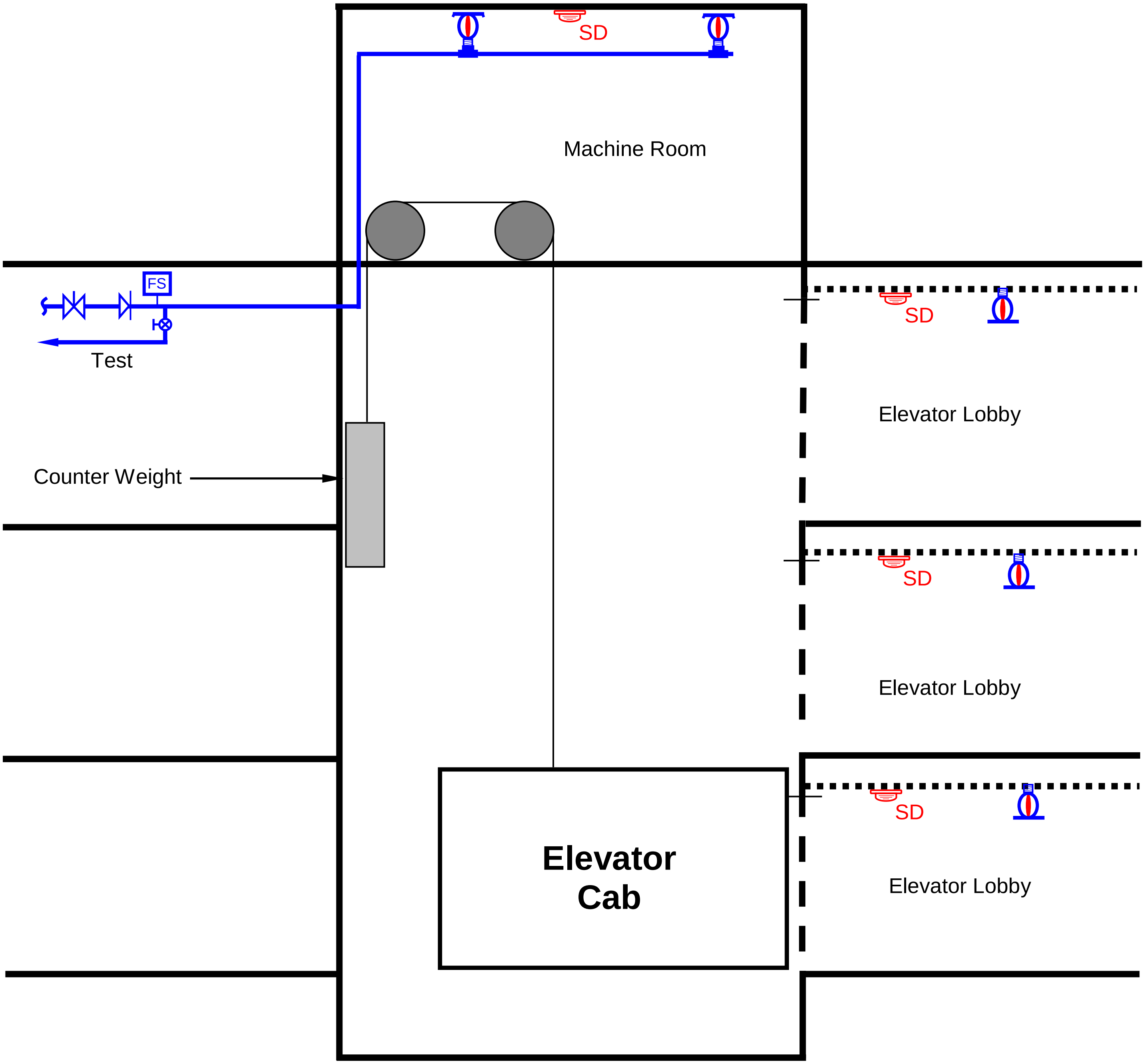


Figure 4-3 Direct Plunger Hydraulic Elevator

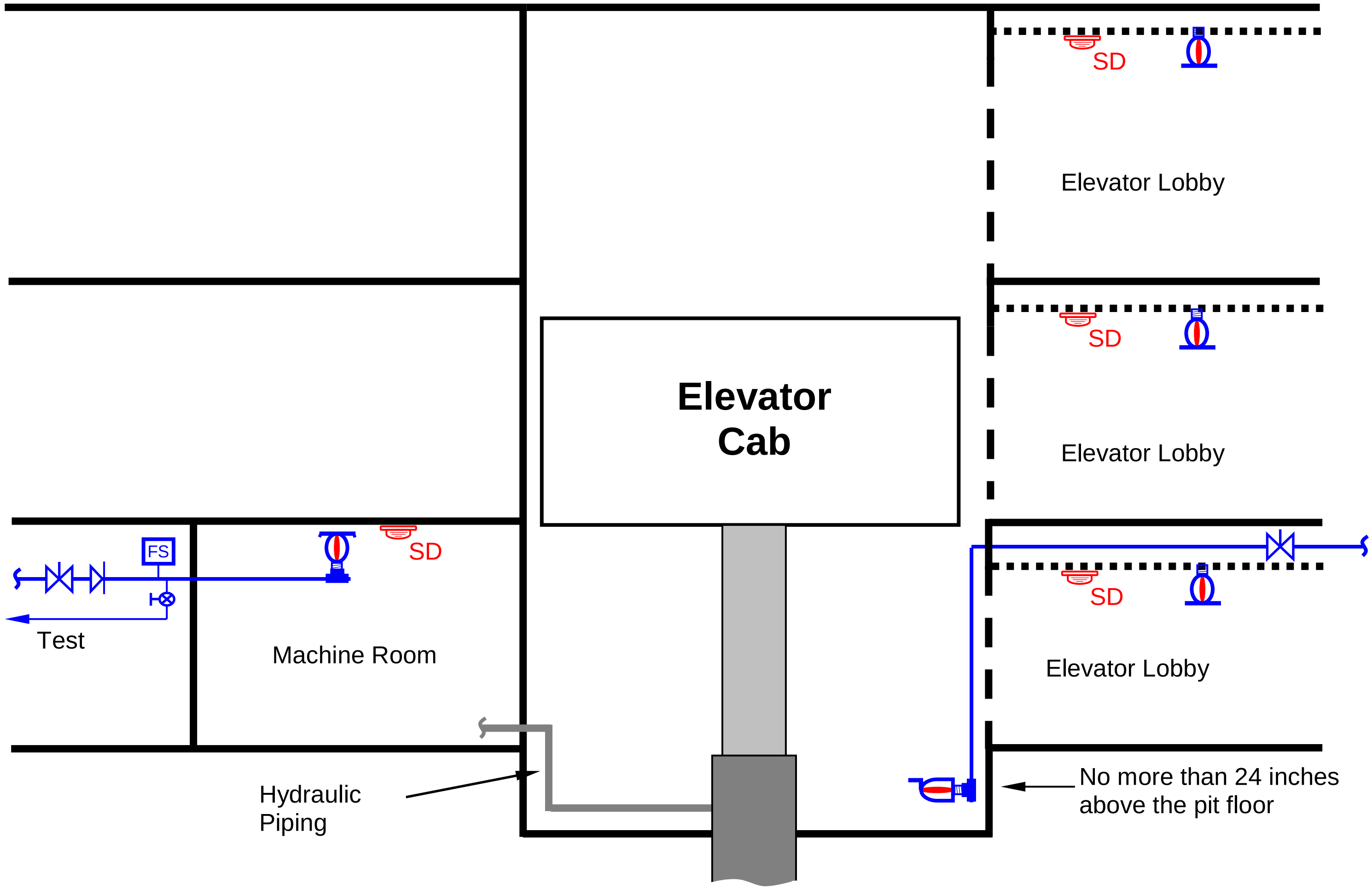
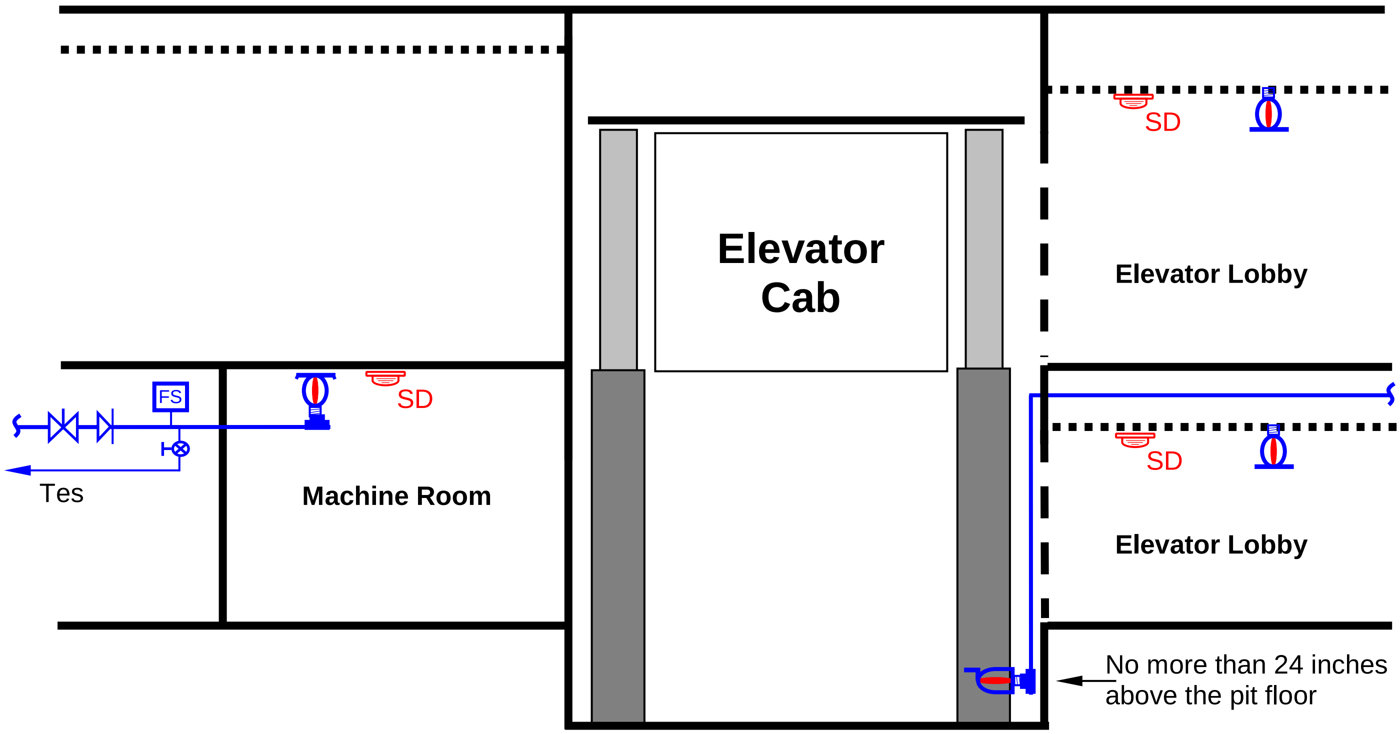


Figure 4-4 Holeless and Roped Hydraulic Elevator



4-17 EMERGENCY SERVICES COMMUNICATIONS CENTERS.

Facilities and equipment that are used for the receipt of alarm signals and telephone calls for assistance, and dispatching of fire, police, or emergency medical services personnel and equipment must comply with this UFC and NFPA 1221.

4-18 FAMILY HOUSING.

4-18.1 General.

This section includes \3\all family housing/3/.

4-18.2 Off-*Installation* Family Housing within the United States and its Territories.

Family housing located outside military *Installations* or bases must comply with provisions of this section and must comply with applicable local fire and building codes when the local fire department has the primary responding responsibility or a local building permit is required.

4-18.3 Family Housing Outside the United States and its Territories and Possessions.

Family housing outside the United States and its territories and possessions, constructed or leased-constructed, must comply with provisions of this section and the Host Nation fire protection requirements.

4-18.4 DoD-Leased Family Housing.

4-18.4.1 DoD personnel occupying DoD-leased housing deserve the same level of protection as those in DoD-owned housing. Implementation of these standards is therefore mandatory for all DoD-leased housing. \5\ /5/This requirement does not apply to housing leased by individuals.

4-18.4.2 New Buildings.

Buildings that are built to lease to DoD must comply with the standards for new construction.

4-18.4.3 Existing Buildings.

For new leases or renewals of leases of existing *Facilities*, the *Facilities* must comply with the requirements for new construction.

4-18.5 *Multi-Family Housing*.

Multi-Family Housing must comply with the IBC and NFPA 101 as required by other sections of this UFC.

4-18.6 One- and Two-Family Housing.

One- and two-family housing must comply with the IRC.\2\

4-18.7 /2/Cooking Areas.

A range top extinguishing system is not required within family housing for cooking areas provided with residential appliances.

4-19 FOOD PREPARATION IN *FACILITIES*.

4-19.1 Commercial Cooking Equipment.

4-19.1.1 Hood and duct systems for commercial cooking equipment that produces smoke or grease-laden vapors must comply with NFPA 96.

4-19.1.2 Range hood fire extinguishing systems must be wet chemical or water assisted wet chemical designed and installed in accordance with NFPA 96.

4-19.2 Residential Cooking Equipment.

4-19.2.1 Non-sprinklered Areas, Other than Housing.

4-19.2.1.1 Residential type range top cooking surfaces must be equipped with a UL 300A listed residential range top extinguishing system or the cooking surface must be equipped with burners and controls that have their temperature limited to a maximum temperature of 662 degrees F (350 degrees C).

4-19.2.1.2 The extinguishing system must be connected to the *Facility* fire alarm system, if provided, to sound a general *Facility* fire alarm and must automatically shut off all sources of fuel and electric power that produce heat to the equipment being protected by that unit.

4-19.2.2 Sprinklered Areas, Other than Housing.

4-19.2.2.1 Residential range top extinguishing systems are not required in sprinklered areas.

4-19.2.2.2 If a residential range top extinguishing system is provided, it must be connected to the *Facility* fire alarm system to sound a general *Facility* fire alarm and must automatically shut off all sources of fuel and electric power that produce heat to the equipment being protected by that unit.

4-19.2.3 Housing.

See "Personnel and Family Housing" section of this UFC for requirements related to cooking facilities in housing.

4-20 HAZARDOUS MATERIALS AND HAZARDOUS WASTE.

4-20.1 General.

Hazardous materials and hazardous waste (hazardous materials) include flammable and combustible liquids, flammable and combustible gases, flammable solids as well as other materials that are classified as hazardous materials. The requirements of this section apply to the storage or use of hazardous materials in excess of the maximum allowable quantities permitted by NFPA 400.

4-20.1.1 Comply with the requirements of NFPA 400, except as noted in this section.

Note: As defined in NFPA 30, hazardous materials storage lockers and premanufactured storage buildings may be used to increase the maximum allowable quantities in accordance with NFPA 400.

4-20.1.1.1 Provide protection for facilities storing flammable and combustible liquids and other petroleum oil lubricant (POL) products in accordance with NFPA 30.

4-20.1.1.2 Class IIIB combustible liquids must be protected as required by NFPA 30 for Class IIIA combustible liquids in accordance with UFC 3-460-01 and NFPA 30.

4-20.1.2 A single building is often used for storage of both flammable and combustible liquids and hazardous materials. Requirements for the storage of hazardous waste are separate and distinct from the storage of hazardous materials.

4-20.1.3 Comply with the requirements of UFC 4-440-01.

4-20.1.4 All other hazardous materials storage and use must comply with NFPA 400.

4-20.2 Hazardous Materials Storage Areas.

4-20.2.1 Maximum Storage Height and Arrangement.

The maximum allowable height and arrangement for storage of hazardous materials must be in accordance with NFPA 400.

4-20.2.2 Fire Protection.

4-20.2.2.1 Complete automatic sprinkler protection must be provided throughout all hazardous material areas regardless of area or construction type.

4-20.2.2.2 \4\/4/Where the rack storage arrangement for hand picking operations provides multiple levels of storage less than 6 feet (1.8 m) above the walking surface and in-rack sprinklers are required for the storage arrangement, provide one extra row of in-rack sprinklers in the longitudinal flue space at the 3 feet (915 mm) level.

4-20.2.3 Hazardous material storage areas or rooms must be identified in accordance with NFPA 704.

4-20.2.4 In rooms storing water reactive materials, provide automatic sprinklers that can be isolated with an indicating valve. Locate the indicating valve outside the water reactive storage area.

4-20.3 Hazardous Waste Storage *Facilities*.

For hazardous waste storage *Facility* requirements, comply with NFPA 400 \6\ and UFC 4-440-01, /6/ except as noted below.

4-20.3.1 Fire Protection.

The following minimum criteria must be provided:

a. Exterior walls must consist of 4-hour fire-resistive construction when the *Facility* is attached to a structure or it is located within 10 feet (3 m) of another building or property line.

b. Exterior walls must consist of 2-hour fire-resistive construction when the *Facility* is located more than 10 feet (3 m) but less than or equal to 50 feet (15.3 m) from a building or property line.

c. Exterior walls must be of noncombustible construction when the *Facility* is more than 50 feet (15.3 m) from another building or property line.

d. Interior walls/ceilings must be 4-hour fire barriers if the *Facility* shares at least one wall with a *Facility* that houses other occupancies.

e. Interior walls/ceilings must be a minimum 2-hour fire barrier when the area of the room is greater than 300 ft^2 (28 m^2) and the *Facility* is not located within a structure that houses other occupancies.

f. Interior walls/ceilings must be a minimum 1-hour fire barrier when the area of the room is 300 ft^2 (28 m^2) or less and the *Facility* is not located within a structure that houses other occupancies.

4-20.3.2 Sprinkler Protection.

Install sprinkler systems suitable for a corrosive environment.

4-20.4 Spill Control and Containment.

Provide spill control and containment complying with NFPA 400 for hazardous materials and hazardous waste storage areas.

4-20.5 Electric Wiring and Equipment.

\2\Where flammable liquids are dispensed or transferred between containers, electric wiring and equipment must be suitable for classified locations in accordance with NFPA 70. Where flammable liquids are not dispensed or transferred between containers, unclassified locations for electrical equipment may be provided./2/

4-20.6 Ventilation.

4-20.6.1 Ventilation must be provided for all hazardous materials storage areas. Ventilation must meet the requirements of NFPA 400.

4-20.6.2 Fan motors located outside of the hazardous materials storage area are permitted to be classified for ordinary locations in accordance with NFPA 70.

4-20.7 Prefabricated Structures.

Prefabricated structures (portable or permanent) are permitted to store hazardous materials and hazardous waste provided they meet the requirements of NFPA 400.

4-20.8 Outdoor Storage Limitations and Separation.

4-20.8.1 \2\Outdoor storage must comply with all of the following:

4-20.8.1.1 The building or structure must be constructed of noncombustible materials, and,

4-20.8.1.2 Walls must not obstruct more than two sides of the structure, or, walls may obstruct portions of multiple sides of the structure, provided that the sum of the walls does not exceed 50 percent of the structure's perimeter./2/

4-20.8.2 The outdoor storage area must not be more than 400 feet (122 m) long or wide and each area must be separated by 100 feet (30.5 m).

4-20.8.3 No containers or portable tanks in a pile are permitted to be more than 200 feet (61 m) from a 40 feet (12.2 m) wide minimum fire lane.

4-20.8.4 Fire hydrants must be installed in accordance with NFPA 24, but spaced not more than 300 feet (91 m) apart. Provide a minimum of two hydrants located so that protected exposures can be reached through hose runs not exceeding 300 feet (91 m).

4-21 HIGH-RISE BUILDINGS.

4-21.1 General.

High-rise buildings must be provided with smokeproof enclosures. Design and install in accordance with NFPA 101. Design and install stair pressurization in accordance with NFPA 92.

4-21.2 Emergency Command Center.

4-21.2.1 Emergency command centers must comply with the following:

a. Provided with exterior and interior access.

b. Enclosed by a 1-hour fire-rated barrier.

c. Provide a minimum area of 200 ft^2 (18.5 m^2) with a minimum dimension of 10 feet (3 m).

4-21.2.2 In addition to the requirements of NFPA 101, the emergency command center must also include the following:

a. Air-handling system status indicators and controls.

b. Fire department control panel for smoke control systems (includes visible status indicators and controls).

c. Schematic building plans indicating the typical floor plan and detailing the building core, means of egress, fire protection systems, fire-fighting equipment and fire department access.

4-21.3 Fire Service Access Elevators.

When the occupied floor level exceeds 120 feet (36.5 m) above lowest fire department vehicle access, provide at least two fire service access elevators that comply with Fire Service Access Elevator requirements in the IBC.

Mechanical penthouses and mechanical stories are not considered occupied floor levels.

4-21.4 Buildings Greater than 420 feet (128 m).

The provisions of this UFC are not intended to apply to buildings greater than 420 feet (128 m) in height. For buildings exceeding 420 feet (128 m) in height, the *DFPE* must be consulted for any additional requirements.

4-22 HISTORIC FACILITIES.

4-22.1 General.

Projects in \2\historic facilities are expected to meet the requirements of the chapter entitled “Existing Facilities” in this UFC./2/

4-23 HYDRAULIC SYSTEMS.

4-23.1 General.

Any combustible liquids under pressure must be treated as a flammable liquid.

4-23.2 Petroleum-Based Hydraulic Fluids.

4-23.2.1 Provide automatic sprinklers directly over and at least 20 feet (6.1 m) beyond the hydraulic equipment. Complete sprinkler protection is required if the structure is of combustible construction, regardless of floor area. Sprinklers may be omitted near a single small system or multiple adjacent small systems not exceeding 100 gal (380 L) aggregate capacity, and if the construction is noncombustible and ignition sources are not normally present, and provisions exist for automatic or manual shutdown of the system(s).

4-23.2.2 An automatic switch, activated by sprinkler waterflow alarm, fusible link, or other fire detector, must be provided to shut down the hydraulic system if there is 100 gal (380 L) or more aggregate capacity of hydraulic fluid.

4-23.3 Hydraulic Test Systems.

4-23.3.1 For hydraulic systems that use pressures exceeding 200 psi (1380 kPa), SAE 1010 dead-soft, cold-drawn, seamless-steel tubing (or equivalent) must be used. A safety factor of eight over normal working pressure must be used. For systems with working pressures in excess of 2,500 psi (17,240 kPa), a factor of safety of four times the burst pressure is acceptable. Tubing is preferable to pipe. Tubing can be bent to fit in restricted spaces with a minimum number of fittings, reducing the number of possible leakage points. Solderless, steel fittings of the flareless "locking-sleeve" type or flare type must be used.

4-23.3.2 Use of threaded pipe must be avoided. Where threaded connections are used, requirements of ANSI B1.20.1 must be met. A safety factor of eight over normal pressure must be used.

4-23.3.3 Tubing runs must have as few bends as possible, but must have at least one bend to provide for thermal expansion and contraction. The minimum radius of tube bend must be three tube diameters.

4-23.3.4 Where hose must be used for flexible connections, it must be steel reinforced, designed for the hydraulic fluid being used, and capable of withstanding five times the actual operating pressure. Hose couplings and fittings and minimum bending radius must be in accordance with the hose manufacturer's instructions. Hose must be installed so as not to rub against objects as a result of machine movement, vibration, or pressure surges.

4-23.3.5 Piping and tubing must be anchored or secured to minimize failure due to vibration. Pipe supports must not prevent normal thermal expansion.

4-23.3.6 There must be an accessible, well-marked, emergency shutoff switch for each pump.

4-23.3.7 Provide an automatic shutoff switch to deactivate hydraulic pump upon loss of pressure.

4-24 \2\HYDROELECTRIC GENERATING PLANTS.

4-24.1 Hydroelectric Generating Plants.

Hydroelectric plants must comply with the section in this UFC for "Power Generating And Utilization Equipment" except as modified in this section. Also, hydroelectric plants must comply NFPA 850, especially the chapter for Identification and Protection of Hazards for Hydroelectric Generating Plants, except as modified by this section.

4-24.2 Indoor Transformers

Indoor transformer equipment spaces such as transformer vaults must contain the appropriate fire barrier rating for all partitions and those items installed in the partitions.

4-24.2.1 Automatic fire suppression systems are not required for the following indoor transformers.

a. Dry type indoor transformers.

b. FMDS 5-4 "less flammable" fluid filled transformers contained within 3-hour fire rating barriers.

c. Transformers rated less than 35 kV containing less than 100 gallon capacity and contained within 3-hour fire rating barriers.

4-24.2.2 Automatic fire suppression systems must be provided for all other indoor transformers rated 35 kV or greater and all must be enclosed by 1-hour fire-rated barriers. Fire suppression system type must be one of the following.

a. Water mist system with operating pressure greater than 175 psi in accordance with NFPA 750.

b. Clean agent in accordance with NFPA 2001.

4-24.3 Outdoor Transformers.

Structures and equipment in the vicinity of outdoor oil-filled transformers must be protected by separation, fire barriers, or water spray systems.

4-24.3.1 Where outdoor transformers are located on the hydroelectric plant structure and not protected by water spray systems, provide a structural analysis of the exposed supporting and adjacent structure(s) proving that these structure(s) can withstand the design fire without collapse or severe damage. The design fire must be based upon the "Heat Flux Calculations" of ANSI/IEEE 979. Severe damage is defined as that preventing occupancy or facility use following a fire or based upon an estimated repair cost as compared to estimated project cost.

4-24.3.2 Fire barriers may be constructed of materials other than concrete block or reinforced concrete construction where the materials provide 2-hour fire resistance rating. Fire barriers must be designed to resist wind loads.

4-24.3.3 Where outdoor transformers are located on the hydroelectric plant structure containment must be provided for the transformer oil volume plus the 24 hour, 25 year stormwater volume.

4-24.3.4 Automatic fire suppression water spray systems must comply with the following:

a. The water supply must be adequate for 2 hours of operation of the water spray system at maximum demand. A hose stream demand of 500 gpm (1900 L/min) must only be included for existing facilities with existing hydrants for reuse or replacement.

b. Containment must be provided for the water volume produced by the water supply for 2 hours of operation.

4-24.4 Hydroelectric Generators.

All hydroelectric generators and ancillary equipment contained in generators must be protected by one of the following automatic fire suppression systems regardless of winding insulation material construction.

a. High or Low Pressure CO2 system in accordance with NFPA 12.

b. Clean Agent in accordance with NFPA 2001.

4-24.5 Oil Storage and Oil Purification Rooms.

Oil storage and oil purification rooms must be protected by one of the following automatic fire suppression systems.

a. Water mist system with operating pressure greater than 175 psi in accordance with NFPA 750.

b. Clean Agent in accordance with NFPA 2001.

4-24.6 Paint and Flammable Liquid Storage Rooms.

Paint and flammable liquid storage rooms must be protected with automatic fire suppression as specified for oil storage and oil purification rooms./2/

4-24.7 \5\ Fire Alarm.

For fire alarm, detection, and notification systems, provide secondary power under supervisory conditions for 24 hours and all alarm devices for an additional 15 minutes. /5/

4-25 HYDROGEN FACILITIES.

4-25.1 Liquid Hydrogen (LH_2).

Install LH_2 storage and fueling in accordance with NFPA 52 and FM Global Data Sheet 7-91.

4-25.2 Gaseous Hydrogen (GH_2).

Install GH_2 compression, gas processing, and storage in accordance with NFPA 52 and FM Global Data Sheet 7-91.

4-25.3 Indoor Fueling or Dispensing.

Indoor fueling or dispensing of LH_2 or GH_2 is prohibited.

4-26 HYPERBARIC AND HYPOBARIC CHAMBERS.

4-26.1 Hyperbaric Chambers.

Hyperbaric chambers must comply with NFPA 99 Chapter entitled "Hyperbaric Facilities". Incorporate criteria contained in UFC 4-159-01N and SS 521-AA-MAN-010 into the design of hyperbaric chambers.

4-26.2 Hypobaric Chambers.

Hypobaric chambers must comply with NFPA 99B.

4-27 LABORATORIES.

4-27.1 General.

Laboratories using chemicals must comply with NFPA 45.

[C] 4-27.1

The occupancy specific maximum allowable quantities in NFPA 45 take precedence over the general maximum allowable quantities in NFPA 1.

4-28 HISTORIC RESOURCE LIBRARIES, ARCHIVES, AND FACILITIES.

4-28.1 General.

4-28.1.1 Comply with NFPA 909 or NFPA 232.

For Navy projects, comply with FC 4-760-10N.

4-28.1.2 Libraries storing materials that are not culturally significant (e.g., primary or secondary school library) are not required to comply with this section.

4-28.1.3 Facilities for the restoration of culturally significant materials must comply with this section.

4-28.1.4 Use noncombustible wall and ceiling finish materials.

4-28.1.5 Provide complete automatic wet pipe sprinkler protection throughout *Facilities* containing libraries.

4-28.1.6 Water mist fire protection systems complying with paragraph entitled "Water Mist Fire Protection Systems" in this UFC may be used in those areas of the *Facility* containing rare or unique materials that are particularly susceptible to water damage.

4-29 LIMITED ACCESS AND UNDERGROUND STRUCTURES.

4-29.1 General.

Comply with the requirements of NFPA 101, except as noted below.

4-29.2 Limited Access Structures.

4-29.2.1 A manually activated smoke exhaust system must be provided for structures three stories or more in height. The smoke exhaust system must be designed for a minimum of six air changes/hour throughout the entire building.

4-29.2.2 Provide complete automatic sprinkler protection for all limited access structures regardless of floor area or construction type.

4-29.3 Underground Structures.

4-29.3.1 A manually activated smoke exhaust system must be provided when there are two or more occupied levels or when an occupied level is greater than 30 feet (9.1 m) below grade plane. The smoke exhaust system must be designed for a minimum of six air changes/hour throughout underground occupied levels.

4-29.3.2 Provide complete automatic sprinkler protection for all occupiable underground structures regardless of floor area or construction type.

4-30 MEDICAL FACILITIES.

These facilities must conform to UFC 4-510-01 and NFPA 101.

4-31 MILITARY OPERATIONS ON URBAN TERRAIN (MOUT) TRAINERS.

The DFPE must be consulted during the planning phase to determine what specific fire protection and life safety requirements are necessary.

Note: These structures are unique as they can be designed and constructed to mimic conditions in other locations. Guidance can be found in NFPA 101 for Special Amusement buildings.

4-32 MISSILE ALERT FACILITIES (MAF).

4-32.1 Sprinkler Protection.

Protect all missile alert facilities with a sprinkler system designed and installed in accordance with NFPA 13R. Systems must be supplied from the existing domestic water storage tank; a separate water storage tank is not required. Use dry pendent or dry sidewall heads for rooms/spaces exposed to freezing temperatures.

4-32.2 Heat Detectors.

Thermal detection devices must be provided in rooms, areas and spaces that are not protected by automatic sprinkler protection in accordance with NFPA 13R.

4-32.3 Fire Hydrants.

Provide a dry fire hydrant installed on the domestic water tank to allow local fire departments the ability to draft firefighting water during emergencies.

4-33 MORALE WELFARE AND RECREATION FACILITIES (MWR).

Clubs, bowling centers, craft shops (including hobby shops, woodworking, auto centers), and similar recreational facilities with an occupant load of 50 or more must be protected with automatic sprinkler systems regardless of floor area or construction type.

4-34 NATURAL GAS SERVICE.

4-34.1 General.

4-34.1.1 Gas service mains must be installed in accordance with NFPA 54 and NFPA 58.

4-34.1.2 Gas service mains are not permitted within the perimeter of foundation lines.

4-34.1.3 Provide natural draft cross ventilation for *Facility* crawl spaces containing gas service piping.

4-34.1.4 Raise supply connections from the gas service mains above grade outside the foundation wall\2\./2/

4-34.1.5 Locate pressure regulators outside of the *Facility* or vent to the outside away from air intakes.

4-35 \2\NAVIGATION LOCKS \5\AND LAKE PROJECTS/5/.

\5\This section applies to navigation locks and dams on rivers and other waterways, as well as operating control towers at lake projects.

4-35.1 General.

4-35.1.1 Protection of Petroleum Based Hydraulic Fluid Power Equipment and Hydraulic Fluid Reservoir. Protect hydraulic reservoir and pumping equipment with fire suppression system or separate from remainder of facility by fire barrier walls. A fire suppression system must be an automatic sprinkler, water mist, clean agent, or other suppression system approved by DFPE. Fire barrier walls must be 2-hour rated concrete construction with opening protection.

4-35.2 Navigation Locks./5/

4-35.2.1 Pump Requirements.

Two fire water pumps of the equal size are required, one of which must be redundant. Pump sizing must be based on either the gate spray sprinkler systems or hose stations, whichever is greater. Minimum pump design flow must be 250 gpm, to serve the five hose stations with each flowing 50 gpm. The minimum pump pressure must be 100 psi, and increased as required to provide at least 60 psi at each hose station.

4-35.2.2 Hose Station Requirements.

Hose stations in accordance with NFPA 14 must be located 25 feet upstream and downstream of each gate. These hose stations must be equally spaced at no more than 300 feet intervals along the walls on both sides of the lock chamber. Hose stations will consist of 150 feet of hose in a permanent cabinet. Hose must be 1-1/2 inch synthetic lined and conform to NFPA 1961.

4-35.2.3 Miter Gate Spray System Requirements.

Miter gates (upstream and downstream in lock chamber) must be fitted with a fixed gate spray sprinkler system for coverage of 0.25 gpm/sf of gate. Spray nozzles in accordance with NFPA 15 must be open type with a flat spray pattern operating at 45 psi and a minimum angle of 50 degrees. Nozzle must be brass or stainless steel and sized and spaced to provide complete coverage. Sprinkler piping and bracing must be stainless steel in accordance with NFPA 13 and protected against damage. Connect gate piping with a stainless steel swivel joint with stainless steel ball bearings and grease fittings for lubrication and installed to completely drain. Gate spray system must be separated from hose stations, using a motorized valve.

4-35.2.4 Aboveground Piping Requirements.

Aboveground piping and embedded pipe must be corrosion resistant and in accordance with ASTM A312, Schedule 40. All fittings must have a minimum rated working pressure of 175 psi.

4-35.2.5 Underground Piping Requirements.

Underground piping must be cement-mortar lined ductile-iron with a 150 psi working pressure and in accordance with AWWA C151 and C104. Pipe will be polyethylene encasement in accordance with AWWA C105.

4-35.2.6 Fire Alarm System Requirements.

Provide a fire alarm system in accordance with NFPA 72. The system must consist of an outside electric horn with alarm switches located strategically throughout the project. Electric power for the alarm must be taken from the house-current supply line on the line side of the main switch through an independent switch and circuit breaker. Provide automatic dialers, to facilitate a quick emergency response.

4-35.2.7 Supply Water Intake Requirements.

Water supply to fire pumps may be from the river. If the area is contaminated by zebra mussels, then the fire pump intake must have suitable control strategies implemented. Provide intakes with double type strainers and exterior stainless steel screens./2/

4-36 OXYGEN.

4-36.1 General.

4-36.1.1 Comply with NFPA 55 and NFPA 400, except as modified by this UFC.

4-36.2 Gaseous oxygen (GOX).

4-36.2.1 Bulk GOX Systems.

4-36.2.1.1 Comply with provisions of NFPA 55 for the installation and location of bulk GOX.

4-36.2.1.2 Bulk GOX must be located either above ground and outdoors, or installed in a building of fire-resistant construction that is adequately vented and is used exclusively for storing GOX.

4-36.2.1.3 Containers and associated equipment for Bulk GOX should not be located beneath or be exposed to the failure of electric power lines or piping containing any flammable liquid or gas.

4-36.2.2 GOX System Design.

4-36.2.2.1 GOX systems must be designed to control potential ignition energy mechanisms.

4-36.2.2.2 Automatic safety devices such as system safety valves, flow regulators, and equipment safety features must be installed to automatically control hazards.

4-36.2.2.3 Alarms and warning systems must monitor the parameters of the storage, handling and use of GOX that may endanger personnel and cause property damage.

4-36.2.2.4 System flow velocity in GOX must not exceed 100 feet/second.

4-36.2.2.5 Quick-acting valves must not be used to start or stop GOX systems.

4-36.2.2.6 Remotely operated shutoff valves must be operated only using inert gas or air, and oxygen gas must never be used to operate valves.

4-36.3 Liquid Oxygen (LOX).

4-36.3.1 Liquid Oxygen Tanks.

4-36.3.1.1 Comply with the applicable provisions of NFPA 51 and NFPA 99, regardless of occupancy.

4-36.3.1.2 Fixed tanks having combined capacity of 100 gal (380 L) or less or portable tanks, \2\/2/must comply with applicable provisions NFPA 51 and NFPA 99, regardless of occupancy.

4-36.3.1.3 Where tanks have a single or combined capacity of more than 100 gal (380 L), tanks must be fixed except as modified in the paragraph entitled "Oxygen Bulk Tanks".

4-36.3.2 Oxygen Bulk Tanks.

Use fixed bulk tanks \2\or portable high-pressure bulk units/2/ having a single or combined capacity of more than 100 gal (380 L) that conform to NFPA 55 and NFPA 99 except as modified \2\below:

4-36.3.2.1 Locate bulk oxygen storage out of doors or in a detached noncombustible structure used solely for this purpose and separated as follows:

a. 75 ft (23 m) from:
   1) Aboveground ignitable-liquid tanks of 1,000 gal (3.8 m^3) or greater capacity.
   2) Aboveground tanks of liquefied flammable gases of over 1,000 gal (3.8 m^3) aggregate water capacity.
   3) Low-pressure flammable-gas storage holders of 5,000 ft^3 (140 m^3) or greater capacity.
   4) Unsprinklered combustible buildings.
   5) Combustible yard storage.
   6) Wood exterior walls.

b. 25 ft (7.6 m) from:
   1) Aboveground ignitable-liquid tanks of less than 1,000 gal (3.8 m^3) capacity.
   2) Aboveground tanks of liquefied flammable gases of 1,000 gal (3.8 m^3) or less aggregate water capacity.
   3) Filling or vent connections to underground ignitable liquid tanks.
   4) Low-pressure flammable-gas storage holders of less than 5,000 ft^3 (140 m^3) capacity.
   5) Sprinklered buildings or buildings with both noncombustible construction and light or ordinary hazard occupancy.
   6) High-pressure bulk flammable-gas storage.
   7) Ignitable-liquid unloading stations.

c. 5 ft (1.5 m) from:

1) 1) Noncombustible construction having blank walls 10 ft (3 m) above and 10 ft (3 m) on each side of the equipment.

4-36.3.2.2 Regulators and other control equipment are permitted to be located indoors in a noncombustible building detached or cut off from main buildings or combustible storage. Cutoffs should have at least a 1 hour fire resistance rating.

4-36.3.2.3 Locate outdoor oxygen-storage equipment on a base of crushed stone or concrete./2/

4-36.3.3 \2\Storage/Parking of LOX Carts/2/.

Separation distances for LOX \2\/2/carts are as follows:

4-36.3.3.1 A minimum of 100 feet (30.5 m) from aircraft parking, fueling, or servicing areas.

4-36.3.3.2 A minimum of 100 feet (30.5 m) from any flammable or combustible liquids handling, servicing, processing, or storage area.

4-36.3.3.3 A minimum of 50 feet (15.3 m) from any building.

4-36.3.4 \2\Parking of LOX Vehicles/2/.

Parking for \2\LOX/2/ vehicles that service fixed tanks must be designed in accordance with the separation requirements of NFPA 55 for fixed bulk tanks except as modified in the paragraph entitled "\2\ Storage/Parking of LOX Carts"/2/.

4-36.3.5 LOX Storage for Propellant Applications.

Use liquid oxygen storage for propellant applications that comply with 29 CFR 1910.109 except as modified in the paragraph entitled "LOX Tank and Cart Storage/Parking".

4-36.4 Combined LOX and GOX *Facilities*.

LOX and GOX can use the same *Facility* provided they meet the requirements for each.

4-37 PERSONNEL HOUSING AND SIMILAR LODGING FACILITIES.

4-37.1 General.

This section is applicable to all personnel housing and similar lodging facilities where sleeping occurs, regardless of the number of occupants sleeping.

\6\ /6/ These facilities are commonly referred to as *Billeting* and include barracks, dormitories including apartment style, lodges, temporary or transient living facilities, and sleeping quarters. For duty, and similar rooms, \6\ provide smoke detection in duty room sleeping space and outside the space similar to the follow Section titled “Smoke Detection” below. /6/

4-37.2 Automatic Sprinkler Protection.

Complete automatic sprinkler protection must be provided, regardless of floor area or construction type.

4-37.3 Smoke Detection.

4-37.3.1 Provide smoke detectors in accordance with NFPA 101.

4-37.3.2 A smoke detector must be provided for each sleeping room and the shared/common space of a suite regardless of occupancy or the presence of other detection or protection systems in the *Facility*.

4-37.3.2.1 Upon detection of smoke, an audible signal must be activated in all sleeping rooms and the shared/common space(s) within the *Dwelling Unit*, send a distinct sleeping room smoke detector signal to the *Facility* fire alarm control panel and to the *Installation* fire reporting system, but not activate the *Facility* notification appliances.

Note: The signal to the FACP and fire reporting system may be an alarm or supervisory signal, as determined by the *DFPE*.

4-37.3.2.2 The audible signal in the dwelling unit must be low frequency as required by NFPA 72.

4-37.3.3 Primary and secondary power for the smoke detectors must be provided from the fire alarm control panel. Detectors that are not powered from the fire alarm control panel are not permitted.

4-37.3.4 Activation of a smoke detector in a room dedicated as an ABA/ABAAG accessible room must also activate all visible notification appliances in the room.

4-37.3.5 Sounder bases must not be provided in open sleeping bays with voice evacuation notification. Activation of smoke detector in open sleeping bays must activate building-wide notification appliances.

4-37.4 Cooking Areas.

4-37.4.1 A range top extinguishing system is not required for cooking equipment provided with residential appliances in fully sprinklered *Facilities*. This applies to both the *Dwelling Units* and in common areas.

4-37.4.2 In non-sprinklered areas, a range top extinguishing system must be provided for cooking equipment, regardless of the location in the building.

4-38 PESTICIDE STORAGE AND HANDLING FACILITIES.

4-38.1 General.

4-38.1.1 Locate facilities or operations involving the storage, mixing, or handling of non-flammable pesticides a minimum of 100 feet (30.5 m) from the nearest *Facility* or occupied structure.

4-38.1.1.1 Facilities of Type I construction as defined by the IBC, may be located less than 100 feet (30.5 m) from the nearest *Facility* or occupied structure, but not less than 30 feet (9.1 m) in any case.

4-38.1.1.2 Facilities protected by an automatic sprinkler system may be located less than 100 feet (30.5 m) from the nearest *Facility* or occupied structure, but not less than 30 feet (9.1 m) in any case.

4-38.1.2 Existing facilities involving the storage, mixing, or handling of non-flammable pesticides are permitted in a *Facility* when all the following are provided:

a. The *Facility* is completely protected, including the pesticide area, by an automatic sprinkler system.

b. The pesticide area is separated by not less than one-hour fire-rated construction from the remainder of the *Facility*.

4-38.1.3 Comply with local environmental regulations related to containment of fire sprinkler water discharge.

4-39 PETROLEUM, OILS & LUBRICANTS (POL) FACILITIES.

4-39.1 General.

4-39.1.1 Petroleum fuel facilities consist of but not limited to facilities that receive, store, distribute, or dispense liquid fuels. This includes all storage tanks from bulk storage tanks to individual storage tanks and includes fuel tanks supporting diesel generators, day tanks, and protected aboveground tanks.

4-39.1.2 POL *Facilities* must comply with UFC 3-460-01.

4-39.1.3 Warehouses that store flammable or combustible liquids, regardless of container size or configuration, must comply with the requirements in this UFC.

4-39.2 Fuel Testing Laboratories.

Laboratories must comply with the requirements of \6\ UFC 4-310-03. /6/

4-39.3 Fuel Piers.

Protection for piers with fixed piping systems used for the transfer of flammable or combustible liquids must be in accordance with the following:

a. UFC 4-152.01.

b. UFC 4-150-02.

c. NFPA 30.

d. NFPA 30A.

e. NFPA 307 (if liquids are handled in bulk quantities across general purpose piers and wharves).

f. "Guide on Marine Terminal Fire Protection and Emergency Evacuation", Oil Companies International Marine Forum.

4-40 POWER GENERATING AND UTILIZATION EQUIPMENT.

4-40.1 Power Generating Plants.

Power generating plants must comply with NFPA 850.

4-40.2 Substations.

4-40.2.1 Comply with NFPA 70, NFPA 850 and FMDS 5-4.

4-40.3 Stationary Combustion Engines, Gas Turbines, and Generators.

Internal combustion engines, gas turbines, and generators must comply with NFPA 37 and NFPA 110.

4-40.4 Indoor Transformers.

Indoor transformers must be installed and located in accordance with NFPA 70.

4-40.5 Outdoor Transformers.

4-40.5.1 Outdoor Transformers must be installed and located in accordance with NFPA 70 and ANSI/IEEE 979, except as modified by this UFC.

4-40.5.2 Where transformers are located on or above noncombustible roofs, suitable curbed and drained concrete mats or welded steel plates must be underneath units and located so as not to expose roof structures.

4-40.5.3 Oil-filled transformers must not be installed on combustible roofs.

4-40.5.4 Buildings or equipment exposed by outdoor liquid-insulated transformers must be protected either by separation, a fire barrier, or automatic fire suppression.

4-40.5.4.1 When separation is utilized, the separation distance between *Facilities* and transformers must be as indicated in Table 4-4. The horizontal distance is measured from the edge of the transformer to the *Facility*.

4-40.5.4.2 The separation distance between other equipment (including adjacent transformers) must be as indicated in Table 4-5.

4-40.5.4.3 When fire barriers are utilized, comply with the following:

a. Barriers must be of concrete block or reinforced concrete construction adequate for 2-hour fire resistance.

b. The exposed wall must extend the horizontal and vertical distances from the transformer specified in Table 4-4.

c. Roofs exposed to oil-insulated transformers must be Class A rated for the horizontal distance noted in Table 4-4 for non-combustible construction.

d. For equipment, barriers must extend 1-foot (305 mm) vertically and 2 feet (610 mm) horizontally beyond transformer components that could be pressurized as the result of an electrical fault. This will typically include bushings, pressure relief vents, radiators, tap changer enclosures, and other similar devices.

4-40.5.4.4 When automatic fire suppression is utilized, it must comply with the following:

a. A discharge density of 0.30 gpm/ft^2 (12.2 L/min/m^2) must be provided over transformer surfaces, except areas under the transformer.

b. The water supply must be adequate for 2 hours and must include a hose stream demand of 500 gpm (1900 L/min).

c. Components of the water spray system, such as piping, spray nozzles, and other components must be a minimum of 18 in. (0.45 m) from the transformer.

d. Piping must not pass over the top of the transformer or be exposed by tank relief vents.

e. Do not direct water spray nozzles at bushings.

f. For multiple transformer installations, the water spray system must be designed based on simultaneous operation of the water spray systems for the transformers not meeting the separation distances of Table 4-4.

g. When the ground around the transformer is non-absorbing, water spray must be provided at a density of 0.30 gpm/ft^2 (12.2 L/min/m^2) for the diked area or for a distance of 10 feet (3 m) from the transformer in all directions.

4-40.5.4.5 When utilizing fire barriers or automatic fire suppression, the following additional requirements must be applied:

a. There must be no window openings in first-story walls within a horizontal distance of 10 feet (3 m) from the transformers. Existing window openings must be closed using brick or concrete block.

b. Overhanging eaves, where they exist, must be noncombustible.

Table 4-4 Separation Distance Between Outdoor Insulated Transformer \6\ Containment /6/ and Buildings

Liquid	Liquid Volume gal (m³)	Horizontal Distance[a] 2-hr Fire-Resistant \6\ Wall /6/ ft. (m)	Horizontal Distance[a] Non-Combustible \6\ Wall /6/ ft. (m)	Horizontal Distance[a] Combustible \6\ Wall /6/ ft. (m)	Vertical Distance ft. (m)
Less Flammable	≤10,000 (37.9)	5 (1.5)	5 (1.5)	25 (7.6)	25 (7.6)
	>10,000 (37.9)	15 (4.6)	15 (4.6)	50 (15.2)	50 (15.2)
Mineral Oil	<500 (1.9)	5 (1.5)	15 (4.6)	25 (7.6)	25 (7.6)
	500 - 5,000 (1.9 - 19)	15 (4.6)	25 (7.6)	50 (15.2)	50 (15.2)
	>5,000 (19)	25 (7.6)	50 (15.2)	100 (30.5)	100 (30.5)

[a] If FM-approved transformers are used; the separation distances must follow the requirements of FM Global Data Sheet 5-4, which allows for reduced separation distances.
Less Flammable: See NFPA 70.

Table 4-5 Separation Distance Between Outdoor Fluid Insulated Transformers and Equipment (Including Other Transformers)

Liquid	Fluid Volume gal (m^3)	Distance ft. (m)
Less Flammable	≤10,000 (37.9) >10,000 (37.9)	5 (1.5) 25 (7.6)
Mineral Oil	<500 (1.9) 500 - 5,000 (1.9 - 19) >5,000 (19)	5 (1.5) 25 (7.6) 50 (15.2)
Less Flammable: See NFPA 70.		

4-41 \5\PRIVACY PODS OR PRIVACY ENCLOSURES.

Privacy pods or privacy enclosures (pods) are freestanding enclosures and typically used as a lactation space, temporary private office, sound enclosure, counseling space, or similar use.

4-41.1 Sprinkler Protection.

Pods can be an obstruction to the water distribution rules for automatic sprinklers in the space or room they occupy. Pods must follow Table 4-5a.

TABLE 4-5a Pods Sprinkler Logic Table

INPUTS			RESULTS		
Pod Size*	**Pod Ceiling**	**Room Sprinklers (external to Pod)**	**Sprinkler Required In Pod**	**Modify Room Sprinklers**	**No Room Sprinkler Modification**
Small	Open	Obstructed		X	
Small	Open	Unobstructed			X
Small	Enclosed	Obstructed		X	
Small	Enclosed	Unobstructed			X
Large	Open	Obstructed		X	
Large	Open	Unobstructed			X
Large	Enclosed	Obstructed	X	X	
Large	Enclosed	Unobstructed	X		

* Small pod has a silhouette projected on the floor less than 25 ft^2 (2.3 m^2).
Large pod has a silhouette projected on the floor equal to or greater than 25 ft^2 (2.3 m^2).

4-41.1.1 Open-Grid Ceiling.

Open-grid ceiling is defined in NFPA 13. The open-grid ceiling must cover a minimum of 75% of the pod’s silhouette area to be considered as an open ceiling in Table 4-5a.

4-41.1.2 Grouping: Pods separated by less than 4 feet (1.2 m) are considered a group. The size of the group will be determined by the area of the pods, plus the area between the pods. A group of pods having a total area less than 75 ft^2 (7.0 m^2) will follow the requirements of Table 4-5a; otherwise, a sprinkler must be installed inside of each pod in that group.

4-41.2 Fire alarm.

Pods must meet the notification requirements, either audibility or visual, for a fire alarm system; otherwise, a visual notification appliance must be installed inside the pod.

4-41.3 Life Safety.

The location of pods, including door swing, must not impede or protrude into the required means of egress. /5/

[C] 4-41.3

Example: If a 72-inch (1.8 m) wide corridor has a required egress width of 44-inches (1.1 m) and a 24-inch (0.61 m) wide pod with a door that swings full 180 degrees is located in the corridor, there is no compromise of the means of egress; however, a 36-inch (0.91 m) wide pod, or a pod with a 90degree door swing would not be acceptable.

4-42 RANGES AND REMOTE LOCATIONS.

4-42.1 \2\Water Supply.

When the \6\ *CFPE* /6/ determines a water supply is necessary for the range or remote location, follow the method of calculating minimum water supply as defined in NFPA 1142.

4-42.2 \4\Facilities.

FEMA approved freestanding "FEMA Tank and Pump System (TPS)" or internal "Next Generation FEMA Tank and Pump System (TPS)" are acceptable for use for fixed and relocatable facilities. Installation of the sprinkler system must comply with NFPA 13D./4/

4-42.3 Fire Department Vehicle Access.

Ranges and other remote locations are not required to meet the requirements of the “Fire Department (Emergency) Vehicle Access” section of this UFC or NFPA 1141./2/

4-43 RELOCATABLES.

4-43.1 General.

4-43.1.1 Relocatable facilities must have the same fire protection \2\and/2/ construction \2\/2/requirements as non-relocatable facilities.

4-43.1.2 Provide a minimum separation of 50 feet (15.3 m) between groups of high hazard occupancies, as defined by NFPA 101 and 15 feet (4.6 m) for all other groups.

Note: For Navy, refer OPNAVINST 11010.33 for regulations and restrictions on the use of relocatable facilities.

4-43.2 Location.

4-43.2.1 Do not group critical relocatable facilities, such as electronic equipment vans, to form areas greater than 6,000 ft^2 (557 m^2) for non-sprinklered facilities and 12,000 ft^2 (1,115 m^2) for sprinklered facilities.

4-43.2.2 Do not group relocatable facilities having high hazard occupancies, as defined by NFPA 101, to form areas greater than 4,000 ft^2 (372 m^2) for non-sprinklered facilities and 8,000 ft^2 (743 m^2) for sprinklered facilities.

4-44 SENSITIVE COMPARTMENTED INFORMATION FACILITY (SCIF).

4-44.1 General.

Note: SCIF's should not be confused with radio-frequency shielded enclosures and/or anechoic chambers.

4-44.1.1 See UFC 4-010-05 for additional information.

4-44.1.2 As part of the initial design process for a SCIF, the Certified TEMPEST Technical Authority (CTTA) and the security Accrediting Official (AO) must establish both TEMPEST and physical security building element controls prior to designing means and methods of implementing fire protection systems into the SCIF.

4-44.2 Physical Security Door Hardware.

4-44.2.1 All security door hardware installed on a means of egress door, must comply with the provisions of NFPA 101.

4-44.2.1.1 Sliding deadbolts are strictly prohibited.

4-44.2.1.2 A spin-dial combination lock, similar to the Lockmaster CDX-10, equipped with a life safety push-button feature, is acceptable provided the button feature is enabled at all times the SCIF is occupied.

4-44.2.1.3 Door personnel "access control systems" must not restrict free egress at all times. Badge ID readers may be installed on the interior side of a door for personnel "audit" purposes only, but must not be connected to any physical security door hardware (i.e. electric door strikes, magnetic locks, etc.) that would restrict single-motion door operation.

4-44.3 Fire Alarm and Mass Notification System (MNS).

4-44.3.1 See UFC 4-010-05 for requirements pertaining to the installation of fire alarm and MNS devices within a SCIF.

4-44.3.2 Self-amplified fire alarm audio speakers, and associated wiring circuits, can be installed within a SCIF with concurrence of the CTTA.

Note: Self-amplified speakers are limited to 0.5 - 24VRMS audio input signal levels. Typically, most fire alarm voice systems are designed for 70.7VRMS audio circuits, and therefore careful economic consideration must be made on how to introduce the fire alarm audio signals into a SCIF.

4-44.4 Fire Sprinkler Systems.

4-44.4.1 See UFC 4-010-05 for requirements pertaining to the installation of fire sprinkler piping penetrations into a SCIF.

4-44.4.2 Any security mitigation method imposed directly on a sprinkler pipe must comply with NFPA 13.

4-44.4.3 Metallic dielectric unions or grounding clamp(s) and wire(s) are permitted.

4-45 TENSIONED-MEMBRANE STRUCTURES.

4-45.1 General.

4-45.1.1 Tensioned-membrane (fabric) structures must meet the requirements of NFPA 101 and NFPA 102 as well as all life safety, fire protection, and allowable area requirements for the specific occupancy, in accordance with the other provisions of this UFC.

4-45.1.2 Tensioned-membrane (fabric) structures must also meet the requirements of the applicable use paragraph in this UFC.

4-45.1.3 \5\When this section or other applicable use paragraphs in this UFC require the installation of sprinkler or other fire protection features, the requirements must be identified in the tension-membrane structure procurement documents to ensure the structural elements are adequately designed to support the dead and live loads of the fire protection features.

4-45.2 /5/Allowable Area and Separation Distance.

4-45.2.1 Table 4-6 provides the maximum allowable area and separation requirements for all tension fabric structures intended to exceed 12 months of use.

4-45.2.2 The separation area must be a clear zone adjacent to the tension fabric structure.

4-45.2.2.1 The clear zone cannot be used for storage and must be clear of vegetation (maintained lawn is permitted).

4-45.2.2.2 The clear zone may be used as a street or driveway, but not for vehicle parking.

Note: For Navy, see OPNAVINST 11010.33 for regulations and restrictions on the use of relocatable facilities.

Table 4-6 Basic Allowable Area for Tensioned-Membrane/Fabric Structures

SEPARATION DISTANCE	TYPE of CONSTRUCTION - In Square Feet (Square Meters)			
	Noncombustible Material		Combustible Material	
	Sprinkler Protection	No Sprinkler Protection	Sprinkler Protection	No Sprinkler Protection
20 feet (6 m)	36,000 (3,344)	12,000 (1,114)	24,000 (2,229)	8,000 (743)
40 feet (12 m)	72,000 (6,689)	24,000 (2,229)	48,000 (4,459)	16,000 (1,486)
60 feet (18 m)	UNLIMITED	UNLIMITED	UNLIMITED	UNLIMITED

4-45.3 Tensioned-Membrane (Fabric) Hangars.

Tensioned-membrane (fabric) hangars must comply with the paragraph entitled "Aircraft Facilities".

4-46 TRASH/RECYCLING COLLECTION AND DISPOSAL AREAS.

4-46.1 Central Trash/Recycling Collection and Dumpsters.

Place central trash/recycling collection units and dumpsters 15 feet (4.6 m) or more away from wood frame or metal *Facilities* or from openings in masonry-walled *Facilities*.

4-46.2 Collection, Baling, Processing and Storage Rooms.

Rooms for collection, baling and storage must be separated from the remainder of the building by a 1-hour fire barrier and protected with automatic sprinklers.

Where the *Facility* is not protected with automatic sprinklers, the sprinkler system is permitted to be connected to the domestic water system when permitted by NFPA 13.

4-46.3 Trash/Recycling Chutes.

Provide automatic sprinklers in all trash/recycling chutes installed within a *Facility*

4-47 VEHICLE PARKING, STORAGE, MAINTENANCE, AND REPAIR *FACILITIES*.

4-47.1 General.

4-47.1.1 Facilities used for parking or storage of motor vehicles must comply with NFPA 88A.

4-47.1.2 Facilities used for maintenance and repair of motor vehicles must comply with NFPA 30A.

4-47.1.3 Facilities used for the fueling and dispensing of compressed natural gas (CNG) or liquefied natural gas (LNG) for vehicles or vessels must comply with NFPA 52.

4-47.2 Refueler Vehicle Facilities.

Facilities that are covered and enclosed on at least three sides and that are used for the parking, storage, maintenance, and repair of aircraft refueler vehicles must comply NFPA 30A and be provided with the following features:

4-47.2.1 Automatic sprinkler system \4\ throughout.

4-47.2.2 /4/Class I Division 1 electrical equipment and wiring throughout the entire pit area (below floor level) in accordance with NFPA 70.

4-47.2.3 Class I Division 2 electrical equipment and wiring throughout the entire servicing area and areas not suitably cut-off in accordance with NFPA 70.

Note: This includes the area up to the underside of the roof.

4-48 WAREHOUSE AND STORAGE *FACILITIES*.

4-48.1 General.

4-48.1.1 Comply with UFC 4-440-01, except as modified by this UFC.

4-48.1.2 This section applies to *Facilities* (except ordnance) with a ceiling height greater than 12 feet (3.7 m) used for storage, shipping, receiving, packing, and processing of materials.

4-48.1.3 Storage of hazardous materials, including flammable or combustible liquids, must comply with this section and the requirements of the section "Hazardous Materials and Hazardous Waste" in this UFC.

4-48.2 Sprinkler Protection.

4-48.2.1 Complete automatic sprinkler protection must be provided for warehouses and storage *Facilities*, regardless of floor area or construction type.

4-48.2.1.1 Automatic sprinkler systems may be omitted for *Facilities* with an area less than 5,000 ft^2 (465 m^2) with approval of the *DFPE.*

Note: See the "Planning" section of this UFC for guidance on determining if sprinkler protection may be omitted for smaller *Facilities*.

4-48.2.1.2 \2\The use of extended coverage control mode specific application sprinklers is permitted./2/

4-48.2.2 Sprinkler protection must include covered loading docks.

4-48.2.3 Sprinkler protection must follow the design requirements found in NFPA 13. The design density, area of application and hose stream requirements of \3\paragraph "Automatic Sprinkler Systems" in "Fire Protection Systems"/3/ chapter of this UFC do not apply to high-pile storage as defined by NFPA 13.

4-48.2.3.1 Sprinkler protection, at a minimum, must be based on Class IV, non-encapsulated commodities, as defined by NFPA 13, unless a more severe class of storage is anticipated, and must be based on the maximum potential height of storage. The maximum potential height of storage is based on the roof or ceiling height.

4-48.2.4 If provided, in-rack sprinklers must be supplied from risers that are separate from the ceiling sprinklers, except in existing facilities.

4-48.2.5 Racks with solid shelves over 12 feet (3.7 m) in height must be protected with in-rack sprinklers at every tier or shelf level.

4-48.2.6 Sprinkler riser control valves must be readily accessible to the fire department from the exterior.

4-48.2.7 Duration.

The water supply must be capable of providing the minimum duration requirements of NFPA 13 for the protection method selected.

4-48.2.8 Hose Stream Allowance.

Provide a hose stream allowance as required by NFPA 13 for the protection method selected.

4-48.2.9 Roof Slope.

Maximum roof slope must be in accordance with NFPA 13.

4-48.3 Bin Storage.

4-48.3.1 Requirements.

4-48.3.1.1 Protect in accordance with NFPA 13, except as noted below.

4-48.3.1.2 The ceiling density must be increased by 10 percent or one additional level of in-rack sprinklers where combustible bins are stored in racks.

4-48.3.1.3 Mini-storage and retrieval systems and carousel storage must be protected in accordance with FM Global Data Sheet 8-33 or FM Global Data Sheet 8-34.

4-48.4 Column Protection.

Steel columns must be protected as required by NFPA 13.

4-48.5 *Fire Areas*.

4-48.5.1 Warehouse *Fire Area*s must not exceed 60,000 ft^2 (5,574 m^2). Warehouse *Fire Area*s may be increased to 120,000 ft^2 (11,148 m^2) when all of the following provisions are met:

4-48.5.1.1 Ceiling sprinkler design area must be increased by 10 percent. This requirement does not apply when ESFR sprinklers are utilized.

4-48.5.1.2 Dedicated looped *service mains* must be provided with enough sectional valves to isolate each *Service Lateral* around the warehouse.

4-48.5.2 Separation of *Fire Areas*.

4-48.5.2.1 *Fire Areas* must be separated from other *Fire Area*s by 4-hour fire walls in accordance with the IBC Chapter entitled "Fire and Smoke Protection Features".

4-48.5.2.2 Other occupancies, such as offices or shops, must be separated from the warehouse and storage area by a minimum of 1-hour fire-rated construction, unless a higher rating is required by the IBC.

4-48.6 Conveyor and Mechanical Handling System Penetrations.

4-48.6.1 When mechanical handling systems, such as conveyors, penetrate fire barriers, the opening must be protected by a fire door or fire shutter.

4-48.6.2 When a fire door or shutter is not feasible due to the operation of the conveyor, the *DFPE* must be consulted to determine the appropriate protection criteria.

4-49 WATERFRONT FACILITIES.

Waterfront and harbor facilities must comply with all of the following, as applicable:

a. NFPA 303.

b. NFPA 307.

c. NFPA 312.

d. UFC 4-152-01.

e. UFC 4-150-02.

f. UFC 4-151-10.

g. UFC 4-213-10.

h. UFC 4-213-12

i. NAVSEA OP-5 (for Navy only).

4-50 \3\WILDLAND-URBAN INTERFACE LOCATIONS.

4-50.1 General.

As required by Executive Order 13728, facilities within the wildland-urban interface must follow the requirements of the International Wildland-Urban Interface Code./3/

CHAPTER 5 GENERAL BUILDING HEIGHTS AND AREAS

5-1 GENERAL.

Allowances or exceptions that require the *Facility* to be protected throughout by an approved automatic sprinkler system may only be applied where the system is an approved, electrically supervised automatic sprinkler system as described in NFPA 101. References to IBC Section 903.3.1.1 are replaced with NFPA 13. References to IBC Section 903.3.1.2 are replaced with NFPA 13R.

5-2 BUILDING HEIGHT LIMITATIONS.

Conform to the requirements of IBC Chapter 5.

5-3 BUILDING AREA LIMITATIONS.

Conform to the requirements of IBC Chapter titled "General Building Heights and Areas \6\ except as modified by this UFC /6/.

[C] 5-3

IBC Chapter 5 does not permit area increases for sprinkler systems if the sprinkler system is designed per NFPA 13R.

5-4 OCCUPANCY SEPARATION.

5-4.1 General.

5-4.1.1 Occupancy separation must comply with the IBC Chapter 5. Do not use NFPA 101 for occupancy separation requirements, except as noted below.

5-4.1.2 NFPA 101 must be utilized for occupancy separations of medical funded projects, healthcare, ambulatory healthcare, and all facilities required to comply with The Joint Commission standards.

5-4.1.3 \3\For the location of an occupancy within a facility, see paragraph "NFPA 101" in Chapter "Use and Occupancy Classification" of this UFC./3/

5-5 INCIDENTAL USE.

NFPA 101 must be utilized for protection from hazards. IBC requirements for separation of incidental uses are not permitted.

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CHAPTER 6 TYPES OF CONSTRUCTION

6-1 GENERAL.

Conform to the requirements of IBC Chapter 6, except as modified by this UFC.

6-2 SEPARATION BETWEEN BUILDINGS.

Conform to the requirements of the IBC, except as modified by this UFC.

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CHAPTER 7 FIRE AND SMOKE PROTECTION FEATURES

7-1 GENERAL.

Conform to the requirements of NFPA 101 except as noted below.

Where IBC Chapter 5 or 6 specifically references IBC Chapter 7, utilize the specific IBC Chapter 7 reference.

Note: For example, IBC Section 508.4.4.1 specifically references IBC Sections 707 and 711. When utilizing IBC Section 508.4.4.1, utilize IBC Sections 707 and 711, otherwise IBC Sections 707 and 711 are not to be used unless specifically referenced.

7-2 MARKING AND IDENTIFICATION.

Conform to the requirements of the IBC for marking and identification of fire walls, fire barriers, fire partitions, smoke barriers, smoke partitions or any other wall required to have protected openings.

For Navy and NRO, stenciling must be provided and spaced no more than 10 foot, measured edge to edge horizontally along the wall or partition.

7-3 NON-LOAD BEARING PARTITIONS AND BARRIERS.

Comply with NFPA 101 for fire resistance ratings of non-load bearing partitions and barriers, except occupancy separation as indicated in Chapter 5.

7-4 PROTECTION OF STRUCTURAL MEMBERS.

7-4.1 General.

Comply with IBC Chapter 7 for protection of structural members, except as noted below.

7-4.2 Sprayed Fire-Resistant Materials.

7-4.2.1 Sprayed fire-resistant materials must be medium or high density cementitious or an intumescent thin-film coating.

Note: Intumescent thin-film coating is not the same material as intumescent paint.

7-4.2.2 Mineral fiber or low-density cementitious materials are not permitted.

7-4.2.3 Provide UL-listed floor/ceiling and UL-listed roof/ceiling assemblies that do not require the underside of the roof or floor deck to have spray-applied fireproofing. The assembly must be designed so only columns, beams, and trusses receive spray-applied fireproofing to achieve the rating for the assembly.

7-4.3 Ceilings.

Listed floor/ceiling or roof/ceiling assemblies that utilize suspended gypsum wallboard or acoustical tile ceilings must not be used to achieve required fire resistance rating of building structural elements.

7-5 SMOKE AND HEAT VENTS.

7-5.1 General.

7-5.1.1 Smoke and heat vents must not be provided unless specifically required by this UFC.

Note: Smoke and heat vents should be considered in *Facilities* where a high rate of heat release is anticipated during a fire such as indoor firing ranges with rubber impact zones.

7-5.1.2 Where provided in *Facilities* without automatic sprinklers, smoke and heat vents must be arranged to operate automatically in accordance with NFPA 204.

7-5.1.3 Where provided in *Facilities* with automatic sprinkler protection, smoke and heat vents must be arranged to operate in the manual mode only.

Note: Skylights can be used as a method of providing manual smoke and heat vents.

7-6 HIGH VOLUME LOW SPEED (HVLS) FANS.

Comply with NFPA 13, except all HVLS fans must be interlocked to shut down immediately upon any fire alarm activation.

7-7 PLASTIC PIPE AND CONDUIT.

7-7.1 Penetrations.

Penetrations by plastic pipe or conduit through fire-rated walls, partitions, shafts, and floors must be fire stopped by an approved or listed method in accordance with ASTM E814 or UL 1479.

7-7.2 Prohibited Locations.

Plastic pipe and conduit must not be installed in exit stair enclosures, or in air plenum spaces, unless specifically listed for that application.

CHAPTER 8 INTERIOR FINISHES

8-1 GENERAL.

Conform to the requirements of NFPA 101.

8-2 DROP-OUT PANELS.

Drop-out panels, as defined in NFPA 13, must not be used.

8-3 INSULATION.

8-3.1 Requirements.

8-3.1.1 Use thermal and acoustical insulation with a flame spread (FS) rating not higher than 75, and a smoke developed (SD) rating not higher than 150 when tested in accordance with ASTM E84 (NFPA 255).

8-3.1.2 Exposed insulation in concealed spaces of sprinklered buildings must be specified to have a flame spread of 25 or less and a smoke developed rating of 50 or less (including \2\/2/covering).

Note 1: This is to prevent the space from being defined as a combustible concealed space, which would require sprinkler protection in accordance with NFPA 13.

Note 2: Acceptable types of insulation blankets per Federal Spec HH-521F are Type I, Type II (Class A only), and Type III (Class A only).

8-3.2 Exceptions to Insulation Criteria.

For certain types of insulation installation, the exceptions described in paragraphs entitled "Flame Spread – No Smoke Developed Rating Limitation" and "No Flame Spread or Smoke Limitation" below will apply.

8-3.2.1 Flame Spread - No Smoke Developed Rating Limitation.

Compliance with the SD rating limitation is not required, and a FS rating up to 100 is permitted for insulation, including insulating sheathing installed within wall assemblies. In such installations, conform to the requirements for interior finish with a minimum fire resistance rating of 15 minutes when tested in accordance with ASTM E119.

8-3.2.2 No Flame Spread or Smoke Limitation.

Compliance with FS and SD limitations are not required for the following applications:

a. Insulation installed above poured concrete or poured gypsum roof decks, nominal 2-in. (50.8 mm) thick tongue-and-groove wood plank roof decks, or precast roof deck panels or planks that are approved by a Nationally

Recognized Testing Laboratory (NRTL), as noncombustible roof deck construction.

b. Insulation installed above roof decks where the entire roof construction assembly, including the insulation, is UL-listed as Fire Classified, or FM-approved for Class I roof deck construction or equal listing or classification by a NRTL.

c. Insulation contained entirely within panels where the entire panel assembly used in the construction application meets the cited FS and SD limitations.

d. Insulation isolated from the interior of the building by masonry walls, masonry cavity walls, insulation encased in masonry cores, or concrete floors.

e. Insulation installed over concrete floor slabs and completely covered by wood tongue-and-groove flooring without creating air spaces within the flooring system.

f. Insulation completely enclosed in hollow metal doors.

g. Insulation installed between new exterior siding materials and existing exterior siding or wood board, plywood, fiberboard, or gypsum exterior wall sheathing.

Note: The exception to SD limitations described in this paragraph is not applicable to correctional facilities.

CHAPTER 9 FIRE PROTECTION SYSTEMS

9-1 FIRE DEPARTMENT (EMERGENCY) VEHICLE ACCESS.

9-1.1 All-Weather Ground Access.

All *Facilities* greater than 5,000 ft^2 (465 m^2), or more than two stories in height, must have at least one means of all-weather ground access to allow emergency vehicles unimpeded access to the *Facility*. All-weather ground access must be paved, start from the road, and terminate no farther than 33 feet (10 m) from an exterior door accessible for fire department ingress (i.e. a stair door or some other exterior door that provides access to the *Facility* interior). The route between the access surface and exterior door must be able to be traversed without the use of a ladder.

An engineered all-weather surface that is not paved may be provided if approved by the *DFPE*.

9-1.2 Aerial Apparatus Access.

New facilities four stories or more in height and all new warehouses must be provided with suitable all-weather ground access for aerial apparatus on a minimum of two sides of the perimeter of the structure. The access \6\ for buildings four stories or more in height /6/ must be parallel to at least one entire side of the *Facility* with windows \6\ or other openings /6/ to allow aerial access \6\ for fire department ingress /6/ to the entire side. The distance between the aerial apparatus access and the *Facility* must be based on the responding aerial apparatus and *Facility* height and be approved by the *DFPE*.

[C] 9-1.2

The intent of this paragraph is to provide aerial apparatus access to two sides of the building for all buildings four stories or more in height and for all warehouses. It is also the intent to provide aerial access on one side along the entire side of the building with window or other opening access for buildings four stories or more in height so that the aerial apparatus has multiple locations to set up operations and accommodate aerial rescue operations. Consideration should be given to providing roof access locations for warehouse facilities to accommodate aerial suppression operations.

9-1.3 Vehicle Access.

All force protection equipment, such as bollards or gates, must not require more than one person to remove or open. Access may require fire apparatus to drive over a curb. Any locking device controlling vehicle access must be under control of the fire department or 24-hour security personnel located at the specific *Facility*. Dimensions of fire lanes and turnarounds must comply with NFPA 1. Vehicle access must be coordinated with the *Installation* or responding fire department.

9-1.4 Fire Department Connection.

Facilities with fire department connections for fire suppression systems must be provided with suitable all-weather ground access surface for any apparatus within 150 feet (45 m) of such fire department connections.

9-2 *FIRE FLOW* FOR *FACILITIES*.

9-2.1 Sprinklered *Facilities*.

\4\Provide *Fire Flow* for sprinklered *Facilities* in accordance with NFPA 1 or 1,000 gpm at 20 psi (3,785 L/min at 138 kPa), whichever is greater/4/. Where the *Fire Flow* cannot be met, the *DFPE* is permitted to approve a reduction in *Fire Flow*. *Fire Flow* is calculated independently of the *Fire Water Demand.*

9-2.2 Non-sprinklered *Facilities*.

Fire Flow must be in accordance with NFPA 1, except the following special *Facilities*.

9-2.2.1 Ship Berthing and Drydock *Facilities*.

Refer to the paragraph entitled "Waterfront *Facilities*" for *Fire Flow* requirements for ship berthing and drydock facilities.

9-2.2.2 \3\Aircraft Parking and Refueling *Facilities*.

A minimum *Fire Flow* of 1,000 gpm (3,785 L/min) for a 2-hour duration is to be provided for all such *Facilities*.

9-2.2.3 Yard and Outdoor Storage.

9-2.2.3.1 Yard and outdoor storage must comply with the requirements of NFPA 80A, and FM Global Data Sheet 1-20.

9-2.2.3.2 Aisle widths and separation distances must be maintained to limit the exposure to nearby *Facilities* and to facilitate manual firefighting operations.

9-2.2.4 Vehicle Parking Areas.

A minimum *Fire Flow* of 500 gpm (1900 L/m) for a 2-hour duration must be provided for all such areas.

9-2.3 \3\Family Housing.

The *Fire Flow* for family housing must be as follows:

a. One-story - 500 gpm (1,900 L/min) for 90 minutes.

b. Two-story - 750 gpm (2,840 L/min) for 90 minutes.

c. Three-story and above - 1,000 gpm (3,785 L/min) for 90 minutes./3/

9-3 *SERVICE MAINS AND LATERALS*.

9-3.1 General.

9-3.1.1 *Service Mains and Service Laterals* must comply with AWWA M31, NFPA 24 and UFC 3-230-01, except where specifically modified by this UFC.

9-3.1.2 \2\For service laterals \6\ /6/, the velocity must not exceed 10 feet per second (3 m/s)./2/

9-3.1.3 This section applies to both dedicated (fire only) and combined (domestic and fire) water distribution systems.

9-3.1.4 For *Service Mains* served by fire pumps or *Service Laterals* serving fire pumps, velocities must be calculated using 150 percent of the rated capacity of the fire pump.

9-3.1.5 Provide appropriate corrosion protection based on pipe material and corrosive properties of the water supply and earth.

9-3.1.6 Where cathodic protection is indicated based upon present conditions, comply with the following \6\ UFC 3-570-01, Cathodic Protection. /6/

9-3.2 *Service Mains*.

9-3.2.1 *Service Mains* must be sized to accommodate *Fire Flow* plus domestic and industrial demands that cannot be restricted during fires.

9-3.2.2 *Service Mains* must be looped to provide at least 50 percent of the required *Fire Flow* in case of a single break.

9-3.2.3 *Service Mains* must not be dead-end.

9-3.2.4 *Service Mains* must be sized so that the minimum residual pressure available, at 150 percent of a *Facility* fire pump rating, if provided, is not less than 20 psi.

9-3.3 *Service Lateral*s.

9-3.3.1 Not more than two fire hydrants can be located on a *Service Lateral*.

9-3.3.2 Minimum size *Service Lateral* for fire sprinkler systems must be not less than 6-in. (150 mm) in diameter.

9-3.3.2.1 For NFPA 13R systems, the *Service Lateral* is permitted to be 4-in. (100 mm) if supported by hydraulic calculations.

9-3.3.2.2 For NFPA 13D systems, the minimum *Service Lateral* size must be based on hydraulic calculations.

9-3.3.3 The minimum residual pressure in a *Service Lateral* must not be less than 20 psi at the greater of *Fire Flow* or *Fire Water Demand*. This residual pressure must be maintained at the inlet of the backflow preventer or suction side of the fire pump, whichever is closer to the *Service Main*.

9-3.3.4 A *Service Lateral* supplying a fire pump must be able to support 150 percent of the fire pump rated capacity without falling below the required net positive suction head (NPSH) at the suction side of the pump. Where NPSH cannot be met at 150 percent of the fire pump rated capacity, the *DFPE* is permitted to reduce the required flow at NPSH, but in no case is it permitted to be less than the required fire suppression system demand.

Note: Piping downstream of the fire pump is not a *Service Lateral*. Piping downstream of the fire pump must be sized based on the *Fire Water Demand* of the *Facility* or the minimum required by NFPA 20, whichever is greater, not 150 percent of the fire pump rated capacity.

9-3.4 Valves.

9-3.4.1 Control valves must be provided in each source of water supply, such as tanks and pumps.

9-3.4.2 A control valve must be provided on the *Service Lateral* downstream of the connection to the *Service Main*.

9-3.4.3 A sufficient number of sectional valves must be provided on the *Service Main*, so that not more than a combined total of five hydrants or the *Service Laterals* to not more than three separate buildings are out of service due to a single break.

9-3.4.4 Sectional valves on *Service Mains* may be key-operated type. New valves must open by counter-clockwise rotation of the stem.

9-3.4.5 Supervision.

When provided, PIV's must be supervised using a lock or tamper seal, at a minimum.

9-3.5 Fire Hydrants.

9-3.5.1 Fire hydrants must be UL-listed, FM-approved, or listed or classified by an NRTL and must have two 2 1/2-in. (65 mm) hose outlets and one 4 1/2-in. (115m) outlet with national standard fire hose threads in accordance with NFPA 1963.

Comply with the *Installation* fire department or local responding fire department when they require a different arrangement or hose threads.

9-3.5.2 Wet barrel or California-type hydrants are preferable in areas where there is no danger of freezing. Dry barrel or traffic-type hydrants must be used in areas where there is a danger of freezing. Hydrants must be aboveground type and match the type used on the *Installation*.

9-3.5.3 In DoD *Installations* serviced by only local fire departments, hydrant hose threads must meet local requirements.

9-3.5.4 See AWWA Manual M 17 and AWWA Manual M 31 for additional information.

Note: Overseas *Installations* with current below grade hydrants in accordance with local national policy are acceptable.

9-3.5.5 \1\/1/Hydrant caps/barrels must be color coded to prevent cross-connection. In the absence of an *Installation* established color code standard, the following colors must be used; red for non-potable water, yellow for potable water, and purple for reclaimed/reuse water. All hydrants must also be marked based on the *Fire Flow* capacity, in accordance with NFPA 291 or by the *Installation* established marking standard

9-3.5.6 Clearly mark each new hydrant with an identification number assigned by the *Installation*.

9-3.5.7 Construction Requirements.

a. Installation must be in accordance with NFPA 24 except as modified by this UFC.

b. Hydrants must be installed adjacent to paved areas, accessible to fire department apparatus.

c. *Service Lateral* supplying hydrants must be minimum 6-in. (150 mm) and valved at the connection to the *Service Main*.

d. Barrels must be long enough to permit at least 18-in. (450 mm) clearance between the center of the 4 1/2-in. (115 mm) outlet and grade.

e. The ground must be graded so that any surface drainage is away from the hydrant.

f. The 4 1/2-in. (115 mm) outlet must be perpendicular to the street to allow straight connection to the pumper.

g. Landscaping, fencing, bollards and similar must be located a minimum of 24-in. (610 mm) from the \4\vertical/4/ centerline of the hydrant and not directly in front of any outlet.

h. \6\ Install fire hydrants adjacent to airfield pavement not more than 24 inches (610 mm) above the level of the adjacent airfield pavement. Local airfield obstruction authority may approve individual hydrants up to 30 inches (760 mm) above the adjacent airfield pavement. /6/

[C] 9-3.5.7.h

For additional information see the Service specific airfield clearance criteria. The measurement is taken from the airfield pavement (aircraft travel surface) edge closest to the hydrant, not the paved or unpaved shoulder. Standard airfield construction includes slopes to the airfield pavement, paved shoulder, and unpaved shoulder that provide adequate clearance to install commercially available hydrants with a listed grade to top height of 24 to 30 inches (610 to 760 mm). Where the recommended negative shoulder slope is not present or the slope is positive, the hydrant may have to be installed in a designed excavation with retaining walls sized to accommodate all hose connections. The use of subsurface / below grade hydrants should be avoided.

9-3.5.8 Spacing Requirements.

9-3.5.8.1 A sufficient number of hydrants must be provided so that *Fire Flow* can be met without taking more than 1,250 gpm (4,740 L/min) from any single hydrant.

9-3.5.8.2 All parts of the *Facility* exterior must be within 350 feet (106 m) of a hydrant with consideration given to accessibility and obstructions.

9-3.5.8.3 Hydrants must be located with consideration given to emergency vehicle access.

9-3.5.8.4 Hydrants must be spaced in accordance with the following requirements:

a. At least one hydrant must be located within 150 feet (45 m) of the fire department connection.

b. Hydrants protecting warehouses must be spaced \2\along the sides of the *Facility* with fire department access/2/ at 300 feet (91 m) maximum intervals.

c. Exterior storage and military/tactical equipment/vehicle parking must be provided with hydrants spaced at 300 feet (91 m) maximum intervals around the perimeter.

Note: Military/tactical equipment/vehicle parking applies to large parking areas typically found at reserve facilities or similar locations. \6\ /6/

d. Hydrant spacing must be spaced at 600 feet (182 m) maximum intervals for non-sprinklered family housing.

e. Hydrant spacing must not exceed 1,000 feet (305 m) in areas where all family housing is provided with sprinkler protection.

f. \2\ Fire hydrants protecting aircraft parking and servicing aprons must be spaced at 300 feet (91 m) maximum intervals along one side./2/

9-3.5.9 Protection.

Hydrants located adjacent to parking areas, vehicle traffic areas or other areas subject to mechanical damage, must be protected by bollards. The bollards must be located so they are not directly in front of an outlet. The bollards must allow clearance to attach hoses, allow for the removal of the hydrant caps, and for the hydrant to be opened and closed without obstructions. Refer to UFC 3-260-01 where bollards are required for hydrants located adjacent to aircraft parking and servicing aprons.

9-3.6 Pressure-Regulating Valves (PRVs).

9-3.6.1 \6\ General.

9-3.6.1.1 All dedicated fire protection piping, including *Distribution Mains*, *Service Mains*, *Service Laterals*, risers, interior sprinkler piping, must be designed to withstand the maximum available pressure, without the use of PRVs.

9-3.6.1.2 Combination fire and domestic distribution system is permitted to use PRVs if normal pressures exceed 175 psi (690 kPa), subject to the approval of the *CFPE*. The design must be such that routine domestic flow causes the PRV to function daily, or at least once per week. Designs are not permitted that have PRVs (normally closed) supplying pipes that only flow during a fire event or periodic testing.

9-3.6.1.3 In large *Installations* with terrain that has grade elevation changes exceeding 100 feet (30.5 m), the use of PRVs in the form of altitude valves is acceptable. Specific approval of the *CFPE* is required. The design must be such that the valve(s) routinely activate. Designs are not permitted that have PRVs (normally closed) supplying pipes that only flow during a fire event or periodic testing. /6/

9-4 *FACILITY* ON-SITE WATER STORAGE.

9-4.1 General.

9-4.1.1 On-site fire protection water storage must comply with NFPA 22, except where specifically modified by this UFC.\2\

9-4.1.2 /2/The discharge or suction line(s) from each individual tank or reservoir section must be sized to deliver the maximum required flow.

9-4.2 Quantity.

9-4.2.1 The total \2\usable/2/ supply stored \2\/2/must be \2\equal to 120% of/2/ the *Facility's* maximum required *Fire Water Demand* for the applicable duration specified in this UFC\2\ plus any applicable domestic or industrial/2/ demand.

9-4.2.2 In calculating the fire protection water storage requirement, a reduction in storage capacity is acceptable if an adequate replenishment source is available. Factors that must be evaluated include the reliability of the makeup supply, its sustained flow capacity, its method of operation (automatic or manual), and flow limitations imposed by the capacity of treatment operations.

9-4.3 Replenishment of Storage.

The water storage must be capable of being self-replenished to its required volume within 48 hours, during normal domestic and industrial consumption of the supplying utility.

9-4.4 Monitoring.

9-4.4.1 The water level must be remotely monitored in accordance with NFPA 22 and NFPA 72 by the *Installation Fire Alarm Reporting System*.

9-4.4.2 In locales subject to freezing, water temperature of aboveground storage tanks must likewise be monitored by the *Installation Fire Alarm Reporting System.*

9-5 FIRE PUMPS.

9-5.1 General.

9-5.1.1 Fire pumps must comply with NFPA 20, except where specifically modified by this UFC.

9-5.1.2 Fire pumps must be located in a detached, noncombustible pump house or located in a fire-rated room in accordance with NFPA 20 with direct access from the exterior.

9-5.1.3 Maintenance access must be provided to the pump and driver so that either can be removed from the fire pump room. Access is permitted to be via double doors or overhead door directly to the exterior. This is in addition to the normal means of egress required by NFPA 101.

9-5.1.4 Provide a minimum of 3 feet (915 mm) of clearance on one side of the fire pump assembly for maintenance and in front of the pump controller or the minimum required by NFPA 70. A clear width of 3 feet must be provided from the room entry to the fire pump assembly and controller.

9-5.1.5 Provide a minimum of 3 feet (915 mm) access to and in front of all equipment and 6-in. (150 mm) behind the equipment, (e.g., control valves, check valves, etc.).

9-5.1.6 Provide labeling on the surfaces of the piping in the pump room to show the water flow direction and pipe function (e.g., "Suction", "Discharge", "To Fire Dept. Connection", "To Bypass", "To Test Header", "To Standpipe", "To Sprinkler System").

Provide white painted stenciled letters and arrows, a minimum of 2-in. (50 mm) in height and visible from at least three sides when viewed from the floor.

9-5.1.7 The maximum \2\fire suppression system demand must/2/ not exceed 140 percent of rated pump capacity. The pressure at the inlet of the pump at 150 percent of the rated pump capacity must not be less than the required net positive suction head in accordance with NFPA 20. Where NPSH cannot be met at 150 percent of the fire pump rated capacity, the *DFPE* is permitted to reduce the required flow at NPSH, but in no case is it permitted to be less than the required fire suppression system demand.

9-5.1.8 Terminate all drainage piping and test piping from the fire pump or associated appurtenances (e.g., circulation relief valve, bowl drains, etc.), including backflow preventers, to a floor drain or to the exterior of the *Facility* so it will not cause damage.

9-5.1.8.1 Provide concrete pads or splash blocks where discharge location is to other than a concrete slab. Splash blocks must be large enough to mitigate erosion and must not become dislodged during a full flow of the drain. Ensure all discharged water drains away from the *Facility* and does not cause property damage

9-5.1.8.2 Discharge to the exterior must not interfere with exiting from the *Facility*. Water discharge must not cross an exit or exit discharge.

9-5.1.8.3 Drainage piping of less than 3/4-in. (20 mm) may discharge to a floor drain.

9-5.1.9 Full flow relief valve piping must discharge safely in accordance with NFPA 20. If an on-site water storage tank or reservoir is provided, the piping must discharge back to the tank or reservoir.

9-5.1.10 \2\For DLA, a reserve fire pump of the same size must be provided when the total value at risk is greater than $100 million./2/

9-5.2 Pump Type.

A fire pump may be either a horizontal or vertical centrifugal pump, or a vertical turbine pump; whichever is most economical and appropriate for the intended use.

9-5.3 Pump Start and Shutdown.

9-5.3.1 Fire pumps must be arranged to start automatically.

9-5.3.2 Fire pumps must be arranged to automatically shut down after reaching the stop pressure and the expiration of \3\the minimum run time determined by NFPA 20/3/. Stop pressure must be at least 5 psi below maximum churn pressure at the lowest available static pressure.

Note: The lowest available static pressure should be utilized in determining churn pressure so that the stop pressure can be achieved with low pressure. The 5 psi differential is used to allow for gauge error.\2\

9-5.3.3 /2/Fire pump activation (run) must transmit an alarm condition to the *Installation* receiving station, or remote receiving station, but not activate the *Facility* notification appliance circuits (i.e. no audible/visual notification in the protected *Facility*(s)).

9-5.4 Pump Drive.

9-5.4.1 Electric power must comply with NFPA 20. Where electric power is available from a *Reliable Power Source* of adequate capacity, electric motor driven fire pumps must be used.

9-5.4.2 When a *Reliable Power Source* is not available, electric motor driven fire pumps must be provided with a secondary power source (i.e. emergency generator with automatic transfer switch). See Chapter 2 for the definition of *Reliable Power Source*.

9-5.4.3 A diesel engine driven fire pump is permitted in lieu of an electric motor driven fire pump when a *Reliable Power Source* is not available.

Note: Air Force preference is to utilize electric motor driven fire pump(s) with a secondary power source when a *Reliable Power Source* is not available.

9-5.4.4 Diesel engine driven fire pumps must not be arranged to start automatically upon loss of normal power.

9-5.5 Controllers.

9-5.5.1 Soft start, reduced voltage controllers are required for electric motor driven fire pumps equal to or greater than 100 hp or when the fire pump is connected to an emergency generator.

9-5.5.2 Any starting method permitted by NFPA 20 is acceptable for electric motor driven fire pumps less than 100 hp\2\/2/ and \2\not connected to an emergency generator/2/\6\ /6/.

9-5.5.3 Limited service controllers are permitted when approved by a NRTL and NFPA 20.

9-5.5.4 Variable speed controllers are permitted when approved by a NRTL.

9-5.6 Pump Bypass.

Provide a bypass in accordance with NFPA 20 around all fire pumps that take suction from a *Service Lateral*.

9-5.7 Electric Circuits for Diesel Engine Driven Pumps.

Provide separate hard-wired electric circuits for the pump controller, engine starting system battery charger and hard-wired electric circuit for the engine block heater.

9-5.8 Test Connections.

9-5.8.1 Provide a test header manifold on the *Facility* exterior that permits flow testing directly from the header. Coordinate the location of test header with other disciplines to ensure flow from test header does not discharge onto other equipment or cause property damage.

9-5.8.2 Provide a flow meter installed in accordance with NFPA 20.

9-5.8.2.1 The flow meter must be installed in series with the test header unless it is piped to discharge into a water storage tank or reservoir.

9-5.8.2.2 Where a water storage tank or reservoir provides suction to the fire pump, the flow meter discharge must be piped back to a water storage tank or reservoir.

9-6 FIRE SUPPRESSION SYSTEMS.

9-6.1 General.

9-6.1.1 This section applies to all fire suppression/extinguishing systems including, but not limited to: automatic sprinkler systems; water spray systems; foam systems; standpipe systems; dry chemical extinguishing systems; wet chemical extinguishing systems; clean agent fire extinguishing systems; water mist fire protection systems; carbon dioxide systems; and, halon 1301 systems.

9-6.1.2 Fire suppression systems must be designed and installed in accordance with the applicable NFPA standard, except where specifically modified by this UFC.

9-6.2 Connections to *Fire Alarm Reporting Systems*.

9-6.2.1 Where fire suppression systems are installed in or at *Facilities* on *Installation*s with *Fire Alarm Reporting Systems*, the fire suppression systems must be connected to the *Fire Alarm Reporting System* for transmission of alarms, supervisory and trouble signals. \3\NFPA 13D systems are not required to be connected to the *Fire Alarm Reporting System*./3/

9-6.2.2 Where installed in areas without an *Installation Fire Alarm Reporting System*, the fire suppression system must be connected to a remote supervising station for alarm, supervisory and trouble signals.

9-6.3 Plans and Calculations.

9-6.3.1 All working (shop) drawings, regardless of the type of fire suppression system, must meet the drawing requirements in NFPA 13 for Working Drawings, unless the system specific standard has requirements for working drawings.

9-6.3.2 For new or modified systems, working (shop) drawings and calculations must be prepared by an individual that has obtained National Institute for Certification in Engineering Technologies, Automatic Sprinkler Systems, Level III certification or Special Hazards Suppression Systems, Level IV certification, as applicable to the project. The *QFPE* must review the shop drawings, hydraulic calculations and material submittals. The shop drawings must bear the *Review Stamp* of the *QFPE* prior to submitting the fire extinguishing system shop drawings to the *DFPE*.

For Army projects, construction (shop) drawings and calculations must be prepared by, or prepared under the immediate supervision of, the *QFPE*. The *QFPE* must affix their professional engineering stamp with signature to the shop drawings, calculations and material data sheets, indicating approval prior to submitting the fire extinguishing system shop drawings to the *DFPE*. The *QFPE* must monitor the installation of the fire protection systems and certify in writing that the fire protection systems have been constructed and operate as intended in the design plans and specifications.

9-6.3.3 When 20 or less sprinklers are modified or relocated, shop drawings, hydraulic calculations and material submittals are not required to be submitted.

9-6.3.4 The preparer of the shop drawings must perform calculations (i.e. hydraulic calculations, agent flow calculations) in accordance with the applicable NFPA standard, demonstrating that the design will provide an adequate supply for the fire suppression systems. Calculations must be submitted no later than the first shop drawing submission.

9-6.3.5 Hydraulic calculations must include a minimum pressure drop across backflow preventers. \3\For a reduced pressure backflow preventer, use a minimum of 12 psi (82.7 kPa). For a double check backflow preventer, use a minimum of 8 psi (55.2 kPa)./3/

9-6.3.6 When nitrogen is utilized in dry or preaction sprinkler systems, a C-factor of 120 is permitted to be used in hydraulic calculations.

9-6.3.7 The dimension from the edge of standpipes and fire suppression system risers to the nearest adjacent wall(s) must be indicated on the drawings when located in stairs or other portions of the means of egress.

9-6.3.8 The *QFPE* must consult with the DFPE or *Installation* fire safety agency to clarify location of fire department connection(s) or type of hose threads.

Note: The *Installation* fire safety agency will typically be the fire department.

9-6.4 Waterflow Testing.

Conduct waterflow tests, in accordance with the procedures contained in NFPA 291 to determine available water supply for the water-based fire extinguishing systems. The flow test must be performed under the direction of the *QFPE*.

Note: Hydraulic calculations should be based on a waterflow test that was performed no more than 6 months prior to submission of the calculations.

9-6.5 *Fire Water Demand.*

Domestic demand and hose stream are not required to be included in the *Fire Water Demand* when supplied from a utility or source separate from that supplied to the fire suppression system (i.e. tank for fire, water main for hydrant or domestic). Domestic or industrial demands are not included in the *Fire Water Demand* where means are provided to restrict these demands during a fire incident.

9-6.6 Backflow Prevention and Cross Connection Control.

The installation of backflow prevention and cross connection control must comply with AWWA Manual M 14.

9-6.6.1 Potable Water Supply.

For new fire suppression systems using water only, follow the *Installation* requirements for proper type of backflow prevention.

9-6.6.2 Installation \6\ of Backflow Preventers /6/.

9-6.6.2.1 Install a reduced pressure type backflow prevention device where antifreeze, foam or other chemicals are added into the system.

9-6.6.2.2 For locations subject to freezing, backflow preventers must be located in the *Facility* or within a heated enclosure. Provide a low temperature supervisory alarm connected to the *Facility* FACP for heated enclosures. Heat trace must not be used unless a heated enclosure cannot be provided.

9-6.6.2.3 Install horizontal backflow preventers so that the bottom of the assembly is no greater than 24-in. (610 mm) above the finished floor/grade. Install vertical backflow preventers so that the upper operating handwheel is no more than 6 feet (1.8 m) above the finished floor/grade.

9-6.6.3 Prior to the installation of backflow preventers in an existing fire suppression system, a thorough hydraulic analysis, including hydraulic calculations and flow test, must be performed to ensure that the water supply is still adequate for the system with the backflow preventer. If the backflow preventer causes the demand to exceed the water supply, the backflow preventer must not be installed until the water supply is corrected to support the new demand.

9-6.6.4 When installed as part of a fire pump system, piping and fittings suitable for potable water must be used upstream of the backflow preventer in accordance with local environmental requirements. The backflow preventer must be located where required by NFPA 20 unless the local environmental requirements differ.

9-6.6.5 Test Header.

9-6.6.5.1 All new water-based fire suppression systems must have test valves installed downstream of the backflow preventer. These valves must be angle or globe valves with 2.5-inch male National Standard Hose Threads with cap and chain. Provide one valve for each 250 gpm, and fraction thereof, of system design flow (e.g., a volumetric waterflow rate of 450 gpm would require two valves).

9-6.7 Meters.

Where meters are installed on a *Service Lateral* serving fire suppression systems, hydrants, or standpipe systems, they must be listed by a NRTL as fire service meters.

9-6.8 Painting and Labeling.

9-6.8.1 Labeling must be in accordance with MIL-STD-101, except as modified by this section.

9-6.8.2 Provide labeling on the surfaces of all feed and cross mains to show the pipe function (e.g., "Sprinkler System", "Fire Department Connection", "Standpipe"). \2\For pipe sizes 4-inch and larger (100 mm),/2/ provide white painted stenciled letters and arrows, a minimum of 2-in. (50 mm) in height and visible from at least two sides when viewed from the floor. \2\For pipe sizes less than 4-inch (100 mm), provide white painted stenciled letters and arrows, a minimum of 0.75-in. (18 mm) in height and visible from the floor./2/

9-6.8.3 All fire suppression system valves must be marked with permanent tags indicating normally open or normally closed.

9-7 AUTOMATIC SPRINKLER SYSTEMS.

9-7.1 General.

9-7.1.1 Automatic sprinkler systems must comply with NFPA 13, except where specifically modified by this UFC.

9-7.1.2 When automatic sprinkler protection is required by this UFC, it is meant that a wet pipe sprinkler system is to be provided, unless environmental concerns indicate otherwise (e.g., freezing conditions).

9-7.1.3 Sprinkler systems must use equipment and devices listed by a NRTL.

9-7.2 Application Requirements.

9-7.2.1 Complete automatic sprinkler protection must be provided \5\ where required by other codes or standards and for the following/5/:

9-7.2.1.1 Single-story, Type I or II construction *Facilities* greater than 15,000 ft^2 (1,394 m^2) gross floor area

9-7.2.1.2 Multi-story *Facilities*, regardless of floor area or construction type.

9-7.2.1.3 Single-story, Type III, IV and V construction greater than 5,000 ft^2 (465 m^2)

9-7.2.1.4 As specified by other sections of this UFC.

9-7.2.1.5 As required by the IBC for area, height or construction type modifications.

9-7.2.1.6 \2\ See the paragraph entitled "Automatic Sprinkler Systems" in the "Planning (Contract Document Development)" section of the "Introduction" Chapter in this UFC./2/

9-7.2.2 The requirement for automatic sprinkler protection for tension fabric structures must be determined by the DFPE

9-7.2.3 New or modified automatic sprinkler protection for existing *Facilities* must comply with the requirements of the "Existing Facilities" chapter of this UFC.

9-7.2.4 Sprinkler protection must be provided for additions \6\ or Modifications, as defined by NFPA 101, /6/ of existing *Facilities* if the entire gross floor area of the *Facility* (including the addition, if provided) exceeds the area limitations noted above \2\ or is multistory/2/.

9-7.2.4.1 \3\\2\The addition or portion of the building being modified must include sprinkler protection and be designed to support /3/sprinklers for the remainder of the *Facility*/2/.

9-7.2.4.2 \6\ Sprinkler protection is not required for minor Modifications when approved by the *CFPE*. /6/

9-7.3 Design Requirements.

9-7.3.1 *Facilities* requiring sprinkler protection must be provided with sprinkler systems that are designed using the Area/Density Method of NFPA 13, except the discharge requirements for non-storage occupancies must be in accordance with Table 9-3, unless otherwise specified in this UFC.

Note: Common DoD hazard classifications that are not noted in NFPA 13 can be found in Appendix B.

9-7.3.1.1 Residential occupancies must comply with the residential design criteria in NFPA 13, NFPA 13R or NFPA 13D, as applicable.\2\

9-7.3.1.2 /2/Storage occupancies, in mixed use *Facilities*, must follow the miscellaneous storage and storage provisions of NFPA 13.

9-7.3.2 Wet pipe, single-interlock preaction, and non-interlock preaction sprinkler systems must use the requirements for “wet” listed in Tables 9-3 and 9-4. Dry pipe, double-interlock preaction and deluge systems must use the requirements for “dry” listed in Tables 9-3 and 9-4.

9-7.3.3 Where NFPA 13 uses the term ordinary hazard group 1 or ordinary hazard group 2, the density, k-factor, hose stream and duration must be in accordance with the ordinary hazard classification listed in Tables 9-3 and 9-4.

9-7.3.4 Where NFPA 13 uses the term extra hazard group 1 or extra hazard group 2, the density, k-factor, hose stream and duration must be in accordance with the extra hazard classification listed in Tables 9-3 and 9-4.

Table 9-3 Sprinkler Design Demand and Minimum K-Factor

		(gpm/ft²)/ft² (mm/min)/m²[minimum K factor]							
		Ceiling Height up to 30 ft (9.1 m)		Ceiling Height >30-45 ft (9.1 m - 13.7 m)		Ceiling Height >45-60 ft (13.7 m - 18.3 m)		Ceiling Height >60 - 100 ft (18.3 m - 30.5 m)	
Hazard Classification		Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Light	Design	0.1/1500 (4/140)	0.1/1500 (4/140)	0.2/2500 (8/230)	0.2/3500 (8/330)	0.2/2500 (8/230)	0.2/3500 (8/330)	12 @ 7 psi	NA
	K-factor	5.6 (80)	5.6 (80)	11.2 (160)	11.2 (160)	11.2 (160)	11.2 (160)	25.2 (360)	NA
Ordinary	Design	0.2/2500 (8/230)	0.2/3500 (8/330)	0.2/2500 (8/230)	0.2/3500 (8/330)	0.2/2500 (8/230)	0.2/3500 (8/330)	12 @ 7 psi	NA
	K-factor	8.0 (115)	8.0 (115)	11.2 (160)	11.2 (160)	11.2 (160)	11.2 (160)	25.2 (360)	NA
Extra	Design	0.3/2500 (12/230)	0.3/3500 (12/330)	0.3/3600 (12/340)	0.3/4600 (12/430)	0.5/3000 (20/280)	0.5/4000 (20/370)	12 @ 7 psi	NA
	K-factor	11.2 (160)	11.2 (160)	11.2 (160)	11.2 (160)	11.2 (160)	11.2 (160)	25.2 (360)	NA
Note: For ceiling heights > 60 feet, the design demand is based on the number of sprinklers at an end sprinkler pressure (i.e. 12 sprinklers at 7 psi end pressure).									

9-7.3.5 Hose stream requirements must be in accordance with Table 9-4 unless otherwise modified by this UFC.

Table 9-4 Hose Stream Demand and Duration

Hazard Category	Hose Demand, gpm (lpm) Ceilings 60 ft (18.3 m) or less	Hose Demand, gpm (lpm) Ceilings greater than 60 ft (18.3 m)	Duration, min
Light	250 (950)	500 (1900)	60
Ordinary	250 (950)	500 (1900)	60
Extra	500 (1900)	500 (1900)	90

9-7.3.6 The design areas noted above or in NFPA 13, as applicable, must be increased by 30 percent for sloped ceilings that exceed a slope of 2 in 12.

9-7.3.7 The design area reductions in NFPA 13 for quick-response sprinklers are not permitted.

9-7.4 Sprinkler Coverage.

9-7.4.1 In *Facilities* protected by automatic sprinklers, sprinklers must provide coverage throughout the *Facility*.

9-7.4.1.1 Sprinklers may be omitted where permitted by NFPA 13, NFPA 13R or NFPA 13D, as applicable.

9-7.4.1.2 Sprinklers may be omitted from small rooms in specific occupancies in accordance with NFPA 101.

9-7.4.2 Sprinklers must be provided in electrical rooms, regardless of the fire resistance rated separation.

9-7.4.3 The use of extended coverage sprinklers is not permitted \2\except as noted below.

9-7.4.3.1 Extended coverage sprinklers may be used for the protection of loading docks.

9-7.4.3.2 Extended coverage sprinklers maybe used for the protection of historic structures and unique spaces subject to the written approval of the DFPE./2/

9-7.4.4 Listed or approved residential sprinklers are permitted to be used at their listed/approved spacing and coverage.

9-7.5 Hydraulic Calculations.

9-7.5.1 Sprinkler systems must be designed using hydraulic calculations.

9-7.5.1.1 Sprinkler systems permitted by this UFC to be supplied from the domestic plumbing may be designed using the pipe schedule method in NFPA 13.

9-7.5.1.2 The addition of no more than 20 sprinklers to an existing system is permitted to be designed using the pipe schedule based on the layout of the existing system.

9-7.5.2 Where the sprinkler system is supplied by interconnected risers, the sprinkler system must be hydraulically calculated using the hydraulically most demanding single riser. The calculations must not assume the simultaneous use of more than one riser.

9-7.6 Piping.

9-7.6.1.1 Galvanized piping is only permitted for deluge sprinkler systems, valve trim piping and drain piping exposed to the *Facility* exterior.

9-7.6.1.2 Black steel pipe must be used for the addition, repair or relocation of existing galvanized pipe in wet pipe, dry pipe or preaction systems.\2\

9-7.6.2 /2/Piping 2-in. (50 mm) and less must be minimum Schedule 40. Piping larger than 2-in. (50 mm) must be minimum Schedule 10. \2\For DLA, use Schedule 40 steel piping for all sprinkler systems and all pipe sizes.

9-7.6.3 CPVC is only permitted for residential occupancies. \6\ Air Force permits the use of CPVC and other listed plastic sprinkler pipe in any occupancy for which an approved listing exists when installed in strict accordance with the approved listing. /6/

9-7.6.4 /2/Plain end fittings with mechanical couplings and fittings that use steel gripping devices to bite into the pipe are prohibited.

9-7.6.5 Steel piping with wall thickness less than Schedule 40 must not be threaded.

9-7.6.6 Saddle tees using rubber gasket fittings are only permitted when connecting to existing piping for additions or modifications. Saddle tees must use a connection method that completely wraps around the pipe.

9-7.6.7 Fittings, mechanical couplings, and rubber gaskets must be from the same manufacturer.

9-7.6.8 The use of flexible sprinkler hose with fittings intended for direct connection to sprinklers \2\must be approved by the \6\ *DFPE* /2/ /6/.

9-7.6.9 Changes in pipe sizes must be made through tapered reducing pipe fittings.

9-7.6.10 Threaded fittings must use Teflon tape or manufacturer's approved joint compound.

9-7.7 Nitrogen Generation Systems.

9-7.7.1 Design the nitrogen generation system so all equipment is installed within the confines of the riser room with the exception of a connection for a manual gas analyzer.

9-7.7.2 Provide a nitrogen generation system that is capable of delivering a minimum of 98 percent nitrogen composition throughout all of the system piping within 14 days from the commencement of the inerting process.

9-7.7.3 The nitrogen generation system must be self-contained with "drop-in" operability with a simple one step direct connection of the nitrogen gas supply line to each zone.

9-7.7.4 The use of stand-alone compressed nitrogen bottle system is not permitted.

9-7.7.5 A process that involves continuous venting of the piping network is not permitted.

9-7.7.6 Any air maintenance device used in conjunction with the nitrogen generation system must be listed or approved for use on sprinkler systems.

9-7.8 Preaction Systems.

9-7.8.1 Preaction systems must utilize nitrogen complying with the "Nitrogen Generation Systems" section of this UFC\2\/2/.

9-7.9 Dry Pipe Systems.

9-7.9.1 Dry pipe systems must utilize \2\/2/nitrogen \2\complying with the "Nitrogen Generation Systems" section of this UFC./2/

9-7.9.2 The delivery of water from the dry pipe valve to the system test connection \2\must not exceed 60 seconds/2/. Water delivery times must be measured starting at the normal nitrogen\2\/2/ pressure on the system.

9-7.9.3 All rubber gasket grooved-end pipe fittings for dry pipe systems must be listed or approved for dry pipe systems.

9-7.10 System Requirements.

9-7.10.1 Provide a minimum clearance of 3 feet (915 mm) access to and in front of all equipment and 6-in. (150 mm) behind the equipment (e.g., control valves, backflow preventer, check valves, floor control valve assemblies, waterflow switches, etc.).

9-7.10.2 Thrust rod all pipe penetrations through the grade floor slab, unless flanged or welded joints are used throughout the below slab piping. All pipe penetrations through the grade floor slab must be sleeved and sealed.

9-7.10.3 The *QFPE* must coordinate with the Structural Engineer to determine the proper seismic design category for the project, in accordance with the IBC or ASCE guidelines. Seismic restraint is not required for Seismic design category A or B, except as otherwise required in this UFC.

Note: See UFC 3-301-01 for more information.

9-7.10.4 Drain and Test Connections.

9-7.10.4.1 Provide a permanently piped drain/test connection for each waterflow switch, including the waterflow switch for elevator power shunt.

9-7.10.4.2 Terminate all main drains and inspector's test connections piping to the exterior of the *Facility* so it will not cause damage. Discharge to the exterior must not interfere with exiting from the *Facility*. Water discharge or runoff must not cross an exit or exit discharge path. Do not discharge to the roof.

9-7.10.4.3 Termination points interior to the building are permitted to be approved by the *DFPE* when exterior termination is not practical.

9-7.10.4.4 Provide concrete splash blocks at all drain and inspector's test connection discharge locations if not discharging to a concrete surface. Splash blocks must be large enough to mitigate erosion and must not become dislodged during a full flow of the main drain. Ensure all discharged water drains away from the *Facility* and does not cause property damage.

9-7.10.4.5 Any drains, test connection pipe, etc., that penetrate the exterior wall must do so no greater than 2 feet (610 mm) above finished grade, and at no time below grade.

9-7.10.4.6 The drain/test connection must be piped to a location that will accept full flow and will not cause property damage when water is discharging.

Note: Comply with any applicable state or local environmental requirements pertaining to the handling of sprinkler discharge water.

9-7.10.5 Individual floor control assemblies are to be provided for each respective floor when there are three or more floor levels. Floor area meeting the IBC definition of a mezzanine is not considered a floor level when applying this requirement.

9-7.10.6 Provide a dedicated control valve assembly for piping serving rooms that require shunt-tripping of equipment power prior to or simultaneously to the application of water. Locate the control valve assembly outside of the area it serves in an easily accessible identified location.

9-7.10.7 Normally open valves required by NFPA 13 or NFPA 13R \4\/4/to be supervised must be electrically supervised (i.e. tamper switch).

9-7.10.8 Normally closed valves required by NFPA 13, NFPA 13R or NFPA 13D to be supervised must be locked or sealed, unless otherwise required by this UFC.

9-7.10.9 Provide listed or approved sprinkler guards for sprinklers that are less than 7 feet (2.1 m) above finished floor (in unfinished areas) or subject to mechanical damage or can be grabbed from the floor level.

9-7.10.10 Sprinklers installed in any detention areas, regardless of the *Facility* occupancy classification, must be listed/approved institutional sprinklers.

9-7.10.11 Piping up to the backflow preventer, when the fire protection system is connected to a domestic water source, must be disinfected. Disinfection of all other aboveground fire protection system piping is not required.

9-7.11 Family Housing.

When sprinkler systems are provided in family housing in geographic locations having a 99.6% dry bulb temperature less than 32°F (0°C) per UFC 3-400-02 Engineering Weather Data, sprinkler piping is prohibited from being located in attic spaces or exterior walls (except for the incoming service). Locate upper story piping only in interior walls and utilize sidewall sprinklers.

9-8 WATER SPRAY SYSTEMS.

Water spray systems must comply with NFPA 15 and the "Fire Suppression Systems" requirements of this UFC.

9-9 FOAM SYSTEMS.

9-9.1 General.

9-9.1.1 Foam systems must comply with NFPA 11 and NFPA 16, and the "Fire Suppression Systems" requirements of this UFC, except as modified below.\4\

9-9.1.2 /4/New systems must use potable water or a water source that is supplied from a potable water system (i.e. a water storage tank that is filled from a potable water system). The use of saltwater, brackish or other untreated water source must be approved by the \6\ *CFPE* /6/.

9-9.1.3 Foam storage tanks must be labeled indicating vendor, model, type, and quantity of foam held within the tank via permanent sign.

9-9.1.4 \2\Consider all local environmental regulations to determine the control, treatment and/or remediation measures for the discharge of fire suppression effluent./2/

9-9.2 Piping.

9-9.2.1 Foam solution piping must be Schedule 40 steel pipe.

9-9.2.2 Foam concentrate piping must be stainless steel pipe with roll grooved fittings, welded joints and fittings, or flanged joints and fittings. If using welded joints and fittings, consideration must be given to the maintenance of the system and provide flanged joints at certain locations to allow for the ease of maintenance and equipment removal. Gasket material must be approved by the foam concentrate manufacturer.

9-9.2.3 Any concealed concentrate piping must use welded or flanged fittings.

9-9.2.4 Trim piping on all deluge valves, flow control valves, and alarm check valves must be brass.

9-9.2.5 Foam concentrate lines must be located above grade.

9-9.3 Aqueous Film-Forming Foam (AFFF) \4\Systems/4/.

9-9.3.1 \4\Installation of a new AFFF system is prohibited.

9-9.3.2 Discharged AFFF solution must be contained and collected. The containment and collection system must use double-walled \6\ /6/ storage tank(s) for collection of the AFFF solution. \6\/4//6/

9-9.3.3 Foam Systems that utilize AFFF must only use AFFF concentrate meeting Military Specification MIL-F-24385F.

9-9.4 Foam Concentrate Pumps.

Foam concentrate pumps must be used where the distance from the tank to the proportioner exceeds 50 feet (15.3 m), or the manufacturer recommended distance based on water supply, whichever is less.

9-9.5 Foam Concentrate Storage Tanks.

9-9.5.1 Foam concentrate storage tanks can be atmospheric or horizontal bladder.

9-9.5.2 Do not use vertical bladder tanks.

9-9.5.3 Atmospheric tanks must be translucent or opaque, double-walled, polyethylene.

9-9.6 Foam Concentrate Control Valves.

9-9.6.1 For automatic control of foam concentrate, provide valves listed or approved for use with foam concentrate.

9-9.6.2 Isolation control valves must be full port ball type with an operating handle that indicates the on/off position of the valve. Unit must be socket weld or flanged type. Valve body and ball must be 316 stainless steel complying with ASTM A351.

9-9.6.3 All foam system valves affecting foam delivery must be electrically supervised for correct position.

9-9.7 Foam Concentrate Spill Control.

9-9.7.1 Spill control must be provided around foam storage tank(s) to help prevent spilled/leaked foam concentrate from reaching any drains.

9-9.7.2 Spill control must consist of a minimum 4-in. (100 mm) high concrete berm or similar and sized for the full volume of the tank. Double-walled polyethylene tanks can qualify as acceptable spill control provided there are no taps or outlets in the sides or bottom of the tank.

9-9.8 Test Liquid.

Surrogate test liquid (alternate test liquid) is permitted to be used for initial acceptance testing and routine testing if the liquid and test method is approved by a *DoD Component*.

9-9.9 Foam Discharge.

Foam solution discharge for maintenance and testing purposes must be in accordance with local *Installation* environmental requirements.

9-10 STANDPIPE SYSTEMS.

9-10.1 General.

When required, standpipe systems must comply with NFPA 14 and the "Fire Suppression Systems" requirements of this UFC, except as modified below.

Residual pressure requirements for *Facilities* under 150 feet (45 m) in height may be met by fire department apparatus when hydraulic calculations demonstrate that fire department apparatus can provide the required pressure via the building fire department connection(s)\6\ /6/.

9-10.2 Class I Standpipe Systems.

9-10.2.1 A Class I standpipe system must be provided in all required exit stairs of *Facilities* four stories or more in height.

9-10.2.2 For *Facilities* less than four stories in height, \2\provide a/2/ Class I standpipe system\2\ where all portions/2/ of the building (on any floor) \2\cannot be reached from an exterior door in less than/2/ 450 feet (140 m).

9-10.2.2.1 When required by this section, standpipes must be installed in all required exit stairs and on both side of horizontal exits.

9-10.2.3 Standpipes and hose valves must not encroach into the means of egress especially on stair landings.

9-10.3 Class II and III Standpipes.

Class II and III standpipes, as defined in NFPA 14 are not permitted.

9-11 DRY CHEMICAL EXTINGUISHING SYSTEMS.

Note: Fixed dry chemical extinguishing systems are appropriate for the protection of certain types of special occupancies, hazards, and facilities such as dip tanks, and other operations involving flammable liquids.

9-11.1 General.

Dry chemical extinguishing system must comply with NFPA 17 and the "Fire Suppression Systems" requirements of this UFC, except as modified below.

9-11.2 Limitations.

Dry chemical agents must not be used to protect sensitive electronics. Dry chemical extinguishing systems must not be used for the protection of cooking equipment.

9-12 WET CHEMICAL EXTINGUISHING SYSTEMS.

Note: Fixed wet chemical extinguishing systems are suitable for protection of certain types of special occupancies, hazards, and facilities, such as cooking surfaces, cooking exhaust systems, and dip tanks.

9-12.1 General.

Wet chemical extinguishing systems must comply with NFPA 17A and the "Fire Suppression Systems" requirements of this UFC, except as modified below.

9-12.2 Testing.

Testing must be performed by liquid discharge, utilizing the manufacturer’s recommended flushing concentrate, to demonstrate equal distribution of chemical and no leakage at pipe joints.

9-13 CLEAN AGENT FIRE EXTINGUISHING SYSTEMS.

Note: Clean agent fire extinguishing systems are suitable for protection of certain types of special occupancies, hazards, and facilities.

9-13.1 General.

9-13.1.1 Clean agent fire extinguishing systems must comply with NFPA 2001 and the "Fire Suppression Systems" requirements of this UFC, except as modified below.

9-13.1.2 Clean agent fire extinguishing systems are not permitted to substitute for required automatic sprinkler systems.

9-13.1.3 Fire extinguishing agents that have been identified for future manufacturing or use limitations must not be used, regardless if current installation is permitted by regulatory authorities in the country of application.\1\/1/

9-13.2 Requirements.

9-13.2.1 Provide stand-alone (not dependent upon the *Facility* fire alarm system for operation) control panels that are listed for releasing device service and monitored by the *Facility* fire alarm system.

9-13.2.2 Careful consideration must be given to compartment under/over-pressurization during the discharge of total flooding clean agent systems. Pressure relieving vents, located near the finished ceiling, may be necessary to regulate rapid pressure changes during discharge. Comply with the manufacturer's recommended procedures relative to enclosure venting.

9-13.2.3 Provide a manually activated \2\permanent/2/ exhaust system to facilitate the extraction of any remaining clean agent after the required hold time of the total flooding clean agent system.

9-13.2.3.1 The exhaust system can be integrated into the HVAC system for the enclosure, but in no case \2\/2/ designed for less than six air changes per hour.

9-13.2.3.2 The manual activation switch must be located outside of the protected area.

9-13.2.3.3 Permanent signage must be provided indicating "Fire Suppression Exhaust System – Fire Department Use Only".

9-14 WATER MIST FIRE PROTECTION SYSTEMS.

Note: Water mist fire protection systems are suitable for protection of certain types of special occupancies, hazards, and facilities. Water mist fire protection systems are not a substitute for required automatic sprinkler systems.

9-14.1 General.

9-14.1.1 Water mist fire protection systems must comply with NFPA 750 and the "Fire Suppression Systems" requirements of this UFC, except as modified below.

9-14.1.2 Provide stand-alone (not dependent upon the *Facility* fire alarm system for operation) control panels that are listed for releasing device service and monitored by the *Facility* fire alarm system.

9-15 CARBON DIOXIDE SYSTEMS.

Note: Carbon dioxide (CO_2) systems are normally effective against flammable liquid (Class B) and energized electrical (Class C) fires.

9-15.1 General.

9-15.1.1 Carbon dioxide system must comply with NFPA 12 and the "Fire Suppression Systems" requirements of this UFC, except as modified below.

9-15.1.2 New total flooding systems are not permitted in normally occupied areas.

9-15.1.3 Do not locate CO_2 piping in any area where a pipe break or leak could make a normally occupied area untenable.

9-15.1.4 Careful consideration must be given to compartment under/over-pressurization during the discharge of total flooding CO_2 systems. Comply with NFPA 12 and the manufacturer's recommended procedures relative to enclosure venting.

9-15.1.5 Provide a manually activated exhaust system to facilitate the extraction of any remaining CO_2 after the required holding time of the total flooding CO_2 system. The exhaust system can be integrated into the HVAC system for the enclosure but in no case \2\/2/ designed for less than six air changes per hour. The manual activation switch must be located outside of the protected area.

9-16 HALON 1301 SYSTEMS.

9-16.1 General.

Installation of a new Halon 1301 system is prohibited except by special approval of \1\Service Signature Authority/1/.

9-16.2 Halon Turn-In Procedures.

For projects involving the demolition of existing Halon 1301 systems, refer to the following for turn-in requirements: http://www.dla.mil/aviation

9-17 PORTABLE FIRE EXTINGUISHERS.

9-17.1 General.

General purpose portable fire extinguishers \4\must be provided where required by NFPA 101./4/

9-17.2 Location.

9-17.2.1 When provided, portable fire extinguishers must be located in accordance with NFPA 10.

9-17.2.2 If provided in *Electronic Equipment Areas*, clean agent type portable fire extinguishers must be used.

9-17.2.3 Portable fire extinguishers utilizing carbon dioxide (CO_2) are only permitted to be used in enclosed rooms if they exceed 1,000 ft^2 (92.9 m^2).\2\

9-18 /2/FIRE ALARM SYSTEMS.

9-18.1 General.

\4\Provide fire alarm systems when required by NFPA 101 or when automatic detection or suppression systems are required./4/

9-18.1.1 Fire alarm systems (detection and notification) must comply with the applicable provisions of NFPA 72 and the ABA, except as modified by this UFC.

9-18.1.1.1 Buildings or portions of the building that are not required to comply with ABA/ABAAG, must still comply with NFPA 72.

9-18.1.2 Fire alarm systems must be independent, stand-alone systems that are not an integral part of a security, energy monitoring and control system (EMCS), or other system.

9-18.1.2.1 The fire alarm system must be combined with a *Facility* mass notification system or with a combination *Facility* mass notification and public address system when mass notification is required by UFC 4-010-01. The fire alarm system, or combined *Facility* mass notification and fire alarm system, may be separate from a public address system.

9-18.1.2.2 The fire alarm system is permitted to be connected to the EMCS or similar system to affect shutdown of HVAC units that require shutdown according to UFC 4-010-01 and UFC 4-021-01, but are otherwise not required to be controlled by the fire alarm system.

9-18.1.2.3 Fire alarm systems may be connected to security systems or an EMCS for monitoring purposes only, but must in no way rely on those other systems for operation or reporting.

9-18.1.3 Wireless interior fire alarm systems and devices are not permitted.

9-18.2 Plans and Calculations.

For new or modified systems, construction (shop) drawings and calculations must be prepared by an individual that has obtained National Institute for Certification in Engineering Technologies, Fire Alarm Systems, Level III certification, at a minimum. The *QFPE* must review the shop drawings, calculations and material submittals. The shop drawings must bear the *Review Stamp* of the *QFPE* prior to submitting the fire alarm system shop drawings to the *DFPE*.

For Army, construction (shop) drawings and calculations must be prepared by, or prepared under the immediate supervision of, the *QFPE*. The *QFPE* must affix their professional engineering stamp with signature to the shop drawings, calculations and material data sheets, indicating approval prior to submitting the fire alarm system shop drawings to the *DFPE*. The *QFPE* must monitor the installation of the fire alarm system and certify in writing that the fire alarm system has been constructed and operates as intended in the design plans and specifications.

9-18.3 *Fire Alarm Reporting System.*

9-18.3.1 *Fire Alarm Reporting Systems* must conform to NFPA 72 and NFPA 70.

9-18.3.2 The *Facility* fire alarm system must be connected to the *Fire Alarm Reporting System*.

9-18.3.3 The following signals, at a minimum, must be transmitted via the *Fire Alarm Reporting System*:

a. Alarm signal by device type (e.g., waterflow, manual pull station, sleeping room smoke detector).

b. General supervisory signal.

c. General trouble signal.

9-18.3.4 New exterior fire alarm boxes are not required at DoD *Installations*, nor is it required to replace existing boxes that are not needed for the transmission of automatic alarms.

9-18.3.5 *Fire Alarm Reporting Systems* must provide the following where applicable:

a. Transmission of coded signals to fire department headquarters or other central locations;

b. Permanent record of alarm signal, time, and date;

c. Automatic supervision of alarm initiating circuits;

d. Automatic testing of radio signaling devices;

e. A dedicated transmitter that will transmit alarm, supervisory and trouble signals for each *Facility*; and

f. Transmitters must be listed or approved for use with the existing *Fire Alarm Reporting System*.

9-18.4 Control Panels.

9-18.4.1 The fire alarm control panel must be analog/addressable, site programmable panel, and must have, or be capable of, the following:

a. The ability to store at least 400 events in the history log. These events must be stored in a non-volatile memory and remain in the memory until the memory is downloaded or cleared manually.

b. Resetting of the control panel must not clear the memory from being retrieved on the integral LCD display.

c. An integral LCD 80 character (minimum) alphanumeric display.

d. Provide all smoke detectors connected to the FACP with an adjustable alarm verification feature. Initially set the alarm verification at 20 seconds.

Existing fire detection systems that are controlled by *Facility* management, energy or utility management systems are permitted to remain.

9-18.4.1.1 A conventional control panel is permitted to be used for systems monitoring sprinkler system alarm, supervisory and trouble conditions only as permitted by NFPA 101 (e.g. a warehouse).

9-18.4.2 \3\/3/Locate the control panel and supplemental control panels in a year-round environmentally conditioned space within the *Facility* that complies with the environmental conditions required in the panel approval or listing.

Note: Environmental condition values (temperature and humidity) are taken from UFC 3-400-02.

9-18.4.3 If the fire alarm control panel is not located at the designated primary entrance, provide a remote annunciator at the designated primary entrance unless directed otherwise by the contract documents. Provide remote annunciator with control functions the same as the main control panel. Control functions must be accessible only by user code or secured behind a locked panel.

9-18.5 Detection.

Note: Detection systems, especially smoke detection systems, require significant maintenance. It is critical that the required detectors are properly installed and maintained. Providing detectors in locations that are not required increases the already high maintenance costs of alarm systems and strains the maintenance program for critical detection systems. If a *Facility* warrants protection and criteria does not require detection, protection must be accomplished by a wet pipe sprinkler system. Wet pipe sprinklers provide superior protection with little maintenance.

9-18.5.1 General.

9-18.5.1.1 Fire detection systems must be provided in areas required by this UFC or where required by NFPA standards and must be limited to these applications unless an *Exemption* is approved\1\/1/.

9-18.5.1.2 The area of protection for smoke detection devices permitted by NFPA 72 must be reduced by 50 percent where destratification (ceiling) fans are used (e.g., this may require additional smoke detectors for that area being protected).

9-18.5.1.3 The above reduction is in addition to any other reductions in spacing required by NFPA 72 (e.g., high ceiling, high air-flow).

9-18.5.2 Requirements.

Detection systems must be arranged to alert *Facility* occupants and to transmit an alarm signal via a *Fire Alarm Reporting System*.

9-18.6 Notification.

9-18.6.1 Notification must be provided throughout the entire *Facility* \6\ when a fire alarm system is provided. /6/

9-18.6.2 Where a mass notification system is required, fire alarm notification must be via a voice evacuation system and must serve as the method of notification for the mass notification system.

9-18.6.3 Audible and Visible Notification Appliances.

a. Provide a minimum of one notification appliance circuit per floor. Each notification appliance circuit must include 25 percent spare capacity.

b. Sleeping room speakers must produce a 520 Hz signal temporal three (T3) signal for fire in accordance with NFPA 72.

c. Provide a 520 Hz signal temporal four (T4) signal for carbon monoxide in accordance with NFPA 72 when required by the "Carbon Monoxide (CO) Detection" section of this UFC.

d. The provision of a sounder base does not negate the requirement of the *Facility*'s audible notification appliances for each sleeping room.

e. The performance requirements for audible notification must be met with all doors, fire shutters, movable partitions, and other similar devices closed.

f. Visible notification must be provided in all normally occupied, public and common use areas (e.g., break rooms, corridors, auditoriums or conference rooms).

g. Visible notification must be provided in all normally unoccupied areas (such as mechanical rooms, electrical rooms, janitor rooms, storage areas, communication closets and other similar spaces) greater than 900 ft^2 (84 m^2).

h. Visible notification is required in any normally unoccupied area where the ambient noise is loud enough to require hearing protection (e.g., compressor room).

i. Visible notification must be provided in all offices that are designed for, or may contain, more than four persons at any one time. For Air Force, visual notification must be provided in all offices that are designated for, or may contain, two or more persons at any one time.

Note: This must be determined by the furniture plan. If \3more than four/3/ chairs with work surfaces are assigned to the room, visible notification is required. For Air Force if two or more chairs (with or without work surfaces) are assigned to the room, visual notification is required.

j. Visible notification is not required in single person offices, unless the office is assigned to a person with a hearing impairment that would require a visible notification appliance.

k. Visible notification is not required in bathrooms serving single person offices, unless the office is assigned to a person with a hearing impairment that would require a visible notification appliance.

l. Visible notification appliances must be provided with a clear lens marked "Alert". The use of "Fire" is not permitted.

9-18.6.4 Mass Notification System (MNS).

Refer to UFC 4-021-01.

9-18.6.5 Voice Message.

For systems using voice evacuation or combined with the mass notification system, the default fire alarm voice evacuation message\2\ should/2/ be a female voice and state the following:

> (Temporal 3 Alert Tone) "May I have your attention please. May I have your attention please. A fire emergency has been reported in the building. Please leave the building by the nearest exit or exit stairway. Do not use the elevators". <provide a 2 second pause> "May I have your attention please..." (repeat the message).

Installations with formally established and approved/published in accordance with the Service/Agency policy standard signals and messages are permitted to utilize those standard signals and messages. \2\/2/The general format must be a specific alert signal tone(s) followed by a voice announcement(s) and then repeats the cycle for a specific number of cycles or continuously as appropriate for the message.

Note 1: For single-story *Facilities*, delete "or exit stairway. Do not use the elevators" from the voice message.

\2\Note 2: See "Appendix E" for guidance on other messages./2/

9-18.7 Initiating Devices.

9-18.7.1 Sprinkler Waterflow.

Provide a separate address for each sprinkler waterflow switch.

9-18.7.2 Sprinkler System Supervisory Air or Gas.

Monitor high and low air or gas pressure on dry pipe and preaction systems on a per riser room basis as a supervisory function with the *Facility* fire alarm system.

9-18.7.3 Valve Tamper.

No more than five adjacent valve tamper switches within the same room are permitted to be monitored by the same addressable device or supervisory circuit.

9-18.7.4 Manual Pull Station.

9-18.7.4.1 \2\Manual pull stations must be provided at all exits, regardless of occupancy. Manual pull stations must be located within five feet of the exit door. The 200 foot travel distance to a manual pull station noted in NFPA 101 is not applicable./2/

9-18.7.4.2 Provide addressable double-action type manual pull stations with mechanical reset features. If the manual pull station requires a key for reset, it must be the same key as required for the fire alarm control panel.

9-18.7.4.3 Conventional single-action manual pull stations are permitted in hazardous areas, wet and damp locations, and other areas where specialty listings are required. Where a conventional manual pull station is used, it must be provided with a separate address.

9-18.7.5 Smoke Detection.

9-18.7.5.1 Provide 24 Vdc photoelectric smoke detectors in all sleeping rooms and duty rooms located in business or other occupancies. Not applicable to inpatient sleeping rooms of healthcare occupancies.

9-18.7.5.2 Upon detection of smoke, an audible signal must be activated in the respective sleeping room, dwelling unit/suite or duty room, send a distinct signal to the *Facility* fire alarm control panel, if required by other sections of this UFC, and to the *Installation* fire reporting system, but not activate the *Facility* notification appliances.

9-18.7.5.3 See Chapter 4 for Open Bay Personnel Housing.

9-18.7.5.4 The audible signal must be low frequency as required by NFPA 72.

9-18.7.6 Under-floor Smoke Detector Identification.

When under-floor smoke detectors are provided, provide a framed CAD drawn floor plan showing the location of the devices in the room and their corresponding address. Locate a single framed drawing of the location of the smoke detectors outside of the space and adjacent to the main entrance.

9-18.8 Power Disconnect.

For disconnecting power supplies, provide listed control relays located within 3 feet (915 mm) of the shunt trip breaker. Operation of relay must be controlled by a listed fire alarm control unit. Relay must function within the voltage and current limitations of the fire alarm control unit. Relay contacts must be listed for the connected load.

9-18.9 Wiring, Circuits and Conduit.

9-18.9.1 \6\/6/ Pathways for addressable detection, notification, and signaling line circuits \6\ must be Class B, unless otherwise approved by the Service *DFPE*. /6/

9-18.9.2 All conductors must be installed in conduit (EMT minimum).

9-18.9.3 Conductors.

9-18.9.3.1 Pull all conductors splice free; conductors must be continuous from device to device. The use of wire nuts, crimped connectors, or twisting of conductors is prohibited.

9-18.9.3.2 Run all wiring to and within control panels in the vertical or horizontal plane, make all turns at 90 degree angles, and tightly bundle, wrap, and identify all conductors individually with permanent markings. Conductor markings must be printed labels, permanently affixed to the conductor via shrink wrap.

9-18.9.4 Conductor Type.

9-18.9.4.1 Wiring may be solid copper or stranded as permitted by NFPA 70.

9-18.9.4.2 All signaling line circuits must be minimum 18 AWG. Initiating device and notification appliance circuits must be minimum 16 AWG.

9-18.9.4.3 Initiating device circuits used for optical flame detection devices must use shielded cable.

9-18.9.5 Device Termination.

All devices must have screw terminals. Where devices are only provided with pigtails from the manufacturer, pigtails must be landed on terminal strips mounted within the junction box.

9-18.9.6 Conductor Terminations.

All terminations must be at a terminal strip or the device screw terminals. Terminal strips are only permitted where direct connection to a device is not possible. (e.g., pigtails off a rate-compensating heat detector).

9-18.9.7 Identification.

9-18.9.7.1 \5\In unfinished areas, all /5/ conduit, junction/back boxes, covers, and couplings, when provided, must be factory painted red \5\/5/(e.g., above ceilings, mechanical rooms, \4\concealed spaces,/4/ etc.).

9-18.9.7.2 \5\In finished areas, all /5/\4\exposed/4/ conduit, junction/back boxes, covers and couplings, when provided, \4\\5\/5/ must be factory painted red\5\ or /5/conduit, junction/back boxes, covers, and couplings are permitted to be painted to match the room finish and/4/ the inside cover of the junction box must be identified as "Fire Alarm"\4\/4/.

9-18.10 Surge Suppression.

9-18.10.1 Provide surge suppression (SPD) for all signaling line circuits, indicating device circuits, or notification appliance circuits that leave or enter a *Facility's* exterior enclosure.

9-18.10.2 SPD must be provided at the first location where connections are made that is close to where the circuit enters or leaves the *Facility*, prior to connection to any other devices when feasible.

9-18.10.3 SPD is not required for devices connected directly to the *Facility* exterior when the *Facility* itself is provided with lightning protection (i.e. an electric bell or speakers mounted on the exterior wall of the *Facility*.)

9-18.11 Power.

9-18.11.1 Provide primary power in accordance with UFC 3-520-01. This includes the provision of a lock-on circuit breaker.

9-18.11.2 Provide SPD on all 120 Vac circuits to control panels, subpanels, transmitters, amplifier panels, and booster panels. SPD must have both a UL 1449 and UL 1283 listing and must be located in an adjacent hinged terminal box.

9-18.11.3 Secondary Power.

Provide rechargeable batteries per NFPA 72 to operate the fire alarm system under supervisory conditions for 48 hours and all alarm devices for an additional 15 minutes. Where the fire alarm system also serves as a mass notification system, refer to UFC 4-021-01 for additional requirements.

9-18.12 Releasing Control Panels.

9-18.12.1 In addition to the requirements specified above for fire alarm control panels, panels used for control or release of fire suppression systems must be listed by a NRTL for releasing service.

9-18.12.1.1 Provide a separate releasing panel independent of the *Facility* fire alarm system panel to activate the system.

9-18.12.1.2 A combined fire alarm/releasing panel is permitted for small *Facilities* with the approval of the *DFPE*.

9-18.12.2 Electronic solenoids used for release of the suppression system must be listed by a NRTL for use with both the releasing panel and the suppression equipment.

9-18.12.3 Provide rechargeable batteries per NFPA 72 to operate the releasing panel under supervisory conditions for 48 hours and alarm conditions for an additional 15 minutes. Include the full current draw of the solenoid in the battery calculations.

9-18.12.4 When more than one panel is used, each panel must be monitored independently by the *Facility* fire alarm control panel.

9-18.12.5 Locate the panel adjacent to, but not in, the hazard/area served. The releasing panel and supplemental control panels must be located in a year-round environmentally conditioned space that complies with the environmental conditions required in the listing.

9-18.12.6 When required, pre-discharge and discharge alarms must consist of audible and visible notification appliances that are different than the *Facility* fire alarm system notification appliances.

9-19 CARBON MONOXIDE (CO) DETECTION.

9-19.1 General.

9-19.1.1 Provide carbon monoxide detection in facilities with combustible fuel burning equipment (e.g., air handling units, heaters, stoves, fireplaces).

9-19.1.2 Carbon monoxide detection must conform to the requirements of NFPA 72 and the manufacturer’s requirements, except as modified by this UFC.

9-19.1.3 Carbon monoxide detectors must be powered by the fire alarm control panel (i.e. 24 Vdc). Where a fire alarm system is not provided, 120 Vac \2\ carbon monoxide alarms/2/ are permitted.

9-19.2 Installation.

9-19.2.1 Detectors must be located in each room/space where the fuel burning appliances(s) are located.

9-19.2.2 \2\Where HVAC equipment utilizes fuel burning equipment, one detector must be located downstream of the fuel burning equipment./2/

9-19.2.3 \3\For large open spaces with ceiling heights greater than 12 feet, i.e, storage facilities, aircraft hangar bay, large industrial spaces, and similar spaces, carbon monoxide detection is not required./3/

9-19.3 Notification.

9-19.3.1 Where a fire alarm voice evacuation system is provided, activation of a carbon monoxide detection device must initiate a unique voice notification message.

9-19.3.1.1 The alert signal portion of the voice alarm message for carbon monoxide detection must be a 520 Hz temporal 4 (T-4) signal. The alert signal must repeat twice before the voice announcement.

9-19.3.1.2 A sample message is as follows: (Temporal 4 Alert Tone) "Attention….Attention….Carbon monoxide has been detected in the building. Please leave the building by the nearest exit." (Temporal 4 Alert Tone)

9-19.3.2 Where a voice evacuation system is not provided, activation of a carbon monoxide detector must initiate an audible alarm distinctly different from other audible alarm signals in the *Facility*. Distinct visible notification is not required.

9-19.3.3 When part of the fire alarm system, activation of a carbon monoxide detector must send a separate "carbon monoxide detector" alarm signal to the *Fire Alarm Reporting System*.

9-19.3.4 Sleeping room audible appliances must provide a 520 Hz temporal 4 (T4) signal for carbon monoxide in accordance with NFPA 72. The provision of a sounder base does not negate the requirement of the *Facility's* audible notification appliances for each sleeping room."

9-20 SMOKE CONTROL SYSTEM

9-20.1 General.

9-20.1.1 Design must be in accordance with NFPA 92.

9-20.1.2 Design parameters must be documented and be based on industry standards of practice, such as the SFPE Handbook of Smoke Control Engineering. Other source documents, such as peer-reviewed research articles, may be used with approval of the *DFPE*.

9-20.1.3 Controls must be designed and listed as required by NFPA 92.

9-20.1.4 Fire alarm control unit must be ANSI/UL 864, category UUKL listed.

9-20.1.5 HVAC controls must be ANSI/UL 864, category UUKL listed where required by NFPA 92.

9-20.1.6 Fire alarm system sequence of operations matrix must include all automatic and firefighter's smoke control station functions.

9-20.1.7 Design must include a preliminary test plan.

9-20.2 Installation.

9-20.2.1 Prior to installation and programming, provide a single submittal that includes all smoke control system components.

9-20.2.2 Submittal must document all aspects of integration between the involved systems and trades, such as the interface between the fire alarm and HVAC systems.

9-20.2.3 Documentation must include the physical interface and logic interface. Physical interface description must include location of control devices and wiring diagrams for all components. Logic interface description must include the complete sequence of operations, from input to final output.

9-20.2.4 Submittal must include an updated test plan, tailored to the specific devices and arrangements to be installed. Test plan must include all proposed test procedures.

9-20.3 Testing.

9-20.3.1 Testing must be in accordance with NFPA 92.

9-20.3.2 Individual components must be tested in accordance with the relevant UFC. For example, fire alarm system components must be tested in accordance with UFC 3-600-01 and NFPA 72. Fans must be tested in accordance with Air Movement and Control Association (AMCA) Publication 203.

9-20.3.3 Submit a revised test plan that incorporates any as-built conditions that differ from the smoke control submittal, prior to the start of any acceptance testing.

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CHAPTER 10 MEANS OF EGRESS

10-1 GENERAL.

10-1.1 Requirements.

Comply with NFPA 101 for all components and features related to means of egress. IBC must not be used for any means of egress features, except as specifically noted below.

10-1.2 Accessible Means of Egress.

Comply with NFPA 101 \6\ and the Section below titled "Accessible Means of Egress". /6/

10-2 MEANS OF EGRESS MARKING.

10-2.1 Requirements.

10-2.1.1 Incandescent or fluorescent fixtures are not permitted for new installation or replacement of fixtures.

10-2.1.2 Use of the graphic emergency exit symbols with and without directional arrows (NFPA 170 or Host Nation equivalents) in lieu of the text "EXIT" is permitted.

10-2.1.3 In locations outside the United States and its territories and possessions, additional markings may be required to remain consistent with local national standards; colors must be consistent with local national standards, and bilingual signs are recommended.

10-2.2 Radioluminous Exit Signs.

Radioluminous exit signs are not permitted in DoD *Facilities*.

10-2.3 Photoluminescent Exit Signs and Markings.

10-2.3.1 Photoluminescent exit signs and egress path markings are permitted and must be designed and installed per the requirements of NFPA 101. The charging light source must be continually illuminated at all times with normal power. The charging light source must not be on a switched circuit.

10-2.3.2 The illumination source must be energized at all times during building occupancy. Such lighting must not be controlled by automatic timers, automatic sensors including area occupancy sensors, or accessible manual switches. Controls for such lighting must be accessible only to authorized personnel.

10-3 OCCUPANT LOAD.

10-3.1 Occupant load factors.

Occupant load must be calculated in accordance with NFPA 101, except as noted in Table 10-1 below:

Table 10-1 Supplemental Occupant Load Factors

Use	Occupant Load Factor (sf/person)
Waiting spaces other than those in theaters and assembly occupancies where persons are admitted to the building at times when seats are not available	15 net
Exhibit galleries, museums	30 net
Courtrooms, hearing rooms – other than fixed seating areas	40 net
Conference rooms with tables and chairs	15 net
Community shelters (e.g., spaces designated for 'shelter in place' for \2/2/hurricane, disaster recovery, or similar)	20 net
\2\Community shelters for tornado	7 net/2/
Recreation – indoor tennis courts	50 gross
Recreation – squash, racquetball	4 per court
Locker rooms	50 gross or maximum anticipated number, whichever is higher
Bowling centers	5 persons per lane plus 7 net for additional areas
Dormitories (bunks)	50 gross
Mechanical, electrical, other building equipment spaces	500 gross
IT equipment rooms including those with small work areas in accordance with NFPA 75 or telecommunications rooms in accordance with NFPA 76	300 gross
Manufacturing areas	200 gross
Parking garages	200 gross
Telecommunications buildings (standalone)	500 gross
Aircraft hangars – aircraft storage and servicing areas	500 gross
Magazines and bunkers	Maximum anticipated number of personnel

10-3.2 Maximum occupant load.

The maximum occupant load for any space or *Facility* must not exceed one person per 7 ft^2 (0.65 m^2) of net floor space or the maximum capacity of the required egress components, whichever is less.

10-4 STAIR TO ROOF ACCESS.

Stair to roof access must be in accordance with the IBC.

10-5 \5\COMMUNICATING SPACE.

Communicating spaces must meet the open and unobstructed provision of NFPA 101. Smoke detection is not an alternative method of meeting this provision./5/

10-6 \6\ RESERVED. /6/

10-7 \6\ ACCESSIBLE MEANS OF EGRESS.

10-7.1 Where Required.

An accessible means of egress must be provided for newly designed and constructed facilities, and altered or leased portions of existing facilities unless exempted directly by ABA Standards Chapter 2, Scoping Requirements, or this Section

10-7.1.1 When more than one means of egress is required from the space, each accessible area must be provided with at least two accessible means of egress unless otherwise exempted in NFPA 101 paragraph 7.5.4.1.1.2 through paragraph 7.5.4.1.1.4.

10-7.1.2 Where two exits are required from any portion of the accessible exit access, the exit doors must be separated by a distance of at least one-half of the length of the maximum overall diagonal dimension of the building or area served. Where the building is sprinkler protected, the separation distance is permitted to be one-third of the length of the maximum overall diagonal. [NFPA 101, section 7.5.4.2]

10-7.1.3 A single accessible means of egress is permitted for a mezzanine.

10-7.1.4 A single accessible means of egress is permitted where the common path of travel of the accessible route for access to the wheelchair spaces meets the following requirements:

- The clear width of aisles with seating on both sides is at least 30 inches where serving 14 seats or less, 36 inches where serving 50 seats or less, or 42 inches where serving more than 50 seats.
- The clear width of aisles with seating on one side is at least 30 inches where serving 14 seats or less or 36 inches where serving more than 14 seats.

- The clear width between an aisle stair handrail and seating where an aisle does not serve more than five rows on one side is at least 23 inches.

10-7.2 Continuity and Components.

Accessible means of egress are required to be continuous to a public way or area of refuge and must consist of at least one of the following components: accessible routes, enclosed exit stairway, accessible elevator, platform lift, horizontal exit, or smoke barrier.

10-7.2.1 Accessible stories that are four or more stories above or below a story of exit discharge must have at least one elevator. Where elevators are required, a smokeproof enclosure is not required in sprinkler protected buildings. [NFPA 101 paragraph 7.5.4.7 and paragraph 7.5.4.8]

10-7.3 Enclosed Exit Stairways.

10-7.3.1 Where the exit providing egress from an area of refuge to a public way includes stairs, the clear width must be 48 inches.

10-7.3.2 The 48-inch clear width is not required where the area of refuge is separated by a horizontal exit.

10-7.3.3 The 48-inch clear width is not required in existing stairs with a clear width of 37 inches.

10-7.3.4 Areas of refuge are not required in fully sprinklered buildings. [NFPA 101 paragraph 7.2.12.2.3]

10-7.4 Elevators.

Where an elevator provides access from an area of refuge to a public way, the following criteria must be met [NFPA 101, paragraph 7.2.12.2.4]:

a. Elevator must be approved for fire fighter’s emergency operations as provided in ASME A17.1/CSA B44.

b. Power supply must be protected against interruption from fire occurring within the building but outside the area of refuge.

c. Elevator must be located in a shaft system meeting the requirements for smokeproof enclosures.

10-7.5 Platform Lifts.

Platform lifts are not permitted to be part of an accessible means of egress, except where they are part of one of the following accessible routes:

10-7.5.1 An accessible route to a performing area and speakers' platforms in assembly occupancies.

10-7.5.2 An accessible route to spaces that are not open to the general public with an occupant load of five or less.

10-7.5.3 An accessible route within a dwelling or sleeping unit.

10-7.5.4 An accessible route to wheelchair seating spaces located in outdoor dining terraces intended for participation in or viewing of outdoor activities where the means of egress from the dining terraces to a public way are open to the outdoors.

10-7.5.5 An accessible route to raised judges' benches, clerks' stations, jury boxes, witness stands, and other raised or depressed areas in a court.

10-7.5.6 An accessible route where existing exterior site constraints make use of a ramp or elevator infeasible.

10-7.6 Areas of Refuge.

Required areas of refuge must have accessible means of egress meeting all requirements in NFPA 101, paragraphs 7.2.12.2 and 7.2.12.3 and meet requirements for maximum travel distance requirements for the occupancy in NFPA 101, section entitled "General".

10-7.6.1 Areas of refuge must be sized to accommodate one wheelchair space of 30 inches by 48 inches for each 200 occupants, based on the occupant load of the area of refuge and areas served by the area of refuge. Wheelchair spaces are not permitted to reduce the required means of egress width for the occupant load served and to not less than 36 inches. [NFPA 101 paragraph 7.2.12.3.1]

10-7.6.2 Areas of refuge are required to be separated by a barrier having a minimum 1-hour fire resistance rating, unless a greater rating is required by other provisions in the Life Safety Code or if the existing barrier has a minimum 30-minute fire resistance rating (NFPA 101 §7.2.12.3.4).

10-7.6.3 Areas of refuge are required to be provided with two-way communication between area of refuge and central control point. If the central control point is not constantly attended, the area of refuge must also have controlled access to a public telephone system. Location of central point to be approved by the fire department. Two-way communication must include both audible and visible signals (NFPA 101 §7.2.12.1.1 and §7.2.12.2.5).

10-7.6.4 Areas of refuge with two-way communication systems are required to have instructions on the use of the area under emergency conditions. Instructions must include the following:

a. Directions to find other accessible means of egress.

b. Persons able to use the exit stairway do so as soon as possible unless assisting others.

c. Information on planned availability of assistance in the use of stairs or supervised operation of elevators and how to summon such assistance.

d. Directions for use of the emergency communications system.

10-7.6.5 Areas of refuge must be identified by a sign reading: AREA OF REFUGE that conforms to the requirements of the ABA Standards and display the international symbol of accessibility. Signs must also be located at each door opening providing access to the area of refuge, at all exits not providing an accessible means of egress, and where necessary to indicate clearly the direction to an area of refuge. Signs are required to be illuminated as required. Tactile signage complying with the ABA Standards must be located at each door opening to an area of refuge (Replaces NFPA 101 §7.2.12.3.5).

10-7.7 Signage.

Signage indicating the location of an accessible means of egress is required at exits and elevators serving a required accessible space but not providing an approved accessible means of egress.

10-7.8 Exterior Area for Assisted Rescue.

An exterior area for assisted rescue must be provided and be open to the outside air and meet the requirements specified in the following paragraphs:

10-7.8.1 An exterior area for assisted rescue must be at least 50% open, and the open area above the guards must be distributed so as to minimize accumulation of smoke or toxic gases.

10-7.8.2 Exterior exit stairways that are part of the means of egress for the exterior area for assisted rescue must provide a clear width of 48 inches.

10-7.8.3 Exterior areas for assisted rescue must have identification as required for area of refuge complying with paragraph 10-7.6.5. /6/

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CHAPTER 11 ACCESSIBILITY

11-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 11 provisions.

CHAPTER 12 INTERIOR ENVIRONMENT

12-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 12 provisions.

CHAPTER 13 ENERGY EFFICIENCY

13-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 13 provisions.

CHAPTER 14 EXTERIOR WALLS

14-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 14 provisions.

CHAPTER 15 ROOF ASSEMBLIES AND ROOFTOP STRUCTURES

15-1 ROOF COVERINGS.

Use roof coverings approved and listed by a NRTL. Class C roof coverings, as defined in the UL Roofing Materials and Systems Directory, are only permitted for single and duplex style housing and *Facilities* less than or equal to 5,000 ft^2 (465 m^2).

15-2 ROOF DECK ASSEMBLIES.

15-2.1 General.

15-2.1.1 For non-sprinklered *Facilities* or *Facilities* \2\greater than or equal to/2/ 8,000 ft^2 (743 m^2), roof deck assemblies must be FM Class I approved, or UL-listed as fire classified or equal listing or classification by an NRTL.

15-2.1.2 Where a non-combustible roof is installed over an existing combustible roof, the existing combustible roof materials must be removed or the space between the existing and new roof must be protected as a combustible concealed space per NFPA 13.

Note: FM Class I or II ratings and UL "Fire Classified" ratings are measures of the resistance, of the entire roof assembly, to ignition from exposure to a fire within the building, heating the underside of the roof deck. These two ratings cannot be equated and are not interchangeable.

15-2.1.3 Where the HVAC or similar equipment is located on the existing roof and not removed, the space between the existing and new roof must be protected as and considered a combustible concealed space per NFPA 13.

15-2.1.4 Rooftop solar photovoltaic (PV) panels must be mounted to facilitate application of water from fire department vehicles to fires on the roof deck surface. Arrangement of PV panels must meet the requirements of UFC 3-440-01.

CHAPTER 16 STRUCTURAL DESIGN

16-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 16 provisions.

CHAPTER 17 SPECIAL INSPECTIONS AND TESTS

17-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 17 provisions.

CHAPTER 18 SOILS AND FOUNDATIONS

18-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 18 provisions.

CHAPTER 19 CONCRETE

19-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 19 provisions.

CHAPTER 20 ALUMINUM

20-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 20 provisions.

CHAPTER 21 MASONRY

21-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 21 provisions.

CHAPTER 22 STEEL

22-1 GENERAL.

For fire protection requirements, no changes to the IBC chapter 22 provisions.

CHAPTER 23 WOOD

23-1 FIRE RETARDANT TREATED (FRT) WOOD.

Conform to the requirements of IBC for permitted use of FRT wood. FRT plywood must not be used in any part of the roof or roofing system.

\2\/2/

CHAPTER 24 GLASS AND GLAZING

24-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 24 provisions.

CHAPTER 25 GYPSUM BOARD, GYPSUM PANEL PRODUCTS AND PLASTER

25-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 25 provisions.

CHAPTER 26 PLASTIC

26-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 26 provisions.

CHAPTER 27 ELECTRICAL

27-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 27 provisions.

CHAPTER 28 MECHANICAL SYSTEMS

28-1 AIR HANDLING.

28-1.1 General.

Fire protection features for air handling, heating, ventilation, and exhaust systems, such as duct smoke detectors, fire dampers and smoke dampers, must comply with the requirements of NFPA 90A, except as modified by this UFC.

Duct smoke detectors are not required where air distribution systems are incapable of spreading smoke beyond the enclosing walls, floors and ceilings of the room or space in which the smoke is generated.

\2\Duct smoke detectors are not required when the air distribution system supplies a space or room that has area smoke detection./2/

28-1.2 Plenums.

Plenums may be used as an integral part of an air handling system only if they conform to the requirements of NFPA 90A. Under no circumstances may combustible materials be located within the plenum space. Electrical wiring passing through the space, including telephone and communication wiring must be plenum rated or must be in metal conduit.

Rooms or areas that form a plenum space or that are used as a plenum must not be occupied for any purpose except during repairs or maintenance operations to the air handling equipment.

28-1.3 Computer Room Air Conditioning (CRAC).

28-1.3.1 CRAC units must not automatically shut down if electronic equipment remains energized and heat generated in the room will be sufficient to activate sprinkler heads.

CHAPTER 29 PLUMBING SYSTEMS

29-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 29 provisions.

CHAPTER 30 ELEVATORS AND CONVEYING SYSTEMS

30-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 30 provisions.

Comply with requirements of the "Elevators" section of this UFC.

CHAPTER 31 SPECIAL CONSTRUCTION

31-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 31 provisions.

CHAPTER 32 ENCROACHMENTS INTO THE PUBLIC RIGHT-OF-WAY

32-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 32 provisions.

CHAPTER 33 SAFEGUARDS DURING CONSTRUCTION

33-1 GENERAL.

For fire protection requirements, no changes to the IBC Chapter 33 provisions.

CHAPTER 34 EXISTING FACILITIES

34-1 GENERAL.

34-1.1 Minimum Requirements.

Facilities, as they exist, must meet the requirements of NFPA 101, for existing occupancies. *Facilities* that do not meet the requirements of NFPA 101 for existing occupancies must conform to one of the following:

a. Upgrade the deficiency to meet the existing occupancy requirements, or

b. Establish management protocols to provide a level of life safety equivalent to that required by NFPA 101 for existing occupancies, until an upgrade project can be completed. Management protocols must be in writing and approved by the \6\ *CFPE* /6/.

34-1.2 \2\/2/Work in Existing Facilities.

34-1.2.1 Conform to the requirements of the Building Rehabilitation chapter of NFPA 101 for design and construction projects in existing buildings \5\except as specified in this UFC.

The entire facility, at a minimum, must comply with the applicable existing occupancy chapter of NFPA 101 before beginning the project for work in existing facilities. The project may include bringing the facility into compliance with the applicable occupancy chapter of NFPA 101. /5/

[C] 34-1.2.1

The areas of the facility where no work is being performed must meet the applicable existing occupancy chapter of NFPA 101. Thus if the work involves 5,000 ft^2 of an existing 15,000 ft^2. office building, then the remaining 10,000 ft^2 not involved in the project must be brought up to meet the applicable existing occupancy chapter of NFPA 101 before beginning the project or be included as part of the project.

34-1.2.2 Where multiple categories of rehabilitation work are planned as part of a single project, identify each category of rehabilitation work to be performed, including what is required and what will be provided, within each one.

34-1.2.3 Phasing of construction and demolition operations must be planned so that the integrity of fire-rated separations, smoke-tight boundaries, means of egress, exit enclosures, and vertical openings are maintained to the highest level possible.

34-1.2.3.1 The phasing plan must ensure that obstruction of the means of egress is avoided or minimized.

34-1.2.3.2 If exits are obstructed during construction, provide alternate means of egress and exit routes during each phase of construction and identify the alternate routes on the construction drawings as part of the phasing plan(s).

34-1.2.4 Minimize, to the extent possible, any impairments or disruptions to active fire protection features. Delineate phasing of construction to ensure that installations of new features (or systems) or modifications to existing ones are expedited.

34-1.2.4.1 Where possible, maintain existing systems in service until the replacement work has been deemed operational.

34-1.2.5 Prior to taking any actions to impair a fire protection feature or disrupt its performance, ensure alternative procedures have been prepared and incorporated and confirm that official notification of system impairments and schedules have been given to the staff of the *Facility*.

34-1.2.6 \2\See paragraph "Automatic Sprinkler Systems" in the "Fire Protection Systems" Chapter of this UFC for additional requirements./2/

34-1.2.7 \5\Where the Building Rehabilitation chapter of NFPA 101 requires newly constructed elements, components, and systems to comply with new construction requirements in the Code, then it must also comply with new construction requirements in this UFC.

34-1.2.8 Floor plan reconfigurations that exceed 50 percent of the area of a floor require that the entire floor be brought up to the requirements for new construction in this UFC and NFPA 101. The means of egress serving this floor, including portions not located on this floor, must conform to the requirements for new construction in this UFC and NFPA 101. The notification appliances for the fire alarm and mass notification system must be upgraded throughout the remainder of the building as required to provide a uniform notification strategy. Floor plan reconfigurations that bring the building more into compliance with NFPA 101 must not count towards the 50 percent floor area threshold.

[C] 34-1.2.8

The intent of upgrading fire alarm and mass notification devices throughout the remainder of the building is to provide a uniform notification strategy. For example, a facility may have existing clear and amber strobes throughout with no textural signs. The new requirement may be only clear strobes with textural signs. The floor being brought up to new UFC and new NFPA 101, and means of egress serving this floor, will require clear strobes and textural signs installed per the new criteria. The remainder of the floors will be modified so there are only clear strobes and textural signs, and the work must not make these other floors less conforming to the UFC and NFPA 101.

34-1.2.9 If the project cost exceeds 50 percent of the building replacement value, then the entire building must be brought up to the requirements for new construction. Project costs to bring the building more into compliance with NFPA 101 must not count towards the 50 percent threshold.

[C] 34-1.2.9

The intent of meeting requirements for new construction in this UFC is that this also applies to any requirements in applicable UFC 4-series, unless the UFC 4-series states otherwise.

34-1.2.10 Dimensional criteria for existing stairs in NFPA 101 for height of risers, tread depth, headroom, and height between landings is acceptable in lieu of meeting the requirements for new construction. The minimum headroom for existing buildings per NFPA 101 is acceptable in lieu of meeting the requirements for new construction.

[C] 34-1.2.10

If feasible, the new dimensions in NFPA 101 for height of risers, tread depth, headroom, and height between landings should be followed. Any reconstruction should involve the entire stair so there is no change in these dimensions when descending from the highest level. However, the intent of allowing use of the existing stair criteria in NFPA 101 for riser height, tread depth, headroom, and height between landings is to avoid very expensive or even unfeasible structural modifications to the facility. Utilities such as HVAC and lighting are not a reason to follow headroom requirements for existing buildings in NFPA 101 in lieu of the requirements for new.

34-1.3 /5/Change in Use.

34-1.3.1 When a change in use occurs, the area of the change, and its associated means of egress, must comply with the requirements for new construction.

34-1.3.1.1 When any \5\building with an occupant load of less than 11, or portion thereof, is changed from its current use of a building with an occupant load greater than 10, personnel housing and similar lodging facilities, or assembly occupancy /5/ for one year or more, the building must meet the requirements for new construction.

[C] 34-1.3.1.1

Examples would include: a warehouse (occupant load less than 11) being changed to administrative use with an occupant load greater than 10; an administrative use with an occupant load of less than 11 being changed to an assembly occupancy or personnel housing and similar lodging facilities; an assembly occupancy being changed to personnel housing and similar lodging facilities, or vice versa.

34-1.3.1.2 When any building, or portion thereof, is \5\changed /5/ from its current use to support a mission that will exist for one year or more, the building must meet the requirements for new construction.

[C] 34-1.3.1.2

An example would include a *Facility* used as a hangar that is going to be changed to a warehouse.

34-1.3.1.3 Changing groups of occupants within the occupancy classification does not constitute a change of use; however, any deficiencies must be corrected prior to the new occupants occupying the space.

[C] 34-1.3.1.3

An example of changing groups of occupants would include an *Installation* Personnel function occupying the office space formerly used by an *Installation* Contracting function.

34-1.3.2 When a change in use results in a higher occupant load that exceeds the existing egress capacity, the *Facility* must meet the requirements for new construction as specified in this UFC.

34-1.4 Vacant Buildings.

34-1.4.1 When a vacant building is considered for reuse, the building must be evaluated for the occupancy that is planned to be in the building and all deficiencies must be corrected prior to occupancy. This includes a building to be reused for the same occupancy, i.e., last use was a warehouse and the new use will be a warehouse.

34-1.4.2 The vacant building must be evaluated to the requirements for new construction in this UFC and NFPA 101.

34-2 PHASED PROJECTS.

34-2.1 General.

\5\Projects or programs involving floor plan reconfiguration that will encompass more than 50 percent of the area of a floor, or project or program costs exceeding 50 percent of the building replacement value,/5/ that are planned in a phased approach or have separate projects to improve various parts of the facility must conform to the requirements of \5\new construction as stated above

34-2.1.1.1 /5/These requirements are not applicable if the time from the start of design of the first phase to the start of design of the phase \5\involving floor plan reconfiguration that exceeds 50 percent of the area, or project cost exceeds 50 percent of the building replacement value,/5/ is greater than five years.

34-3 COOKING AREAS.

Cooking equipment in common areas in existing, non-sprinklered *Facilities* that are provided with residential type range top cooking surfaces must be equipped with an approved residential range top extinguishing system or the stoves must be equipped with burners and controls that have their temperature limited to a maximum temperature of 662 degrees F (350 degrees C). The range top extinguishing system must be connected to the *Facility* fire alarm system to sound a general *Facility* fire alarm and must automatically shut off all sources of fuel and electric power that produce heat to the equipment being protected by that unit.

34-4 DETENTION AND CORRECTIONAL *FACILITIES*.

\5\/5/ Navy facilities must also comply with MIL HDBK 1037/4.

34-5 ELECTRONIC EQUIPMENT AREAS.

For existing facilities that contain non-plenum rated cables under the raised floor and do not have an automatic fire extinguishing system under the raised floor must provide a \2\/2/clean agent fire extinguishing system for the area below the raised floor.

34-6 FAMILY HOUSING.

34-6.1 Projects that exceed 50 percent of the Replacement Cost.

34-6.1.1 1-hour fire-resistive construction must be provided between *Dwelling Unit*s, and between the *Dwelling Unit* and attached parking.

34-6.1.2 Sprinkler protection must be provided throughout the *Facility*, designed and installed in accordance with \3\NFPA 13, NFPA 13R, or NFPA 13D as applicable/3/.

34-6.1.3 Multiple-station, interconnected, hard-wired, 120 Vac smoke detectors must be provided inside each sleeping room and at least one on each floor, including basements.

34-6.1.4 Air Force allows interconnected wireless smoke alarms for use in single-family and duplex housing.

34-6.2 Projects that are less than 50 percent of the Replacement Cost.

34-6.2.1 Multiple-station, interconnected, hard-wired, 120 Vac smoke detectors must be provided inside each sleeping room and at least one on each floor, including basements. Air Force allows interconnected wireless smoke alarms for use in single-family and duplex housing.

34-6.2.2 Sprinkler protection must be considered for installation in the *Facility*.

34-7 FIRE PROTECTION SYSTEMS.

34-7.1 General.

See the paragraphs entitled "Fire Suppression Systems" \2\and “Automatic Sprinkler Systems”/2/ in the "Fire Protection Systems" Chapter in this UFC for requirements related to backflow prevention devices.

34-8 FIRE ALARM SYSTEMS.

34-8.1 General.

34-8.1.1 When the existing control panel is replaced, it must be replaced with a new addressable control panel.

34-8.1.1.1 Existing devices are permitted to remain when listed for use with the new control panel or they are interfaced via listed monitor modules or control modules.

34-8.1.1.2 Battery calculations must be submitted to verify the power supply provided is capable of supporting the electrical load of the new and existing devices.

34-8.1.2 Where a new control panel is provided as part of a partial *Facility* \5\rehabilitation/5/, the renovated areas must comply with the requirements of this section. The existing circuits in the non-renovated areas of the *Facility* are permitted to be connected to the new fire alarm control panel via monitor modules or control modules.

34-9 HAZARDOUS MATERIALS.

Existing storage and use of flammable and combustible liquids must comply with NFPA 30.

Existing storage and use of other hazardous materials must comply with NFPA 400.

34-10 PERSONNEL HOUSING.

34-10.1 \5\Common Areas.

Cooking areas in existing, non-sprinklered *Facilities* that are provided with residential type range top cooking surfaces must be equipped with an approved residential range top extinguishing system or the stoves must be equipped with burners and controls that have their temperature limited to a maximum temperature of 662 degrees F (350 degrees C). The range top extinguishing system must be connected to the *Facility* fire alarm system, if provided, to sound a general *Facility* fire alarm and must automatically shut off all sources of fuel and electric power that produce heat to the equipment being protected by that unit.

34-10.2 Air Force.

Existing Air Force non-sprinklered *Facilities* with the following features are considered acceptable until protection is compliant with the "Personnel Housing and Similar Lodging Facilities" section of this UFC is provided: Heat and smoke detection installed in each sleeping room and the shared/common space of a suite. Activation of the heat detector must sound a general building alarm and transmit a signal to the fire department or to a constantly monitored central location. Activation of the smoke detector must sound a local alarm within the room/suite. The smoke detector is permitted to be powered from an unsupervised 120 Vac source. The use of battery backup for secondary power is not required./5/

34-11 ROOF COVERINGS.

For re-roofing existing nonconforming metal roof decks, roofing components (insulation, underlayment, etc.) must be specified as having a maximum flame spread rating of 75 and a maximum smoke-development rating of 150 in accordance with ASTM E84.

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APPENDIX A REFERENCES

AMERICAN CORRECTIONAL ASSOCIATION (ACA)

http://www.aca.org/

Planning and Design Guide for Secure Adult and Juvenile Facilities

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.ansi.org

ANSI B1.20.1, Pipe Thread

ANSI/IEEE 979, Guide for Substation Fire Protection

AMERICAN WATER WORKS ASSOCIATION (AWWA)

http://www.awwa.org

AWWA Manual M 14, Recommended Practice for Backflow Prevention and Cross Connection Control

AWWA Manual M 17, Installation, Field Testing and Maintenance of Fire Hydrants

AWWA Manual M 31, Distribution System Requirements for Fire Protection

ASME INTERNATIONAL

http://www.asme.org/

ASME A17.1, Safety Code for Elevators and Escalators

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

http://www.astm.org

ASTM A351, Standard Specification for Casting, Austenitic for Pressure-Containing Parts

ASTM E84, Standard Method of Test of Surface Burning Characteristics of Building Materials

ASTM E119, Standard Test Methods for Fire Tests of Building Construction and Materials

ASTM E136, Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750ºC

ASTM E814, Standard Test Method for Fire Tests of Penetration Firestop Systems

DEPARTMENT OF DEFENSE, WASHINGTON HEADQUARTERS SERVICE

http://www.dtic.mil/whs/directives/

\3\DESR 6055.09, Defense Explosives Safety Regulation/3/

DEPARTMENT OF THE AIR FORCE

http://www.e-publishing.af.mil/

AFMAN 91-201, Explosives Safety Standard

AFTO 00-25-172, Ground Servicing of Aircraft and Static Grounding/Bonding

\6\ /6/

DEPARTMENT OF THE ARMY

385-100, Safety Manual

AR 385-10, The Army Safety Program

AR 420-90, Facilities Engineering Fire and Emergency Services

DA PAM 385-61, Toxic Chemical Agent Safety Standards

EM-385-1-1, Safety and Health Requirements Manual

U.S. Army National Guard NGR 385-64, U.S. Army Ammunition and Explosives Safety Standards

DEPARTMENT OF DEFENSE

MIL-STD-101, Standard Practice, Color Code for Pipelines and for Compressed Gas Cylinders

MIL-STD-3007, Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications

DoDI 4165.56, Relocatable Buildings

DEPARTMENT OF THE NAVY

MIL-F-24385F, Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, for Fresh and Seawater

NAVSEA OP-5, Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation, and Shipping

OPNAVINST 11010.33, Procurement, Lease and Use of Relocatable Buildings

NAVAIR 00-80R-14, NATOPS Aircraft Firefighting and Rescue Manual

NAVAIR 00-80T-109, Aircraft Refueling NATOPS Manual

SS 521-AA-MAN-010, U.S. Navy, Diving and Manned Hyperbaric Systems Safety Certification Manual

\6\ DEPARTMENT OF DEFENSE SUPPLEMENTAL TECHNICAL CRITERIA

https://www.wbdg.org/ffc/dod/supplemental-technical-criteria

TSFPEWG G 3-600-01.01-18, Air Force Fire Protection Engineering Criteria and Technical Guidance for Mission Continuity of Electronic, Information Technology, and Telecommunications Equipment Installations /6/

\3\EXECUTIVE ORDER

Executive Order 13728, Wildland-Urban Interface Federal Risk Mitigation of 18 May 2016/3/

FACTORY MUTUAL GLOBAL (FM)

http://www.fmglobal.com/

FM Global Data Sheet 1-20, Protection Against Exterior Fire Exposure

FM Global Data Sheet 1-53, Anechoic Chambers

FM Global Data Sheet 5-4, Transformers

FM Global Data Sheet 7-91, Hydrogen

FM Global Data Sheet 8-33, Carousel Storage and Retrieval Systems

FM Global Data Sheet 8-34, Automatic Storage and Retrieval Systems

INTERNATIONAL CODE COUNCIL (ICC)

http://www.iccsafe.org

IBC, International Building Code®

IFC, International Fire Code®

IRC, International Residential Code®

IWUIC, International Wildland-Urban Interface Code®

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

www.nfpa.org

NFPA 1, Fire Code

NFPA 10, Standard for Portable Fire Extinguishers

NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam

NFPA 12, Standard on Carbon Dioxide Extinguishing Systems

NFPA 13, Standard for the Installation of Sprinkler Systems

NFPA 13R, Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies

NFPA 13D, Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes

NFPA 14, Standard for the Installation of Standpipe and Hose Systems

NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection

NFPA 16, Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems

NFPA 17, Standard for Dry Chemical Extinguishing Systems

NFPA 17A, Standard for Wet Chemical Extinguishing Systems

NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection

NFPA 22, Standard for Water Tanks for Private Fire Protection

NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances

NFPA 30, Flammable and Combustible Liquids Code

NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages

NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines

NFPA 45, Standard on Fire Protection for Laboratories Using Chemicals

NFPA 51, Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes

NFPA 52, Vehicular Gaseous Fuel Systems Code

NFPA 54, National Fuel Gas Code

NFPA 55, Compressed Gases and Cryogenic Fluids Code

NFPA 58, Liquefied Petroleum Gas Code

NFPA 70, National Electrical Code®

NFPA 72, National Fire Alarm and Signaling Code®

ANSI/NFPA 75, Standard for the Fire Protection of Information Technology Equipment

NFPA 76, Standard for the Fire Protection of Telecommunications Facilities

NFPA 80A, Recommended Practice for Protection of Buildings From Exterior Fire Exposures

NFPA 88A, Standard for Parking Structures

NFPA 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems

NFPA 92, Standard for Smoke Control Systems

NFPA 96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

NFPA 99, Health Care Facilities Code

NFPA 99B, Standard for Hypobaric Facilities

NFPA 101, Life Safety Code®

NFPA 102, Standard for Grandstands, Folding and Telescopic Seating, Tents, and Membrane Structures

NFPA 110, Standard for Emergency and Standby Power Systems

NFPA 150, Fire and Life Safety in Animal Housing Facilities Code

NFPA 170, Standard for Fire Safety and Emergency Symbols

NFPA 204, Standard for Smoke and Heat Venting

NFPA 220, Standard on Types of Building Construction

NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations

NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials

NFPA 291, Recommended Practice for *Fire Flow* Testing and Marking of Hydrants

NFPA 303, Fire Protection Standard for Marinas and Boatyards

NFPA 307, Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves

NFPA 312, Standard for Fire Protection of Vessels During Construction, Conversion, Repair, and Lay-Up

NFPA 400, Hazardous Materials Code

NFPA 409, Standard on Aircraft Hangars

NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response

\3\NFPA 750, Standard on Water Mist Fire Protection Systems

NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

NFPA 855, Standard for the Installation of Stationary Energy Storage Systems

NFPA 909, Protection of Cultural Resource Properties - Museums, Libraries, and Places of Worship

NFPA 1141, Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas

NFPA 1142, Standard on Water Supplies for Suburban and Rural Fire Fighting

NFPA 1144, Standard for Reducing Structural Ignition Hazards from Wildland Fire

NFPA 1221, Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems

NFPA 1963, Standard for Fire Hose Connections

NFPA 2001, Standard on Clean Agent Fire Extinguishing Systems

NFPA 5000, Building Construction and Safety Code®

SOCIETY OF AUTOMOTIVE ENGINEERS

https://www.sae.org/

SAE 1010, Steel Properties

SOCIETY OF FIRE PROTECTION ENGINEERS

http://www.sfpe.org

SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings

UNDERWRITERS LABORATORY (UL)

http://www.ul.com/

UL 864, Standard for Control Units and Accessories for Fire Alarm Systems

UL 1283, Electromagnetic Interference Filters

UL 1449, Surge Protective Devices

UL 1479, Fire Tests of Through-Penetration Firestops

UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

UNIFIED FACILITIES CRITERIA (UFC) AND FACILITIES CRITERIA (FC)

http://www.wbdg.org/references/pa_dod.php

FC 4-420-07F, Nuclear Weapons-Capable Maintenance and Storage Facilities

FC 4-740-14N, Navy and Marine Corps Child Development Centers

FC 4-760-10N, Navy Museums and Historic Resource Facilities

UFC 1-200-01, General Building Requirements

UFC 3-230-01, Water Storage, Distribution, and Transmission

UFC 3-301-01, Structural Engineering

UFC 3-400-02, Design: Engineering Weather Data

UFC 3-460-01, Design: Petroleum Fuel Facilities

UFC 3-520-01, Interior Electrical Systems

UFC 3-570-01 - Cathodic Protection

UFC 4-010-01, DoD Minimum Antiterrorism Standards for Buildings

UFC 4-020-01, DoD Security Engineering Facilities Planning Manual

UFC 4-021-01, Design and O&M: Mass Notification Systems

UFC 4-150-02, Dockside Utilities for Ship Service

UFC 4-151-10, General Criteria for Waterfront Construction

UFC 4-152-01, Design: Piers and Wharves

UFC 4-159-01N, Design: Hyperbaric Facilities

UFC 4-211-01, Aircraft Maintenance Hangars

UFC 4-211-02, Aircraft Corrosion Control and Paint Facilities

UFC 4-213-10, Design: Graving Drydocks

UFC 4-213-12, Drydocking Facilities Characteristics

UFC 4-215-01, Armories and Arms Rooms

UFC 4-310-03, DoD Fuels Laboratory Standards

UFC 4-510-01, Design: Medical Military Facilities

UFC 4-740-06, Youth Centers

UFC 4-740-14, Design: Child Development Centers

UNITED STATES ACCESS BOARD

http://www.access-board.gov/

ABA/ABAAG, Architectural Barriers Act and Architectural Barriers Act Accessibility Guidelines

UNITED STATES DEPARTMENT OF LABOR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

http://www.ecfr.gov/cgi-bin/text-idx?tpl=%2Findex.tpl

29 CFR 1910.109, Explosives and Blasting Agents

UNITED STATES HOUSE OF REPRESENTATIVES, OFFICE OF THE LAW REVISION COUNSEL

http://uscode.house.gov/

USC Title 10, Chapter 8, Subchapter II, Military Child Care

USC Title 15, Section 272, Utilization of Consensus Technical Standards by Federal Agencies

USC Title 15, Section 2225, Hotel-Motel Fire Safety

USC Title 15, Section 2227, Fire Administration Authorization Act ("Fire Safety Act")

USC Title 42, Section 4151 Architectural Barriers Act Of 1968

APPENDIX B OCCUPANCY HAZARD CLASSIFICATION FOR DETERMINING AUTOMATIC SPRINKLER DENSITIES AND HOSE STREAM DEMANDS

B-1 CLASSIFICATION OF OCCUPANCIES.

The principal occupancy classifications are light hazard, ordinary hazard, and extra hazard. Listed below are the classifications with examples of common DoD occupancies listed under each. Where an occupancy is not listed, the applicable NFPA standard must be used, along with engineering judgment, to determine the appropriate occupancy hazard classification.

B-1.1 Light Hazard Occupancies.

Occupancies or portions of occupancies where the quantity and combustibility of the contents are low and fires with relatively low rates of heat release are expected. Small, scattered amounts of flammable liquids in closed containers are allowable in quantities not exceeding 5 gal (20 L) per *Fire Area*. This classification includes but is not limited to the following occupancies:

a. Clinics (dental, outpatient, patient areas only)

b. Mess areas

c. Dispensaries (patient areas only)

d. Drill halls (not used for storage or exhibition)

e. Disciplinary barracks

f. Child Development Centers

B-1.2 Ordinary Hazard Occupancies.

Occupancies or portion of occupancies where quantity and combustibility of contents is moderate, storage does not exceed 12 feet (3.7 m), and fires with moderate rate of heat release are expected. Moderate, scattered amounts of flammable liquids in closed containers are allowable in quantities not to exceed 50 gal (189 L) per *Fire Area*. Small amounts of flammable liquids may be exposed as required by normal operations. This classification includes but is not limited to the following occupancies:

g. Armories

h. Sheet metal shops

i. Bowling alleys

j. Ship fitting shops

k. Clubs (officer, enlisted personnel, etc.)

l. Kitchens and bakery

m. Small stores

n. Fitness Centers

o. Gymnasiums

p. Theaters and auditoriums

q. Welding shops

r. Forge shops

s. Laundries

t. Mechanical rooms, with or without boilers or fuel-fired equipment

u. Electrical rooms, other than transformer vaults

v. Small storage rooms

w. Commissaires

x. Exchanges

y. Aviation depots

z. Electrical maintenance shops

aa. \6\ /6/Laboratories

bb. Refrigeration and air compressor rooms

cc. Machine rooms

dd. Printing shops (using inks having flash points above 110°F (44°C)

ee. Libraries

ff. Piers and wharves

gg. Vehicle repair garages

hh. Woodworking shops

B-1.3 Extra Hazard Occupancies.

DoD occupancies, that might be classified as extra hazard, are often addressed by unique occupancy specific criteria/guidance rather than being addressed generically as extra hazard.

B-1.4 Special Occupancies.

Special occupancies are *Facilities* or areas that DoD does not assigned a specific occupancy hazard classification because of special protection requirements. Refer to Chapter 4 for fire protection requirements for the following occupancies:

ii. Flammable and combustible liquids

jj. Aircraft hangars

kk. Engine test cells

ll. \6\ Engine and generator rooms /6/

mm. Missile assembly

nn. Ordnance plants

oo. Rubber tire storage

pp. Warehouses (piled or rack storage)

qq. Foam rubber or plastic storage

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APPENDIX C PROCEDURE FOR PERFORMANCE-BASED FIRE SAFETY DESIGN

C-1 EQUIVALENT LEVEL OF SAFETY AND PROTECTION.

Any proposed performance-based fire safety design must demonstrate, to the satisfaction of the \6\ *CFPE* /6/, a level of safety equivalent to the minimum applicable prescriptive requirements of this UFC.

C-2 FIRE SAFETY DESIGN DOCUMENTATION.

Any *Facility* designed using performance-based fire safety design methods must have supporting documentation, including a Fire Protection Engineering Design Brief, Performance-Based Design Report, Specification, Drawings, Building Operation & Maintenance Manuals, and Warrant of Fitness.

C-2.1 Fire Protection Engineering Design Brief.

This is a separate document from the project \4\ Fire Protection Design Analysis/4/, prepared by the *QFPE* and containing general qualitative project information that has been agreed upon by the *Stakeholders*. As a minimum, the design brief includes the project scope, *Facility* and occupant characteristics, project goals and objectives, performance criteria, design fire scenarios, technical references and resources, at least two trial designs, documentation of project design engineers and their qualifications, and a record of agreement on the aforementioned components.

C-2.1.1 Project Scope.

This section describes the boundaries of the performance-based design as agreed upon by all *Stakeholders*, and includes realistic and sustainable design information regarding *Facility* use, design purpose and approach, project constraints, and applicable regulations. The project budget must be clearly defined, so that the limitations and available budget for the proposed solutions can be known.

C-2.1.2 Facility and Occupant Characteristics.

Facility characteristics include an accurate and complete description of the *Facility* construction, operations, systems, physical contents and occupants. Occupant characteristic description includes the number, age, *Facility* familiarity, gender, occupant loading, and potential for self-preservation of a *Facility's* occupants. Accurately identify any necessary occupant response and interaction needed to provide hazard mitigation or securing of specific process or operational equipment. The occupant load is the maximum number of people realistically expected to occupy an area, as agreed upon by the *Stakeholders*, but not less than the prescriptive occupant load densities of NFPA 101.

C-2.1.3 Goals.

Detail and document the goals of life safety, property protection, continuity of operations, and the limitation of the environmental impact of the fire, as defined by NFPA 101, and as additionally defined by the *Stakeholders*. Adequately address the allied fire safety goals of historic preservation and environmental protection from fire protection measures. Identify each goal - realistically, quantifiably, and remaining constant throughout the design process. Address each goal by each proposed trial design, regardless of the goal's individual importance.

C-2.1.4 Objectives and Acceptable Levels of Risk.

Clearly identify *Stakeholder* and design objectives associated with each of the required and user-defined goals.

C-2.1.4.1 *Stakeholder* objectives are the specific project objectives based upon agreed fire safety goals and must be stated in terms of objectives, functional statements, or performance objectives. *Stakeholders*' objectives may be defined in terms of acceptable or sustainable loss or in terms of an acceptable level of risk. Where a design requires the determination of an acceptable level of risk, the \6\ *CFPE* /6/ must ensure that the appropriate *Stakeholders* make the determination. The level of risk may affect an entire base/community/command; therefore it is essential to ensure the persons determining the level of risk are authorized to do so.

C-2.1.4.2 Design objectives are developed by the design engineer based on the *Stakeholder* objectives, and are stated in engineering terms. Use design objectives as the basis for the development of performance criteria, against which the predicted performance of a trial design will be evaluated.

C-2.1.5 Performance Criteria.

Develop quantitative performance criteria to represent the intent of each design objective and retained prescriptive requirement. Completely describe and document these criteria. The performance criteria reflect the event consequences that need to be avoided to fulfill the design objectives, and include realistic values that are capable of being evaluated or measured using existing engineering tools and methods.

C-2.1.5.1 The performance criteria must be a combination of the life safety and property protection criterion, along with criteria developed from *Stakeholder* objectives.

Note: NFPA 101 and the SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings provide guidance regarding the development and evaluation of appropriate performance criteria.

C-2.1.6 Design Fire Scenarios.

Document complete descriptions of the reasoning, intent, and details of all required and *Stakeholder* defined fire scenarios. Use realistic and accurate fire scenarios, with respect to all fire elements, including initial fire location, early rate of growth in fire severity, and smoke generation. Indicate in the description of the fire scenarios all applicable data, characteristics and assumptions, which must remain consistent between all fire scenarios. Ensure the omission of certain details will not reduce the reality of the proposed design fire scenario. The *QFPE* must justify any design fire scenario data that is omitted or cannot be considered by available evaluation methods, and this justification must be noted and approved by the \6\ *DFPE* /6/.

C-2.1.7 Technical References and Resources.

Thoroughly document all technical references, including methodologies, data and sources. Identify the scientific basis of each engineering calculation method or model. Develop, review and validate these methods using a consensus, peer-review process, or obtain from resource publications. Where the chosen methods do not permit the incorporation of all data or do not accurately address the incorporation of the data, perform a sensitivity analysis for any design, performance criteria, or fire scenario data that cannot be included or used in the chosen methods. Address all degrees of conservatism and factors of safety, and clearly identify the limitations of the calculation methods. Any method whose outcome is significantly altered by the omission of trial design or fire scenario details must not be approved, and the omission of critical data is prohibited. The use of proprietary and non-peer reviewed data or source is not permitted. The \6\ *DFPE* /6/ must approve the assessment methods, data, and sources, and confirm the validity of all technical references and resources prior to the design evaluation. Provide the technical reviewer, upon request, any technical references or resources.

C-2.1.7.1 The performance criteria must be capable of being proved or measured using existing engineering tools and methods.

C-2.1.8 Trial Designs.

Identify and document the general details, including the proposed construction, systems, and protection methods. Include in the documentation the safety factors associated with each trial design, as agreed upon by the *Stakeholders*. Clearly identify the impact of the safety factors so that a reasonable decision can be made as to whether their level is appropriate and sufficient. State any retained prescriptive requirements. Where the interaction of emergency response personnel is a designed protection method, accurately identify and confirm the impact and responsibility of the emergency personnel.

The performance criteria must be equally considered and addressed by each trial design against each fire scenario.

Evaluate each trial design in each fire scenario using the agreed upon performance criteria.

C-2.1.9 Project Team and Qualifications.

Provide the qualifications and contact information for the entire design team, including the *QFPE* as part of the required documentation. A performance-based, fire safety design must be prepared by a *QFPE* with experience in performance-based fire safety design and specific experience with the engineering tools and methodologies that are anticipated for a particular project.

C-2.2 Performance-Based Fire Safety Design Report.

This documentation must be prepared by the *QFPE*, and used for general guidance. The report must indicate that the *Facility* was designed using a performance-based fire safety design approach, and must convey the expected hazards, risks, and system performance over the entire *Facility* life-cycle. Include the project scope, design goals and objectives, performance criteria, design fire scenarios, critical design assumptions, critical design features, final design, cost benefit analysis, design engineer's qualifications and capabilities, and data and evaluation method references.

C-2.2.1 Cost Benefit.

The performance-based fire safety design report must indicate how the performance-based design maximizes the benefits/cost ratio while maintaining a level of safety equivalent to the established prescriptive requirements. A performance-based design must not be undertaken where the prescriptive requirements provide the same level of safety for a lesser cost. Where multiple acceptable proposed design scenarios exist, the cost benefit analysis must aid in the identification and determination of the best solution.

C-2.3 Building O&M Documentation.

The *QFPE* must produce Building Operation and Maintenance documentation for the facility based on the objectives, performance criteria, limitations, and final design. Include all associated specifications and design drawings, and a description of the required maintenance procedures that need to be performed to ensure continued compliance with performance-based fire safety design.

C-2.4 Warrant of Fitness.

The host-tenant agreement must require that an annual Warrant of Fitness be prepared for any subsystem, system, or *Facility* that has been designed using performance-based fire safety design methods. Submit this warrant to the \6\ *DFPE* /6/ for review and assurance that the current facility characteristics comply with the requirements of the approved performance design. This warrant must reflect any existing or proposed changes in *Facility* occupancy, operation, features, systems, or emergency personnel response. Where emergency response is a critical element in the accepted fire safety design, reevaluate the design when changes are made to the operational procedures, location, or structure of the emergency response personnel.

C-3 REVIEW OF TRIAL DESIGNS.

Provide every performance-based fire safety design with a technical review, and develop a Review Brief. Analyze each trial design to determine the compliance with the required performance criteria. The reviewer must be an individual capable of providing a thorough evaluation of the proposed design, and must have the same minimum qualifications as the *QFPE*. If the authority responsible for the review of the performance-based fire safety design does not have the required qualifications, they must direct the designer to submit the design to a qualified third party for review.

C-3.1 Review Brief.

The Review Brief details how each proposed design compares with the required fire safety goals, objectives and performance criteria. The Brief provides a brief description of the details of each trial design, the technical resources and references, any concerns about steps in the design process and general concerns about the designer's performance-based fire safety design approach. The Brief indicates the acceptability of each design, the reasoning for each acceptance or rejection, and which design is recommended for final acceptance. It must also discuss levels of confidence over validation. The Brief must indicate how personnel and property protection are considered, which objectives the design stresses, a statement of what has been checked, the design solution, and the entire design approach and process.

C-3.2 Third Party Review.

When required, an assigned third party must provide an objective review of the project, and must not provide the actual fire safety design. When a third party is reviewing the design, the \6\ *DFPE* /6/ remains a *Stakeholder* and ultimately is responsible for the approval of the final design. When a review is assigned to a third party, provide the \6\ *DFPE* /6/ with a Review Brief.

C-3.3 Compliant Fire Safety Design.

A compliant fire safety design must meet the stated performance criteria when subjected to each design fire scenario. A subsystem, system or *Facility* design that complies with all requirements of the applicable prescriptive criteria is deemed as satisfying the minimum fire safety goals and objectives, and does not need to be evaluated against the design fire scenarios. Completely evaluate a performance-based fire safety design that incorporates only portions of applicable prescriptive criteria, as it is not considered to provide the minimum levels of protection.

Where a design does not meet the performance criteria, it may be revised and reevaluated. The revision must not reduce any agreed upon goals, objectives, performance criteria, or level of performance to ensure a proposed design complies with the stated requirements. Criteria may be changed based on additional analysis and the consideration of additional data.

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APPENDIX D INTERNATIONAL BUILDING CODE AND NFPA 220 EQUIVALENTS

This table provides the corresponding types of construction from the various codes. This table is for information only.

IBC	NFPA 220
	Type I (442)
Type I-A	Type I (332)
Type I-B	Type II (222)
Type II-A	Type II (111)
Type II-B	Type II (000)
Type III-A	Type III (211)
Type III-B	Type III (200)
Type IV (HT)	Type IV (2HH)
Type V-A	Type V (111)
Type V-B	Type V (000)

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APPENDIX E RECOMMENDED FIRE ALARM AND EMERGENCY NOTIFICATION MESSAGES

GENERAL ANNOUNCEMENTS AND PAGING

AUDIBLE in the following sequence:

Pre-announcement Sound – Ding-Dong – Percussive pairs of 700 and 570 Hz tones each damped to zero (one cycle)

Announcement – spoken message.

VISIBLE none

FIRE EMERGENCY / FIRE ALARM {GENERIC} MESSAGES:

AUDIBLE [Audible must sound for not less than 180 seconds (NFPA 72)] in the following sequence:

Alert Sound – NFPA Temporal 3 (T-3) - 422-775Hz upward sweep over 850 ms for three-pulses each separated by 1 second followed by a 1.5 second delay (repeat 2 cycles)

Announcement: Voice – Tom (repeat 2 cycles):

Option 1: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT.*

Option 2: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION*

Option 1E: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT DO NOT USE THE ELEVATORS.*

Option 2E: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT; DO NOT USE THE ELEVATORS AND REPORT TO YOUR ASSEMBLY LOCATION*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

CARBON MONOXIDE DETECTION {GENERIC} MESSAGES:

AUDIBLE [Audible must sound for not less than 180 seconds (NFPA 72)] in the following sequence:

Alert Sound – Temporal 4 (T-4) pattern tone - 520Hz over 850 ms for four-pulses each separated by 1 second followed by a 1.5 second delay (repeat 2 cycles)

Announcement: Voice – Tom (repeat 2 cycles):

Option 1: *CARBON MONOXIDE HAS BEEN DETECTED IN THE BUILDING; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT.*

Option 2: *CARBON MONOXIDE HAS BEEN DETECTED IN THE BUILDING; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

Note: The Security / Force Protection messages are only shown as examples if prerecorded messages are desired. Security / Force Protection situations are a variety of circumstances and having a prerecorded message or a variety of messages that will satisfy all conditions will be very difficult and may provide inaccurate information for the situation at hand. Give careful consideration in determining if Security / Force Protection prerecorded messages are going to be used.

SECURITY / FORCE PROTECTION THREATS {GENERIC} MESSAGES

SHELTER IN PLACE:

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – Siren - 600-1250 hz up and down sweep in 4 seconds; 1.5 second delay (repeat 2 cycles)

Announcement: Voice – Tom (repeat 2 cycles):

Option 1: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE TAKE SHELTER IN A DESIGNATED SAFE AREA IMMEDIATELY.*

Option 2: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE SEEK A DESIGNATED SAFE LOCATION IMMEDIATELY.*

Option 1E: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE TAKE SHELTER IN A DESIGNATED SAFE AREA IMMEDIATELY; DO NOT USE THE ELEVATORS.*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

EVACUATE:

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – Hi-Lo - 780 to 600 hz alternately, 0.52 each (repeat 2 cycles)

Announcement: Voice – Tom (repeat 2 cycles):

Option 1: *A [force protection emergency] [ ] HAS BEEN DECLARED;; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT.*

Option 2: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION*

Option 1E: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT DO NOT USE THE ELEVATORS.*

Option 2E: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT; DO NOT USE THE ELEVATORS AND REPORT TO YOUR ASSEMBLY LOCATION*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

Note: The Weather / Natural Disaster Warnings (Tornado, Tsunami, Hurricane, Earthquake, Volcano, Etc.) messages are only shown as examples if prerecorded messages are desired. Weather / Natural Disaster situations will come in a variety of circumstances and having a prerecorded message or a variety of messages that will satisfy all conditions will be very difficult and may provide inaccurate information for the situation at hand. Give careful consideration in determining if Weather / Natural Disaster Warning prerecorded messages are going to be used.

WEATHER / NATURAL DISASTER WARNING(S) (TORNADO, TSUNAMI, HURRICANE, EARTHQUAKE, VOLCANO, ETC.) {GENERIC} MESSAGES

AUDIBLE - [Audible must continue to sound for not less than 180 seconds] in the following sequence:

Alert Sound – NOAA Standard alert tone - 1050 hz (8 seconds)

Announcement: Voice – Donna (repeat 2 cycles) (Systems may have multiple weather/natural disaster warning messages depending on the individual installation requirements and potential weather threats):

<u>SHELTER IN PLACE:</u>

Option 1: *A [weather] [ ] EMERGENCY HAS BEEN DECLARED; PLEASE TAKE SHELTER IN A DESIGNATED SAFE AREA IMMEDIATELY.*

Option 2: *A [weather] [ ] EMERGENCY HAS BEEN DECLARED; PLEASE SEEK A DESIGNATED SAFE LOCATION IMMEDIATELY.*

Option 1E: *A [weather] [ ] EMERGENCY HAS BEEN DECLARED; PLEASE TAKE SHELTER IN A DESIGNATED SAFE AREA IMMEDIATELY; DO NOT USE THE ELEVATORS.*

Option 2E: *A [weather] [ ] EMERGENCY HAS BEEN DECLARED; PLEASE SEEK A DESIGNATED SAFE LOCATION IMMEDIATELY; DO NOT USE THE ELEVATORS.*

<u>EVACUATE:</u>

Option 1: *A [earthquake] [ ] EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT.*

Option 2: *A [earthquake] [ ] EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION.*

Option 1E: *A [earthquake] [ ] EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT; DO NOT USE THE ELEVATORS.*

Option 2E: *A [earthquake] [ ] EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION; DO NOT USE THE ELEVATORS.*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *strobe or other listed appliance.*

Textual message signs (if provided).

ALL CLEAR RETURN TO NORMAL OPERATIONS MESSAGES

AUDIBLE in the following sequence:

Pre-announcement Sound – Ding-Dong – Percussive pairs of 700 and 570 Hz tones each damped to zero (one cycle)

Announcement: Voice – Donna *(repeat two cycles)* – THE *EMERGENCY HAS BEEN RESOLVED; RETURN TO NORMAL OPERATIONS*

VISIBLE none

AUTOMATED MONTHLY TEST MESSAGES

SCHEDULE the first Wednesday of each month at 1200 hours local.

AUDIBLE in the following sequence:

Pre-TEST Sound – NOAA Standard alert tone - 1050 hz (8 seconds)

Announcement: Voice – Tom – TEST, TEST, TEST, THIS IS AN EMERGENCY NOTIFICATION AUDIO SYSTEM TEST; *YOU MAY CONTINUE NORMAL OPERATIONS, TEST, TEST, TEST.*

VISIBLE [Visible must flash/operate during the pre-test sound and the announcement and then stop]:

\5*Clear* /5/ *strobe or other listed appliance.*

Textual message signs (if provided).

<u>SPECIAL OCCUPANCIES</u>

FIRE EMERGENCY / FIRE ALARM {Child Development Centers and Medical Facilities including Ambulatory} MESSAGES:

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – Three Pulse Chime - 575Hz, three-0.5 second pulses separated by 0.5 seconds followed by a 1.5 second delay (repeat 3 cycles)

Announcement: Voice – Donna (repeat 2 cycles):

For outside assembly: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO THE ASSEMBLY LOCATION*

For those Centers with horizontal exiting: A FIRE EMERGENCY HAS OCCURRED IN THIS PART OF THE BUILDING; PLEASE MOVE TO THE [define area} SAFE AREA.

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

CARBON MONOXIDE DETECTION: {Child Development Centers and Medical Facilities including Ambulatory} MESSAGES:

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – Four Pulse Chime - 575Hz, four-0.5 second pulses separated by 0.5 seconds followed by a 1.5 second delay (repeat cycles)

Announcement: Voice – Donna (repeat 2 cycles):

For outside assembly: *CARBON MONOXIDE HAS BEEN DETECTED IN THE BUILDING; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO THE ASSEMBLY LOCATION*

For those Centers with horizontal exiting: CARBON MONOXIDE HAS BEEN DETECTED IN THIS PART OF THE BUILDING; PLEASE MOVE TO THE [define area} SAFE AREA.

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

SECURITY / FORCE PROTECTION THREATS MESSAGES (Child Development Center and Medical Facilities including Ambulatory)

SHELTER IN PLACE:

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – Chime – Percussive 700 Hz chime tone for 10 seconds (one cycle)

Announcement: Voice – Donna (repeat 2 cycles):

Option 1: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE TAKE SHELTER IN A DESIGNATED SAFE AREA IMMEDIATELY.*

Option 2: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE SEEK A DESIGNATED SAFE LOCATION IMMEDIATELY.*

Option 1E: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE TAKE SHELTER IN A DESIGNATED SAFE AREA IMMEDIATELY; DO NOT USE THE ELEVATORS.*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

<u>EVACUATE:</u>

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – Chime – Percussive 700 Hz chime tone for 10 seconds (one cycle)

Announcement: Voice – Donna (repeat 2 cycles):

Option 1: *A [force protection emergency] [ ] EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT.*

Option 2: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION*

Option 1E: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT DO NOT USE THE ELEVATORS.*

Option 2E: *A [force protection emergency] [ ] HAS BEEN DECLARED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT; DO NOT USE THE ELEVATORS AND REPORT TO YOUR ASSEMBLY LOCATION*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

FIRE EMERGENCY / FIRE ALARM {Aircraft Hangar} MESSAGES:

AUDIBLE [Audible must sound for not less than 180 seconds] in the following sequence:

Alert Sound – NFPA Temporal Whoop - 422-775Hz upward sweep over 850 ms for three-pulses separated by 1 second followed by a 1.5 second delay (repeat 2 cycles)

Announcement: Voice – Tom (repeat 2 cycles):

<u>ACTIVATION FROM SUPPRESSION SYSTEM, MANUAL FIRE ALARM STATION, OR DETECTION (if provided) IN THE AIRCRAFT SERVICING AREA</u>

Option 1: *A FIRE EMERGENCY HAS OCCURRED IN THE AIRCRAFT SERVICING AREA; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT. DO NOT EXIT THROUGH THE AIRCRAFT SERVICING AREA.*

Option 2: *A FIRE EMERGENCY HAS OCCURRED IN THE AIRCRAFT SERVICING AREA; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION. DO NOT EXIT THROUGH THE AIRCRAFT SERVICING AREA.*

Option 1E: *A FIRE EMERGENCY HAS OCCURRED IN THE AIRCRAFT SERVICING AREA; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT DO NOT USE THE ELEVATORS. DO NOT EXIT THROUGH THE AIRCRAFT SERVICING AREA.*

Option 2E: *A FIRE EMERGENCY HAS OCCURRED IN THE AIRCRAFT SERVICING AREA; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT; DO NOT USE THE ELEVATORS AND REPORT TO YOUR ASSEMBLY LOCATION. DO NOT EXIT THROUGH THE AIRCRAFT SERVICING AREA.*

<u>ACTIVATION FROM SUPPRESSION SYSTEM, MANUAL FIRE ALARM STATION OR DETECTION (if provided) IN THE ADJACENT SUPPORT AREA</u>

Option 1: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT.*

Option 2: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT AND REPORT TO YOUR ASSEMBLY LOCATION*

Option 1E: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT DO NOT USE THE ELEVATORS.*

Option 2E: *A FIRE EMERGENCY HAS OCCURRED; PLEASE LEAVE THE BUILDING BY THE NEAREST EXIT; DO NOT USE THE ELEVATORS AND REPORT TO YOUR ASSEMBLY LOCATION*

VISIBLE [Visible must flash/operate until system is reset]:

\5*Clear* /5/ *Strobe or other listed* \5*clear* /5/ *appliance.*

Textual message signs (if provided).

Messages will be generated by the text- to-speech system Speechify*,* Nuance, 2005 as used by NOAA for weather information and Emergency Alert System (EAS) messaging. The voices used will be "Tom" and "Donna" as identified for each message type. The current Nuance text-to-speech product is *Vocalizer 5.0,* Nuance, 2013.

NFPA 72 sound pressure levels applies to "public mode" notification devices "Alert Sound – NFPA Temporal Whoop - 422-775Hz upward sweep over 850 ms for three-pulses separated by 1 second followed by a 1.5 second delay". Sound levels are measured:

a. Maximum level at 10 feet horizontally perpendicular to the notification appliance at 5.5 feet above the finish floor.

b. Minimum levels at no closer than ten feet from walls and other vertical obstructions at 5.5 feet above the finish floor.

NFPA 72 sound pressure levels apply to "private mode" fire alarm notification device as required in NFPA 72.

NFPA 72 sound pressure levels do not apply to other notification devices.

NFPA 72 voice intelligibility applies to all voice messages. Intelligibility measurements are not required in large open areas such as industrial work areas, warehouses, and aircraft servicing areas, garages, and similar facilities.

APPENDIX F ABBREVIATIONS AND ACRONYMS

°F	degrees Fahrenheit
°C	degrees Celsius
A&E	Architectural and Engineering Services
ABA	Architectural Barriers Act
ABAAG	Architectural Barriers Act Accessibility Guidelines
ACA	American Correctional Association
ADP	Automatic Data Processing
AFCEC	Air Force Civil Engineer Center
AFFF	Aqueous Film-Forming Foam
AFMAN	Air Force Manual
AFTO	Air Force Technical Order
\6\ /6/	
ANSI	American National Standards Institute
AR	Army Regulation
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATFP	Anti-Terrorism Force Protection
AWG	American Wire Gauge
AWWA	American Water Works Association
BIA	Bilateral Infrastructure Agreement
CAD	Computer Aided Drafting
CDC	Child Development Center

\6\ CFPE	Component Fire Protection Engineer /6/
cm^2	square centimeter(s)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CRAC	Computer Room Air Conditioning
CSS	Central Security Service
\6\ DA	Department of the Army
DESR	Defense Explosives Safety Regulation /6/
DFPE	Designated Fire Protection Engineer
DLA	Defense Logistics Agency
DoD	Department of Defense
DoDI	Department of Defense Instruction
DPDT	Double-Pole, Double-Throw
ECB	Engineering Construction Bulletins
EM	Engineering Manual
EMCS	Energy Monitoring and Control System
ESFR	Early Suppression Fast-Response Sprinklers
ETL	Engineering Technical Letters
FAAA	Fire Administration Authorization Act
FACP	Fire Alarm Control Panel
FC	Facilities Criteria
FM	Factory Mutual Global
FPE	Fire Protection Engineer
FRT	Fire Retardant Treated Plywood
FS	Flame Spread Rating

ft	feet; foot
ft^2	square feet; square foot
gal	gallon(s)
GH_2	Gaseous hydrogen
GOX	Gaseous Oxygen
gpm	gallons per minute
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
HP	Horsepower
HVAC	Heating, Ventilating and Air Conditioning
HVLS	High Volume Low Speed
HZ	Hertz
IBC	International Building Code
ICC	International Code Council
IEEE	Institute of Electrical and Electronics Engineers
IFC	International Fire Code
in	inch(es)
in^2	square inch(es)
IRC	International Residential Code\2\
/2/kPa	kilopascal
L	liter(s)
LCD	Liquid Crystal Display
LEC	Electroluminescence
LED	Light Emitting Diode
LH_2	Liquid Hydrogen

LOX	Liquid Oxygen
m	meter(s)
m^2	square meter(s)
MAF	Missile Alert Facilities
MIL-HDBK	Military Handbook
min	minute
mm	millimeter(s)
ms	milliseconds
NARA	National Archives and Records Administration
NATOPS	Naval Air Training & Operating Procedures Standardization
NAVAIR	Naval Air Systems Command
NAVFAC	Naval Facilities Engineering Systems Command
NAVSEA	Naval Sea Systems Command
NCEES	National Council of Examiners for Engineering & Surveying
NFPA	National Fire Protection Association
NGA	National Geospatial-Intelligence Agency
NGR	National Guard Regulation
NPSH	Net Positive Suction Head
NRO	National Reconnaissance Office
NRTL	Nationally Recognized Testing Laboratory (as defined on the OSHA website https://www.osha.gov/dts/otpca/nrtl/nrtllist.html)
NSA	National Security Agency
OHESS	Office of Occupational Health, Environmental & Safety Services
OPNAVINST	Naval Operations Instructions
P.E.	Registered Professional Engineer

PIV	Post Indicator Valve
POL	Petroleum Oil Lubricant
PRVs	Pressure-Regulating Valves
psi	pounds per square inch
PV	Photovoltaic
QFPE	Qualified Fire Protection Engineer
RPA	Remotely Piloted Aircraft
s	second(s)
SAE	Society of Automotive Engineers
SD	Smoke Developed Rating
SFPE	Society of Fire Protection Engineers
SOFA	Status of Forces Agreements
SPD	Surge protection device
\2\UAS	Unmanned Aerial System/2/
UAV	Unmanned Aerial Vehicle
UFAS	Uniform Federal Accessibility Standard
UFC	Unified Facilities Criteria
UL	Underwriters Laboratories Inc.
USC	United States Code
Vac	volts alternating current
Vdc	volts direct current
WHS	Washington Headquarters Services

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APPENDIX G \3\ CRITERIA FOR PROJECTS IN JAPAN

Purpose: The intent of this Appendix is to provide clarification on the use of Japanese products and standards. Japanese products and standards should be used to the maximum extent possible providing it does not change the intended level of life safety and fire protection specified in this UFC. Example: It is acceptable to use Japanese emergency public address system in lieu of a NRTL listed mass notification system; however, for sprinkler protection of various facilities, the paragraph “Design Requirements” in the “Fire Protection Systems” chapter of this UFC will be followed (see below for more specific requirements pertaining to these systems). The DFPE can make project level decisions based on the intent of this Appendix.

G-1 **GENERAL**. This appendix provides guidance on the specifically negotiated equivalencies/alternatives for all construction and facility maintenance in Japan in achieving the intended fire and life safety performance for DoD missions and personnel in accordance with this UFC.

G-1.1 DFPE. A DFPE is an individual who is a registered professional engineer (P.E.) who has passed the fire protection engineering written examination administered by the National Council of Examiners for Engineering and Surveying (NCEES) and has a minimum of five (5) years of relevant fire protection engineering experience. Where this section states DFPE, it means the DFPE as defined in this section, and it also includes an authorized representative deemed qualified by the DFPE.

G-1.2 Applicability. The requirements of this Appendix apply to all Host Nation Funded and Constructed DoD projects in Japan.

G-1.2.1 Japanese standards, materials, and installation practices will be used to achieve the criteria policy requirements of this UFC to the maximum extent practical and as modified below.

G-1.2.2 When the Japanese market place cannot accommodate a UFC required feature, means will be provided to achieve that requirement. Example, Japanese fire alarm standards do not provide for visual notifications and products do not exist in the market place, however, Japanese fire alarm equipment can power NRTL listed visual notification devices. Solution is to install NRTL listed visual devices powered by the Japanese equipment.

G-1.2.3 When Japanese standards do not mandate a feature normally required by this UFC such as circuit supervision, means will be identified to ensure Japanese optional features are included as mandatory requirements in Host-Nation projects. Example, UFC requires circuit supervision, certain types of Japanese control panels offer optional circuit supervision. Solution is to limit control panel choices to those panels offering optional circuit supervision.

G-1.3 Criteria Evaluations.

G-1.3.1 DFPE will coordinate with the Host Nation to evaluate and determine acceptable fire protection engineering policy, criteria, codes, manufactured equipment and materials to meet the intent of this UFC. If the DFPE is unable to successfully negotiate suitable alternatives, the DFPE will coordinate and obtain approval from the DoD Fire Protection Engineering Working Group (FPEWG).

G-1.3.2 The DFPE will submit coordinated alternatives to the FPEWG for inclusion in this Appendix.

G-1.4 Products, Standards, and Installation Methods Evaluations.

G-1.4.1 The DFPE will coordinate with the Host Nation to determine acceptable Japanese materials, equipment and installations standards meeting the intent of this UFC.

G-1.4.2 DoD service DFPE for Japan will share any approvals/disapprovals with the other services and the DOD FPEWG.

G-1.5 Host Nation Design Process.

G-1.5.1 Criteria and concept packages including the development of the Life Safety and Building Code plans and analysis, architectural floor plans and the fire protection design analysis, in English, will be under the review and oversight of a QFPE and reviewed and approved by the DFPE. The packages will comply with NFPA 101, Life Safety Code, and the International Building Code (IBC), as referenced and modified by this UFC. A fire protection design analysis meeting the section “Fire Protection Design Analysis and Life Safety Plans” will be included in the packages.

G-1.5.2 Design drawings, plans, and specifications are developed by Host Nation qualified engineers and architects. DFPE reviews the drawings, plans, and specifications to ensure compliance with this UFC.

G-1.5.3 During the construction and acceptance process, the DFPE will review shop drawings with identified changes from the design drawings to ensure compliance with criteria. The DFPE will provide construction inspection support when needed or requested. The DFPE will witness final acceptance testing of all fire protection systems.

G-1.6 Host-Nation Requirements.

G-1.6.1 Host Nation requirements in excess of this UFC do not require approval by the \6\ *CFPE* /6/.

G-1.6.2 The QFPE services is limited to the criteria and concept package submittal stages only. The process identified in paragraph “Applicability” in this Appendix will meet the QFPE requirements during the construction and acceptance stages.

G-1.6.3 The code compliance certification is not required to address compliance with host-Nation Codes and standards. The QFPE will review the criteria and concept package drawings and document in writing that the package is in compliance with the this UFC and all applicable fire protection and life safety design criteria. A Host Nation fire protection consultant is not required

G-1.6.4 For conflicts between this UFC and the Host-Nation fire protection criteria, the DFPE will be consulted.

G-1.6.5 Fire protection features installed to exclusively comply with Japanese fire protection requirements are not required to be documented in the fire protection design analysis.

G-1.6.6 Identifying code/criteria conflicts and DFPE approved design solutions to meet the requirements of the UFC will be documented in the fire protection design analysis.

G-1.6.7 Shop drawing prepared in accordance with the Japanese Building Standards and Fire Service Law and reviewed in accordance with this Appendix meet the intent of this UFC. NICET preparation of the shop drawings and QFPE reviews are not required.

G-1.7 Acceptance Testing. Inspections, evaluations, and approvals required under the Japanese Fire Service Act should be conducted jointly by the local Japanese Fire Authority and the cognizant DoD activity. Failure of the DoD authority to participate will not limit the Japanese Fire Authority from executing the requirements of the Japanese Fire Service Act.

G-1.7.1 Japanese authorities, generally, only evaluate the features required by Japanese law (The Building Standard Act and the Fire Service Act). DoD will normally accept the Japanese determination the Japanese required features are acceptable/unacceptable.

G-1.7.2 It is DoD's responsibility to evaluate all additional DoD requirements and their appropriate interface with the Japanese required features ensuring a complete and usable facility system.

G-2 **AIRCRAFT HANGARS**.

G-2.1 General. Use the requirements of UFC 4-211-01, Aircraft Maintenance Hangars.

G-2.2 Optical Detectors and Releasing Controls. Comply with paragraphs “Releasing Service Fire Alarm Control Unit (RSFACU)” and “Optical Flame Detection” in Chapter “Air Force Specific Criteria” in UFC 4-211-01, and paragraph “Releasing Service Fire Alarm Control Unit (RSFACU)” in Chapter “Navy Specific Criteria” in UFC 4-211-01.

G-2.3 Floor Grate Nozzles and Flow Control Valves. Comply with paragraph "\6\ /6/ Trench Nozzle System" in Chapter "General Hangar Requirements" in UFC 4-211-01.

G-2.4 Other Components. Japanese materials and installation practices are acceptable.

G-3 **ELEVATORS**

G-3.1 Doors. The use of a 60 minute elevator door is acceptable regardless of the required fire rating of the shaft.

G-3.2 Fire Service Operations. Fire service emergency operations Phase I and Phase II in accordance with ASME A17.1 are required on all elevators.

G-3.3 Shaft and Machine Room. Elevator shaft and machine room will be fire rated in accordance with NFPA 101 with the exception of the elevator doors and machine room doors. These doors are allowed to be 60 minute fire doors regardless of the required fire rating of the shaft or machine room.

G-4 **FIRE ALARMS AND MASS NOTIFICATION.**

G-4.1 General. Install fire alarm systems where required by this UFC, including referenced codes and standards as modified by this UFC.

G-4.2 Control Panels.

G-4.2.1 Fire Alarm and Notification. Japanese traditional Type P1 control panels and Japanese addressable Type R are permitted to be used when traditional or addressable type panels are required by this UFC. Type R will be used when an emergency communication system is provided.

G-4.2.1.1 All the Japanese optional features for supervision of devices and circuits are required regardless of which panel is used.

G-4.2.1.2 Detection devices, manual pull stations, supervisory devices will be provided where required by this UFC.

G-4.2.1.3 Visual notification appliances are required. Listed devices by a NRTL will be used and located in accordance with the distribution requirements of NFPA 72.

G-4.2.1.4 Audible notification devices are required. Japanese devices will be used and located in accordance with installation standards referenced is this UFC.

G-4.3 Mass Notification.

G-4.3.1 Japanese emergency public address systems will be used to provide mass notification. This meets the intent of UFC 4-021-01.

G-4.3.2 All available Japanese optional features for supervision of speakers and circuits are required when used on DoD installation in Japan.

G-4.3.3 Provide audible notification devices in all areas and rooms when the audible requirements of NFPA 72 cannot be met.

G-4.3.4 Mass notification system are recommended to be used for general paging.

G-4.3.5 Voice intelligibility may be assessed by the manual method and approved by the DFPE.

G-5 **FIRE DOORS.**

G-5.1 General. Fire doors of an equal or greater fire resistance will be provided where fire doors are required by this UFC.

G-5.1.1 Latching. All fire doors must be able to latch in the closed position.

G-5.1.2 Use of a Japanese design specification 20- and 60-minute fire door is permitted. Doors must be labeled as required by Japanese standards. See Figures G-5.1.3.1 and G-5.1.3.2 for door label examples and locations.

G-5.1.3 Use of a Japanese tested and labeled 60-minute door is permitted.

Fig G-5.1.3.1 60 Minute Label

FIG G-5.1.3.2 Label Location

G-6 FIRE PUMPS.

G-6.1 Vertical Lift Fire Pumps. Fire pumps for vertical lift such as taking suction from a cistern as is found in many Japanese sprinkler and other fire protection systems will be Japanese vertical turbine type.

G-6.2 Supervision of Power for Electric Fire Pumps. The loss of power, reverse polarity, and pump running conditions must be monitored and a signal must be sent to a constantly attended location, normally the fire alarm receiving center.

G-7 WATER SUPPLY.

G-7.1 Water Supply for Sprinklers and Fire Protection Systems. When Japanese 20 minute cisterns are used, an automatic resupply connection will be provided meeting the design demand for not less than 40 minutes.

G-7.2.1 The Japanese 20-minute cistern is not considered a water storage tank. (Reference: 9-4)

G-8 SMOKE AND CARBON MONOXIDE ALARMS.

G-8.1 General. Install smoke and carbon monoxide alarms as required in this UFC.

G-9 SPRINKLERS.

G-9.1 General. Provide sprinkler protection when required by this UFC, including referenced codes and standards as modified by this UFC. Sprinklers protection will be designed in accordance with the Japanese technical requirements based on using Japanese equipment.

G-9.1.1 Japanese residential type sprinklers are permitted anywhere a NRTL type residential sprinkler is allowed to be used.

G-9.1.2 Japanese condominium style sprinklers are permitted in multi-story apartment applications.

G-9.2 Special Conditions. Situations where requirements do not exist in Japanese technical requirements, use technical requirements referenced in this UFC. The use of Japanese equipment is acceptable if such products exist in the Japanese market.

G-9.2.1 Ceiling Height Above 30 Feet (10m). Provide ceiling sprinklers. Design will be based on area and density requirements in the “Fire Protection Systems” chapter of this UFC.

G-9.2.2 Storage Above 12 Feet. Provide ceiling sprinklers. Design will be based on area and density methods in NFPA 13.

G-10 **REFERENCES**

G-10.1 Japanese Laws and Related Government Standards. The following Japanese documents are available in English translations:

G-10.1.1 The Building Standard Law of Japan, The Building Center of Japan, http://www.bcj.or.jp/en/

G-10.1.2 The Building Standards Law Enforcement Order, The Building Center of Japan, http://www.bcj.or.jp/en/

G-10.1.3 The Building Standards Law Enforcement Regulation, The Building Center of Japan, http://www.bcj.or.jp/en/

G-10.1.4 The Ministerial Order Concerning Designated Qualifying Examination Body and Others Based on the Building Standard Law, The Building Center of Japan, http://www.bcj.or.jp/en/

G-10.1.5 The Fire Service Law of Japan, http://www.kaigai-shobo.jp/pdf/Fire_Service_Act_eng.pdf

G-10.1.6 Ministerial Ordinance for Enforcement of the Fire Service Law, http://www.kaigai-shobo.jp/pdf/Ministerial_Ordinance_eng.pdf

G-10.1.7 Japanese Industrial Standards, Japanese Standards Association, https://www.jsa.or.jp/en/ /3/

UFC 3-601-02
7 October 2021
Change 1, 18 April 2025

UNIFIED FACILITIES CRITERIA (UFC)

FIRE PROTECTION SYSTEMS INSPECTION, TESTING, AND MAINTENANCE

UNIFIED FACILITIES CRITERIA (UFC)

FIRE PROTECTION SYSTEMS
INSPECTION, TESTING, AND MAINTENANCE

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	18 April 2025	Chapters 1 - 3, throughout

This UFC supersedes UFC 3-601-02, dated 8 September 2010.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense agencies, and the DoD field activities in accordance with USD (AT&L) Memorandum, dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing Service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD Working Group. Recommended changes with supporting rationale may be sent to the respective DoD Working Group by submitting a Criteria Change Request (CCR) via the internet site listed below.

UFCs are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-601-02, *Fire Protection Systems Inspection, Testing, and Maintenance*

Superseding: UFC 3-601-02, dated 8 September 2010, and all subsequent changes.

Description of Changes: This Unified Facilities Criteria (UFC) provides best practice maintenance methods from the DoD, other government agencies, and the private sector for inspection, testing, and maintenance of fire protection systems. Criteria for the following technical areas was added/updated/revised:

- Update Naval Facilities Engineering Command to Naval Facilities Engineering System Command.
- Update Naval Facilities Engineering System Command signature block.
- Adds U.S. Space Force.
- Revises the term “authority having jurisdiction (AHJ)” to conform to UFC 1-200-01 and UFC 3-600-01.
- Life-cycle guidance, Section 2-2.2, “Fire Detection and Alarm System.”
- Fire watch procedures.
- Extreme weather events and natural disasters – guidance for pre-event preparation, trans-event actions, post-event recovery actions.
- Nitrogen generation systems.
- Low-pressure water mist systems.
- Hybrid water mist systems.
- Deletes product information in Halon system ITM
- Fire and smoke barrier opening protectives.
- Heat and combustion products removal and venting systems.
- Ignitable liquid floor drainage assemblies.
- Guidance on AFFF control during ITM (2020 National Defense Authorization Act).
- General guidance on life cycle and obsolescence.
- Air Force guidance on excess features (2008 A4C Policy Letter).
- Navy requirements for contract technicians qualifications.

Reasons for Document:

- This UFC provides updated requirements for inspection, testing, and maintenance (ITM) of fire protection and life safety features in DoD facilities.

Impact:

- Personnel safety and continuity of mission are primary considerations.

Unification Issues:

- None.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This Unified Facilities Criteria (UFC) has been developed from an evaluation of Department of Defense (DoD) facilities, from surveys of maintenance methods, and from selection of the best practices of the DoD, other government agencies, and the private sector. This UFC is based on recognized reliability-centered maintenance (RCM) concepts and reliability-centered risk management. It was prepared using model building maintenance codes, National Fire Protection Association (NFPA®) National Fire Codes®, industry standards, and other recognized standards to the maximum extent feasible. It does not directly adopt the tasks requirements from the model codes. Personnel safety and continuity of mission were primary considerations.

1-2 PURPOSE AND SCOPE.

This UFC provides requirements for inspection, testing, and maintenance (ITM) of active and passive fire protection and life safety features in DoD facilities. Do not deviate from these criteria without prior approval of the Component office of responsibility.

Compliance with criteria issued in accordance with this UFC does not constitute an exception to the public laws. Fire protection criteria must conform to the requirements of this UFC and the NFPA National Fire Codes®, except as modified by this UFC and specifically referenced by this UFC. Additional criteria include portions of the FM Global Property Loss Prevention Data Sheets, as specifically referenced by this UFC.

This UFC for DoD compliance with all U.S.C. Title 10, 15 and 29 occupational health and safety requirements related to fire protection feature maintenance fully meets the intent of the U.S.C. requirements. Any questions related to compliance should be directed to the Component office of responsibility.

1-3 APPLICABILITY.

\1 In addition to the applicability of UFC 1-200-01, paragraph 1-3, this UFC applies to USACE Civil Works. It also applies **/1/** to DoD-leased facilities where DoD, as the lessee, is responsible for maintaining the fire protection and life safety features.

In **\1** Navy-leased **/1/** facilities where the lessor is responsible for maintaining the fire protection and life safety **\1** features **/1/**, the **\1** Navy **/1/** lessee should use this UFC as a guide along with the requirements of the lease contract to the extent possible.

1-3.1 Commercial Facilities on Government Property.

\1 This UFC does not apply to commercially owned and occupied facilities on DoD installations. **/1/** In commercially owned facilities occupied via a ground lease, inspection, testing, and maintenance of fire protection systems will be the sole responsibility of the commercial lessee. The lease agreement may use as guides:

- this UFC;
- the requirements of the local (off-installation) authority having jurisdiction;
- the lessee's internal ITM standards; or
- national consensus codes and standards.

1-4 AUTHORITY.

10 U.S.C. § 1794 requires **\1 ** life threatening **/1/** ITM deficiencies identified in youth program facilities be corrected immediately **\1** or the facility closed by the installation commander **/1/**; non-life-threatening ITM deficiencies **\1** identified in youth program facilities **/1/** may be waived **\1** by the installation commander **/1/** for up to 90 days **\1** while corrections are undertaken **/1/**, after which the **\1** installation commander **/1/** is required to close the facility **\1** when corrections are incomplete **/1/** until corrections are completed.

15 U.S.C. § 272 identifies the necessary consensus technical standards required to implement policy objectives and activities within the area of fire protection engineering including the ITM of installed fire protection features.

1-5 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms.

1-6 REFERENCES.

Appendix **\1** C **/1/** contains a list of references used in this document. The publication date of the code or standard is not included. Unless otherwise specified, the most recent edition of the referenced publication applies.

1-7 OBJECTIVE.

ITM tasks in this UFC represent the minimum required to achieve a 99 percent overall system reliability in response to an actual fire event.

A byproduct of the reliability centered maintenance analysis is a list of ITM tasks and how often they must be accomplished (frequencies) to achieve the minimum desired 99 per cent (0.99) reliability. The methodology used to develop the ITM tasks in this UFC is summarized in AFCESA/CES Technical Report 01-10, "Risk Based Reliability Centered Maintenance of DoD Fire Protection Systems, 1999 (Defense Technical Information Center AD-A392898)." The model used in the report assumed a system demand of one event in fifty (1/50) years and a task effectiveness (ITM is "done right") of 99 percent. This RCM analysis emphasized task thing to do and is it done right?") and timeliness ("Is it done before a demand?"). The resulting list of tasks and frequencies, therefore, considers frequency and probability effectiveness ("Is it the right of demands and failures.

1-8 CRITERIA.

Use the task frequencies in this UFC in lieu of the tasks and frequencies in the National Fire Codes.

1-8.1 Systems and Applications Not Covered.

When a specific system or application is not addressed by this UFC, follow national building codes, recognized industry standards, and standard engineering practices. In the absence of technical information, contact the DoD Component office of responsibility.

This UFC does not cover acceptance testing, system commissioning, or integrated systems testing. Do not use this UFC for construction contract acceptance or commissioning of fire protection systems or features.

Fire Emergency Services (FES) operations, staffing, and equipment are not addressed in this UFC.

1-8.2 Medical Facilities.

Medical facilities require Joint Commission **\1** accreditation. **/1/** Follow the task frequencies indicated in the related NFPA codes and standards, except when otherwise approved by the Joint Commission.

1-8.3 Conflicts.

If a conflict exists between this UFC and any other DoD document, referenced code, standard, or publication, this UFC takes precedence.

1-9 COMPONENT OFFICE OF RESPONSIBILITY.

The term “authority having jurisdiction (AHJ)” as used in the codes and standards referenced in this UFC means the Component technical representative for fire protection engineering (CFPE) assigned to the Military Service or Defense Component office of responsibility or the Service delegated designated fire protection engineer (DFPE). For additional information on the CFPE and DFPE, see UFC 3-600-01 and Service-specific delegation direction.

The Component offices of responsibility are:

- U.S. Army: HQ USACE/CECW-CE.
- U.S. Navy: NAVFACENGSYSCOM HQ, Chief Fire Protection Engineer
- U.S. Marine Corps: NAVFACENGSYSCOM HQ, Chief Fire Protection Engineer
- U.S. Air Force: AFCEC/CO
- U.S. Space Force: AFCEC/CO

- Defense Logistics Agency (DLA): DS-IE
- National Geospatial-Intelligence Agency (NGA): Security and Installations
- National Reconnaissance Office (NRO): MS&O/ESO
- Washington Headquarters Service (WHS): Office of the Pentagon Fire Marshal
- National Security Agency/Central Security Service: Office of Occupational Health, Environmental and Safety Services (NSA/CSS OHESS).]

1-10 PERSONNEL QUALIFICATIONS.

1-10.1 ITM Tasks.

ITM tasks must be performed by technicians qualified in the maintenance and repair of the specific fire protection system or subsystem.

"Qualified" personnel must only perform ITM and repair tasks on systems for which these personnel have been specifically qualified. Qualified personnel **\1** are permitted to **/1/** supervise other less qualified personnel in the execution of the tasks covered in this UFC. At no time will apprentice-level technicians be allowed to execute the ITM tasks in this UFC without a qualified co-worker on the job site.

1-10.2 Qualified Personnel.

1-10.2.1 Technicians.

\1 Technicians **/1/** meeting any of the following are qualified personnel:

- Recognized journeyman or craftsman-level qualifications for fire protection systems:
  - National Institute for Certification in Engineering Technologies (NICET) Level II **\1** or higher **/1/** certification in Fire Alarm Systems;
  - NICET **\1** Level II certification in Inspection and Testing of Fire Alarm Systems **/1/**;
  - NICET Level II **\1** or higher **/1/** certification in Inspection and Testing of Water-Based Systems; or
  - NICET **\1** certification in **/1/** Special Hazard Suppression Systems.

NICET Level I personnel must work under the direct supervision of a NICET level **\1** III or IV certified **/1/** technician. **\1** Level IV technicians are authorized to supervise personnel across all technical areas covered in this UFC.) **/1/**

- Other recognized journeyman or craftsman-level qualifications for the specific fire protection feature, formalized labor organization-based journeyman training, or similar programs.

- Technicians completing the Fire Suppression Systems Maintenance course (J3AZR3E451 01FB) at the Technical Training Center, Sheppard Air Force Base, Texas. The 82nd Training Wing, 782nd Training Group, 366th Training Squadron, provides engineer craftsman skills training for all DoD branches. **\1** Air Force personnel have priority for enrollment; a total of 10 percent of annual enrollments will be allocated across all other branches on a first-come, first-serve basis. (366TRS.WFSM.Supplemental@us.af.mil) /1/
- Individually qualified or endorsed by an equipment manufacturer for the specific equipment item maintained.
- A valid, current qualification or license from any state (or local jurisdiction if delegated authority by the state). Local jurisdictions and other organizations may require varying levels of continuing education to maintain recognized journeyman or technician-level qualifications.
- Military personnel holding specific Service qualifications equivalent to journeyman or craftsman technicians and approved by their unit commander.

In OCONUS locations, local nation technicians must hold either one of the previously listed qualifications or a national/local license issued by the government where the installation is located. Individual Status of Forces Agreements (SOFA) will take precedence where technical qualifications are addressed. Overseas locations **\1** will **/1/** contact their command Fire Protection Engineering office (or Component office of responsibility) for **\1** additional **/1/** guidance on local qualification requirements.

1-10.2.2 BOS Contractors.

Installation or base operating support (BOS) contractors must have at least one qualified **\1** supervisor **/1/** technician (1-10.2.1) present on the installation when contractor personnel are executing ITM and repair tasks. All ITM and repair tasks will be accomplished under the supervision of a qualified technician.

Navy BOS contractors must have the specific qualifications identified in Appendix A for Fire Protection ITM technicians.

1-10.2.3 Other Contractors.

Other Service contractors performing ITM and repair tasks must have at least one qualified technician (1-10.2.1) present on the job site when contractor personnel are executing ITM and repair tasks.

Other Navy contractors must have the specific qualifications identified in Appendix A for Fire Protection ITM technicians.

1-10.3 Other Inspections.

This UFC also lists inspection tasks **\1** to **/1/** be performed during other regularly scheduled facility inspections or evaluations that are not part of the ITM requirements covered herein. Qualified fire prevention personnel, safety personnel, maintenance technicians, or other individuals **\1** are qualified to **/1/** perform these inspection tasks.

1-11 RECORDS.

Each installation must maintain a permanent record of completed ITM tasks in accordance with each agency's program for reoccurring facility maintenance record keeping. Records **\1\ /1/ \1** must be readily available to craft persons and supervisors **/1/**. Where no agency-wide programs exist, records must be developed locally. Records must be maintained for every facility and include, as a minimum, each ITM task, date scheduled, date completed, and the technician completing the task.

When ITM actions modify or change systems or features from the original as-built configuration, the ITM activity is responsible for identifying the required changes to the maintainer of the as-built records.

1-12 SYSTEM IMPAIRMENT OR OUT-OF-SERVICE TAGGING.

System ITM technicians must physically mark any impaired or out-of-service fire protection feature using a red tag.

Impaired and out-of-service tags must provide the following minimum information:

- identification of the system inspected
- employer of the technician performing the inspection
- name of technician
- licenses or certification information required by the component office of responsibility
- interval of inspection

Inspection tags are to be made of durable, weatherproof, colorfast material and must be securely attached to the system pressure gauge, control panel, or other readily visible part of the system.

1-13 SYSTEM IMPAIRMENT OR OUT-OF-SERVICE NOTIFICATION/ WARNING.

Building managers must notify building occupants, users, and the public whenever any of the systems specified in Chapter 2 are either out of service or impaired **\1** and increasing **/1/** risk to any occupants. (Occupational Safety and Health Administration [OSHA] general industry standards are contained in Title 29, Code of Federal Regulations [CFR], Parts 1910.160(b)(2) Occupational Safety and Health Standards, Fire Protection, Fixed extinguishing systems, general and 1960.26(b)(5) Basic Program Elements For Federal Employees Occupational Safety and Health, Programs and Related Matters, Subpart D – Inspection and abatement, Conduct of inspections).

The sign shown in Figure 1-1 must be posted by the facility manager, custodian, official in charge of the workplace, or a person empowered to act, **\1\ /1/** at all principal public and employee entrances to the building. The sign must appear as follows:

- 7 inches high by 10 inches wide in an American National Standards Institute (ANSI) Z535.2-2011-compliant format
- safety orange background color
- black type and graphic
- Arial font (ANSI Z535.1 2017)

\1\ Note: This sign can be downloaded as an editable PDF from https://www.wbdg.org/dod/ufc/ufc-3-601-02 for local printing. **/1/** Signs complying with this format **\1** can **/1/** be ordered from many commercial safety sign manufacturers on a wide variety of materials. **\1** Commercial **/1/** computer software **\1** and hardware **/1/** is available to print this and other safety signs on color printers.

Figure 1-1 System Out-of-Service or Impaired Sign

1-14 REPAIR OR CORRECTION OF IMPAIRMENTS TO SYSTEM OR FEATURE PERFORMANCE.

\1

1-14.1 Response to Abnormal Conditions.

NFPA 72 Chapter 26 provides guidance for the response to abnormal conditions received at the proprietary supervising/alarm receiving centers.

- Alarm signals – Notify the appropriate responders for immediate response.
- Supervisory signals – Dispatch personnel to arrive within 2 hours to investigate and correct the abnormal conditions.
- Trouble signals – Dispatch personnel to arrive within 4 hours to initiate maintenance and repair actions as necessary.

/1/

1-14.2 Impairment Correction.

Correct impairments affecting the performance of installed fire protection features immediately when identified using the highest priority in the appropriate work identification and management system. These processes must meet the OSHA general industry standards requirements for repair or correction of impairments (29 CFR Part 1910.160(b)(2) and 160(b)(6)).

1-14.3 Maintenance Activity Notifications.

The maintenance activity must notify the local fire emergency service authority and the facility or area user when impairments cannot be corrected immediately when identified. The maintenance activity must also advise the facility or area user of the need to post the Warning sign, Figure 1-1, Out-of-Service or Impaired Sign. The fire authority must advise and consult with the facility or area user to determine the immediate measures that must be taken to ensure personnel safety and mission continuity.

1-14.4 Extended Impairment Measures.

When the impairment will exist for more than 72 hours, the local maintenance activity, the local fire authority, the local safety authority, and the facility or area user must jointly develop written compensatory measures to ensure personnel safety and, to the maximum degree possible, mission continuity. **\1\ /1/** The facility user is the lead to coordinate the compensatory measures package. The jointly developed package must also identify the remaining mission risk exposure. In the absence of compensatory measures, evacuate the facility or stop operations. Implementation of compensatory measures must not reduce the priority of the correction of the impairment.

1-14.4.1 Mitigating Measures.

The need for mitigating measures is typically determined on a case-by-case basis. This considers the building, occupancy type, nature and duration of impairment, building occupancy level during the impairment period, active work being conducted on the fire protection features during the impairment, condition of other fire protection systems and features (for example, sprinklers, structural compartmentation), and hazards and assets at risk.

Appropriate mitigating measures **\1\ /1/** range from simple occupant notification to increased fire safety checks or inspections by user or installation fire and safety personnel to full-time fire watch; for example, measures **\1\ /1/** range from minor operational changes to completely ceasing operations. Determining factors vary from testing-related impairments and maintenance activities during **\1** routine **/1/** business through extensive impairments to high-value, high-hazard situations.

1-14.4.2 New Extended Impairments.

The maintenance activity must inform installation and operational commanders of new impairments not corrected within 72 hours, of the jointly developed compensatory measures being recommended, and of the remaining mission risk exposure.

1-14.4.3 Commander Actions.

Commanders **\1** can **/1/** require evacuation of the workplace until impairments are corrected (OSHA general industry standard: 29 CFR Part 1910 Subpart L App A, *Fire Protection*).

Commanders **\1** can **/1/** also limit operations and have an emergency action plan **\1** specifying **/1/** evacuation actions (OSHA general industry standard: 29 CFR Part 1910 Subpart L App A).

1-14.4.4 Fire Watch.

1-14.4.4.1 Fire Watch Personnel Qualifications.

A fire watch is a dedicated function: the individual(s) assigned fire watch responsibilities as mitigating or compensatory measures would not be expected to have other duties beyond fire safety, occupational safety, or security. **\1\ /1/** Dedicated fire safety, occupational safety, or security personnel **\1\ /1/** can be assigned to conduct mitigating or compensatory fire watch activities as part of their functions.

Fire Watch personnel must also be trained in the use of portable fire extinguishers.

1-14.4.4.2 Fire Watch Procedures.

When fire watches are specified as a mitigating or compensatory measure in response to fire protection system impairments, comply with the following requirements:

- Fire watch personnel must make rounds visually observing the area under watch at scheduled times. **\1\ /1/** The area under watch is observed at least once an hour; however, more frequent observation may be necessary.
- Fire watch personnel must keep a record of all time periods of duty, including a signed log entry or other auditable reporting method for each time the facility was patrolled.
- Fire watch personnel must use the telephone or radio equipment to summon aid in case of an emergency.
- Fire watch personnel must notify building occupants in case of an emergency and evacuation is necessary.
- Impairment of fire sprinkler or fire alarm systems protecting the entire facility will require the rounds include all spaces throughout all levels, including the inspection of basements, attics, and concealed spaces.
- Impairment of fire sprinkler or fire alarm systems protecting a portion of the building will require the rounds include all spaces impacted by the impairment.

1-15 SYSTEM IMPAIRMENTS AND REPAIRS AND CORRECTIONS REPORTING.

The maintenance activity must regularly inform installation and operational commanders, not less than twice a year, of the system impairments, compensatory measures in place, projected correction completions, and corrections completed since the last report.

1-16 EXTREME WEATHER EVENTS AND NATURAL DISASTERS.

Extreme weather events, hurricanes, tornados, and severe cold temperature events, as well as other natural disasters **\1** including **/1/** earthquakes and wildland fires, can impact the availability and performance of fire protection systems **\1** and life safety features **/1/**. Fire protection system impacts include broken piping, broken sprinklers, water damage to electrical and electronic system components, and damage to the utility infrastructure serving these systems. These events also increase the risk of accidental fires.

When sufficient warnings are provided, ITM activities and building inspection activities **\1\ /1/** reduce the impact of these events on the fire protection systems. Additional ITM activities during and after these events can **\1\ /1/** help to reduce property damage and bring the facilities back online sooner.

1-16.1 Hurricanes, Typhoons, and Tropical Storms.

Hurricanes, typhoons, and tropical storms **\1\ /1/** cause building damage due to high wind velocities, impacts from wind-borne objects, and water damage due to heavy rains and local flooding. Advance notice of these storm events does allow time to initiate some ITM tasks **\1\ /1/ \1** to **/1/** reduce the impact of these events on fire protection systems.

1-16.1.1 Pre-Event Actions.

Pre-event ITM actions include:

- Work with installations facilities maintenance personnel to make sure the building envelope is adequately secured. If doors, windows, skylights, and other building openings are broken or not adequately secured, bring it to the attention of installation facilities maintenance personnel so these conditions can be corrected, or temporary measures can be put in place to secure the buildings.
- Verify electrical and fire alarm junction boxes are closed up, conduit is closed up, and the fire alarm panels are closed up and secured.
- Verify firewater storage tanks are filled.
- Verify sufficient fuel supplies are provided for engine driven fire pumps and emergency generator installations.
- Verify fire pump houses are provided with protection from flooding. Ensure drains in the pump rooms are flowing adequately and provide sand bags at pump room entrances if necessary, to prevent flooding of the pump room in low lying areas.

1-16.1.2 Actions During the Event.

Safety of all persons sheltering on the installation regardless of affiliation takes priority during these storm events. Inspection, damage control activities, and system repairs will need to wait until hazardous conditions subside and these activities can be undertaken without risk to personnel.

1-16.1.3 Post Event Actions.

Post event ITM actions include:

- Initial ITM tasks **\1\ /1/** focus on damage control: shutting down damaged systems to reduce water damage **\1** and control of fire extinguishing agents **/1/**.
- Perform visual inspections of all systems, including all system piping and equipment, to identify system damage and to prioritize system repairs.
- Verify radio fire alarm reporting antennas are still in place and connected.
- Verify water supply availability to each facility. Work with installation facility and utilities maintenance personnel to identify damage and repair requirements for the installation water supply.

- Verify if fire alarm systems have been subjected to water damage. Identifying specific alarm system trouble conditions at the fire alarm control panel (FACP) can help to investigate and prioritize system repairs.
- Initiate system impairment procedures for any buildings re-occupied prior to system repairs being completed.
- When the water supply feeding the facility has been damaged, the underground piping needs to be adequately flushed.
- Any water-based fire suppression systems damaged, or are located in buildings structurally damaged, **\1** must **/1/** be subjected to hydrostatic testing prior to putting the systems back in service.

1-16.2 Tornados.

Tornados **\1\\ /1/** cause damage to buildings and building systems due to high wind velocities, impacts from wind-borne objects, and water damage.

1-16.2.1 Pre-Event Actions.

Tornado warnings can provide some advanced warning to seek shelter, but there is not usually sufficient time to initiate any pre-event ITM tasks after these warnings. Prior to tornado season, however, ITM actions include:

- Work with installation facilities personnel to **\1** ensure **/1/** the building envelope is adequately secured. If doors, windows, skylights, and other building openings are broken or not adequately secured, bring it to the attention of installation facilities personnel so these conditions can be corrected, or temporary measures can be put in place to secure the buildings.
- Verify electrical and fire alarm junction boxes are closed up, conduit is closed up, and the fire alarm panels are closed up and secured.
- Verify firewater storage tanks are filled.
- Verify sufficient fuel supplies are provided for engine driven fire pumps and emergency generator installations.

1-16.2.2 Actions During the Event.

Safety of all persons sheltering on the installation regardless of affiliation takes priority during these tornado events. Inspection, damage control activities, and system repairs will need to wait until hazardous conditions subside and these activities can be undertaken without risk to personnel.

1-16.2.3 Post Event Actions.

Post event ITM actions include:

- Initial ITM tasks **\1\ /1/** focus on damage control, shutting down damaged systems to reduce water damage **\1** and control of fire extinguishing agents **/1/**.
- Perform visual inspections of all systems, including all system piping and equipment, to identify system damage and to prioritize system repairs.
- Verify water supply availability to each facility. Work with installation facility and utilities maintenance personnel to identify damage and repair requirements for the installation water supply system.
- Initiate system impairment procedures for any buildings re-occupied prior to system repairs being completed.
- When the water supply feeding the facility has been damaged, the underground piping needs to be adequately flushed.
- Any water-based fire suppression systems damaged or located in buildings structurally damaged **\1** must **/1/** be subjected to hydrostatic testing prior to putting the systems back in service.

1-16.3 Flooding and Extreme Rain Events.

Flooding and extreme rain events cause damage to buildings and building systems due to water infiltration and water immersion.

1-16.3.1 Pre-Event Actions.

Pre-event ITM actions include:

- Work with installation facilities personnel to make sure the building envelope is adequately secured. If doors, windows, skylights, and other building openings are broken or not adequately secured, bring it to the attention of base facilities personnel so these conditions can be corrected, or temporary measures can be put in place to secure the buildings.
- Verify electrical and fire alarm junction boxes are closed up, conduit is closed up, and the fire alarm panels are closed up and secured.
- Verify fire water storage tanks are filled.
- Verify sufficient fuel supplies are provided for engine driven fire pumps and emergency generator installations.
- Verify fire pump houses are provided with protection from flooding. Ensure drains in the pump rooms are flowing adequately and provide sand bags at pump room entrances if necessary to prevent flooding of the pump room in low lying areas.

1-16.3.2 Actions During the Event.

Safety of base personnel and contractor personnel takes priority during these heavy rain and flood events. Inspection, damage control activities, and system repairs will need to wait until hazardous conditions subside and these activities can be undertaken without risk to personnel.

ITM actions during the event include:

- Periodic inspection of accessible fire pump installations to ensure pump facilities remain protected from flooding.
- Periodic inspection of fire water storage tanks to identify tank damage and required repairs.
- Respond to system activations or trouble conditions to provide damage control during the event, when safe to do so.

1-16.3.3 Post Event Actions.

Post event ITM actions include:

- Initial damage control: shutting down damaged systems to reduce water damage **\1** and controlling fire extinguishing agents **/1/**.
- Perform visual inspections of all systems, including all system piping and equipment, to identify system damage and to prioritize system repairs.
- Verify water supply availability to each facility. Work with installation facility and utilities maintenance personnel to identify damage and repair requirements for the Installation water supply system.
- Initiate system impairment procedures for any buildings re-occupied prior to system repairs being completed.
- When the water supply feeding the facility has been damaged, the underground piping needs to be adequately flushed.
- Any water-based fire suppression systems damaged or located in buildings structurally damaged **\1** must **/1/** be subjected to hydrostatic testing prior to putting the systems back in service.

1-16.4 Arctic Vortices and Other Low Temperature Extremes.

Sustained freezing temperatures can lead to frozen fire protection piping, resulting in pipe failures, water leakage, and property damage, in addition to rendering the fire protection systems out of service. System design and installation takes this freezing potential into account; therefore, ITM activities associated with systems in areas subject to severe cold temperatures must focus on the equipment provided to protect these systems from freezing.

Low temperature events can occur via two different modalities; the first is a known weather event where the installation weather office can issue advance weather warning allowing for pre-event actions to prevent damage; the second is an unplanned/ unanticipated utility system failure requiring emergency response action in a compressed time frame to prevent adverse facility/mission impacts.

1-16.4.1 Pre-Event Actions.

Several ITM tasks identified in the ITM tables in Chapter 2 for water-based fire protection systems involve equipment provided to prevent these systems from freezing. These tasks need to be scheduled prior to the onset of cold weather so the equipment functions as required.

Pre-event actions include:

- Work with Installation facilities personnel to make sure the building heating systems are operating properly. If building heating systems do not appear to be operating properly, bring it to the attention of Installation facilities personnel so these conditions can be corrected.
- Verify dry-pipe sprinkler systems are in good operating condition.
- Verify drum drips are in good condition and are drained.
- Verify ball drips are in operating condition.
- Where low temperature alarms are provided, these sensors and their alarm outputs **\1** must **/1/** be checked for proper operation and alarm notification.
- Verify eaters provided in non-occupied fire pump rooms, fire riser rooms, and other similar locations are working properly, and thermostats are set appropriately.
- Verify proper operation of firewater storage tank heaters where provided.

1-16.4.2 Actions During the Event.

Action plans addressing utility system failures are based on the anticipated duration of the utility outage. The most critical utilities are electrical, steam, hot water and/or an area wide facility control system maintaining the facility environmental systems.

ITM actions during the event include:

- Monitor building temperatures and low temperature alarms, particularly in unoccupied or low-occupancy buildings. This includes fire riser rooms, fire pump installations, and firewater storage tank installations.
- If sprinkler systems need to be shut down due to low temperature conditions, implement system impairment procedures.

1-16.5 Earthquakes.

Severe earthquakes can result in building structural damage or failure, failure of sprinkler system piping, and sprinkler system piping damage from impacting building walls and ceilings, or other structural members or equipment. The local utility infrastructure supporting the fire protection systems **\1** can **/1/** be damaged in the earthquake.

Post-earthquake building fires are a significant risk due to structural damage and damage to building utilities resulting from an earthquake.

1-16.5.1 Pre-Event Actions.

Although there is typically no warning of a strong earthquake event, ITM tasks identified in the ITM Tables in Chapter 2 are important to ensuring the survivability of these fire protection systems during an earthquake. Performing the required visual inspections of piping, hangars, and bracing improves the robustness and survivability of these systems.

Also, keep firewater storage tanks filled, and ensure adequate fuel supplies for engine driven fire pumps and generators are maintained at all times.

1-16.5.2 Post-Earthquake Actions.

- Initially, ITM tasks focus on damage control: shutting down damaged systems to reduce water damage **\1** and controlling fire extinguishing agents **/1/**.
- Perform visual inspections of all systems, including all system piping and equipment, to identify system damage and to prioritize system repairs.
- Verify water supply availability to each facility. Work with installation facility and utilities maintenance personnel to identify damage and repair requirements for the installation water supply system.
- Initiate system impairment procedures for any buildings re-occupied prior to system repairs being completed.
- When the water supply feeding the facility has been damaged, the underground piping needs to be adequately flushed.
- Any water-based fire suppression systems damaged or located in buildings structurally damaged **\1** must **/1/** be subjected to hydrostatic testing prior to putting the systems back in service.
- Fire alarm systems **\1** will **/1/** have been subjected to mechanical damage as well. Identifying specific alarm system trouble conditions at the FACP can help to investigate and prioritize system repairs.
- After initial fire sprinkler system visual inspections have been completed, conduct an investigation of the underground fire protection supply piping.

This **\1** includes **/1/** hydrant flow testing and fire sprinkler system main drain testing. Results of the post event tests **\1** must **/1**/ be compared to previous test results to identify any compromised underground piping.

1-16.6 Wildland Fires.

Wildland fires can result in large-scale destruction to installation facilities and utilities. Although building fire protection systems **\1** can **/1/** be overwhelmed by the severe fire exposure from wildland fires, operational sprinkler systems within exposed buildings reduce building damage and reduce the fire exposure to adjacent buildings.

1-16.6.1 Pre-Event Actions.

Pre-event ITM actions include:

- Verify firewater storage tanks are filled.
- Verify sufficient fuel supplies are provided for engine driven fire pumps and emergency generator installations.
- Verify fire hydrants are accessible and vegetation is not blocking or hindering access to hydrants.
- Work with installation facilities personnel to make sure buildings are adequately secured. If doors, windows, skylights, and other building openings are broken or not adequately secured, bring it to the attention of installation facilities personnel so these conditions can be corrected, or temporary measures can be put in place to secure the buildings.

1-16.6.2 Actions During Wildfire Events.

Safety of base personnel and contractor personnel takes priority during wildland fire events. Inspection, damage control activities, and system repairs will need to wait until hazardous conditions subside and these activities can be undertaken without risk to personnel.

ITM actions during the event include:

- Periodic inspection of accessible fire pump installations to ensure pump facilities remain operational and adequate fuel supplies are being maintained for fire pumps and emergency generators.
- Periodic inspection of firewater storage tanks to identify any tank damage, and to verify water supplies remain available for firefighting use.
- Respond to system activations or trouble conditions to provide damage control during the event, if safe to do so.

1-16.6.3 Post Wildland Fire Actions.

- Initially ITM tasks focus on damage control: shutting down damaged systems to reduce water damage **\1** and controlling fire extinguishing agents **/1/**.
- Perform visual inspections of all systems, including all system piping and equipment, to identify system damage and to prioritize system repairs.
- Verify water supply availability to each facility. Work with installation facility and utilities maintenance personnel to identify damage and repair requirements for the installation water supply system.
- Initiate system impairment procedures for any buildings re-occupied prior to system repairs being completed.
- When the water supply feeding the facility has been damaged, the underground piping needs to be adequately flushed.
- Any water-based fire suppression systems damaged or located in buildings structurally damaged, must be subjected to hydrostatic testing prior to putting the systems back in service.

1-17 LIFE CYCLE/OBSOLESCENCE.

Fire protection features have widely-varying operational life cycles and degrees of obsolescence. Some of these are code- or standard-driven and are addressed in the Chapter 2 text and tables requiring specific replacement schedules. Other fire protection feature life cycles are driven by more esoteric requirements **\1** determining **/1/** when components and systems must be replaced. Simply being old does not make features obsolesce.

- Manufacturers' expiration dates: Manufacturer establishes a specific expiration date based on manufacture date or installation date; target plan and program for replacement within one year of the date.
- Manufacturer's modification or updates: Failure to install manufacturer recommended modifications or updates within one year of recommended installation date. Target plan and program installation with the manufacturer's recommended time frame.
- Manufacturer's obsolescence: Manufacturer announces phase-out or ceases to support a product line or model. Target plan and program replacement for not later than one year after manufacturer's end of support.
- Software upgrades or updates: Failure to install vendor required or recommended upgrades or updates within 30 days of vendor recommended installation date.

- Software obsolescence: Vendor announces they will cease to provide maintenance and update support for software. Target plan and program replacement for not later than one year after manufacturers' end of support.

1-18 EXCESS FEATURES \1\ (AIR FORCE ONLY) /1/.

For Air Force, removal of existing installed fire protection features in excess of the minimum requirements for new construction established in UFC 3-600-01 is authorized in accordance with Air Force policy established by HQ USAF/A7C Memorandum, "Excess Fire Protection Features," 17 June 2008, and codified in this UFC. Removal of **\1** unrequired **/1/** features reduces unnecessary ITM requirements and unnecessary sustainment, repair, and maintenance costs. Features will not be removed reducing fire protection below the new construction level mandated in UFC 3-600-01. Consult with AFCEC/COS (afcec.rbc@us.af.mil) for additional information and guidance.

\1

1-19 REPLACEMENT PARTS.

Replacement parts must conform to the original equipment manufacturer's recommendations. When required parts are not available, see paragraph 1-16. Replace listed parts with listed parts conforming to the original listing standard or current edition of the standard when indicated by the manufacturer's recommendations. Listing by the original listing nationally recognized testing laboratory is not required.
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CHAPTER 2 FACILITY SYSTEMS

2-1 ITM METHODOLOGY.

The objective of ITM for fixed fire protection systems is to assure systems will function on demand. RCM analysis identifies any defects responsible for system malfunction and how they can be detected and corrected before a fire.

2-1.1 Features Requiring Maintenance.

All fire protection and life safety features installed in DoD facilities must be maintained in accordance with this UFC. Features disabled in place pending removal are not considered installed **\1** and do not require maintenance when appropriately locked and tagged as out-of-service pending removal **/1/**.

2-1.2 Non-required Features.

A critical component of any RCM program is ensuring the components being maintained are required to be present. Remove fire protection features not specifically required by UFC 3-600-01 to minimize the maintenance workload burden. Non-required features can be abandoned in place pending final removal if all public interface devices (for example, manual fire alarm pull stations) are removed.

2-2 ITM TASK DESCRIPTIONS AND FREQUENCIES.

2-2.1 Task Descriptions.

The ITM tasks in Tables 2-1 through 2-31 and 3-1 through 3-3 were selected to ensure the fire protection system will function on demand. Technical tasks must be performed according to the manufacturer's instructions.

2-2.1.1 Electrically Supervised Components.

Electrical supervision of components increases the likelihood that conditions or faults will be detected without an inspection activity. In these cases, the ITM task is to respond to the alarm and to test the supervisory device (for example, valve tamper switch) periodically. Accordingly, the tables reflect the improved fault or condition detection by specifying less frequent inspections. Different frequencies are recommended for monitored and for unmonitored fire alarm control equipment. A monitored system transmits supervisory and trouble conditions to a remote supervising station (for example, installation fire reporting system).

2-2.1.2 Event-Driven Tests.

Some tests **\1** will **/1/** be event driven. For example, a main drain test is specified to verify the open condition of a control valve on the water supply to a sprinkler or water spray system and needs to be performed when the control valve has been operated for maintenance or testing.

2-2.1.3 Excluded National Fire Code Tasks.

Some tasks recommended in the National Fire Codes are not included in these frequency tables. The detailed analysis documented in AFCESA/CES Technical Report 01-10, *Risk Based Reliability Centered Maintenance of DoD Fire Protection Systems,* excluded tasks that did not contribute to the overall system operational reliability and did not need to be performed. These deleted tasks do not improve the operability of the systems because: (1) the faults they detect are not significant; (2) the faults are detected by other tasks or means; or (3) the faults will be self-evident ("fix it when it breaks") and do not significantly impair the system. The deleted tasks are not required to be accomplished and must not be included in reoccurring maintenance programs.

2-2.1.4 Non-ITM Activities.

Inspection activities listed at the end of each ITM table are not part of the ITM program, but are part of building overall inspection and are listed for information only. They were not included in the model used to develop the 99 percent reliability requirements; however, they must be incorporated into each DoD Component activity's fire prevention, safety, facility condition, and related inspection or evaluation program.

2-2.1.5 Fire Extinguishers.

Maintenance of portable fire extinguishers and fire extinguisher cabinet maintenance is not addressed in this UFC.

2-2.2 Fire Detection and Alarm Systems.

The type and frequency of ITM tasks for fire detection and alarm systems depend on whether the system is monitored or not. Guidance on the tasks is contained in the "Inspection, Testing, and Maintenance" section of NFPA Standard 72 (NFPA 72), *National Fire Alarm and Signaling Code®*. Residential smoke alarms are addressed in Chapter 3 of this UFC.

WARNING

Fire alarm systems with abnormal conditions (multiple trouble conditions) are outside their minimum tested or listed operating parameters and may not meet their performance requirement for receipt or transmission of subsequent alarm or additional trouble conditions.
(Table 2-1, Task Monthly, 1.2 and Task Annual 2.5)

WARNING

Any fire alarm system with more than three unexplained activations (fire indication conditions) within a 6-month period is experiencing a system instability requiring evaluation by a qualified technician or engineer; **\1** implement **/1/** appropriate corrective measures immediately

CAUTION

Alarm systems in a single TROUBLE condition **\1** must **/1/** be able to transmit an ALARM condition while in trouble; however, because a TROUBLE condition is not a normal or acceptable alarm system status, immediate maintenance action is indicated. (Table 2-1, Task Monthly, 1.2; Task Annual 2.5; and Table 2-2, Task Annual 1.5)

CAUTION

The ITM tasks specified also apply to fire suppression releasing panels and fire detection devices for fire suppression releasing service. Personnel testing systems must be knowledgeable of and experienced with the operation of these fire suppression systems and the hazards involved with inadvertent activations of these systems. Prior to performing any of the testing described in the tables, secure the fire suppression system from inadvertent activation by disconnecting release solenoids or actuators; closing control valves; or performing other actions required to secure the systems during the testing period. **\1** Do not use bypass switches employing a system program as the sole means of safeguarding a releasing system. **/1/** (Table 2-1, Task Annual 3.b.1 and 3.b.6; and 2-year Tasks 2.1 and 2.4)

Table 2-1 Fire Detection and Alarm System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Panels and Annunciator Equipment (unmonitored only)	1. Inspect panel condition (connections, fuses, light-emitting diodes [LEDs]). 2. Resolve any trouble indications.
Annually	1. Control Panel and Annunciator Equipment (monitored)	1. Test to verify proper receipt of alarm, supervisory, and trouble signals (inputs, one of each type) and operation of notification appliances and auxiliary functions (outputs, one of each type). 2. Verify all lamps and LEDs are illuminated. 3. Load test backup batteries using a meter (when provided). 4. Verify condition of power supplies and batteries. 5. Resolve any trouble indications.
	2. Remote Power Supplies and Notification Appliance Circuit Power Extenders	1. Verify all lamps and LEDs are illuminated. 2. Load test backup batteries using a meter (when provided). 3. Verify condition of power supplies and batteries.
	3. Initiating Devices: a. Manual Fire Alarm Stations	1. Verify station is accessible (visual).
	b. Radiant Energy-Sensing Detectors (optical detectors)	1. If used for releasing service, inhibit releasing function. 2. Test to verify alarm initiation and receipt. 3. Verify no facility change affects performance. 4. Verify alignment of the positioning markings at all adjustment locations. 5. If used for releasing service, configure system for automatic operation. 6. If used for releasing service, restore to releasing service.
	c. Gas Detectors	1. Test to verify alarm initiation and receipt. 2. Verify no facility change affects performance.

Frequency	Component	Tasks
	d. Carbon Monoxide Detectors	1. Test to verify alarm initiation and receipt. 2. Verify no facility change affects performance.
	4. Notification Appliances and Voice Communication (telephone, speakers, horns, and strobe lights)	1. Test to verify operability.
	5. Digital Alarm Transmitters and Receivers	1. Test to verify operability.
	6. Radio Alarm Transmitters and Receivers	1. Test to verify operability.
2 Years	1. Initiating Devices: a. Manual Fire Alarm Stations	1. Operate to verify alarm receipt.
	b. Heat Detectors (restorable) (Remove devices not required by UFC 3-600-01.)	1. Test with a heat source to verify alarm initiating and receipt. 2. Verify no facility change affects performance.
	c. Smoke Detectors (single-station detectors, system detectors, and air sampling detectors) (Remove devices not required by UFC 3-600-01 or other directives.)	1. Test with manufacturer-approved smoke simulant to verify smoke entry and alarm initiation and receipt. 2. Verify no facility change affects performance.
	d. Supervisory Devices (low air pressure, temperature, water level)	1. Test to verify initiation and receipt of supervisory alarm.
	2. Fire Suppression Devices (low air pressure, temperature, water level)	1. Inhibit releasing function. 2. Test to verify proper operation and system response. 3. Configure system for automatic operation. 4. Restore releasing function.

Frequency	Component	Tasks
5 Years	1. Smoke Detectors (Remove devices not required by UFC 3-600-01.)	1. Test detector sensitivity to ensure the detector has remained within its listed and marked sensitivity range (or 4 percent obscuration light gray smoke, if not marked).
10 Years	1. Carbon Monoxide Detectors	1. Replace detectors.
	2. Radiant Energy-Sensing Detectors (optical detectors)	1. Verify manufacturer's service life for detection elements. UV detection element's **\1\ /1/** service life is 10 years; others vary by manufacturer. 2. Replace detectors exceeding manufacturer's recommended service life for detection elements.
	3. **\1** Rate Compensated Detectors **/1/**	1. **\1** Replace detectors exceeding manufacturer's recommended service life. **/1/**
	4. **\1** Smoke Alarms (single station or interconnected **/1/**	1. **\1** Replace smoke alarms. **/1/**
20 Years **\1** and As Part of Other Building Inspection (not part of ITM requirements) **/1/**	1. Smoke Detectors **\1** not monitored internally or by the control panel for sensitivity or obscuration as appropriate, **/1/** (single-station detectors, and system detectors)	1. Replace detectors.

Frequency	Component	Tasks
	2. Air Sampling Smoke Detectors	1. Replace detection element.
	3. Control Panel and Annunciator Equipment	1. Verify manufacturer's service life for control elements. 2. Verify manufacturer has continued technical and parts support for the specific model. 3. Replace control equipment exceeding manufacturer's recommended service life limits or if the manufacturer has ceased to provide technical and parts support.
	4. Entire System	1. Visually check: a. Detectors unblocked and uncovered. b. Panels secured and indicator lamps functional. c. Notification appliances in place. d. Manual stations in place and unobstructed. 2. Exercise evacuation notification appliances for audibility, clarity, and visibility.

2-2.3 Mass Notification Systems.

Guidance on these tasks is contained in the *Inspection, Testing, and Maintenance* section of NFPA 72.

The inspection, testing, and maintenance of combined fire alarm and mass notification systems must comply with Section 2-2.2 in addition to this section.

Table 2-2 Mass Notification System ITM Tasks

Frequency	Component	Tasks
Annually	1. Fire Alarm Control Panel with Integrated Mass Notification (FMCP)	1. Test to verify proper receipt of signals (inputs) from Local Operating Consoles (LOCs) and the installation's site-wide system and operation of notification appliances and auxiliary functions (outputs). 2. Verify all lamps and LEDs are illuminated. 3. Load test backup batteries using a meter (when provided). 4. Verify condition of power supplies and batteries. 5. Resolve any trouble indications.
	2. LOCs	1. Verify station is accessible (visual).
	3. Notification Appliances and Voice Communication (speakers and strobe lights)	1. Test to verify operability.
	4. Text Message Signs	1. Test to verify operability.
2 Years	1. FMCP and LOCs	1. Operate microphone to verify proper operation. 2. Operate all pre-recorded message activation switches to verify proper operation. 3. Operate all notification zone selection switches, if provided, to verify proper operation.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. FMCP and LOCs are not blocked or obstructed. b. Panels secured and indicator lamps functional. c. Notification appliances in place. 2. Exercise notification appliances for audibility, clarity, and visibility.

2-2.4 Installation Fire Alarm Reporting Systems.

Reserved

2-2.5 Carbon Monoxide (CO) Detection.

Carbon monoxide detectors installed as initiating devices on fire alarm and detection systems are covered in Section 2-2.2. ITM requirements for single station carbon monoxide alarms installed in buildings without fire alarm systems are provided below. Guidance on the tasks is contained in the “Inspection, Testing, and Maintenance” section of NFPA 72.

Table 2-3 Carbon Monoxide (CO) Detection ITM Tasks

Frequency	Component	Tasks
Annually	1. Single Station Carbon Monoxide Alarms	1. Test to verify alarm activation. 2. Verify no facility change affects performance.
7-10 Years	1. Single Station Carbon Monoxide Alarms	1. Replace Detector

2-2.6 Hydrants and Monitors.

Technical guidance on the tasks is contained in UFC 3-230-02; American Water Works Association (AWWA) Manual 17 (M17), *Fire Hydrants: Installation, Field Testing, and Maintenance,* for hydrants and monitors supplied from potable distribution systems; and NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* for hydrants and monitors supplied by non-potable distribution systems. **\1** Accomplish **/1/** flow testing in accordance with AWWA M17, Chapter 6.

WARNING

Flow tests results that have decreased more than 20 percent from the previous test readings or the original acceptance readings indicate an emergency situation. In this case, immediate distribution system flow testing is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent to which the sprinkler systems are compromised. (Table 2-4, Task 5-Year 1.2 and Table 2-5, Task 5-Year 1.2)

CAUTION

Flow tests results that have decreased more than 10 percent from previous test readings or the original acceptance readings require immediate evaluation to determine the cause. (Table 2-4, Task 5-Year 1.2 and Table 2-5, Task 5-Year 1.2)

Table 2-4 Hydrant ITM Tasks

Frequency	Component	Task
2 Years	1. Hydrants (public and private potable water distribution systems) 2. Hydrants - dedicated fire protection water distribution systems 3. Hydrants - reuse (gray) water systems if specifically installed to meet a fire protection requirement.	1. Inspect for accessibility, leaks, and worn threads. 2. Lubricate hydrant to ensure ease of operation. 3. Flush the hydrant not less than 1 minute or until water runs clear, whichever is longer. 4. Verify drainage of barrel (after all operations and before cold weather).
5 Years	1. Underground and Exposed Piping	1. Conduct flow tests as recommended by AWWA M17, Chapter 6. Coordinate with the 2-year ITM tasks whenever possible. **\1** Not less than **/1/** 20 percent of the installation's hydrants must be tested each year. At the end of **\1** each **/1/** 5-year cycle, every hydrant must have had a flow test conducted and recorded. Select test hydrants **\1** to ensure **/1/** piping condition/flow capability in each area of the installation is verified **\1** each year **/1/**.) 2. Document flow test results and provide a copy to the fire and emergency service organization delivering fire suppression services for the installation. 3. Verify results are within acceptable limits or identify corrective measures.
After Flow	1. Strainers	1. Inspect and clean after each flow.
As Required	1. Hydrants	1. Apply protective coatings (paint) to prevent corrosion. 2. Identify by hydrant barrel color code the water distribution system to which the hydrant is connected, per AWWA Standards: a. potable water b. non-potable fire protection water c. non-potable reuse (gray) water 3. Identify by hydrant bonnet (top) color code the water flow available from the hydrant. (Color codes follow AWWA or NFPA 291 recommendations **\1** unless local alternatives are officially adopted **/1/**.)
Following System or	1. Underground Distribution and Valves.	1. Conduct flow tests as recommended by AWWA M17, Chapter 6. **\1\ /1/**

Frequency	Component	Task
Hydrant Modification or Repair		

Table 2-5 Yard Hydrant Monitors and Hose Houses ITM Tasks

Frequency	Component	Task
2 Years	1. Yard Monitor Nozzles (**\1** dedicated fire protection water distribution systems and **/1/** non-potable systems)	1. Inspect for condition. 2. Conduct flow test to verify proper function and range of motion. 3. Lubricate to ensure proper operating conditions.
	2. Hose Houses	1. Inspect for accessibility and physical condition. 2. Verify inventory and equipment condition. 3. Replace hose that has exceeded the expected service life.
5 Years	1. Underground and Exposed Piping	1. Conduct flow tests as recommended by AWWA M17 Chapter 6. (**\1** Not less than **/1/** 20 percent of the installation's hydrants **\1** must **/1/** be tested each year. At the end of **\1** each **/1/** 5-year cycle, every hydrant has had a flow test conducted and recorded. **\1\ /1/** 2. Document flow test results. 3. Verify results are within acceptable limits or identify corrective measures.
After Flow	1. Strainers	1. Inspect and clean after each flow.

2-2.7 Water Supply Tanks.

Technical guidance on these tasks is contained in NFPA 22, *Standard for Water Tanks for Private Fire Protection,* and NFPA 25.

Table 2-6 Water Supply Tank ITM Tasks

Frequency	Component	Tasks
Weekly (during freezing weather)	1. Tank Heating System (without electric supervision)	1. Verify water temperature. 2. Verify operability of tank heaters.
Monthly	1. Control Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
Quarterly	1. Water Level (without remote supervision of water level)	1. Verify proper water level in tank.
Before the Onset of Freezing Weather	1. Tank Fill Valve Enclosure Heating	1. Verify operability at the beginning of the heating season (annually for constant cold areas).
	2. Low Temperature Alarm	1. Verify initiation and receipt of alarm at the beginning of the heating season.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Water Level (with remote electric supervision of water level)	1. Verify proper water level in tank.
	3. Tank Heating System (with remote electric supervision of water temperature)	1. Verify operability of tank heater (prior to cold weather). 2. Test temperature alarms to verify proper operation. (Maintain thermometer in accordance with manufacturer’s recommendations.)
	4. Tank	1. Inspect exterior for condition, damage, corrosion, and accessibility. 2. Verify air pressure (for pressure tanks).
	5. Cathodic Protection	1. Inspect to ensure proper operation.
2 Years	1. Control Valves (including drain valves)	1. Operate valve through entire travel to verify function. 2. Lubricate valves to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Water Level Alarms and Level Indicators	1. Test water level alarms to verify operability and set points.

Frequency	Component	Tasks
	3. Automatic Fill Valve	1. Actuate valve automatically by lowering the water level in the tank. 2. Measure refill rate and record data.
	4. Tank Vent	1. Inspect and clean tank vents.
3 Years	1. Tank (without cathodic protection)	1. Conduct internal tank inspection to determine condition and amount of corrosion.
5 Years	1. Tanks (with cathodic protection)	1. Conduct internal tank inspection to determine condition and amount of corrosion.
	2. Pressure Gauges	1. Calibrate or replace gauges.
	3. Check Valves	1. Inspect interior of valves.
	4. Level Indicator Test	1. Calibrate level indicator.
	5. Automatic Fill Valve	1. Perform internal inspection of automatic fill valve.

2-2.8 Fire Pumps.

Technical guidance on these tasks is contained in NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* and NFPA 25. When generators are installed specifically to meet fire protection requirements, or generators are used to provide standby power for fire pumps, conduct all the requirements related to the engine drives on the generator engines. These requirements must not supersede requirements for generators serving demands other than fire protection. Generators serving both fire protection and other demands must conform to the most stringent guidance.

WARNING

Fire pump systems with redundant pumps must have all pumps and pump drivers in-service to meet redundancy requirements. Redundant pumps are not spare or stand-by pumps. Redundant pumps ensure the minimum number pumps will start if any minimum required pump fails to start. A redundant pump out-of-service means the pumping capacity is degraded/impaired and any supported fire protection features downstream are degraded/impaired. Two or more pumps out-of-service where there is redundancy means the pumping system is out-of-service as are all the supported fire protection features downstream. (Table 2-7, Tasks Monthly 6.1)

WARNING

Fire pump stations without redundant pumps must have all pumps and pump drivers in-service. A pump or pump driver out-of-service means the pumping capacity is out-of-service and any supported fire protection features downstream are out-of-service. (Table 2-7, Tasks Monthly 6.1)

Table 2-7 Fire Pump ITM Tasks

Frequency	Component	Tasks
Monthly	1. Pump House	1. Inspect for proper condition, ventilation, and heating. 2. Check packing leakage for proper water lubrication. 3. Verify proper drainage.
	2. Control Valves and Isolation Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
	3. Pressure Gauges	1. Check reading and verify gauge operability.
	4. Controllers	1. Verify automatic controllers are in the automatic (AUTO) setting. 2. Inspect electric connections. 3. Operate manual and automatic starting methods. 4. Resolve all trouble indications.
	5. Batteries	1. Verify proper charge. (Replace batteries in accordance with the driver manufacturer's recommendations or when the full recharged battery voltage or current falls below either the driver or battery manufacturer's recommendations.)
	6. Pumps	1. Start and churn to verify operability. (Where equipment permits, allow water to flow back to the source.) [Operate electric pumps for 10 minutes and operate engine-driven pumps for 30 minutes.] 2. Verify operation of relief valves. 3. Verify fuel level (for engine-driven pumps). 4. Inspect exhaust system for leaks (for engine-driven pumps). 5. For engine driven pumps, start again using second battery set and churn to verify operability. (Where equipment permits, allow water to flow back to the source.)

Frequency	Component	Tasks
Semi-Annually	1. Fuel (**\1** combustion engine-drivers **/1/**)	1. **\1** Verify fuel level if not supervised. **/1/**
Annually	1. Control Valves (sealed, locked, and electrically supervised)	1. Verify proper valve position.
	2. **\1** Combustion Engine Drivers **/1/**	1. **\1** Change all fluids per manufacturer's guidance. 2. Change all filters per manufacturer's guidance. **/1/**
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Controllers	1. Calibrate pressure switches. 2. Exercise circuit breakers and switches to verify operability. 3. Inspect fuses.
	3. Pumps	1. Check coupling alignment to ensure the shaft is aligned. 2. Check pump shaft endplay. 3. Lubricate bearings. 4. Lubricate couplings. 5. Lubricate right-angle drives.
	4. Relief Valves	1. Calibrate valves.
	5. Emergency Power Supply	1. Test to verify availability and capacity for pump motor.
	6. **\1** Fuel (combustion engine-drivers) **/1/**	1. **\1** Sample fuel and test to verify quality. **/1/**
5 Years	1. Pump	1. Conduct flow test to verify pump output. Test **\1** will **/1/** be through a flow meter returning the water to a storage reservoir or through the test header. Recirculation of water to the suction piping is not permitted. In a multi-pump installation, each pump may be tested separately at not less than 100 percent design capacity for 30 minutes. 2. Verify the results are within acceptable limits or identify corrective measures.
	2. Gauges and Flow Meters	1. Calibrate or replace flow meter prior to fire pump flow test.
\1 As Required **/1/**	1. **\1** Generators Providing Emergency	1. **\1** Follow Service-specific generator maintenance guidance for

Frequency	Component	Tasks
	Power to Electric Fire Pumps When Required. **/1/**	emergency/standby generators. **/1/**

2-2.9 Backflow Prevention Devices.

Technical guidance on the tasks is contained in UFC 3-230-02 and AWWA Manual 14 (M14). Backflow prevention and cross-connection devices are considered part of the water distribution system; however, their maintenance and full operation is critical to the function of fire suppression systems supplied by the potable distribution system. UFC 3-230-02 requires each installation to have a backflow prevention and cross-connection maintenance program. All backflow prevention devices are required to have a test connection downstream of the backflow device capable of flowing the fire protection system's maximum fire flow demand. Reduced pressure backflow prevention devices have a specific approved friction loss operating range; full flow testing is required to demonstrate the device is operating within the manufacturer's listed friction loss curves.

Table 2-8 Backflow Prevention Device ITM Tasks

Frequency	Component	Tasks
Annually	1. All Backflow Prevention Devices	1. Conduct full flow test to ensure flow and pressure meet or exceed system demand.
5 years	1. All Backflow Prevention Devices	1. Conduct internal inspection of backflow prevention assembly to verify all components operate correctly, move freely, and are in good condition.

2-2.10 Standpipe Systems.

Detection devices for actuation, where provided, are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on the tasks is contained in NFPA 14, *Standard for the Installation of Standpipes and Hose Systems,* and NFPA 25.

Table 2-9 Standpipe Systems ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
Semi-Annually	1. Hose Connection and Pressure Reducing Valves	1. Inspect for damage, leaking, missing caps, and obstructions.

Frequency	Component	Tasks
Annually	1. Fire Department Connections	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
2 Years	1. Piping	1. Inspect for damage to piping and pipe supports.
	2. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate stem. 3. Verify valve supervisory switches detect a change in valve position. 4. Verify proper valve position
5 Years	1. Standpipe	1. Conduct flow test to verify flow capacity and minimum discharge pressure. (Test must confirm only flow/pressure -- not duration of supply). 2. Hydrostatic test to ensure integrity (dry standpipe systems only).
	2. Pressure Reducing Hose Valves	1. Conduct flow test to verify operation of pressure reducing hose valves (test to confirm pressure and flow). 2. Confirm setting of pressure reducing hose valves.
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. connections for obstruction c. piping for leaks d. riser condition

2-2.11 Wet Pipe Automatic Sprinkler Systems.

Technical guidance on the tasks is contained in NFPA 25. Residential sprinkler systems are addressed in Chapter 3.

WARNING

Main drain static or residual test pressures that have decreased more than 20 percent from the original acceptance readings or the previous test readings indicate an **\1\ /1/** emergency situation. In this case, immediate distribution system flow testing is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent to which the sprinkler systems are compromised. (Table 2-10, Task Annual 4.3)

CAUTION

Main drain static or residual test pressures that have decreased more than 10 percent from the previous test readings require immediate evaluation to determine the cause. (Table 2-10, Task Annual 4.3)

Table 2-10 Wet Pipe Sprinkler System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seal, lock, or electric supervision)	1. Verify proper valve position.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Water Flow Alarm Devices	1. Verify initiation and receipt of alarm (alternate use of alarm test line and inspector's test connection annually). 2. Verify operation of exterior water flow alarm (if present). 3. Verify alarm test valve alignment and tamper switch (if sealed or electrically supervised).
	3. Alarm Valve and Trim	1. Visually check the exterior of valves, gauges, trim alignment. 2. Verify valve pressure and legibility of the hydraulic nameplate.

Frequency	Component	Tasks
	4. Main Drain	1. Conduct a main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.
	5. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions **\1** and replace missing caps/covers **/1/**. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
5 Years	1. Alarm Valve	1. Clean and inspect internally to verify condition.
	2. Anti-freeze Loops	1. Determine solution type. If solution type is no longer permitted or cannot be positively identified, drain system completely and replace with an acceptable solution. 2. Confirm correct solution mixture.
	3. Strainers	1. Inspect internally and clean to good condition.
	4. Automatic Air Release Valve	1. Confirm proper operation.
10 Years	1. Gauges	1. Calibrate or replace gauges.
	2. Dry Barrel Sprinklers	1. Replace all sprinklers. **\1**[1]**/1/**
20 Years **\1** and Every 10 Years Thereafter **/1/**	1. **\1** Fast-Response Sprinklers and Extra High Temperature Sprinklers **/1/**	1. Replace all **\1** sprinklers or test a sample of sprinklers to verify response characteristics.[1] **/1/**
50 Years and Every 20 Years Thereafter	1. Standard Sprinklers	1. Replace all sprinklers or test a sample of sprinklers to verify response characteristics. **\1**[1]**/1/**

Frequency	Component	Tasks
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. sprinklers for obstruction c. piping for leaks d. riser condition e. verify sprinkler spares

\1[1]**/1/** A representative sample of sprinklers for testing must consist of one (1) percent of the sprinklers installed of the same type, with a minimum of four (4) sprinklers sampled. Submit sprinklers to a **\1** nationally **/1/** recognized testing laboratory for these tests.

2-2.12 Dry Pipe Automatic Sprinkler Systems.

Technical guidance for these tasks is contained in NFPA 25.

WARNING

Main drain static or residual test pressures that have decreased more than 20 percent from the original acceptance readings or the previous test readings indicate an **\1\ /1/** emergency situation. In this case, immediate distribution system flow testing is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent to which the sprinkler systems are compromised. (Table 2-11, Task Annual 4.3)

CAUTION

Main drain static or residual test pressures that have decreased more than 10 percent from the previous test readings require immediate evaluation to determine the cause. (Table 2-11, Task Annual 4.3)

Table 2-11 Dry Pipe Automatic Sprinkler System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seal, lock, or electric supervision)	1. Verify proper valve position.
Before the Onset of Freezing Weather	1. Low Point Drains	1. Drain all low points to remove condensation prior to the cold season.
	2. Dry Pipe Alarm Valve Enclosure Heating	1. Verify operability at the beginning of the heating season (annually for constant cold areas).
	3. Low Temperature Alarm	1. Verify initiation and receipt of alarm at the beginning of the heating season.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Water Flow Alarm Devices	1. Operate alarm test valve to verify initiation and receipt of alarm. 2. Verify alarm test valve alignment and tamper switch (if sealed or electrically supervised).
	3. Dry Pipe Alarm Valve and Trim	1. Visually inspect the exterior of valves, gauges, trim alignment. 2. Verify valve pressure and legibility of the hydraulic nameplate. 3. Verify valve position of provided quick opening devices are in the normal position.
	4. Main Drain	1. Conduct main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.

Frequency	Component	Tasks
	5. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
	6. Low Point Drains	1. Drain all low points to remove condensation prior to the cold season.
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Dry Pipe Alarm Valves	1. Trip valve to verify operability. 2. Inspect internal condition before resetting and clean valve seat. 3. Check priming water level (before and after trip test).
	3. Quick-Opening Devices	1. Test to verify operability.
	4. Low/High Air Pressure Alarms	1. Test to verify initiation and receipt of supervisory alarms.
	5. Automatic Air Pressure Maintenance Devices	1. Inspect to verify proper operation.
5 Years	1. Strainers	1. Inspect internally and clean to verify condition.
10 Years	1. Gauges	1. Calibrate or replace gauges.
10 Years	1. Dry Barrel Sprinklers	1. Replace all.[1]
20 Years **\1** and Every 10 Years Thereafter **/1/**	1. **\1** Fast-Response Sprinklers and Extra High Temperature Sprinklers **/1/**	1. Replace all **\1** sprinklers or test a sample of sprinklers to verify response characteristics.[1] **/1/**
50 Years and Every 20 Years Thereafter	1. Standard Sprinkler	1. Replace all sprinklers or test a sample of sprinklers to verify response characteristics. **\1**[1]**/1/**
Following System Modification or	1. Main Drain (following maintenance or repair	1. Conduct main drain test to verify supply (valve position).

Frequency	Component	Tasks
Repair	action requiring the water supply to be shut off)	2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify the results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch x 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. sprinklers for obstruction c. piping for leaks d. riser condition e. sprinkler spares

\1[1]**/1/** A representative sample of sprinklers for testing must consist of one (1) percent of the sprinklers installed of the same type, with a minimum of four (4) sprinklers sampled. The sprinklers must be submitted to a **\1** nationally **/1/** recognized testing laboratory for these tests.

2-2.13 Deluge Sprinkler Systems.

Detection devices for actuation are addressed in Section 2-2.2, “Fire Detection and Alarm Systems.” Technical guidance on these tasks is contained in NFPA 25 and NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

WARNING

Main drain static or residual test pressures that have decreased more than 20 percent from the original acceptance readings or the previous test readings indicate a **\1\ /1/** emergency situation. In this case, immediate distribution system flow testing is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent to which the sprinkler systems are compromised. (Table 2-12, Task Annual 4.3)

CAUTION

Main drain static or residual test pressures that have decreased more than 10 percent from the previous test readings require immediate evaluation to determine the cause. (Table 2-12, Task Annual 4.3)

Table 2-12 Deluge Sprinkler System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seal, lock, or electric supervision)	1. Verify proper valve position.
Before the Onset of Freezing Weather	1. Valve and Riser Heated Enclosure (if provided)	1. Verify operability at the beginning of the heating season.
	2. Low Temperature Alarm	1. Verify initiation and receipt of alarm at the beginning of the heating season.
	3. Low Point Drains	1. Drain all low points after deluge valve test and before cold weather.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Water Flow Alarm Devices	1. Operate alarm test valve to verify initiation and receipt of alarm. 2. Verify alarm test valve alignment and tamper switch (if sealed or electrically supervised).
	3. Deluge Alarm Valve and Trim	1. Inspect exterior of valves, gauges, trim alignment. 2. Verify valve pressure and legibility of hydraulic nameplate.
	4. Main Drain	1. Conduct a main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.
	5. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.

Frequency	Component	Tasks
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Deluge Valve	1. Trip to verify operability. 2. Verify manual actuators are operable. 3. Inspect internal condition and clean valve seat before resetting.
	3. Low Point Drains	1. Drain all low points after each valve trip.
5 Years	1. Strainers	1. Inspect internally and clean to verify condition.
10 Years	1. Gauges	1. Calibrate or replace.
	2. Deluge Valve	1. Conduct full flow test.
	1. Distribution System	1. Verify nozzle (sprinkler) coverage during flow test. 2. Inspect piping and nozzles for condition and location.
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. sprinklers/nozzles for obstruction c. piping for leaks d. riser condition e. sprinkler spares 2. Ensure: a. manual stations are in place and unobstructed. b. detectors are unblocked/uncovered. c. panels are secured and indicator lamps functional. d. notification appliances are in place.

2-2.14 Pre-Action Automatic Sprinkler Systems.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 25.

WARNING

Main drain static or residual test pressures that have decreased more than 20 percent from the original acceptance readings or the previous test readings indicate an **\1\ /1/** emergency situation. In this case, immediate distribution system flow is indicated. Immediately conduct main drain tests on all adjacent sprinkler testing systems to determine the extent to which the sprinkler systems are compromised. (Table 2-13, Task Annual 4.3)

CAUTION

Main drain static or residual test pressures that have decreased more than 10 percent from the previous test readings require immediate evaluation to determine the cause. (Table 2-13, Task Annual 4.3)

Table 2-13 Pre-Action Automatic Sprinkler System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seal, lock, or electric supervision)	1. Verify proper valve position.
Before the Onset of Freezing Weather	1. Valve and Riser Heated Enclosure (if provided)	1. Verify operability at beginning of heating season.
	2. Low Temperature Alarm	1. Verify initiation and receipt of alarm at the beginning of the heating season.
	3. Low Point Drains	1. Drain all low points before cold weather (if unheated area).
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Water Flow Alarm Devices	1. Operate alarm test valve to verify initiation and receipt of alarm. 2. Verify alarm test valve alignment and tamper switch (if sealed or electrically supervised).
	3. Pre-Action Valve and Trim	1. Inspect exterior of valves, gauges, trim alignment. 2. Verify valve pressure and legibility of hydraulic nameplate.

Frequency	Component	Tasks
	4. Main Drain	1. Conduct a main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.
	5. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Pre-Action Valve	1. Trip to verify proper operation. 2. Verify function of manual actuators (if provided). 3. Inspect internal condition and clean valve seat before resetting.
	3. Low Point Drains	1. Drain all low points after pre-action valve trip test.
	4. Air Supply (if present)	1. Test automatic air pressure maintenance device. 2. Test low/high air supply alarms.
5 Years	1. Strainers	1. Clean and inspect interior to verify condition.
10 Years	1. Gauges	1. Calibrate or replace gauges.

Frequency	Component	Tasks
10 Years, and Every 10 Years Thereafter	1. Dry Sprinklers	1. Replace all sprinklers or test a sample of sprinklers to verify response characteristics.[1]
20 Years, and Every 10 Years Thereafter	1. Fast-Response Sprinklers and Extra High Temperature Sprinklers	1. Replace all sprinklers or test a sample of sprinklers to verify response characteristics. **\1**[1]**/1/**
50 Years, and Every 10 Years Thereafter	1. Standard Sprinklers	1. Replace all sprinklers or test sample closed-head sprinklers to verify response characteristics. **\1**[1]**/1/**
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. sprinklers for obstruction c. piping for leaks d. riser condition e. sprinkler spares 2. Ensure: a. manual stations are in place and unobstructed. b. detectors are unblocked/uncovered. c. panels are secured and indicator lamps functional. d. notification appliances are in place.

\1[1]**/1/** A representative sample of sprinklers for testing must consist of one (1) percent of the sprinklers installed of the same type, with a minimum of four (4) sprinklers sampled. The sprinklers must be submitted to a **\1** nationally **/1/** recognized testing laboratory for these tests.

2-2.15 Nitrogen Generation Systems.

Technical guidance for these tasks is contained in NFPA 25 and the manufacturer's recommendations.

Table 2-14 Nitrogen Generation System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Generation System	1. Verify generation system is free of physical damage. 2. Verify proper valve positions. 3. Verify generation system is in **\1** automatic **/1/** operating condition. 4. Verify the power wiring to the generation system is free of physical damage. 5. Verify piping from generation system to system served is intact and free of physical damage.
Annually	1. Filter Elements	1. Replace the activated carbon and coalescing filter elements.
	2. Intake Filters	1. Clean the air compressor intake filter elements, replace intake filters if necessary.
	3. Strainer Screens	1. Clean air tank blow-down strainer screens.
	4. System Concentration	1. Verify the generation system is maintaining a nitrogen composition of 98% in the system served. Verify nitrogen composition at remote test locations.
2 Years	1. System Operation	1. Verify generation system operates on the proper pressure drop and ceases operation at the proper set point. 2. Verify generation system does not overheat or present any unusual noise or vibration during operation. 3. Verify the means of anchoring the generation system to the structure is secure, tight, and free of physical damage.
	2. Safety Relief Valves	1. Manually test safety relief valves.
5 Years	1. Leakage Test	1. Inspect system served by generation system for leaks by conducting a pressure loss test.
	2. System Performance	1. Verify generation system restores **\1\\ /1/**gas pressure and concentration in the system served within the required timeframe.

2-2.16 Water Spray Systems.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 25.

WARNING

Main drain static or residual test pressures that have decreased more than 20 percent from the original acceptance readings or the previous test readings indicate an **\1\ /1/** emergency situation. In this case, immediate distribution system flow testing is indicated. Immediately conduct main drain tests on all adjacent sprinkler systems to determine the extent the sprinkler systems are compromised. (Table 2-15, Task Annual 4.3)

CAUTION

Main drain static or residual test pressures that have decreased more than 10 percent from the previous test readings require immediate evaluation to determine the cause. (Table 2-15, Task Annual 4.3)

Table 2-15 Water Spray System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seal, lock, or electric supervision)	1. Verify proper valve position.
Before the Onset of Freezing Weather	1. Valve and Riser Enclosure Heater	1. Verify operability at the beginning of the heating season.
	2. Low Temperature Alarm	1. Verify initiation and receipt of alarm at the beginning of the heating season.
	3. Low Point Drains	1. Drain all low points before cold weather.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Water Flow Alarm Devices	1. Operate to verify initiation and receipt of alarm. 2. Verify alarm test valve alignment and tamper switch (if sealed or electrically supervised).
	3. Deluge Valve and Trim	1. Inspect exterior of valves, gauges, trim alignment. 2. Verify valve pressure and legibility of hydraulic nameplate.

Frequency	Component	Tasks
	4. Main Drain	1. Conduct a main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.
	5. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Water Spray Valve	1. Trip to verify operability. 2. Verify manual actuators (if provided). 3. Inspect interior of valve and clean valve seat before resetting.
	3. Low Point Drains	1. Drain all low points after pre-action valve trip test.
	4. Distribution System	1. Verify nozzle (sprinkler) coverage during flow test. 2. Verify spray pattern. (If experience shows nozzles are not moved, this can be extended to 10 years or after modifications.) 3. Inspect piping hangers, sprinklers, and nozzles for condition and location.

Frequency	Component	Tasks
5 Years	1. Strainers	1. Clean and inspect interior to verify condition.
10 Years	1. Gauges	1. Calibrate or replace.
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. sprinklers for obstruction c. piping for leaks d. riser condition e. sprinkler spares 2. Ensure: a. manual stations are in place and unobstructed. b. detectors are unblocked/uncovered. c. panels are secured and indicator lamps functional. d. notification appliances are in place.

2-2.17 Water Mist Systems.

Table 2-16 lists required ITM tasks for high-pressure water mist systems. Detection devices for actuation are addressed in Section 2-2.2, “Fire Detection and Alarm Systems.” Technical guidance on these tasks is contained in NFPA 25 and NFPA 750, *Standard on Water Mist Fire Protection Systems*.

Table 2-1 contains required ITM tasks for low-pressure water mist systems.

For hybrid water mist systems, use the specific manufacturer’s ITM frequencies and procedures.

Table 2-16 High Pressure Water Mist System ITM Tasks

Frequency	Component	Task
Weekly	1. Water Tanks (without electric remote supervision of water level)	1. Check water level.
	2. Air Compressor/Receiver/ Cylinders (without electric remote supervision of air pressure)	1. Check air pressure.
Semi-annually	1. Pumps	1. Complete churn test to ensure operability.
	2. Air Compressors	1. Start to ensure operability.
	3. System Operating Components	1. Inspect to verify valve is aligned and free of damage.
Annually	1. Water Tanks (remote electrically supervised and monitored)	1. Check water level detection device and supervisory controls.
	2. Air Compressors/Receivers/ Cylinders (electric remote supervision of air pressure)	1. Check air pressure and supervisory pressure switch.
	3. Water Flow Alarm	1. Operate to verify initiation and receipt of alarm.
	4. Pumps	1. Conduct full flow functional test.
	5. Pressure Relief Devices	1. Manually operate to ensure operability.
	6. Manual Actuators	1. Verify operability.
	7. Control Valve (sectional water supply valve)	1. Verify operability and position.
5 Years	1. Pressure Cylinders (normally at atmospheric pressure)	1. Pressurize to verify operability.
	2. System	1. Conduct flow test.
	3. Water	1. Verify water quality when refilling.
	4. Water Tanks	1. Drain and refill tank. 2. Inspect tanks for structural integrity (interior and exterior) prior to refilling.
	5. Water Mist Nozzles Subject to Harsh Environments	1. Replace all nozzles or test a sample of nozzles to verify response characteristics.[1]

Frequency	Component	Task
5-12 Years	1. Storage Vessels	1. Conduct hydrostatic test for pressure cylinders in accordance with OSHA and U.S. Department of Transportation (DOT) standards.
20 Years	1. Water Mist Nozzles in Areas Other Than Harsh Environments	1. Replace all nozzles or test a sample of nozzles to verify response characteristics.[1]
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. nozzles for obstruction c. piping for leaks d. riser condition e. nozzle spares 2. Ensure: a. manual stations are in place and unobstructed. b. detectors are unblocked/ uncovered. c. panels are secured and indicator lamps functional. d. notification appliances are in place.

\1[1]**/1/** A representative sample of nozzles for testing must consist of one (1) percent of the nozzles installed of the same type, with a minimum of four (4) nozzles sampled. The nozzles must be submitted to a **\1** nationally **/1/** recognized testing laboratory for these tests.

2-2.18 Foam and Foam-Water Systems.

WARNING

Use of any fire suppression foam concentrate or solution containing per- or poly-fluorinated alkylated substances (PFAS) for inspection, test, and maintenance is not permitted

WARNING

Release of any fire suppression foam concentrate, **\1** solution, or testing surrogates, **/1/** regardless of chemical composition, during inspection, test, and maintenance to the environment, is not permitted.

CAUTION

Release of any non-PFAS foam concentrate, solution, or testing surrogates to a regulated waste stream including industrial or sanitary treatment facilities must be fully permitted and authorized by the system operator and by appropriate regulatory authorities.

Table 2-17 addresses low-expansion foam systems for **\1** ignitable **/1/** liquid tanks as covered in NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam.* Table 2-18 addresses low-expansion foam spray and sprinkler systems, including AFFF, as covered in NFPA **\1** 11 **/1/**. Table 2-19 addresses low-expansion foam monitor nozzle systems for multiple applications as covered in NFPA 11. Table 2-20 addresses low-expansion grate nozzle foam systems for aircraft hangar applications as covered in NFPA 11. Table 2-21 addresses high-expansion foam systems as covered in NFPA 11.

Detection devices for actuation are addressed in Section 2-2.2, “Fire Detection and Alarm Systems.”

\1

2-2.18.1 Disposal of Foam Concentrates.

All foam concentrates, foam-water solutions, or testing surrogates discharged during ITM processes must be contained, collected, and disposed of in accordance with current environmental guidance (Title 15 United States Code (U.S.C.) Chapter 115, *Perfluoroalkyl and Polyfluoroalkyl Substances and Emerging Contaminants*).

Fluorine surfactant-based foam (commercial or military specification AFFF concentrate or solution waste) must be disposed of using approved methods. Removed parts including bladders and tanks contaminated with fluorine-based foams must be disposed of using approved methods.

2-2.18.2 PFAS-Containing Concentrates.

Replace all PFAS-containing foam concentrates with DoD- or Component-approved fluorine free foam concentrates not later than by 2024 unless extended by the Secretary of Defense to 2026.

The 2020 National Defense Authorization Act requires DoD to stop any non-emergency release of per- and polyfluoroalky (PFAS) substances, a broad group of chemicals including PFOA, PFOS, GenX, and others. The 2020 NDAA requires DoD to phase out the use PFAS substances by 2024 (SecDef extendable until 2026). AFFF (military specification and commercial products) and FFFP are PFAS-containing substances and will be phased out. Non-PFAS containing foam concentrates include high expansion foams (Hi-Ex), fluorine free foams (FFF), and testing surrogates, and are not affected by the 2020 NDAA phase-out. At the date Change 1 of this UFC, some Components have issued specific phase-out guidance; others are still developing guidance. Consult with the appropriate CFPE for additional/evolving information and guidance.

2-2.18.3 Maintenance of Locked Out/Tagged Out Systems.

Foam concentrate systems locked out/tagged out by Service/Agency specific direction do not require maintenance actions. Other system components remaining in service require maintenance appropriate the in-service components.

2-2.18.4 Systems Converting from AFFF to FFF.

Systems converted from Military Specification aqueous film forming foam (AFFF) to Military Specification fluorine free foam (FFF) MIL-PRF 72325 will continue to provide the maintenance actions for FFF as required for AFFF. FFF foam concentrate, and solution will require the same containment and mitigation action as AFFF. Release to ground, storm, or surface water is not permitted. Reporting of FFF releases/discharges will conform to Service specific environmental guidance.
/1/

Table 2-17 Low-Expansion Foam System for Ignitable Liquid Tank ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
Annually	1. Foam Concentrate	1. Inspect for quality and evidence of sludge or deterioration. 2. Take sample and test in accordance with manufacturer’s instructions.
	2. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	3. System Actuators	1. Confirm function of all manual and automatic actuation functions.
	4. Foam Concentrate Strainers	1. Inspect and clean if necessary.
	5. Distribution Piping/Discharge Devices	1. Ensure discharge devices are free of damage. 2. Inspect pipe and hangers to verify support and pitch.

Frequency	Component	Tasks
	6. Main Drain	1. Conduct main drain test to verify supply (valve position). 2 Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.
	7. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
2 Years	1. Foam Proportioning System/ Foam Pumps	1. Test to verify operability and proper proportioning (concentration must be within 10 percent of original acceptance test results, but no more than 10 percent below minimum design standard). 2. Flush pumps after operation.
	2. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
5 Years	1. Distribution Piping (including underground)	1. Spot-check piping interior for evidence of deterioration.
	2. Strainers (water supply)	1. Inspect and clean if necessary.
	3. Fire Department Connection	1. Hydrostatically test piping from the fire department connection to the fire department check valve at 150 psi (10 bar) for 2 hours.
10 Years	1. Foam Concentrate Tank	1. Drain, flush, and perform internal inspection for corrosion. If pressure vessel, perform hydrostatic test.

Frequency	Component	Tasks
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. generators for obstruction (air intake or foam discharge) c. generator nozzles for obstruction and generator screens for damage d. piping for leaks e. riser condition 2. Ensure: a. panels are secured and indicator lamps functional. b. notification appliances are in place. c. manual stations are in place and unobstructed.

Table 2-18 Low Expansion Foam Spray and Sprinkler System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seal, lock, or electric supervision)	1. Verify proper valve position.
Semi-Annually	1. Foam Concentrate	1. Inspect for quality and evidence of sludge or deterioration. 2. Verify adequate supply.
	2. Foam Proportioning System/ Foam Pumps (if provided)	1. Test pump to ensure operability. 2. Inspect proportioning system for proper valve alignment and system condition. 3. Flush pumps after operation.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.

Frequency	Component	Tasks
	2. Foam Concentrate	1. Take sample and test in accordance with manufacturer's instructions.
	3. Foam Concentrate Strainers	1. Inspect exterior to ensure blow down valve is closed.
	4. Main Drain	1. Conduct main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify **\1\ /1/** the results are within acceptable limits or identify corrective measures.
	5. Fire Department Connection	1. Verify accessibility and condition. 2. If caps are removed or missing, check for obstructions. 3. Verify system check valve is not leaking. 4. Verify gaskets are present. 5. Lubricate if swivels do not rotate smoothly. 6. Verify proper operation of ball drip drain prior to the cold season.
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
	2. Foam Proportioning System	1. Conduct full flow test to ensure proper system function. 2. Verify proper concentration (concentration must be within 10 percent of original acceptance test results, but no more than 10 percent below minimum design standard).
	3. Actuators	1. Verify operability of manual and automatic actuators.

Frequency	Component	Tasks
	4. Distribution System	1. Verify nozzle (sprinkler) coverage during flow test. 2. Inspect piping hangers, sprinklers, and nozzles for condition and location.
	5. Foam Concentrate Strainers	1. Inspect and clean after flow test.
5 Years	1. Balancing Valve	1. Flush to prevent concentrate buildup on diaphragm.
	2. Strainers (water supply)	1. Inspect and clean if necessary.
10 Years	1. Foam Concentrate Tank	1. Drain, flush, and perform internal inspection for corrosion. If pressure vessel, perform hydrostatic test.
20 Years, and Every 10 Years Thereafter	1. Fast-Response Sprinklers and Extra High Temperature Sprinklers	1. Replace all sprinklers or test a sample of sprinklers to verify response characteristics.[1]
50 Years, and Every 10 Years Thereafter	1. Standard Sprinklers	1. Replace all sprinklers or test sample closed head sprinklers to verify response characteristics.[1]
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify the results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.

Frequency	Component	Tasks
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. sprinklers/nozzles for obstruction c. piping for leaks d. riser condition e. sprinkler spares 2. Ensure: a. detectors are unblocked/uncovered. b. panels are secured and indicator lamps functional. c. notification appliances are in place. d. manual stations are in place and unobstructed.

\1[1]**/1/** A representative sample of sprinklers for testing must consist of one (1) percent of the sprinklers installed of the same type, with a minimum of four (4) sprinklers sampled. The sprinklers must be submitted to a **\1** nationally **/1/** recognized testing laboratory for these tests.

Table 2-19 Low Expansion Foam Monitor Nozzle System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
Annually	1. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
	2. Foam Concentrate	1. Inspect for quality and evidence of sludge or deterioration. 2. Inspect to verify adequate supply. 3. Take sample and test in accordance with manufacturer's instructions.
	3. Foam Concentrate Strainers	1. Inspect exterior to ensure blow down valve is closed.
	4. Nozzle and Nozzle Driver	1. Lubricate in accordance with manufacturer's directions. 2. Ensure nozzle elevation is set to not apply foam on aircraft surfaces. 3. Manually operate oscillation with garden hose to ensure proper movement and pattern.

Frequency	Component	Tasks
	5. Main Drain	1. Conduct main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify the results are within acceptable limits or identify corrective measures.
2 Years	1. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify the valve supervisory switches detect a change in valve position.
	2. Foam Proportioning System/Foam Pumps (if provided)	1. Conduct full flow test to ensure proper system function. (**\1** Perform test **/1/** using a test connection or through the foam nozzles. Discharge only until full foam flow appears from each nozzle; then end foam injection.) 2. Verify proper concentration. (Concentration must be within 10 percent of original acceptance test results, but no more than 10 percent below minimum design standard). 3. Flush pumps after operation.
	3. Actuators	1. Verify operability of manual and automatic actuators.
	4. Distribution System	1. Verify nozzle coverage during flow test (water only). 2. Inspect piping hangers and nozzles for condition and location.
	5. Foam Concentrate Strainers	1. Inspect and clean after flow test.
5 Years	1. Balancing Valve	1. Flush to prevent concentrate buildup on diaphragm.
	2. Strainers (water supply)	1. Inspect and clean if necessary.
10 Years	1. Foam Concentrate Tank	1. Drain, flush, and perform internal inspection for corrosion. If pressure vessel, perform hydrostatic test.

Frequency	Component	Tasks
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. nozzle for obstruction c. piping for leaks d. riser condition 2. Ensure: a. detectors are unblocked/ uncovered. b. panels are secured and indicator lamps functional. c. notification appliances are in place. d. manual stations are in place and unobstructed.

Table 2-20 Low Expansion Grate Nozzle Foam System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
Annually	1. Foam Concentrate	1. Inspect for quality and evidence of sludge or deterioration. 2. Inspect to verify adequate supply. 3. Take sample and test in accordance with manufacturer's instructions.
	2. Foam Nozzles	1. Inspect to verify condition.
	3. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.

Frequency	Component	Tasks
2 Years	1. Foam Nozzles	1. Conduct test to verify operability. (Test **\1\ /1/** with water only.)
	2. Actuators	1. Verify all manual and automatic actuator function.
	3. Foam Proportioning System/Foam Pumps (if provided)	1. Conduct full flow test to ensure proper system function. (**\1** Perform test using **/1/** a test connection or through the foam nozzles. Discharge only until full foam flow appears from each nozzle, then end foam injection.) 2. Verify proper concentration. (Concentration **\1** must **/1/** be within 10 percent of original acceptance test results, but no more than 10 percent below minimum design standard). 3. Flush pumps after operation.
	4. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
10 Years	1. Foam Concentrate Tanks	1. Drain, flush, and perform internal inspection for corrosion. If pressure vessel, perform hydrostatic test.
After Activation	1. Strainers	1. Inspect and clean after system actuation or flow test.
	2. Manual Pull Stations	1. Visually Inspect NEMA 4 pull stations to confirm seals prevented foam **\1** -water **/1/** from entering device. 2. Internally inspect all non-NEMA 4 pull stations for damage.
	3. Flushing	1. Flush system upon completion of any testing where foam concentrate has been introduced to the system.
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify results are within acceptable limits or identify corrective measures. 4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.

Frequency	Component	Tasks
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually Check: a. Pipe hangers, seismic bracing, and mounts. b. Nozzles for obstruction. c. Piping for leaks. d. Riser condition. 2. Ensure: a. Detectors unblocked/uncovered. b. Panels secured and indicator lamps functional. c. Notification appliances in place. d. Manual stations in place and unobstructed.

Table 2-21 High-Expansion Foam System ITM Tasks

Frequency	Component	Tasks
Monthly	1. Control Valves (without seals, locks, or electric supervision)	1. Verify proper valve position.
Annually	1. Foam Concentrate	1. Inspect for quality and evidence of sludge or deterioration. 2. Inspect to verify adequate supply. 3. Take sample and test in accordance with manufacturer's instructions.
	2. Foam Generator	1. Inspect to verify condition from ground level and proper valve alignment.
	3. Main Drain	1. Conduct main drain test to verify supply (valve position). 2. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge. 3. Compare results with results from previous main drain tests and original acceptance test. 4. Verify results are within acceptable limits or identify corrective measures.
	4. Control Valves (sealed, locked, or electrically supervised)	1. Verify proper valve position.
2 Years	1. Foam Generator	1. Conduct test to verify operability. (Water-powered **\1** must be accomplished **/1/** with water only.)

Frequency	Component	Tasks
	2. Actuators	1. Verify all manual and automatic actuators function.
	3. Foam Proportioning Systems/Foam Pumps (if provided)	1. Conduct full flow test to ensure proper system function. (**\1** Perform test **/1/** using a test connection. **\1\ /1/** 2. Verify proper concentration. (Concentration **\1** must **/1/** be within 10 percent of original acceptance test results, but no more than 10 percent below minimum design standard.) 3. Flush pumps after operation.
	4. Control Valves	1. Operate valve through entire travel to verify function. 2. Lubricate valves and stems to ensure operability. 3. Verify valve supervisory switches detect a change in valve position.
After Water-only Test and Foam Flow Test	1. Strainers	1. Inspect and clean after flow test.
After System Activation	1. Strainers	1. Inspect and clean after system activation.
	2. Manual Pull Stations	1. Visually inspect NEMA 4 pull stations to confirm seals prevented foam from entering device. 2. Internally inspect all non-NEMA 4 pull stations for damage **\1** or foam or moisture incursion. 3. Replace all pull stations indicating foam or moisture incursion. **/1/**
	3. Control Panels	1. Internally inspect all system control units exposed to foam.
	4. Flushing	1. Flush system upon the completion of any testing where foam concentrate has been introduced to the system.
10 Years	1. Foam Concentrate Tank	1. Drain, flush, and perform internal inspection. If pressure vessel, perform hydrostatic test.
Following System Modification or Repair	1. Main Drain (following maintenance or repair action requiring the water supply to be shut off)	1. Conduct main drain test to verify supply (valve position). 2. Compare results with results from previous main drain tests and original acceptance test. 3. Verify the results are within acceptable limits or identify corrective measures.

Frequency	Component	Tasks
		4. Document static and residual pressure readings on a 3-inch by 5-inch tag and secure it to the system pressure gauge.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers and seismic bracing b. generators for obstruction (air intake or foam discharge) c. generator nozzles for obstruction and generator screens for damage d. piping for leaks e. riser condition 2. Ensure: a. detectors are unblocked/uncovered. b. panels are secured and indicator lamps functional. c. notification appliances are in place. d. manual stations are in place and unobstructed.

2-2.19 Dry Chemical Systems.

Automatic initiating devices (for example, heat detectors, smoke detectors) used for system actuation are addressed in Section 2-2.2, “Fire Detection and Alarm Systems.” Technical guidance for these tasks is contained in NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

There is no requirement to replace existing dry chemical systems protecting cooking surfaces, hoods, and ducts. These existing systems passing the required ITM may continue in service, and these systems may be serviced and repaired as necessary. Existing systems protecting cooking surfaces, hoods, and ducts may not be removed and reinstalled at another location even if the systems met all ITM requirements. All new or replacement systems to protect cooking surfaces, hoods, and ducts must **\1** meet the requirements of UFC 3-600-01 **/1/**.

Table 2-22 Dry Chemical System ITM Tasks

Frequency	Component	Tasks
Semi-Annually	1. Hazard	1. Verify the hazard has not changed.
	2. Piping	1. Inspect piping for obstructions and proper support. 2. Verify presence of required blow-off caps. 3. Verify nozzles are appropriately aimed at the hazard.
	3. Storage Vessels	1. Inspect agent container for condition. 2. Verify storage pressure of propellant.
	4. Agent	1. Verify quantity of agent through ultrasonic measuring.
	5. Actuators	1. Inspect manual actuators for accessibility. 2. Inspect detection devices (fusible links or heat detectors) for contamination, and clean. 3. Test actuation system without agent release. (Coordinate with annual replacement of fixed temperature sensing elements.) 4. Verify interfaces (gas shutoff, power shutoff) operate properly. 5. Replace fixed temperature sensing elements (fusible links/metal alloy type).
5-12 Years	1. Storage Vessels	1. Conduct hydrostatic test for pressure cylinders in accordance with OSHA and DOT standards.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. nozzles for obstruction c. pipe condition 2. Ensure: a. detectors are unblocked/uncovered. b. panels are secured and indicator lamps are functional. c. notification appliances are in place. d. manual stations are in place and unobstructed. e. nozzle covers (blow-off caps) are in place. f. pressure gauge is within operating range.

2-2.20 Wet Chemical Systems.

Automatic initiating devices (for example, heat detectors, smoke detectors) used for system actuation are addressed in Section 2-2.2, “Fire Detection and Alarm Systems.” Technical guidance on these tasks is contained in NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*.

Table 2-23 Wet Chemical System ITM Tasks

Frequency	Component	Tasks
Semi-Annually	1. Hazard	1. Verify hazard has not changed.
	2. Piping	1. Inspect piping for obstructions and proper support. 2. Verify presence of required blow-off caps. 3. Verify nozzles are appropriately aimed at the hazard.
	3. Storage Vessels	1. Inspect agent container for condition. 2. Verify storage pressure of the propellant.
	4. Agent	1. Verify quantity of agent using ultrasonic measuring.
	5. Actuators	1. Inspect manual actuators for accessibility. 2. Inspect detection devices (fusible links or heat detectors) for contamination and clean or replace as necessary. 3. Test actuation system without agent release. 4. Verify interfaces (gas shutoff, power shutoff) operate properly.
		5. Replace fixed temperature-sensing elements (fusible link metal alloy type and automatic sprinkler metal alloy type).
5-12 Years	1. Storage Vessels	1. Conduct hydrostatic test for pressure cylinders in accordance with OSHA and DOT standards.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. nozzles for obstruction and proper alignment c. riser condition 2. Ensure: a. detectors are unblocked/uncovered. b. panels are secured and indicator lamps functional. c. notification appliances are in place.

Frequency	Component	Tasks
		d. manual stations are in place and unobstructed. e. nozzle covers (blow-off caps) are in place. f. pressure gauge is within operating range.

2-2.21 Halon Systems.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*.

WARNING

To prevent accidental release of Halon gas to the environment, do not disconnect and weigh cylinders to accomplish the annual agent quantity verification. Disconnecting cylinders to verify agent quantity damages seals and O-rings. Use only liquid level methods to determine agent quantity. (Table 2-24, Task Annual 5.1)

Table 2-24 Halon System ITM Tasks

Frequency	Component	Tasks
Annually	1. Hazard	1. Verify hazard has not changed.
	2. Piping	1. Inspect piping and nozzles for condition and orientation.
	3. Flexible Hoses	1. Inspect for damage.
	4. Storage Vessels	1. Inspect exterior of storage containers (tanks, spheres, cylinders).
	5. Agent and Propellant	1. Verify quantity of the agent is sufficient. Use ultra-sound or level sensing technology. Do not disconnect and weigh tanks. 2. Verify pressure of the agent/propellant is sufficient and pressure gauge is within operating range.
	6. Actuators	1. Inspect manual actuators for accessibility. 2. Test actuation without agent release.
	7. Auxiliary Equipment	1. Test to verify interfaces (equipment shutdown, dampers, and door closures)

Frequency	Component	Tasks
		operate properly and are activated by the system actuation.
	8. Valves	1. Verify valves are in proper alignment.
2 Years	1. Protected Enclosure/Room	1. Inspect enclosure to verify integrity and ability to maintain agent concentration.
5 Years	1. Cylinders	1. Complete external inspection of non-discharged cylinders to ensure suitability for use.
	2. Flexible Hoses	1. Pressure test hoses to ensure suitability for use.
As Required	1. Agent Cylinders	1. Hydrostatic testing of cylinders is required only when cylinders are to be re-filled/re-charged. Periodic hydrostatic testing is not required.
After Modification to Compartment/ Protected Enclosure	1. Protected Enclosure/Room	1. Inspect enclosure to verify integrity and ability to maintain agent concentration. 2. If uncertainty exists, follow enclosure procedures in NFPA 12A.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. nozzles for obstruction c. piping for leaks d. riser condition 2. Ensure: a. detectors are unblocked/uncovered. b. panels are secured and indicator lamps functional. c. notification appliances are in place. d. manual stations are in place and unobstructed. e. nozzle covers are in place. f. pressure gauge is within operating range.

2-2.22 Clean Agent Systems.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

WARNING

To prevent accidental release of extinguishing agents to the environment, do not disconnect and weigh cylinders to accomplish the annual agent quantity verification. Disconnecting cylinders to verify agent quantity damages seals and O-rings. Use only liquid level methods to determine agent quantity. (Table 2-25, Task Annual 5.1)

Table 2-25 Clean Agent System ITM Tasks

Frequency	Component	Tasks
Annually	1. Hazard	1. Verify hazard has not changed.
	2. Piping	1. Inspect piping and nozzles for condition and orientation.
	3. Flexible Hoses	1. Inspect for damage.
	4. Storage Vessels	1. Inspect the exterior of storage containers (tanks, spheres, cylinders).
	5. Agent and Propellant	1. Verify adequate quantity of agent. Use ultra-sound or liquid level sensing. Do not disconnect and weigh tanks. 2. Verify adequate pressure of agent/propellant and pressure gauge within operating range.
	6. Actuators	1. Inspect manual actuators for accessibility. 2. Test actuation without agent release.
	7. Auxiliary Equipment	1. Test to verify interfaces (equipment shutdown, dampers, and door closures) operate properly and are activated by the system actuation.
	8. Valves	1. Verify valves are in proper alignment.
2 Years	1. Protected Enclosure or Room	1. Inspect enclosure to verify integrity and ability to maintain agent concentration.
5 Years	1. Cylinders	1. Perform complete external inspection of non-discharged cylinders to ensure suitability for use.
	2. Flexible Hoses	1. Pressure test hoses to ensure suitability for use.

Frequency	Component	Tasks
After Modification to Compartment/ Protected Enclosure	1. Protected Enclosure/Room	1. Inspect the enclosure to verify integrity and ability to maintain agent concentration. 2. If uncertainty exists, follow the enclosure procedures in NFPA 2001.
As Part of Other Building Inspection (not part of ITM requirements)	1. Entire System	1. Visually check: a. pipe hangers b. nozzle for obstruction c. piping for leaks d. riser condition 2. Ensure: a. detectors are unblocked/uncovered. b. panels are secured and indicator lamps functional. c. notification appliances are in place. d. manual stations are in place and unobstructed. e. nozzle covers are in place. f. pressure gauge is within operating range.

2-2.23 Carbon Dioxide Systems.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems.*

Table 2-26 Carbon Dioxide System ITM Tasks

Frequency	Component	Tasks
Semi-Annually	1. Liquid Level (low pressure carbon dioxide [CO_2])	1. Verify adequate liquid level with tank level gauge.
Annually	1. Hazard	1. Verify hazard has not changed.
	2. Piping and Nozzles	1. Inspect piping for condition and proper support. 2. Check nozzles for obstruction and alignment.
	3. Flexible Hoses	1. Inspect for damage.
	4. Low Pressure Tanks	1. Check level and pressure gauges. 2. Verify valve alignment.
	5. High Pressure Cylinders	1. Inspect for condition and securing.

Frequency	Component	Tasks
	6. Actuation System	1. Exercise control panel function, including zone valve operation. 2. Inspect manual actuators for accessibility. 3. Check times and time delay (pre-discharge).
	7. Auxiliary Equipment	1. Test to verify interfaces (shutdown, door closers, and dampers) operate properly and are activated by the control panel.
2 Years	1. High Pressure Cylinders	1. Verify CO_2 quantity by weighing cylinders.
After Modification to Compartment/ Protected Enclosure	1. Protected Enclosure/Room	1. Inspect the enclosure to verify integrity and ability to maintain agent concentration. 2. If uncertainty exists, follow the enclosure procedures in NFPA 2001.
As Part of Other Building Inspection (not part of the ITM requirements)	1. Entire System	1. Visually check: a. Pipe hangers. b. Nozzles for obstruction. c. Piping for leaks. d. Riser condition. 2. Ensure: a. Detectors unblocked/uncovered. b. Panels secured and indicator lamps functional. c. Notification appliances in place. d. Manual stations in place and unobstructed. e. Nozzle covers in place.

2-2.24 Emergency Lighting Systems.

Emergency lighting systems include individual battery-powered lighting units, central battery-powered units, and standby generator-powered lighting systems. Technical guidance on the task is located in NFPA 101, *Life Safety Code;* NFPA 110, *Standard for Emergency and Standby Power Systems;* and NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*. Figure 2-2 shows typical systems.

CAUTION

Battery-powered emergency lights generally require from 1 to 7 days to initially charge or to re-charge following a 90-minute discharge or activation. (Table 2-27, Task Annual 2.1)

Table 2-27 Emergency Lighting System ITM Tasks

Frequency	Component	Tasks
Annually	1. Individual Battery-Powered Lighting Units	1. Activate for not less than 90 minutes to verify battery voltage and capacity.
	2. Central Battery-Powered Lighting Systems	1. Activate for not less than 90 minutes to verify battery voltage and capacity.
	3. Emergency Generator-Powered Lighting Systems	1. During regularly scheduled generator and transfer switch maintenance, visually check operation of each emergency generator-powered fixture.
5 to 10 Years	1. Individual Fixtures' Replaceable Batteries or Unitized Fixtures	1. Replace battery or complete unitized fixture in accordance with manufacturer's **\1\ /1/** service life **\1** guidance **/1/**.

Figure 2-1 Typical Emergency Lighting Systems

Typical Emergency Light Units with a 5-year Manufacturer's Estimated Service Life Battery

Typical Emergency Light Units and Florescent Fixture Ballasts with a 10-year Manufacturer's Estimated Service Life Battery

Typical Central Emergency Power Sources with a 10-year Manufacturer's Estimated Service Life Battery

2-2.25 Egress Marking Systems.

Egress lighting systems include individual battery-powered lighting units, central battery-powered units, and standby generator-powered lighting systems. Figures 2-2 and 2-3 show typical units.

\1 New and replacement internally illuminated egress marking fixtures must be Energy Star® compliant. **/1/**

CAUTION

Battery-powered emergency egress marking generally requires from 1 to 7 days to initially charge or to re-charge following a 90-minute discharge or activation. (Table 2-28, Task Annual 4.3)

Table 2-28 Egress Marking System ITM Tasks

Frequency	Component	Tasks
Annually	1. Externally Illuminated and Non-illuminated Marking Fixtures	1. Inspect fixture condition and mounting. 2. Ensure emergency light source, if required, is functional.
	2. Photo-luminescent Marking Fixtures	1. Inspect fixture condition and mounting. 2. Inspect charging light source and mounting. 3. Ensure charging light source is functional (unswitched 5 foot-candles fluorescent or greater). Charging light must be on at all times the building is occupied.
	3. Internally Illuminated Marking Fixtures	1. Inspect fixture condition and mounting. 2. Ensure the bulb or light source is functional. 3. For electroluminescent marking, ensure the power source is operational.
	4. Internally Illuminated Marking Fixtures with Standby Battery Backup	1. Inspect fixture condition and mounting. 2. Ensure the bulb or light source is functional. 3. Activate on battery power for not less than 90 minutes to verify battery voltage and capacity. 4. **\1** Replace any fixtures or battery, if replaceable, that fails to remain illuminated for 90 minutes. **/1/**
	5. Internally Illuminated Marking with Emergency Generator	1. Inspect fixture condition and mounting. 2. Ensure the bulb or light source is functional.

	Backup	3. During regularly scheduled generator and transfer switch maintenance, visually check the operation of each emergency generator-powered fixture.
5 to 10 years	1. Internally Illuminated Marking with Standby Battery Backup	1. Replace battery or fixture if battery is not replaceable (unitized fixture) in accordance with manufacturer's service life **\1** guidance **/1/**.

Figure 2-2 Typical Egress Marking Units with a 10-year Manufacturer's Estimated Service Life Battery

Figure 2-3 Typical Combination Egress Marking and Emergency Light Units with a 5-year Manufacturer's Estimated Service Life Battery (Not Energy Star® Compliant)1

[1]LED egress marking devices without battery backup are **\1\ /1/** considered to have a 25-year **\1\ /1/** service life. (Consult the manufacturer's technical materials for specific guidance.)

2-2.26 Fire and Smoke Barrier Opening-.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Electric hold-open devices are tested as part of the fire alarm system in "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* and NFPA 105, *Standard for Smoke Door Assemblies and Other Opening Protectives*.

Table 2-29 Fire and Smoke Barrier Opening Protection ITM Tasks

Frequency	Component	Tasks
Annually	1. Hinged Fire Doors	1. Test magnetic hold-open devices for release on activation of fire alarm. 2. Inspect closers for proper operation. 3. Verify door closes and latches.
	2. Sliding Doors	1. Test magnetic hold-open devices for release on activation of fire alarm. 2. Ensure weights have a free and unobstructed path of travel. 3. Verify door closes and latches
	3. Rolling or Sliding Fire Shutters	1. Test magnetic hold-open and other mechanical latches or actuators for release on activation of fire alarm. 2. Operate the shutter through its entire travel.
1 Year after Construction and Every 6 Years Thereafter	1. Fire and Smoke Dampers	1. Test electric (magnetic) hold-open and other mechanical latches or actuators for release on activation of fire alarm. 2. Inspect travel path for anything obstructing or interfering with free operation.
As Part of Other Building Inspection (not part of ITM requirements)	1. Hinged Fire Doors	1. Inspect door condition, gaskets, and mounting hardware. Ensure proper lubrication. 2. Inspect fusible links, if present, for paint or other accumulations that slow thermal response.
	2. Sliding Doors	1. Inspect door condition and mounting hardware. Ensure proper lubrication. 2. Inspect fusible links, if present, for paint or other accumulations slowing thermal response. 3. Inspect travel path for anything obstructing or interfering with free operation.
	3. Rolling or Sliding Fire Shutters	1. Inspect door condition and mounting hardware. Ensure proper lubrication. 2. Inspect fusible links, if present, for paint or other accumulations slowing thermal response. 3. Inspect travel path for anything obstructing or interfering with free operation.
	4. Fire and Smoke Dampers	1. Inspect fixture condition and mounting. 2. Inspect fusible links, if present, for paint or other accumulations that slow thermal response.

Frequency	Component	Tasks
	5. Installed Fire Stopping, Listed Sleeves, Penetrations, Seal Bags, and Other Fire Stopping Material	1. Inspect fire-resistive barriers for new or other unprotected penetrations of rated walls, floors, or ceilings.

2-2.27 Smoke Control Systems.

Detection devices for actuation are addressed in Section 2-2.2, "Fire Detection and Alarm Systems." Technical guidance on these tasks is contained in NFPA 92, *Standard for Smoke Control Systems*.

Table 2-30 Smoke Control ITM Tasks

Frequency	Component	Tasks
Semi-Annually	1. Dedicated Systems	1. Operate the smoke control system through each operational sequence provided for in the original system design. 2. Verify the operation of the correct output for each given input. 3. If applicable, conduct tests under standby power.
Annually	1. Fans, Fire and Smoke Dampers, and System Controls	1. Operate the smoke control system through each operational sequence provided for in the original system design. 2. Verify the operation of the correct output for each given input. 3. If applicable, conduct tests under standby power. Testing must determine and document airflow quantities and pressure differences across smoke barrier openings, at the air make-up locations, and at smoke exhaust fans for comparison to original acceptance testing results.

Frequency	Component	Tasks
Upon System Modification or Building Renovations or Additions	1. All Systems	1. Operate the smoke control system through each operational sequence provided for in the original system design. 2. Verify the operation of the correct output for each given input. 3. If applicable, conduct tests under standby power. Testing must determine and document airflow quantities and pressure differences across smoke barrier openings, at the air make-up locations, and at smoke exhaust fans for comparison to original acceptance testing results.

2-2.28 Heat and Combustion Product Removal/Venting Systems.

Technical guidance on these tasks is contained in NFPA 204, *Standard for Smoke and Heat Venting*.

Table 2-31 Heat and Combustion Product Removal/Venting System ITM Tasks

Frequency	Component	Tasks
Annually	1. Mechanically Opened Vents	1. Inspect for changes in appearance, damage to any components, fastener security, weather tightness, presence of foreign objects, and changes in roof flashing condition.
	2. Thermoplastic Drop-out Vents	1. Inspect for changes in appearance, damage to any components, fastener security, weather tightness, and changes in roof flashing condition.
	3. Mechanical Smoke Exhaust Systems	1. Inspect for damage to any components. 2. Verify exhaust outlets and air inlets are unobstructed. 3. Verify power sources. 4. Test system to verify equipment is operational and functions as intended.
5 Years	1. Mechanically Opened Vents	1. Test vents by releasing the restraining cable at the heat-responsive device, releasing the restraint, and allowing the trigger or latching mechanism to operate. 2. Test manual releases to verify vents operate as designed. 3. Verify correct temperature of fusible link.

\1

2-2.29 Ignitable Liquid Floor Drainage Assembly.

Required ITM tasks for are contained in Table 2-32.

a. Internal drainage channel inspection is accomplished using a sewer/drain inspection endoscope (pipe inspection camera).

b. Internal drainage channel cleaning is accomplished using a sewer/drain high pressure (1500 – 3000 psi) jetting hose and nozzle. Rotating nozzles are recommended. Nozzles are inserted from the drainage trench end and travel up to the flushing header and pulled back to clean each channel.

c. Section 2-2.8, "Fire Pumps," provides guidance for maintenance of fire pumps. Maintenance for industrial trash pumps must comply with Section 2-2.8 since these pumps perform a similar critical function to a fire pump for a suppression system.

Table 2-32 Ignitable Liquid Floor Drainage Assembly ITM Tasks

Frequency	Component	Task
Weekly	1. Water Supply Tanks (without electric remote supervision of water level)	1. Check level.
	2. Effluent Collection/Retention Tanks (without electric remote supervision of water level)	1. Check level.
	3. Air Compressor/Receiver/ Cylinders (without electric remote supervision of air pressure) [if present]	1. Check air pressure.
Semi-Annually	1. System	1. Operate full system in maintenance flushing for not less than 5 minutes. Ensure visually equal flow in every channel. 2. Visually inspect the hangar floor for any indication of obstruction or blockage in the deck channels while flushing.
	2. Air Compressors (if present)	1. Start to ensure operability.
	3. System Operating Components	1. Inspect to verify valve alignment and valves are free of damage.
Annually	1. Water/Effluent Tanks (remote electrically supervised and monitored)	1. Check water level detection device and supervisory controls.

Frequency	Component	Task
	2. Air Compressors/Receivers/ Cylinders (electric remote supervision of air pressure) [if present]	1. Check air pressure and supervisory pressure switch.
	3. Liquid Sensors	1. Operate to verify initiation and receipt of alarm. 2. Verify effluent pump start. 3. Verify flushing water valve opens.
	4. Pressure Relief Devices	1. Manually operate to ensure operability.
	5. Manual Actuators	2. Verify operability.
	6. Deck Channels	1. Verify operability, flow, in all channels, and ensure no blockage/ restriction forcing water to backflow through drainage holes. 2. Pressure-wash any channels in the deck indicating blockage or restriction.
	7. Decking and Ramps	1. Visually inspect deck and ramps for missing screws and replace any missing screws with manufacturer's recommended replacements.
	8. Exercise Manual and Automatic Valves.	1. Operate each valve through its full operating range for not less than 2 full cycles. 2. Ensure each valve is reset to the operating position.
5 Years	1. Deck Channels	1. Visually inspect 20% of floor channels using sewer endoscope. 2. If debris is in half or more of channels inspected, conduct 5-10 year deck channel cleaning.
	2. Water Tanks When Used to Supply the Flushing System	1. Drain and refill tank. 2. Inspect tanks for structural integrity (interior and exterior) prior to refilling.
5-20 Years	1. Floor Channels	1. Pressure-wash each channel in the floor deck.
As Part of Other Building Inspection (not part of the ITM requirements)	1. Entire System	1. Ensure: a. manual stations are in place and unobstructed. c. panels are secured and indicator lamps functional.

/1/

CHAPTER 3 MILITARY FAMILY HOUSING SYSTEMS

3-1 SCOPE.

\1

3-1.1 DoD Military Family Housing.

/1/

The maintenance concepts for MFH fire protection systems are based on the management and controls unique to the MFH program. In the civilian sector, an owner or tenant makes a personal choice to occupy a dwelling unit and is responsible for its maintenance and repair and any associated fire protection devices. In MFH, occupants are assigned housing units, and the housing management activity is responsible for the maintenance and repair of units and associated fire protection devices. All MFH occupants are required to attend a briefing on their responsibilities as MFH occupants prior to occupying an MFH dwelling. These briefings include the occupant's responsibilities for conducting tests and cleaning installed fire protection features. On average, MFH maintenance teams conduct change of occupancy maintenance every one to two years; therefore, scheduled maintenance performed by the housing management activity is centered on this change of occupancy.

\1

3-1.2 Privatized Military Family Housing.

Privatized military family housing contractors are responsible for developing their own maintenance programs in accordance with their lease agreement and national consensus codes and standards. Contractors are permitted to adopt requirements of this UFC chapter in meeting their maintenance and safety goals. (Chapter 1, Section 1-3).

/1/

3-2 RESIDENTIAL SMOKE ALARMS.

MFH units are required to have hard-wired, interconnected smoke alarms. Each installation develops programs to train occupants in testing and maintenance actions for installed smoke alarms. Actions required as part of change of occupancy maintenance by the housing management activity are listed **\1** (Table 3-1) **/1/**.

3-3 RESIDENTIAL SPRINKLER SYSTEMS.

New MFH units are required to have sprinkler systems **\1**(UFC 3-600-01, Chapter 4).**/1/**

3-3.1 Multi-Family Residential Buildings.

Residential sprinkler systems in multi-family buildings up to four stories are **\1\\ /1/** constructed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems,* or NFPA 13R, *Standard for the Installation of Sprinkler Systems in Low-Residential Occupancies* **\1** (UFC 3-600-01, Chapter 4). **/1/** Maintain these systems in accordance with the tables in Chapter 2 of this UFC. Building occupants are not expected to conduct **\1** sprinkler **/1/** system tests or maintenance actions.

3-3.2 One- and Two-family Residences and Townhouse-style Units.

Residential sprinkler systems in one- and two-family dwellings and townhouse-style units are **\1** installed **/1/** in accordance with NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*, or NFPA 13R. **\1** (UFC 3-600-01 Chapter 4) **/1/** Installations develop their own programs to train occupants in the testing and maintenance actions required. Actions required as part of change of occupancy maintenance by the housing management activity are listed **\1** (Table 3-1) **/1/**.

3-4 CARBON MONOXIDE ALARMS.

MFH units **\1** must **/1/** have carbon monoxide detectors connected to the building fire alarm system, or they **\1** must **/1/** have single station carbon monoxide alarms. Carbon monoxide detectors connected to the fire alarm system are addressed in Section 2-2.2 in Chapter 2 of this UFC. For single station carbon monoxide alarms, actions required as part of change of occupancy maintenance by the housing management activity are listed in Table 3-3.

3-5 ITM TASK DESCRIPTIONS.

ITM tasks **\1** must **/1/** be part of the housing maintenance conducted between occupancies.

CAUTION

Battery-powered smoke alarms are not permitted, and when found, must be replaced with interconnected hardwired smoke alarms on change of occupancy. Air Force allows hardwired **\1** and **/1/** wireless interconnected smoke alarms for use within single-family and duplex housing. (Table 3-1, Change of Occupancy, Task 3.1)

Table 3-1 MFH Residential Smoke Alarm ITM Tasks

Frequency	Component	Tasks
Change of Occupancy	1. Smoke Alarms (hardwired single-station and multi-station smoke alarms)	1. Activate each smoke alarm with an approved smoke simulant. 2. Remove cover and inspect for grease buildup; replace and relocate smoke alarms with evidence of grease buildup in the smoke alarm. 3. Vacuum smoke alarm and replace cover. 4. Activate each smoke alarm with the installed test button. 5. Replace any smoke alarm failing to activate on either the smoke simulant or the test button.
	2. Backup Battery (if present)	1. Replace battery.
	3. Battery-only powered smoke alarms **\1** if present. **/1/**	1. Replace with hardwired smoke alarms complying with requirements in UFC 3-600-01 for new construction.
10 Years	1. Smoke Alarms (hardwired single-station and multi-station smoke alarms)	1. Replace smoke alarm. If replacing existing smoke alarms without an interconnection feature, replacement smoke alarms must include interconnection, **\1** hardwired or wireless, **/1/** between all smoke alarms in the dwelling unit.

Table 3-2 MFH Residential Sprinkler System ITM Tasks

Frequency	Component	Tasks
Change of Occupancy	1. Sprinklers	1. Inspect all sprinklers. 2. Clean or replace sprinklers as necessary. Sprinklers that have been painted must be replaced; cleaning is not permitted. 3. Inspect ceilings or wall at sprinkler for signs of leakage or water stains.

Frequency	Component	Tasks
	2. Valves	1. Inspect valves to ensure they are open and sealed.
	3. Water Flow and Alarm Devices	1. Test to verify operability.
20 Years and Every 10 Years Thereafter	1. Fast-Response Sprinklers	1. Replace all sprinklers or test a sample of sprinklers to verify response characteristics.[1]

\1[1]**/1/** A representative sample of sprinklers for testing must consist of one (1) percent of the sprinklers installed of the same type, with a minimum of four (4) sprinklers sampled. The sprinklers must be submitted to a **\1** nationally **/1/** recognized testing laboratory for these tests.

Table 3-3 Carbon Monoxide Alarm ITM Tasks

Frequency	Component	Tasks
Change of Occupancy	1. Carbon Monoxide Alarm (hardwired single-station and multi-station alarms)	1. Activate each alarm device with an approved CO simulant. 2. Activate each alarm device with the installed test button. 3. Replace any alarm device failing to activate on either the CO simulant or the test button.
	2. Backup Battery (if present)	1. Replace battery.
10 Years, or Upon End-of-Life Signal from Detector, Whichever Is Less.	1. Combination Smoke/Carbon Monoxide Alarms (hardwired single-station and multi-station alarms)	1. Replace alarm devices. If replacing existing alarm devices without an interconnection feature, replacement alarm devices must include interconnection between all smoke alarms in the dwelling unit.
\1 10 years or **/1/** Upon End-of-Life Signal from Detector **\1** Whichever Is Less. **/1/**	1. Carbon Monoxide Alarms (hardwired single-station and multi-station alarms)	1. Replace alarm device.

APPENDIX A NAVY CONTRACT TECHNICIAN QUALIFICATIONS

A-1 INTRODUCTION.

Contract fire protection inspection, test, and maintenance (ITM) services must be managed by a qualified individual who is NICET Level III certified in fire alarm or NICET Level III certified in special hazards systems. The fire protection services manager provides daily supervision over all fire protection services.

Personnel executing ITM tasks on fire protection systems must be certified in accordance with requirements **\1** in paragraphs A-2 through A-4. **/1/**

A-2 FIRE ALARM SYSTEMS.

- Fire Alarm detection, supervision, and notification controls and devices: NICET Level II certification in Fire Alarm Systems.
- Detection and releasing systems for Special Hazard Systems **\1** including **/1/** those found in aircraft hangars and computer server rooms: NICET Level II certification in Special Hazard Systems.

A-3 WATER BASED SUPPRESSION SYSTEMS.

- Wet Pipe and Dry Pipe Sprinklers: - NICET Level II certification in Inspection and Testing of Water Based Systems.
- Pre-Action, Deluge, Foam and Antifreeze Systems: NICET Level III certification in Inspection and Testing of Water Based Systems.

A-4 SPECIAL HAZARD SYSTEMS.

- Clean Agent, CO_2 and Combination Detection/Releasing Systems: NICET Level II certification in Special Hazard Systems.
- Pre-Engineered Kitchen Fire Extinguishing Systems: NICET Level II certification in Special Hazards Suppression Systems or certified by ICC/NAFED in Pre-Engineered Kitchen Fire Extinguishing Systems.

Personnel without NICET certification **\1** are permitted to **/1/** assist NICET Levels II and III certified personnel in the execution of inspection, testing, maintenance and repair tasks. At no time are uncertified personnel allowed to execute inspection, testing, maintenance and repair tasks without a qualified NICET Level II or III certified person physically present within the same facility where the inspection, testing, maintenance and repair tasks are being executed.

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APPENDIX B GLOSSARY

B-1 ACRONYMS

AFCEC/CO	Air Force Civil Engineer Center, Operations Directorate
AFFF	aqueous film-forming foam
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
AWWA	American Water Works Association
CFPE	Component Fire Protection Engineer
CFR	Code of Federal Regulations
CO_2	carbon dioxide
DFPE	Designated Fire Protection Engineer
DoD	Department of Defense
DOT	U.S. Department of Transportation
FACP	fire alarm control panel
FFF	fluorine free foam
FFFP	film-forming fluoroprotien foam
FMCP	fire alarm control panel with integrated mass notification
HQ USACE	Headquarters U.S. Army Corps of Engineers
Hi-Ex	high expansion foam
ILDFA	ignitable liquid floor drainage assembly
ITM	inspection, testing, and maintenance
LED	light-emitting diode
LOC	local operating console
MFH	Military Family Housing
MS&O/ESO	Management Services and Operations, Environmental Safety Office

NDAA	National Defense Authorization Act
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NRTL	nationally recognized testing laboratory
OSHA	Occupational Safety and Health Administration
PFAS	per- and poly-fluorinated alkylated substances
PFOA	perfluorooctanic acid
PFOS	perfluorooctane sulfonic acid
RCM	reliability-centered maintenance
\1 SAF/IE	Assistant Secretary of the Air Force for Installations and the Environment **/1/**
SecDef	Secretary of Defense
U.S.	United States
UFC	Unified Facilities Criteria
U.S.C.	United States Code

\1

B-2 DEFINITION OF TERMS

Nationally Recognized Test Laboratory (NRTL): CONUS including all states, territories, and possessions; an independent third-party organization that certifies products for the North American market. These organizations are recognized as meeting the legal requirement in 29 CFR 1910.7 to perform testing and certification of products using consensus based test standards. (https://www.osha.gov/nationally-recoganized-test-laboratory-program/current-list-of nrtls)

Nationally Recognized Test Laboratory (NRTL): OCONUS; any organization on the OSHA approved list or an independent third-party organization or governmental organization in a country that certifies products for the country or location market. Some countries allow manufacturer self-certification to government standards under government oversight. See specific country guidance or consult with the CFPE.

/1/

APPENDIX C REFERENCES

AIR FORCE

AFCESA/CES Technical Report 01-10, *Risk Based Reliability Centered Maintenance of DoD Fire Protection Systems*, Jan 1999, DTIC ADA392898 (https://apps.dtic.mil/dtic/tr/fulltext/u2/a392898.pdf)

HQ USAF/A7C Memorandum, "Excess Fire Protection Features," 17 June 2008, (https://usaf.dps.mil/teams/CEDASH/Shared%20Documents/Fire%20Protection%20Engineering/Excess%20Fire%20Protection%20Features%2017%20Jun%2008.pdf CAC AFNet access required)

AMERICAN NATIONAL STANDARDS INSTITUTE

https://webstore.ansi.org/

ANSI Z535.1-2017, *Safety Colors*

ANSI Z535.2-2011, *Environmental and Facility Safety Signs*

AMERICAN WATER WORKS ASSOCIATION

https://www.awwa.org/Publications/Manuals-of-Practice/Manuals-List

AWWA M17, Fire Hydrants: *Installation, Field Testing, and Maintenance*

CODE OF FEDERAL REGULATIONS

https://www.govinfo.gov/app/collection/cfr/

CFR Title 29, Part 1910 Subpart L App A, *Fire Protection*

CFR Title 29, Part 1910.160(b)(2) and 1910.160(b)(6), *Fixed Extinguishing Systems, General*

CFR Title 29, Part 1960.26(b)(5), *Conduct of Inspections*

MILITARY STANDARDS

https://www.wbdg.org/dod/fedmil/mil-std-3007

MIL-STD-3007G, *Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications*

NATIONAL FIRE PROTECTION ASSOCIATION

https://www.nfpa.org or

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies*

NFPA 14, *Standard for the Installation of Standpipes and Hose Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*

NFPA 22, *Standard for Water Tanks for Private Fire Protection*

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*

NFPA 72, *National Fire Alarm and Signaling Code®*

NFPA 80, *Standard for Fire Doors and Other Opening Protectives*

NFPA 92, *Standard for Smoke Control Systems*

NFPA 101, *Life Safety Code*

NFPA 105, *Standard for Smoke Door Assemblies and Other Opening Protectives*

NFPA 110, *Standard for Emergency and Standby Power Systems*

NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*

NFPA 204, *Standard for Smoke and Heat Venting*

NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants*

NFPA 750, *Standard on Water Mist Fire Protection Systems*

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 3-230-02, *Operation and Maintenance: Water Supply Systems*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UNITED STATES CODE

https://www.govinfo.gov/app/collection/uscode/

Title 10 United States Code (U.S.C.) Section 1794, *Child abuse prevention and safety at facilities*

Title 15 United States Code (U.S.C.) Section 272, *Establishment, functions, and activities (NIST)*

Title 15 United States Code (U.S.C.) Section 2227, *Fire safety systems in federally assisted buildings (Fire Administration Authorization Act)*

Title 15 United States Code (U.S.C.) Chapter 115, *Perfuoroalkyl and Polyfluoroalkyl Substances and Emerging Contaminants*

Title 29 United States Code (U.S.C.) Section 1910, Subpart L, *Fire Protection*

Title 29 United States Code (U.S.C.) Section 1960, *Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters*

UFC 3-701-01
17 March 2022
Change 6, 15 May 2025

UNIFIED FACILITIES CRITERIA (UFC)

DoD FACILITIES PRICING GUIDE

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UNIFIED FACILITIES CRITERIA (UFC)

DoD FACILITIES PRICING GUIDE

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location
1	15 Jul 2022	Table 3 PUC updated
2	2 Mar 2023	Updated Tables for FY23 Publication, Added Chapter 6
3	26 Jul 2023	Table 3 PUC updated
4	20 Mar 2024	Updated Tables for FY24 Publication
5	10 Sep 2024	Table 3 PUC updated
6	15 May 2025	Update Tables for FY25 Publication

This UFC supersedes UFC 3-701-01, dated May 2018.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1-1 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-701-01, 23 May 2018.

1-2 PURPOSE AND SCOPE.

The DoD Facilities Pricing Guide supports a spectrum of facility planning, investment, and analysis needs. **6**\ This version of the Guide reflects updated cost and pricing data for FY 2025 intended to support the preparation of **3**\ programming cost /**3**/ estimates for the DoD budget in FY 2028 and beyond. /**6**/ It includes reference information organized into five chapters, as follows:

1-2.1 Chapter 2: Unit Costs for Military Construction Projects.

Chapter 2 describes the usage of facility unit cost data for selected DoD facility types in support of preparing Military Construction (MILCON) project documentation (DD Forms 1391) and other **3**\ programming cost estimates in accordance with UFC 3-730-01 /**3**/.

1-2.2 Chapter 3: Unit Costs for DoD Facilities Cost Models.

Chapter 3 describes the usage of unit costs in support of DoD facilities cost models. These unit costs are based upon the reported average DoD facility size or an established benchmark size, as annotated for each Facility Analysis Category (FAC) in the DoD Real Property Classification System (published separately). These unit costs are intended for macro-level analysis and planning rather than individual facilities or projects.

1-2.3 Chapter 4: Cost Adjustment Factors.

Chapter 4 describes the usage of cost adjustment factors for location and price escalation that are applicable to the base unit costs in both Chapters 2 and 3.

1-2.4 Chapter 5: Replacement Cost.

Chapter 5 describes the usage of the replacement cost. The replacement cost is used as required by other UFCs or design criteria.

1-2.5 \2\ Chapter 6: Unit Cost for Supporting Facilities. /2/

Chapter 6 describes the usage of supporting facilities unit cost in support of preparing Military Construction (MILCON) project documentation (DD Forms 1391) and other **3**\ programming cost estimates in accordance with UFC 3-730-01 /**3**/.

1-3 APPLICABILITY.

6\ This UFC follows the same applicability as UFC 1-200-01, paragraph 1-3, with no exceptions. /**6**/

1-4 DATA TABLES.

All data tables in this UFC are found in a combined file under "Related Materials" accompanying this UFC on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

6\ Source date for the data tables is current as of October 1, 2024. /**6**/

1-5 GLOSSARY.

APPENDIX A contains acronyms, abbreviations, and terms.

1-6 REFERENCES.

APPENDIX B contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 UNIT COSTS FOR MILITARY CONSTRUCTION PROJECTS

2-1 OVERVIEW.

The facility unit costs in this chapter apply to the preparation of programming cost estimates for constructing military facilities in accordance with the methodology described in UFC 3-730-01.

All data tables in this UFC are found under "Related Materials" in a combined file accompanying this UFC on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

2-2 FACILITY UNIT COST TABLE.

Table 2 provides facility unit costs for various DoD facility types in dollars per square meter ($/SM) and equivalent English unit cost data in dollars per square foot ($/SF) as of **6**\ October 2024 /**6**/. The listed facility types represent only those facilities most frequently constructed by the Military Services, and the application of a facility unit cost may not be directly applicable for those facilities with unique requirements. See UFC 3-730-01 for additional guidance on facility unit costs and their application.

The unit costs in Table 2 are average unit costs for new construction based on no less than three project awards per building type occurring since **6**\ September 2021 /**6**/ for Army, Navy, Air Force, Defense Education Activities (for **4**\ dependent /**4**/ school projects) and Defense Health Agency (for medical projects) facilities as entered into the Historical Analysis Generator **6**\ Second Generation /**6**/ (HII) unit cost database prior to **6**\ 05 December 2024 /**6**/. Facility additions which are less than 25% of the Reference Size of the listed facility type, and projects outside of the continental United States (OCONUS), are included only for Family Housing and DoD Schools. For additional information regarding how the facility unit costs are determined, refer to paragraph 2-3, Guidance Unit Cost Development.

2-3 GUIDANCE UNIT COST (GUC) DEVELOPMENT METHODOLOGY.

2-3.1 Data Source.

The data source for the facility unit costs is all reliable **6**\ HII /**6**/ project records, after excluding records for reasons stated in paragraph 2-2. In general, all project records for the CONUS and projects from Alaska and Hawaii are included.

Facility level information from all three Services projects is entered into HII database for comparable service category codes (CATCODEs). Normalized **4**\ facility /**4**/ unit costs are statistically analyzed to eliminate outliers before calculating the guidance unit cost (GUC). Refer to section 2-3.3 for Data Normalization.

2-3.2 Business Rules.

The business rules are reviewed annually prior to updating Table 2 Facility Unit Costs for Military Construction. The business rules include the following components.

- The Tri-Service CATCODEs Cross-walk table groups like service CATCODEs to a common Office of the Secretary of Defense (OSD) Code. OSD Codes are not published and are only utilized for this task of segregating data. A minimum of three projects are required within **4**\ the three-year period /**4**/ to create a dataset. If there is insufficient data available within the three-year period, the dataset search is extended four years.
- Projects are new construction only.
- Projects are located within the CONUS, plus Hawaii and Alaska, except where noted otherwise in Table 2.

2-3.3 Data Normalization.

Each facility-specific data set is normalized to the National Average Area Cost Factor (ACF=1) and number of bidders, and escalated to October of the year of interest, before unit costs are averaged.

- Escalation: The DoD Selling Price Index (DoD-SPI), which is an average of three commonly accepted national construction price escalation indices, is utilized to escalate actual project award cost data to **6**\ 01 October 2024 /**6**/ for this UFC,
- Number of Bidders: Based on actual bid data for the data set,
- Location: Normalize each project award by the appropriate ACF to the national average of 1.0, and
- Facility Size: Normalize each facility award amount in the dataset for facility size, using a normalization process that looks at the facility size as compared to the average facility size of the selected dataset by OSD code.

2-3.4 Primary Facility Included Costs.

The facility unit costs include the following:

- Minimum antiterrorism design features (reference UFC 4-010-01, “DoD Minimum Antiterrorism Standards for Buildings”) inside the building meeting **2**\ /**2**/ standoff distance requirements,
- Sales tax on building materials,

- Building information system costs (e.g., conduits, racks, trays, telecommunication rooms) without any specialized communications requirements,
- Installed (built-in) building equipment and furnishings normally funded with MILCON funds,
- Energy Management Control System (EMCS) connections,
- Intrusion Detection System (IDS) infrastructure, including conduits, racks, and trays,
- Sustainable design and construction features - energy consumption reduction requirements mandated before **2**\\ four years prior to the source date of the data tables /**2**/; and all other sustainable design features for criteria in effect **2**\\ three years prior to the source date of the data tables /**2**/ with the exception of renewable energy generation elements,
- Progressive Collapse premiums for the following specific facility types: Inpatient Hospital/Medical Center and Primary Care Clinic (Attached), **4**\\ and facilities with 3 or more floors, /**4**/
- Standard foundation systems (e.g., strip/spread footings, thickened edge slab for slab on grade).

2-3.5 Primary Facility Excluded Costs.

3\\ The unit costs do not include the following:

- Gross receipt taxes or gross taxes, gross excise taxes, or state commerce taxes,
- “Acts of God” or unusual market conditions,
- Supporting facility costs,
- Equipment acquired with other fund sources, including pre-wired workstations or furnishing systems, intrusion detection systems,
- Sustainable design and construction features - renewable energy generation elements; energy consumption reduction requirements mandated on or after **2**\\ four years prior to the source date of the data tables /**2**/; and all other features mandated since **2**\\ three years prior to the source date of the data tables /**2**/; these will be estimated separately in accordance with component guidelines and documented on DD Form 1391 per DoD Instruction 4170.11, Installation Energy Management,
- Special foundations (e.g., pre-stressed concrete piles, caissons),
- Intrusion detection system installation,
- Electronic security system (ESS) (rough-in),
- Hazardous and toxic material removal/abatement,

- Base exterior architectural preservation guidelines,
- Enhanced Anti-Terrorism (AT) standards (exceeding the minimum in UFC 4-010-01, or when minimum standoff distances **2**\ /**2**/ are not achieved) construction contingency allowances,
- System commissioning,
- Cybersecurity costs,
- Supervision, inspection, and overhead (SIOH),
- Design costs (design-build contracts), and post-award construction cost growth, for example, resulting from user changes, unforeseen site conditions, or contract document errors and omissions. /**3**/

2-3.6 Primary Facility Cost Considerations.

The following are cost considerations for primary facilities:

- Medical facilities: Unit costs include category A and category B equipment and building infrastructure for category C equipment,
- Housing for Unaccompanied Military Personnel: Unit costs for barracks, dormitories, and Unaccompanied Officers Quarters do not include free-standing kitchen equipment.
- Child Development Centers: Unit costs do not include free-standing food service equipment or playground area and equipment,
- Family housing: Unit costs are based upon gross area and include sprinkler systems or fire-rated construction. Unit costs include post-award design costs,
- Reserve facilities other than reserve centers: Use the unit cost of the appropriate facility type,
- **2**\ /**2**/
- Costs are independent of the acquisition strategy and are not specific to any single construction type.

CHAPTER 3 UNIT COSTS FOR DOD FACILITIES COST MODELS

3-1 OVERVIEW.

This chapter describes the unit costs and related factors used in support of DoD facilities cost models. These unit costs are intended for macro-level analysis and planning and are not reliable for individual facilities or project cost estimates.

Unit costs and related factors are associated with FACs represented by a 4-digit code in the DoD Real Property Classification System (RPCS), which is a hierarchical scheme of real property types and functions that serves as the framework for identifying, categorizing, and modeling the DoD's inventory of land and facilities. FACs are common across the department and suitable for department-wide applications. For each FAC, Table 3 identifies the associated unit cost to be used in DoD facilities cost models and metrics.

Whenever possible, unit costs and factors have been based upon approved government or commercial benchmarks. Detailed supporting data for unit costs is available, and accompanies this UFC on the WBDG web site. All data tables in this UFC are found in a combined file under "Related Materials" accompanying this UFC on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

3-2 PRV UNIT COSTS (PUC).

3-2.1 Definition and Use of PRV Unit Costs.

PRV unit costs (PUC) form the basis of calculating Plant Replacement Value (PRV) in a consistent manner across DoD, representing a complete and useable facility built to current DoD design standards. PUC can also support large-scale program-level cost estimates for re-stationing plans with the addition of allowance for site preparation, earthwork, landscaping, and related factors. PUC should not be used for individual project estimates.

PUC include construction of standard foundations, all interior and exterior walls and doors, the roof, utilities out to the 5-foot line, all built-in plumbing and lighting fixtures, security and fire protection systems, electrical distribution, wall and floor coverings, heating and air conditioning systems, and elevators. PUC does not include project costs such as design, supporting facility costs, special foundations, equipment acquired with other funding sources (e.g., mission-funded components), contingency costs, or supervision, inspection, and overhead (SIOH). PUC also do not include items that are generally considered personal property such as computer systems, and furniture. See paragraph 3-5, Revising Unit Costs, for guidance on requesting changes to PUC in Table 3.

3-2.2 Plant Replacement Value (PRV).

PRV is the cost to design and construct a notional facility to current standards to replace an existing facility on the same site. The factor values are provided in the "Report of the

Plant Replacement Value (PRV) Panel, August 2001-May 2003" published by the Office of the Deputy Under Secretary of Defense (Installations and Environment). The standard DoD formula for calculating PRV is:

Equation 3-1. Calculating PRV

$$PRV = Q \times PUC \times ACF \times HF \times PD \times SIOH \times CF$$

Where:

PRV is plant replacement value

Q is facility quantity, in the same unit of measure as the PUC

PUC is PRV unit cost found in Table 3 of this UFC

ACF is area cost factor found in Table 4-1 of this UFC, to account for geographical differences in the costs of labor, materials, and equipment

HF is an adjustment of 1.05 to account for increased costs for replacement of historical facilities or for construction in a historic district. If the facility does not qualify as "historical", this factor is 1

PD is a factor to account for the planning and design of a facility; the current value of this factor is 1.09 for all but medical facilities, and 1.13 for medical facilities

SIOH is the factor to account for the supervision, inspection, and overhead activities associated with the management of a construction project. Application of SIOH rates will be in accordance with PTDO PDASD(EIE) (14 Apr 2022) for Military Construction Supervision, Inspection and Overhead Fixed Rates for Fiscal Year 2024 and Future projects. For a list of applicable remote locations, refer to NAVFACINST 7820.0 (8 Aug 2022) for Navy and the cognizant design agency for Army and Air Force. The aforementioned documents are included as "Related Materials" accompanying this UFC on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

CF is a factor of 1.05 to account for construction contingencies

3-3 SUSTAINMENT UNIT COSTS (SUC).

3-3.1 Definition.

Sustainment provides for maintenance and repair activities necessary to keep a typical inventory of facilities in good working order over its expected service life. It includes the following:

- Regularly scheduled adjustments and inspections, including maintenance inspections (e.g., fire sprinkler heads, HVAC systems) and regulatory inspections (e.g., elevators, bridges),
- Preventive maintenance tasks,
- Emergency response and service calls for minor repairs, and
- Major repair or replacement of facility components (usually accomplished by contract) that are expected to occur periodically throughout the facility service life.

Sustainment includes regular roof replacement, refinishing wall surfaces, repairing and replacing electrical, heating, and cooling systems, replacing tile and carpeting and similar types of work as well as overhead costs which include architectural and engineering services. It does not include repairing or replacing non-attached equipment or furniture, or building components that typically last more than 50 years (such as foundations and structural members). Sustainment does not include restoration, modernization, environmental compliance, facility leases, specialized historical preservation, general facility condition inspections and assessments, planning and design (other than shop drawings), or costs related to Acts of God, which are funded elsewhere. Other tasks associated with facilities operations (such as custodial services, grass cutting, landscaping, waste disposal, and the provision of central utilities) are also not included.

3-3.2 Use of Sustainment Unit Costs.

Sustainment unit costs represent the annual average sustainment cost for each FAC, and serve as the basis for calculating annual facilities sustainment requirements for DoD using the following formula:

Equation 3-2. Calculating Sustainment Requirement

$$SR = Q \times SUC \times SACF \times I$$

Where:

SR is sustainment requirement

Q is facility quantity, in the same unit of measure as the SUC

SUC is sustainment unit cost found in Table 3

SACF is sustainment area cost factor found in Table 4-1

I is the value(s) representing future-year escalation for operation and maintenance accounts, published in Table 4-4.

The Sustainment Requirement for each qualifying asset in the DoD inventory is aggregated by sustaining organization and sustainment fund type in the Facilities Sustainment Model (FSM), published annually.

3-4 UNIT COST SOURCES.

Unit costs for DoD cost models are developed using a variety of sources. These sources fall into the three categories described below, listed in order of preference of use. The source description and source group for each unit cost are identified in Table 3. Supporting documentation for each unit cost calculation is available in the "Supporting documentation" file download accompanying this UFC document on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

3-4.1 Source 1 Published Data.

Standard, easily accessible published data that is highly applicable to the FAC. Source 1 is the most desirable due to ease of access, general applicability, and lack of bias. Examples include the DoD Tri-Service Committee on Cost Engineering, Service-specific cost guidance (USACE), commercial cost-estimating guidelines or models, or other Government-published cost guidance from federal, state, or local government agencies (e.g., Fairfax County (Virginia) Park Authority). Non-DoD source 1 data may require refinement for application in DoD, but is still considered source 1 if it closely matches the design attributes of the FAC.

3-4.2 Source 2 Similar Data.

Data that is applied to facilities with similar but not identical characteristics (e.g., sewage waste treatment facilities and industrial waste treatment facilities). Source 2 also includes unpublished government or trade association cost data, and Component-validated costs for non-standard facilities that have no commercial counterparts (e.g., missile launch facilities or military ranges).

3-4.3 Source 3 Derived Data.

Unpublished project-specific data derived from Component project documents (e.g., DD Forms 1391) or from calculating costs from reported Plant Replacement Value and inventory, or derived from using a ratio of sustainment to construction from a similar source 1 Facilities Analysis Category (e.g., FAC 2115, Aircraft Maintenance Hangar, Depot derived from FAC 2111, Aircraft Maintenance Hangar).

3-5 REVISING UNIT COSTS.

Users of this UFC are encouraged to suggest revisions to the published cost factors, particularly for facilities unique to their mission. Submit proposed changes as Criteria Change Request (CCR) on the WBDG web site (www.wbdg.org) in accordance with the following guidelines:

- Revised costs should come from an equivalent or superior source,

- Revised costs should be easily audited,
- Revised costs should be consistent with the functional definitions,
- Revised costs should be consistent with the FAC scope, and
- Revised costs should be suitable for application throughout DoD.

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CHAPTER 4 COST ADJUSTMENT FACTORS

4-1 LOCATION ADJUSTMENTS.

Table 4-1 provides area cost factors (ACFs) to be used for adjusting “bare” unit costs to location-specific costs for the most common locations.

All data tables in this UFC are found in a combined file under “Related Materials” accompanying this UFC on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

4-1.1 Application.

4\\ For military construction projects, use the MILCON ACFs with the facility unit costs from Chapter 2 or approved Air Force, Army, or Navy MILCON Pricing Guide and supporting facilities unit cost from Chapter 6. /**4**/ For calculating Plant Replacement Value, use the MILCON ACFs with the appropriate PUCs from Chapter 3. For calculating sustainment costs, use the sustainment ACFs with the appropriate SUCs from Chapter 3. **5**\\ /**5**/

5\\ Do not use the MILCON ACFs to modify detailed quantity take-offs, unit price book (UPB) line items, commercial cost data, or user-generated unit costs. These cost estimating methods and databases have their own processes and factors for adjusting costs to different locations. MILCON ACFs or any component(s) that make up MILCON ACFs are only applicable to construction cost and should not be applied or utilized for any other purpose. /**5**/

4-1.2 Data Source.

In general, the Tri-Service Cost Engineering ACF software program evaluates the local costs for a United States market basket of eight labor crafts, 18 construction materials, and four equipment items. These materials, labor and equipment (MLE) items are representative of the types of products, services, and methods used to construct most military facilities in the United States. Each of the MLE costs is normalized and weighted to represent its contribution to the total cost of a typical facility. The normalized MLE is then modified by seven matrix factors that cover local conditions affecting construction costs. These matrix factors include weather, seismic, climatic (frost zone, wind loads, and HVAC systems), labor availability, contractor overhead and profit, logistics, and labor productivity and are relative to the U.S. standard. The resultant ACF for each location is normalized again by dividing by the 96-Base-City average to provide a final ACF that reflects the relative relationship of construction costs between that location and the 96-Base-City average as 1.00.

MILCON ACFs are calculated using a MLE ratio of 63/35/2. Sustainment ACFs are calculated using a MLE ratio of 46/53/1.

4-1.3 Survey.

Both CONUS and OCONUS construction market surveys were conducted in **6**\ 2024 /**6**/. The CONUS survey covered 213 locations that included 96 Base Cities (two per state in the continental U.S.). The OCONUS survey included 55 locations, and was based on a market basket of goods for typical U.S. labor, material, equipment, and construction methods.

CONUS and OCONUS surveys are performed annually. When local materials and construction methods differ from those represented by the published ACF, specific adjustments may need to be added to the cost estimate to account for any differences. There is no easy correlation between the current MILCON ACFs and previous MILCON ACFs for specific locations. No common benchmarks exist because both the Base City average and the relationships between cities change with each survey. It is possible, however, to compare differences between several locations in this database with differences between the same locations in previous databases.

4-1.4 Force Majeure.

The ACF is not intended to, or capable of, responding to rapid changes in the market place. Examples include Acts of God, accelerated construction schedules, changes in the demand and supply for construction materials, labor, and equipment. An increased demand for labor beyond what the local market can supply may require the enticement of premium pay, overtime hours, temporary living expenses, and travel expenses.

4-1.5 User Requested Revisions.

Users may request revisions to published ACFs when market conditions unexpectedly change. Each request must be initiated as a Criteria Change Request (CCR) on the Whole Building Design Guide (www.wbdg.org). The local cost engineer shall provide updated market basket ACF software input factors with adequate backup documentation to HQUSACE or NAVFAC for them to update the Tri-Service Cost Engineering ACF software.

4-2 ESCALATION.

Tables 4-2, 4-3, and 4-4 provide escalation (inflation) factors used to adjust unit costs in Tables 2 and 3 (expressed in base-year dollars) to the desired year, as follows:

4-2.1 Military Construction.

Military construction **3**\ programming cost /**3**/ estimates that use unit costs from Table 2 should use the military construction escalation factor from table 4-2 for the expected midpoint of construction as described in UFC 3-730-01.

4-2.2 Plant Replacement Value Escalation Rates.

PRV calculations that use PUC from Table 3 should use the escalation factor from Table 4-3 for the desired program year.

4-2.3 Facilities Sustainment.

Modeled facilities sustainment cost estimates that use unit costs from Table 3 should use the O&M escalation factor from Table 4-4 for the desired program year.

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CHAPTER 5 REPLACEMENT COST

5-1 REPLACEMENT COST.

5-1.1 Definition of Replacement Cost.

Replacement cost is a stand-alone cost that represents the total cost to design and construct a new facility based on current codes, UFC and other design criteria that replaces an existing facility. This may be computed using the methodologies in UFC 3-730-01. Replacement cost is distinctly different from the PRV calculation defined in Chapter 3.

The replacement cost includes the demolition and disposal of the existing facility, hazmat removal, and special construction features such as special foundations and historic considerations. The replacement cost generally excludes site work and utilities outside the 5-foot line except when current codes, UFC and other design criteria require utilities and site work outside the 5-foot line to be modified, replaced/modernized and/or upgraded.

5-1.2 Use of Replacement Cost.

Use replacement cost as a benchmark to compare to the renovation cost of an existing facility. For renovation projects, the ratio of renovation cost to replacement cost is used to identify additional facility upgrades (such as **4**\ anti-terrorism/force protection (ATFP) /**4**/, seismic evaluation and retrofit, and sustainability) as determined by the requirements in UFC's or other design criteria.

5-1.3 Considerations.

If the UFC and other design criteria require utilities and sitework outside the 5-foot line to be modified, replaced/modernized, and/or upgraded, the cost for this is included in the replacement cost.

Replacement of an existing facility of the same size and location may not be ideal for every project. If the replacement facility is to be located at a different site from the existing facility, the cost of sitework and supporting facilities should be included.

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CHAPTER 6 \2\ UNIT COST FOR SUPPORTING FACILITIES

6-1 OVERVIEW.

The supporting facilities unit costs in this Chapter apply to the preparation of programming cost estimates **5**\ in accordance with the methodology described in UFC 3-730-01. /**5**/

All data tables in this UFC are found in a combined file under "Related Materials" accompanying this UFC on the WBDG web site: https://www.wbdg.org/dod/ufc/ufc-3-701-01.

6-2 SUPPORTING FACILTIES UNIT COST TABLE.

Table 6 provides supporting facilities unit costs in dollars per unit of measure ($/UOM). The list reflects common cost items that are typically included in construction projects.

6-3 SUPPORTING FACILITY UNIT COST DEVELOPMENT METHODOLOGY.

6-3.1 Methodology and Data Source.

The unit costs for supporting facilities are developed using the **6**\ 2024 /**6**/ Costbook database. The Costbook database provides material, labor, and equipment cost for the CONUS area. The costs were escalated to **6**\ 01 October 2024 /**6**/ using the DoD SPI. Cost items are for new construction only.

The supporting facilities unit costs are built as assemblies in Micro Computer-Aided Cost Engineering System 2nd Generation (MCACES/MII) using cost items from the Costbook database. Mark-ups are applied in the cost estimate to adjust cost items to the average market conditions.

6-3.2 Supporting Facility Included Costs.

The unit costs include the following:

- Installed pricing with full contractor mark-ups
- A summary of mark-ups and other included cost are included in a file under "Related Materials" on the WBDG web site

6-3.3 Supporting Facility Excluded Costs.

The unit costs do not include the following:

- Location Adjustment
- Escalation
- Design Build Cost

- Construction Contingency
- SIOH

/**2**/

APPENDIX A GLOSSARY

A-1 ACRONYMS.

AFCEC	Air Force Civil Engineer Center
AT	Anti-Terrorism
ATFP	Anti-Terrorism/Force Protection
ACF	Area Cost Factor
BIA	Bilateral Infrastructure Agreement
CATCODE	Category Code
CONUS	Continental United States
CCR	Criteria Change Request
DoD	Department of Defense
DoDEA	Department of Defense Education Activity
ESS	Electronic Security System
EMCS	Energy Management Control System
FAC	Facility Analysis Category
FSM	Facilities Sustainment Model
FY	Fiscal Year
GUC	Guidance Unit Cost
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilation, and Air Conditioning
HII	Historical Analysis Generator Second Generation
HNFA	Host Nation Funded Construction Agreements
IDS	Intrusion Detection System
MLE	Materials, Labor, and Equipment
MCACES/MII	Micro Computer-Aided Cost Engineering System 2nd Generation

MILCON	Military Construction
NAVFAC	Naval Facilities Engineering Systems Command
OSD	Office of the Secretary of Defense
O&M	Operation and Maintenance
OCONUS	Outside the Continental United States
PRV	Plant Replacement Value
PUC	PRV Unit Cost
RPCS	Real Property Classification System
SPI	Selling Price Index
SF	Square Foot
SM	Square Meter
SOFA	Status of Forces Agreements
SIOH	Supervision, Inspection, and Overhead
SUC	Sustainment Unit Cost
UFC	Unified Facilities Criteria
U.S.	United States
USACE	United States Army Corps of Engineers
UOM	Unit of Measure
WBDG	Whole Building Design Guide

APPENDIX B REFERENCES

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 3-730-01, *Programming Cost Estimates for Military Construction*

PLANT REPLACEMENT VALUE

Report of the Plant Replacement Value (PRV) Panel, August 2001 – May 2003, R&K Engineering, Inc. for the Office of the Deputy Under Secretary of Defense (Installations and Environment)

UFC 3-730-01
01 March 2024

UNIFIED FACILITIES CRITERIA (UFC)

PROGRAMMING COST ESTIMATES FOR MILITARY CONSTRUCTION

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UNIFIED FACILITIES CRITERIA (UFC)

PROGRAMMING COST ESTIMATES FOR MILITARY CONSTRUCTION

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **\1** ... **/1/**)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-730-01, dated 6 June 2011.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Programming cost estimates are to be prepared as accurately as possible to reflect the cost of providing facilities. To do this, basic data is to be accurate and applied consistently. A basic cost model that reflects all applicable factors derived from accurate data forms the basis for determining facility programming cost at a specific location and under specific conditions.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-730-01, dated 6 June 2011.

1-3 PURPOSE AND SCOPE.

This UFC establishes criteria and standards for development of programming cost estimates for constructing military facilities using published guidance unit cost (GUC) or using a parametric estimating program. The most current GUCs are provided in UFC 3-701-01 or the U.S. Army Corps of Engineers *Army Facilities Pricing Guide, PAX Newsletter 3.2.2*. The Tri-Services approved Parametric Cost Engineering System (PACES) may also be used for development of programming cost estimates for constructing military facilities.

This UFC addresses programming cost estimates for new construction and alteration projects, and includes cost data (based on historic data and experience) and factors for adjusting facility costs to reflect project conditions. This UFC also addresses supporting facilities cost and project cost.

The equations and examples in this UFC are represented in English units. This does not alleviate the requirement to comply with MIL-STD-3007 to use metric units in criteria documents.

1-4 APPLICABILITY.

This UFC applies to military construction (MILCON) and military operations and maintenance (O&M) projects.

1-5 GLOSSARY.

Appendix D contains acronyms, abbreviations, and terms.

1-6 REFERENCES.

Appendix E contains a list of references used in this UFC. The publication date of the code or standard is not included. Unless otherwise specified, the most recent edition of the referenced publication applies.

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CHAPTER 2 ESTIMATING NEW PRIMARY FACILITIES (LESS FAMILY HOUSING)

2-1 COST ESTIMATE PREPARATION.

Cost estimates may be prepared using the latest approved software for each cognizant design agency and other authorized cost and pricing sources.

2-2 COST ESTIMATES USING PUBLISHED GUIDANCE UNIT COST.

2-2.1 Guidance Unit Cost (GUC).

Cost estimates may use GUCs published in either UFC 3-701-01 or the Army *PAX Newsletter 3.2.2*. These publications contain a listing of expected facility unit costs, updated annually. The prices for facilities in both documents are based on criteria existing at the time of preparation, as authorized by existing regulations.

2-2.2 Adjusted Guidance Unit Cost Equation.

A unit cost for a facility, which should reflect the adjusted GUC conditions for the facility, can be obtained by using the following equation:

Equation 2-1. Formula to Estimate Facility Adjusted Guidance Unit Cost

$$\$A = \$GUC \times S \times ACF \times CE \times TU \times DC \times HR \times SS$$

Where:
$A = adjusted guidance unit cost
$GUC = guidance unit cost
S = size factor
ACF = area cost factor
CE = cost escalation
TU = technological updating factor
DC = design contingency
HR = historical requirement factor
SS = site sensitivity factor

2-2.3 Basic Adjustment Factors.

Programming cost estimates are to include proper allowances for all factors that may be reasonably expected to influence cost through the expected construction period. However, deviations which are significantly above or below the factored unit cost must be explained in detail. If the adjusted cost estimate is over the statutory limit (e.g., family housing), a waiver including complete substantiating data is to be requested in accordance with cognizant agency policy.

2-2.3.1 Size Factor (S).

Use size factors in Table 2-1 when facility gross area differs from a similar type facility's reference size (see Table 2 of UFC 3-701-01). Calculate the size ratio by dividing the programmed facility size by the facility reference size. Use the project size factors in Table 2-2 for barracks/dormitories and Table 2-3 for military family housing facilities. The size factors in Tables 2-1 through 2-3 do not include progressive collapse or seismic requirements; calculations for facilities of three or more stories should include these costs.

Note: Table 2 of 3-701-01 is posted with "Related Materials" on the Whole Building Design Guide at: https://www.wbdg.org/FFC/DOD/UFC/ufc_3_701_01_2022_c3_Data_Tables.xlsx.

2-2.3.2 Area Cost Factor (ACF).

The ACF, updated annually, reflects average statistical differences in normal labor, material, and equipment costs for similar facilities built in different geographical locations. See Table 4-1 of UFC 3-701-01 for factors to adjust estimated costs to specific geographical areas.

2-2.3.3 Cost Escalation (CE).

The unit costs shown in Table 2 of UFC 3-701-01 reflect historical costs only, normalized to the "as of" reference date in the table. These costs are to be escalated to the expected midpoint of construction using the appropriate cost escalation. Table 4-2 of UFC 3-701-01 is updated annually and provides data to use to project cost escalation due to inflationary factors affecting construction costs. Determine the midpoint of construction for each facility based on a realistic assessment of the construction schedule. Refer to the cognizant agency for more details. It may be necessary to interpolate between the escalation rates for the months between the stated years. When using the Army PAX Newsletter for projects scheduled differently than the assumed midpoint of construction, follow the guidance in the newsletter.

2-2.3.4 Technological Updating (TU) Factor.

Technological advances in equipment and operational techniques used in some specialized facilities are being developed rapidly, often resulting in obsolescence before design and construction are completed. Also, revisions in criteria to provide life cycle cost benefits may increase initial funding requirements before feedback data can reflect the added cost. A TU factor may be appropriate in these situations. Fully document and explain use of these factors in the cost estimate notes. Table 2-4 lists technological updating factors by DoD Basic Category group codes of facilities.

Table 2-1 Size Factors

Size Ratio	Size Factor	Size Ratio	Size Factor
≤0.0500	1.2750	1.6000	0.9570
0.1000	1.2690	1.6500	0.9550
0.1500	1.2320	1.7000	0.9530
0.2000	1.2020	1.7500	0.9510
0.2500	1.1750	1.8000	0.9490
0.3000	1.1520	1.8500	0.9470
0.3500	1.1320	1.9000	0.9450
0.4000	1.1140	1.9500	0.9430
0.4500	1.0980	2.0000	0.9420
0.5000	1.0840	2.0500	0.9400
0.5500	1.0720	2.1000	0.9390
0.6000	1.0600	2.1500	0.9370
0.6500	1.0500	2.2000	0.9360
0.7000	1.0410	2.2500	0.9350
0.7500	1.0330	2.3000	0.9330
0.8000	1.0250	2.3500	0.9320
0.8500	1.0180	2.4000	0.9310
0.9000	1.0110	2.4500	0.9300
0.9500	1.0050	2.5000	0.9290
1.0000	1.0000	2.5500	0.9280
1.0500	0.9950	2.6000	0.9270
1.1000	0.9900	2.6500	0.9260
1.1500	0.9860	2.7000	0.9250
1.2000	0.9820	2.7500	0.9240
1.2500	0.9780	2.8000	0.9240
1.3000	0.9740	2.8500	0.9230
1.3500	0.9710	2.9000	0.9220
1.4000	0.9680	2.9500	0.9210
1.4500	0.9650	3.0000	0.9210
1.5000	0.9620	3.0500	0.9200
1.5500	0.9600	>3.05	0.9200

Table 2-2 Barracks/Dormitories Project Size Factors

Numbers of Service Members in the Project	Project Size Factor
1-99	1.07
100-149	1.03
150-199	1.00
200-299	0.97
300+	0.95

Table 2-3 Military Family Housing Project Size Factors

Number of Units in the Project	Project Size Factor
1-9	1.25
10-19	1.15
20-49	1.10
50-99	1.04
100-199	1.00
200-299	0.93
300+	0.90

Table 2-4 Technological Updating Factors

DoD Basic Category	Category Series Description	TU Factor
300	Research, Development, Test, & Evaluation facilities	1.10
500	Hospital and medical facilities	1.05

2-2.3.5 Design Contingency (DC).

The cost estimate may include a DC based on the lack of maturity of design data. The DC covers component items that cannot be analyzed or evaluated at the time the cost estimate is prepared; however, these items are susceptible to cost evaluation as engineering and design progresses. The DC depends on the reliability and refinement of the data on which the cost estimate is based, so reliability and refinement diminishes as design progresses from programming through the design completion stage. Though it decreases at each successive design stage, the initial magnitude of the DC at programming depends on the technical complexity of the project for which the cost estimate is being prepared. The level of technical complexity must be a prerequisite for determining the magnitude of the DC. DC is listed in Table 2-5. If a cost and schedule risk analysis (CSRA) is required during programming, develop the design contingency using CSRA. Refer to UFC 3-740-05 for further guidance.

Table 2-5 Design Contingency

Technical Complexity Level	Description	Design Contingency
Low	Site adapted, repetitive standard design project involving routine technology	1.050
Medium	Unique design involving complex technology	1.100
High	Unique design involving highly complex technology	1.200
Ultra-high	Unique design involving extremely complex or innovative technology	1.300

2-2.3.6 Historical Requirements (HR) Factor.

A factor for unique architectural features to comply with HR is permitted for facilities to be built at locations listed in the National Register of Historical Places. The factor for HR is typically 1.05. Deviation above the allowed factor must be explained in detail.

2-2.3.7 Site Sensitivity (SS) Factor.

An SS factor may be necessary for special cases where the unique nature of both the site and the project, in relation to one another, will cause a significant impact on the cost. As recommended practice, analysis for SS factor should consider only those unique site conditions which will influence cost by virtue of the uniqueness of the conditions involved. The method outlined in Section 2-5 may be used to determine the cost impact caused by the influence of a project upon itself, resulting from an extremely large concentration of construction effort, or from extreme site limitations, or from both. Appendix B lists examples of SS considerations and computations with a range of values, where applicable, from above normal to substantially below normal. This listing only provides examples and is not comprehensive.

2-3 COST ESTIMATES USING PARAMETRIC MODELS.

2-3.1 Parametric Cost Estimating.

Parametric cost estimating is a computer-based methodology that uses factors based on engineering parameters developed from historical cost databases, construction practices, and engineering and construction technology. These factors include physical properties that describe project definition characteristics, such as size, building type, foundation type, exterior materials, roof type and materials, number of floors, functional space requirements, and utility requirements. The major advantage of parametric cost estimating is that it can provide detailed construction cost relatively quickly with only limited analysis of the facility. Parametric cost estimating is only as good as the effort expended in identifying the key project inputs. It must be based upon an accurately developed construction scope. All parametric assumptions and key project inputs must be documented to provide rationale for development of the cost estimate. All major entities involved with the project must be energized and actively participate in project scope validation, including installation personnel, the Project Manager, and the Project Delivery Team (PDT). At this time, the only Tri-Services approved computer-based parametric estimating program is PACES, and training is required prior to use.

2-4 OTHER ALLOWABLE COSTS FOR PRIMARY FACILITIES.

There may be situations where additional costs will be required for the project, which are not part of the GUC or parametric model and may be itemized separately. Use of these itemized costs must comply with cognizant design agency guidance and be fully documented and explained in the cost estimate notes.

2-5 ADJUSTED GUIDANCE UNIT COST ESTIMATE EXAMPLE.

The equation for the guidance unit cost adjustment determination is:

$$\$A = \$GUC \times S \times ACF \times CE \times TU \times DC \times HR \times SS$$

Where:
$GUC = guidance unit cost
S = size factor
ACF = area cost factor
CE = cost escalation
TU = technological updating factor
DC = design contingency
HR = historical requirement factor
SS = site sensitivity factor

Paragraphs 2-5.1 through 2-5.10 provide an example for calculating the facility cost estimate for a 48,750 square foot general purpose administration building, Navy category code 61010, to be built at Naval Station Norfolk, Virginia, in the FY25 program. This example assumes a contract award in FY25, a construction start date of Oct 2026, and a construction completion date of Oct 2027.

2-5.1 Step 1 - Unadjusted Cost.

In Table 2 of UFC 3-701-01, find the unit cost for the applicable building type closest to the building type being programmed. The Administrative Facilities: Multi-Purpose Administration facility is the comparable facility with a unit cost of $503/sf and a reference size of 45,000 square feet. **Note:** UFC 3-701-01 Table 2 is updated annually; numbers used within this example may not correspond or be current.

2-5.2 Step 2 - Size Factor.

Calculate a size ratio by dividing the programmed building size by the reference size. Using the closest comparable size ratio, determine the size adjustment factor from Table 2-1 of this UFC. The 48,750 square foot programmed building size divided by the 45,000 square foot reference building size yields a size ratio factor of ~1.08. Using Table 2-1, find the size ratio of 1.05 and obtain an adjustment factor of 0.9950.

2-5.3 Step 3 - Area Cost Factor.

Determine the location adjustment factor from Table 4-1 of UFC 3-701-01. For Naval Station Norfolk, Virginia, the 0.92 applies.

2-5.4 Step 4 - Cost Escalation.

Make allowance for cost growth due to economic factors anticipated between the dates on which the cost and pricing data in Table 2 of UFC 3-701-01 are based and the expected midpoint of construction date for the project being programmed. For this FY25 example project, construction start is Oct 2026 and construction completion is Oct 2027. The midpoint of construction will be six months after the start date. Using UFC 3-701-01, dated March 2022, Change 1, which reflects historical cost and pricing data normalized to Oct 2021 for preparation of the DoD budget for FY25, projected escalation factors from Table 4-2 of UFC 3-701-01 are 1.0000 for October 2021, 1.1062 for October 2026, and 1.1284 for October 2027. The escalation factor to October 2025 would be 1.1062/1.000 or 1.1062. Interpolating for six additional months of projected escalation factor and adding this to the 1.1062 projected escalation factor will provide the total projected escalation factor to be used.

$$(1.1284 - 1.1062) \div 12 = 0.00185$$

$$6 \text{ months} \times 0.00185 = 0.0111$$

$$1.1062 + 0.0111 = 1.1173$$

2-5.5 Step 5 - Technological Updating Factor.

Make allowance for cost adjustment due to updated technology by using the technological updating factor from Table 2-4. For this example, administrative facilities are not represented in the table; therefore, the factor is 1.00.

2-5.6 Step 6- Design Contingency.

Determine the DC in accordance with Table 2-5. The building is considered a low complexity. Using Table 2-5, the DC is 1.05.

2-5.7 Step 7 - Historical Requirements Factor.

Make allowance for cost adjustment due to historical requirements by using the HR factor of 5%, or 1.05.

2-5.8 Step 8 – Site Sensitivity Factor.

Make allowance for cost adjustment due to site sensitivity by using the SS factor of 4.55% or 1.0455.

2-5.9 Step 9 - Adjusted Cost.

Calculate adjusted cost using the equation for the adjusted GUC as follows:

$$\$A = \$GUC \times S \times ACF \times CE \times TU \times DC \times HR \times SS$$

$$\$A = \$503/sf \times 0.995 \times 0.92 \times 1.1173 \times 1.00 \times 1.05 \times 1.05 \times 1.0455$$

$$= \$593.00/sf$$

2-5.10 Step 10 – Facility Cost.

Determine the estimated facility cost by multiplying the size of the facility being programmed by the adjusted unit cost ($A) derived in Step 9, and then round off the product. The size 48,750 square feet multiplied by $593.00 per square foot yields a facility cost estimate of $28,908,750, which when rounded to the nearest million dollars yields $29,000,000.

CHAPTER 3 SUPPORTING FACILTIES COSTS AND PROJECT COSTS.

3-1 SUPPORTING FACILITIES UNIT COSTS.

Cost estimates may use supporting facility unit costs published in UFC 3-701-01. Supporting facilities are items of construction directly related to the project such as utilities, roads and parking, and site improvements. Supporting facilities' unit costs need to be adjusted by applying a location adjustment factor, cost escalation, and design contingency. Specific details for unit costs are defined in paragraphs 3-1.1 through 3-1.1.2.

3-1.1 Munitions and Explosives of Concern (MEC) Unit Cost.

Unit costs for MEC are available in UFC 3-701-01. The unit cost is based on surface area. The user will need to determine the depth necessary for MEC investigation to determine which MEC unit costs to include.

3-1.1.1 MEC Investigation and Removal Process (8 Step).

The following steps are part of a typical MEC investigation and removal process. Other items may need consideration depending upon site conditions.

- Step 1: GPS Survey – Survey of subject site boundaries.
- Step 2: Area Assessment – Walkthrough visual assessment of site for potential items on surface.
- Step 3: Area Preparation – Basic site clearing (does not include vegetation clearing (e.g., trees and shrubs).
- Step 4: Surface Clearance – Scan of surface with metal detectors.
- Step 5: Subsurface Detection – Scan of site with high density metal detectors typically reaching to a depth of 2 feet below surface without excavation.
- Step 6: Excavation – Excavation of site removing the top 2-foot layer to allow subsurface scanning 2 feet below the previous scan.
- Step 7: Access and Identification – Object located by scan and identified as possible MEC or other.
- Step 8: Disposal – Removal and disposal of MEC object.

3-1.1.2 Types of MEC Unit Costs.

Two unit costs are available for MEC based on the required depth of investigation. They are listed below and indicate which steps from paragraph 3-1.1.1 apply.

- Surface Investigation (includes Steps 1-5, 7 and 8) – Investigation and clearing.

- Deep Investigation (includes Steps 1-8) – Clearing to 4 feet below surface.

3-2 PROJECT COST.

Project cost is defined as the sum of construction costs, including primary facility costs, supporting facilities' costs, any other allowable costs, cost allowances for contingencies, other allowances for supervision, inspection, and overhead (SIOH), and design-build design cost.

3-2.1 Construction Contingencies.

As recommended practice, include in each programming cost estimate a separate item as a reserve for construction contingencies to cover construction requirements which cannot be foreseen before the contract is awarded. The contingency reserve is used for some adverse or unexpected condition that cannot be predetermined from the data at hand during engineering and design and at the time of contract award -- usually latent difficulties such as unforeseeable relocations; unforeseeable foundation conditions; utility lines in unforeseeable locations; or other unforeseen problems. The contingency reserve is not an allowance for omissions of work items known to be required, but for which quality or quantity has not yet been determined by specific design.

In addition, as recommended practice, make reasonable allowances for all foreseeable requirements in the cost estimate, or include an allowance for cost adjustment. Application for construction contingency reserves must conform to cognizant design agency guidance. The construction contingency reserve for military construction programs and family housing new or replacement construction will typically be five percent of the total contract cost, but may be higher based on the results of the CSRA. Refer to UFC 3-740-05 for CSRA guidance.

3-2.2 Supervision, Inspection, and Overhead (SIOH).

Including a separate item for SIOH in each programming cost estimate is recommended. Application of SIOH rates must comply with Office of the Assistant Secretary of Defense, Energy, Installations, and Environment Memorandum, "Military Construction Supervision, Inspection, and Overhead Fixed Rates for Fiscal Year 2024 and Future Projects," April 14, 2022 (https://www.wbdg.org/FFC/DOD/UFC/ufc_3-701-01_MilCon_SIOH_Rates_Change_14Apr22.pdf).

For a list of applicable remote locations for Navy, refer to NAVFACINST 7820.0 (8 Aug 22) (https://www.wbdg.org/FFC/DOD/UFC/ufc_3-701-01_NAVFACINST_7820.2_SIOH.pdf), and the cognizant design agency for Army and Air Force.

3-2.3 Design-Build Design Cost.

Design-build projects may include a design-build design cost. The percentage used will comply with cognizant design agency guidance.

3-2.4 Other Allowable Cost.

Other allowable costs may include post-construction contract award services (PCAS), commissioning, other taxes (excise tax, gross receipts tax (GRT)), cybersecurity commissioning, low impact development (LID), sustainability, operations and maintenance support information (OMSI), progressive collapse, and design during construction.

Some states and nations do not have sales tax, but impose either GRTs (named variously among the states) or gross excise taxes. (Delaware, Nevada, Ohio, Oregon, Tennessee, Texas, and Washington have varying amounts of GRTs in lieu of a sales tax. Hawaii has a general excise tax.)

3-3 PROJECT COST ESTIMATE EXAMPLE.

Continuing the example from Chapter 2, determine the project cost by adding contingency and SIOH factors to facility cost with adjusted guidance unit cost and supporting facilities cost. (Assume a supporting facilities cost of $500,000.) Since this project is new construction and location is CONUS, a contingency factor of 1.05 and a SIOH factor of 1.065 should be applied as follows:

$$\text{Project Cost} = (\$28{,}908{,}750 + \$500{,}000) \times 1.05 \times 1.065 = \$32{,}886{,}335$$

In accordance with Appendix A, the project cost is $33,000,000.

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CHAPTER 4 ESTIMATING ALTERATION PROJECTS

4-1 ESTIMATING FACILITY ALTERATON.

Alteration is defined as a change to interior or exterior facility arrangements to improve or change its current purpose. This includes installed equipment made a part of the existing facility, but does not include additions, expansions, or extensions. The procedures described in this paragraph provide a step-by-step method for preparing programming cost estimates for facility alteration when current design data is not available. The procedures are based on the ASTM E1557-09 UNIFORMAT II work breakdown structure (WBS) and relate the alteration work to new facility requirements as a percentage of new work.

Figure 4-1 is an example of a completed DA Form 7307-R. Appendix C tabulates the ratio of WBS cost to facility cost based on DoD military construction historical cost data. Table 4-1 shows the percentage of installation cost required for removal and the percentage cost required for installation.

% of Installation Cost Required for Removal: This is judgmental, assuming a percentage to remove (as compared to 100% for install).

% of Cost Required for Installation: The 35% is based on direct cost breakdown of UFC 3-701-01, paragraph 4-1. MILCON ACFs are calculated using a material/labor/equipment (MLE) ratio of 63/35/2.

Note: DA Form 7307-R, Cost Estimating Worksheet – Facility Alteration, is available at: https://armypubs.army.mil/pub/eforms/DR_a/pdf/A7307_R.pdf.

Table 4-1 Cost of Removal Versus Cost of Installation

WBS#	Description	% of Installation Cost Required for Removal	% of Cost Required for Installation
A10	Foundations	50	35
B10	Superstructure	50	35
B20	Exterior Closure	50	35
B30	Roofing	50	35
C10	Interior Construction	50	35
C30	Interior Finishes	50	35
D10	Conveying	50	35
D20	Plumbing	50	35
D30	HVAC	50	35
D40	Fire Protection	50	35
D50	Electrical	80	35
E10	Equipment	80	35
E20	Furnishings	50	35
F10	Special Construction	50	35

4-2 FACILITY ALTERATION COST ESTIMATE EXAMPLE.

Consider an FY25 alteration project for an existing 40,600 square foot multi-purpose administration building, category code 61010, at Naval Station Norfolk, Virginia, with midpoint of construction of April 2027. Step-by-step procedures using DA Form 7307-R in Figure 4-1 include:

Step 1: Identify the percentage of the building systems to be removed and enter in blocks 16a and 21a. Data for this block should be based on the scope of work (in many cases based on best judgment). A walk-through of the facility to be altered is the best way to obtain accurate data. Assume for this example that the substructure, superstructure, and exterior closure are not affected; that 80% of the interior and special construction is to be replaced; and that 75% of the electrical, mechanical, fire protection and plumbing are to be replaced.

Step 2: Using data obtained from Table 4-1, enter in block 16b the percentage of installation cost required for removal and in block 16c the percentage of cost required for installation.

Step 3: Obtain the ratio of WBS systems cost to facility cost for multi-purpose admin building from Appendix C and enter in blocks 16d and 21b.

Step 4**:** Calculate block 16e by multiplying entries in blocks 16a, 16b, 16c, and 16d. Calculate block 17, removal/demolition factor (RDF), by adding all entries in block 16e, which is 9.6% of the cost to build the building new. To calculate the total removal/demolition cost (RDC) for the project, use the following:

Equation 4-1. Formula to Calculate Removal/Demolition Cost

$$RDC = \$GUC \times S \times ACF \times CE \times TU \times DC \times HR \times SS \times RDF$$

Where:
$GUC = guidance unit cost
S = size factor
ACF = area cost factor
CE = cost escalation
TU = technological updating factor
DC = design contingency
HR = historical requirement factor
SS = site sensitivity factor
RDF = removal/demolition factor

$$RDC = \$503 \times 1.0110 \times 0.92 \times 1.1173 \times 1.00 \times 1.05 \times 1.05 \times 1.0455 \times 0.096 = \$57.84$$

Step 5: Determine replacement/new portion factor. The same method is used in the calculation for removal, except the cost includes 100% labor material and equipment. Calculate block 21c by multiplying entries in blocks 21a and 21b. Calculate block 22, replacement new factor (RNF), by adding all entries in block 21c. Total RNF is 47.5% (block 22) of the cost to build the facility new. Calculate the total new work cost (NWC) as follows:

Equation 4-2. Formula to Calculate New Work Cost

$$NWC = \$GUC \times S \times ACF \times CE \times TU \times DC \times HR \times SS \times RNF$$

$NWC = \$503 \times 1.0110 \times 0.92 \times 1.1173 \times 1.00 \times 1.05 \times 1.05 \times 1.0455 \times 0.475 =$ $\$286.20$

Step 6: Consider adding a special adjustment factor (SAF) due to construction limitations. Allowed demolition/removal and replacement construction limitations include:

- dust protection for adjacent work areas: 2-7%
- limited use of equipment (noise/power) limitations: 1-6%
- limited storage of construction materials: 1-6%
- protection of completed work: 2-6%
- shift work: 2-10%

Any other adjustment factor must be defined and justified. SAF due to construction limitations may be applied either to the total unit cost or to the total cost of the project. Using the SAF from block 25 of the completed DA Form 7307-R, the demolition and replacement costs are adjusted:

Adjusted RDC:

= RDC x (1+SAF%)
= \$57.84 x 1.15 = \$66.52/sf

Adjusted NWC:

= NWC x (1+SAF%)
= \$286.20 x 1.15 = \$329.13/sf

Total alteration cost:

= adjusted RDC + adjusted NWC
= \$66.52/sf + \$329.13/sf
= \$395.65/sf

Step 7: Determine the facility estimated alteration cost by multiplying the area of the facility being programmed for alteration by the total alteration cost as follows:

= \$395.65/sf x 40,600 sf
= \$16,063,390

Step 8: Determine the project cost in accordance with the example in paragraph 3-3.

Figure 4-1 Example of DA Form 7307-R, Cost Estimating Worksheet–Facility Alteration

COST ESTIMATING WORKSHEET - FACILITY ALTERATION

1. PROJECT NUMBER 12345	2. PROJECT TITLE Renovate Administration Building			3. FY 2025
4. BUILDING NUMBER 401	5. LOCATION Fort Bragg, NC			6. HISTORICAL YES NO
7. FACILITY TYPE Multi-Purpose Administration Building	8. CATEGORY CODE 61010	9. FACILITY SIZE *(SF)* 40,600	10. AREA TO BE ALTERED *(SF)* 40,600	11. FUND TYPE *(MCA/OMA/AFH)* MCON
12. ESTIMATOR/OFFICE/DATE J. Smith/MIDLANT/ Jan 2025	13. BASIS OF ESTIMATE Walk-Through		14. MONTHS 12	15. CONST START 10/26

16. REMOVAL/DEMOLITION PORTION OF PRIMARY FACILITY

BUILDING SYSTEM WORK BREAKDOWN	PERCENT OF SYSTEM ALTERED *a*	PERCENT OF LABOR TO REMOVE *b*	LABOR PERCENT TO INSTALL *c*	SYSTEM PERCENT OF TOTAL *d*	TOTAL PERCENT REMOVAL *e*
A10 FOUNDATIONS	0	50	35	6.99	0.0
B10 SUPERSTRUCTURE	0	50	35	13.02	0.0
B20 EXTERIOR CLOSURE	0	50	35	13.03	0.0
B30 ROOFING	0	50	35	2.12	0.0
C10 INTERIOR CONSTRUCTION	80	50	35	9.52	1.3
C30 INTERIOR FINISHES	80	50	35	8.22	1.1
D10 CONVEYING	0	50	35	1.11	0.0
D20 PLUMBING	75	50	35	3.39	0.4
D30 HVAC	75	50	35	19.57	2.6
D40 FIRE PROTECTION	75	50	35	2.39	0.3
D50 ELECTRICAL	75	80	35	17.83	3.7
E10 EQUIPMENT	0	80	35	0.18	0.0
E20 FURNISHINGS	0	50	35	1.14	0.0
F10 SPECIAL CONSTRUCTION	80	50	35	1.49	0.2
				17. RDF	9.6

18. FACILITY TYPE Multi-Purpose Administration Building	19. CATEGORY CODE 61010	20. AREA TO BE ALTERED *(SF)* 40,600

21. REPLACEMENT/NEW PORTION OF PRIMARY FACILITY

BUILDING SYSTEM WORK BREAKDOWN	PERCENT OF SYSTEM REPLACED *a*	SYSTEM PERCENT OF TOTAL *b*	TOTAL PERCENT REPLACED *c*
A10 FOUNDATIONS	0	6.99	0.0
B10 SUPERSTRUCTURE	0	13.02	0.0
B20 EXTERIOR CLOSURE	0	13.03	0.0
B30 ROOFING	0	2.12	0.0
C10 INTERIOR CONSTRUCTION	80	9.52	7.6
C30 INTERIOR FINISHES	80	8.22	6.6
D10 CONVEYING	0	1.11	0.0
D20 PLUMBING	75	3.39	2.5
D30 HVAC	75	19.57	14.6
D40 FIRE PROTECTION	75	2.39	1.7
D50 ELECTRICAL	75	17.83	13.4
E10 EQUIPMENT	0	0.18	0.0
E20 FURNISHINGS	0	1.14	0.0
F10 SPECIAL CONSTRUCTION	80	1.49	1.1
		22. RNF	47.5

23. SPECIAL ADJUSTMENT FACTORS		24. PERCENT TO ADD
a.	DUST PROTECTION FOR ADJACENT WORK AREAS	5.0
b.	LIMITED USE OF EQUIPMENT *(NOISE/POWER LIMITATIONS)*	5.0
c.	LIMITED STORAGE OF CONSTRUCTION MATERIALS	5.0
d.	PROTECTION OF COMPLETED WORK	0.0
e.	SHIFT WORK	0.0
		25. SAF 15.00

DA FORM 7307-R, APR 1994

CHAPTER 5 ESTIMATING FAMILY HOUSING

5-1 FAMILY HOUSING COST MODEL.

Paragraphs 5-1.1 through 5-1.18 may be used to calculate cost estimates for construction of new and replacement family housing.

5-1.1 FY.

FY is the fiscal year in which the project is proposed.

5-1.2 Location.

Location is the installation and state in which the proposed construction will take place.

5-1.3 # Units.

This is the number of family housing dwelling units which will be constructed in this project. Note that for replacement projects, the number of units may be equal to or less than the number of units to be demolished.

5-1.4 AGSF.

AGSF is the average gross square feet (AGSF) of the units proposed for construction. Size of dwelling units must comply with UFC 4-711-01.

5-1.5 $/GSF.

$/GSF is the cost to construct family housing per gross square foot (GSF). The cost will correspond to the fiscal year of the project. Cost includes only the primary facility with sprinklers, including attached two car garage (though GSF of garage is excluded, cost of attached garage GSF is included) and attached exterior bulk storage, but not the supporting infrastructure, demolition, supporting amenities or special construction requirements.

5-1.6 5' Line Cost.

The 5-foot line cost is the cost for the dwelling unit only, and is equal to the number of units multiplied by the AGSF multiplied by the cost per GSF.

5-1.7 ACF.

The ACF adjusts the prescribed costs to the location of the proposed project. These factors are listed in UFC 3-701-01, Table 4-1, and are updated annually based on a construction market survey.

5-1.8 Project Size.

The project size factor allows for economies of scale and depends upon the project size. The prescribed unit cost ($GSF) is based on an average project size. Projects involving a large number of units will realize economies of scale, resulting in a smaller project size factor. Table 2-3 lists project size factors for family housing projects

5-1.9 Project Factor.

The project factor equals the ACF multiplied by the project size factor. One project factor applies to all units being constructed in a project. Do not calculate a separate factor for each type of unit (for example, two-, three-, and four-bedroom junior noncommissioned officers).

5-1.10 Adjusted Housing Cost.

The adjusted housing cost equals the 5-foot line cost multiplied by the project factor.

5-1.11 Solar Cost and Information System Cost.

These are additional costs not captured in the 5-foot line cost. If a project will include solar energy features, multiply the estimated solar cost by the ACF by the number of dwelling units to arrive at the total project solar cost. Note that such features must be justified based on a life cycle cost analysis. The information system cost must be added to every family housing construction project. This cost represents telephone and cable television connections and wiring inside the buildings' 5-foot line. Include cost per dwelling unit for communication and cable television. To arrive at the information system cost, multiply the cost per dwelling unit for communication and cable television by the ACF by the number of dwelling units.

5-1.12 Other.

In some instances, site conditions may involve additional costs for the primary facility (inside the 5-foot building line). Examples include rock excavation, special foundation requirements, soil stabilization, basements, or special architectural features.

5-1.13 Average Unit Cost.

Add the housing unit cost, the solar and information system cost (if any), and any "other" cost, and divide by the number of units.

5-1.14 Supporting Cost.

This includes all work outside the 5-foot building line, such as site preparation, roads, utilities, recreation, landscaping, site amenities, and demolition. Where support cost estimates can be documented, show the unit cost and how derived. Often, support costs for family housing projects are difficult to identity for various reasons. Proposed units may be sited where existing units are planned for demolition or the site is undeveloped. If documenting support cost is difficult, use a percentage of the housing unit cost until a detailed analysis is completed. A separate cost breakout for demolition of existing units is recommended. Environmental conditions and individual state regulations must be considered when determining demolition cost. When using a "generic" for support cost and demolition, consider the ACF to arrive at the total support cost.

5-1.15 Estimated Construction Cost.

The summary subtotal consists of the -housing unit cost; solar cost, if any; other cost, if any; and the support cost.

5-1.16 Project Cost.

The project cost equals the estimated construction cost multiplied by the contingency cost by the SIOH. Include the appropriate design fee for Design-Build projects in project cost. Refer to paragraph 3-2.3.

5-1.17 Rounded Project Cost.

The rounded project cost is the project cost rounded in accordance with the Congressional rounding rule (see Appendix A).

5-1.18 Project Cost/SF.

The project cost per square foot equals the project rounded cost divided by the product of the number of units multiplied by the AGSF.

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APPENDIX A CONGRESSIONAL ROUNDING RULE

Amount	Nearest
Less than or equal to 1,000,000	10,000
1,000,001 to 5,000,000	50,000
5,000,001 to 10,000,000	100,000
10,000,001 to 15,000,000	200,000
15,000,001 to 20,000,000	500,000
20,000,001 or greater	1,000,000

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APPENDIX B SAMPLE SITE SENSITIVITY COST CONSIDERATIONS

Table B-1 Impact Identifier: Housing Availability

Condition	SS factor	Narrative Description of Condition with Resulting Assumptions and Computations
Normal	0	Adequate housing available in local area, no cost impact
Slightly below	+0.0525	Adequate housing not available in local area; however, housing is available within commuting distance. Assumptions: Provide travel allowance to location of adequate housing for key personnel and critical crafts. Computation example: Assume a travel allowance of $60/day ($0.60/mile for a 100-mile round trip commute), using 20 work days per month for a $1200/month travel allowance. Travel Allow Per Month/Avg Monthly Wages x Key Personnel + Critical Crafts Labor Costs as % of Total/Project Costs as 100%. (use $50/hour for a 40-hour work week and 4 weeks per month or $8,000) = Adjustment Factor ($1,200/8,000) x (35%/100%) = 0.0525
Substantially below normal	+0.0700	Inadequate housing in local area. Housing is not available within commuting distance. Assumptions: Provide trailer housing for majority of contractor personnel and skilled crafts. Computation example: Assume rental of trailers and sale of used trailers will not offset all original cost. Land lease and site development cost to be included in project cost. Loss on Trailers Lease and Development Cost/Total Project Cost = Adjustment Factor $2,000,000/$10,000,000 x (35%/100%) = 0.0700

Table B-2 Impact Identifier: Material Availability

Condition	SS Factor	Narrative Description of Condition with Resulting Assumptions and Computations
Normal	0	Project requirements do not exceed the capabilities of the local area. Site is within the normal delivery distance. No cost impact.
Slightly below	+0.0126	Project requirements do not exceed the capabilities of the local area, but site is outside normal delivery range. Assumptions: Additional hauling allowance required. Computation example: Add'l Cost for Hauling Beyond Normal Delivery Zone/Total Normal Mat'l Cost x Mat'l Cost as % of Total/Project Cost as 100% = Adjustment Factor $1,000,000/$50,000,000 x 63% = 0.0126
Substantially below normal	+0.0252	Project requirements exceed the capabilities of the area. Assumptions: Additional hauling allowance and onsite facilities required. Computation Example: Add'l Cost for Hauling & Storage Allowance/Total Normal Mat'l Cost x Mat'l Cost as a % of Total/Project Cost as 100% = Adjustment Factor $2,000,000/$50,000,000 x 63% = 0.0252

Table B-3 Impact Identifier: Local Site Peculiarities*

Condition	SS Factor	Narrative Description of Condition with Resulting Assumptions and Computations
Congested work area	+0.0280	Lost productivity caused by congested work area Assumptions: 3 hrs of non-productivity per week Computations: Unproductive Hrs Per Week/Productive x Labor Cost as a % of Total/Project Cost = Adjustment Factor (3/37) x (35%/100%) = 0.0280
Inadequate parking	+0.0175	Inadequate onsite parking for labor force. Assumptions: $400 per month parking allowance will be required. Computations: Parking Allowance Per Month/Avg Wage Per Month x Labor Cost as a % of Total/Project Cost as 100% = Adjustment Factor ($400/$8,000) x (35%/100%) = 0.0175

***Individual cost model analysis as required to justify each cost consideration**

Table B-4 Sample Site Adjustment Factor Summary

Impact identifier	Condition	SS Factor	Narrative Description of Condition with Resulting Assumptions and Computations
Housing availability	Normal	0	Adequate housing available in the local area
Material availability	Normal	0	Local area can meet all project requirements
Local site peculiarities	Individual analysis to justify each consideration	0.0280	Small congested work site
		0.0175	No parking onsite. No free parking near site.

Site Sensitivity Factor = 0 + 0 + 0.0280 + 0.0175 = 1.0455

Notes:
1. The first number in the SSF equation will always be 1 because the SSF must always be equal to or greater than 1.
2. The method outlined in this appendix may be used to determine the cost impact resulting from an extremely large concentration of construction effort, or from extensive site limitations, or both.
3. Determine the site sensitivity adjustment based on an analysis of site conditions, which will influence cost.
4. Factors applied take into account a material/labor/equipment (MLE) ratio of 63/35/2.

APPENDIX C RATIO OF WBS SYSTEMS COST TO FACILITY COST BY FACILITY TYPE

FACILITY TYPE	A10 Foundations	B10 Superstructure	B20 Exterior Enclosure	B30 Roofing	C10 Interior Construction	C30 Interior Finishes	D10 Conveying	D20 Plumbing	D30 HVAC	D40 Fire Protection	D50 Electrical	E10 Equipment	E20 Furnishings	F10 Special Construction
Intelligence Communications Center	6.14	9.68	7.08	3.87	5.61	7.41	0.52	3.65	21.86	2.3	31.57	0.12	0.05	0.14
Aircraft Operations Building	5.94	14.09	10.79	4.75	7.31	9.91	1.11	3.1	16.53	2.02	24.11	0.16	0.11	0.07
Military HQ/ Operations Building (Operations)	7.33	12.09	9.03	7.31	9.56	6.1	0.31	8.33	19.06	2.89	15.62	0.38	1.21	0.78
Military HQ/ Operations Building (Battalion)	5.56	13.11	9.14	3.91	7.93	8.53	1.46	3.45	18.01	2.3	22.32	1.41	0.18	2.69
General Instructions Building	3.61	11.47	13.66	3	9.69	8.54	0.61	5.94	17.2	2.51	22.56	0.41	0.71	0.09
High Bay Simulation Training Building	7.25	11.78	8.23	3.13	6.31	13.59	0.9	4	19.8	2.34	21.64	0.07	0.01	0.95
Applied Instruction Building	7.01	17.25	11.5	5.42	7.79	7	1.74	5.01	17.89	2.55	14.41	1.6	0.26	0.57
Reserve Center	4.56	12.84	12.22	3.99	7.89	11.15	0.68	5.29	19.68	2.62	18.15	0.78	0.01	0.14
General Purpose Maintenance Hangar	10.29	10.91	15.07	3.79	6.2	4.43	0.48	6.58	13.51	5.73	16.55	0.16	0.05	6.25
High Bay Maintenance Hangar	11.87	27.04	11.59	4.23	4.99	4.1	0.51	3.52	10.17	4.09	16.11	0.45	0.3	1.03
Shop, Vehicle Maintenance, Wheel & Track	13.78	13.34	18.52	3.84	5.18	4.6	1.08	5.19	17.73	1.94	13.95	0.85	0	0
Low Bay General Purpose Warehouse (<16', <15,000sf)	11.86	14.96	13.2	4.99	5.34	4.92	0	3.24	11.86	4.63	14.26	9.67	0	1.07
High Bay General Purpose Warehouse	14.97	16.24	17.92	6.55	6.07	3.56	0.69	2.37	10.48	5.7	12.81	1.81	0.35	0.48
High Explosive Magazine	23.5	27	34.19	2.85	0.03	0.19	0	0.09	0.87	0	9.22	0.08	0	1.98
Armory	8.67	16.47	9.91	6	5.56	3.31	0	3.52	17.14	2.81	16.05	9.47	0.29	0.8
Medical Clinic (<60,000 sf)	5.13	15.34	16.65	2.61	9.23	6.33	0.68	3.98	18.78	2.28	13.37	4.83	0.79	0

	A10	B10	B20	B30	C10	C30	D10	D20	D30	D40	D50	E10	E20	F10
FACILITY TYPE	**Foundations**	**Superstructure**	**Exterior Enclosure**	**Roofing**	**Interior Construction**	**Interior Finishes**	**Conveying**	**Plumbing**	**HVAC**	**Fire Protection**	**Electrical**	**Equipment**	**Furnishings**	**Special Construction**
Mental/ Behavioral Health Clinic	6.59	11.73	12.06	2.79	11.73	7.27	1.27	7.21	18.83	1.04	17.38	1.86	0.15	0.09
Multi-purpose Administrative Facility	6.99	13.02	13.03	2.12	9.52	8.22	1.11	3.39	19.57	2.39	17.83	0.18	1.14	1.49
Enlisted Unaccompanied Personnel Housing	4.07	14.14	11.81	1.82	12.71	11.04	1.17	12.51	12.51	2.31	15.43	0.32	0.01	0.15
Enlisted Mess Hall	9.04	7.8	9.99	4.06	2.73	9.37	0.43	6.69	20.61	1.97	10.70	16.49	0.12	0
Child Development Center (<6 Years Old)	8.65	10.47	11.31	6.37	8.89	7.91	0.52	7.66	16.83	2.78	15.87	2.11	0.03	0.6
Physical Fitness Center	6.35	10.77	11.38	5.39	7.82	8.53	0.26	5.96	20.88	2.13	14.52	2.93	0.18	2.9
Parking Building/ Garages	23.49	44.54	5.89	5.02	1.75	3.04	2.22	2.09	0.23	1.82	9.09	0.82	0	0

APPENDIX D GLOSSARY

D-1 ACRONYMS.

A	adjusted unit cost
ACF	area cost factor
AGSF	average gross square feet
CE	cost escalation
CONUS	Continental United States
CSRA	Cost and Schedule Risk Analysis
DC	design contingency
GRT	gross receipts tax
GSF	gross square feet
GUC	guidance unit cost
HR	historical requirement factor
LID	low impact development
MEC	munitions and explosives of concern
MILCON	military construction
MLE	material/labor/equipment
NWC	new work cost
O&M	operation and maintenance
OMSI	operations and maintenance support information
PACES	Parametric Cost Engineering System
PAX	Programming Administration and Execution
PCAS	post-construction award services
PDT	Project Delivery Team
RDC	removal/demolition cost

RDF	removal/demolition factor
RNF	replacement new factor
S	size factor
SAF	special adjustment factor
SIOH	supervision, inspection, and overhead
SS	site sensitivity factor
TU	technological updating factor
WBS	Work Breakdown Structure

APPENDIX E REFERENCES

DEPARTMENT OF DEFENSE

Office of the Assistant Secretary of Defense, Energy, Installations, and Environment Memorandum, "Military Construction Supervision, Inspection, and Overhead Fixed Rates for Fiscal Year 2024 and Future Projects," April 14, 2022
www.wbdg.org/FFC/DOD/UFC/ufc_3-701-01_MilCon_SIOH_Rates_Change_14Apr22.pdf

NAVFAC Instruction 7820.0, *Supervisor Inspection and Overhead Rates for Remote Locations*, 8 Aug 22
www.wbdg.org/FFC/DOD/UFC/ufc_3-701-01_NAVFACINST_7820.2_SIOH.pdf

U.S. Army Corps of Engineers *Army Facilities Pricing Guide, PAX Newsletter 3.2.2*
www.usace.army.mil/Cost-Engineering/PAX-Newsletter-322-Army-Facility-Unit-Costs/

UNIFIED FACILITIES CRITERIA

www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 3-701-01, *DoD Facilities Pricing Guide*, updated and issued annually.

UFC 3-740-05, *Construction Cost Estimating*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

ASTM INTERNATIONAL

www.astm.org

E1557-09, *Standard Classification for Building Elements and Related Sitework – UNIFORMAT II*

UNIFIED FACILITIES CRITERIA (UFC)

CONSTRUCTION COST ESTIMATING

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UNIFIED FACILITIES CRITERIA (UFC)

CONSTRUCTION COST ESTIMATING

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 3-740-05, dated 8 November 2010.

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Costs estimates are to be prepared as though the Government were a prudent and well-equipped contractor estimating the project. Therefore, the total construction costs, which a prudent, experienced contractor would expect to incur, are to be included in the cost estimate. This philosophy prevails throughout the entire project cycle -- from programming through completion of construction.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-740-05, 8 November 2010.

1-3 PURPOSE AND SCOPE.

This document establishes uniform guidance to describe methods, procedures, and formats for the preparation of cost estimates and associated analyses (price/cost). This guidance applies where services have common requirements, however, for instances where there are differences, use the policies and procedures of the cognizant design agency.

This document addresses the various phases of cost estimating from the initial start of design through modification cost estimates during construction. UFC 3-730-01 - PROGRAMMING COST ESTIMATES FOR MILITARY CONSTRUCTION provides guidance for cost estimating during the initial planning, programming, and budget review phases. The term construction includes remedial action environmental projects, dredging and other construction type work often implemented as service contracts. For the purposes of this document, the term cost engineer applies to qualified individuals, whether employed by the Government or under contract to the Government, who are routinely engaged in the preparation or review of cost estimates.

1-4 APPLICABILITY.

This UFC applies to Military Construction (MILCON) and Military Operations and Maintenance (O&M) projects. “Construction” is defined as construction, alteration, or repair (including dredging, excavating, and painting) of buildings, structures, or other real property. See FAR 2.101.

1-5 GLOSSARY.

APPENDIX C contains acronyms.

1-6 REFERENCES.

APPENDIX D contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

The samples and data referenced in this UFC are found under "Related Materials" accompanying this UFC on the (WBDG) Web site: https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05.

CHAPTER 2 GENERAL

2-1 COST ESTIMATING PHILOSOPHY.

Per Government Accountability Office (GAO-20-195G), the four key elements of a reliable cost estimate are (1) Comprehensive; (2) Well Documented; (3) Credible and (4) Accurate. Therefore, all costs, which a prudent, experienced contractor would expect to incur, are to be included in the cost estimate. Each cost estimate is to be developed as accurately as possible, in as much detail as can be assumed, and be based upon the best information available. This objective is to be maintained during the programming, design, and construction phases of the project. Cost estimating in the Federal government does not intend to be the low bidder but to represent a fair and reasonable cost of a prudent, well equipped contractor.

2-2 RESPONSIBILITY FOR PREPARATION, REVIEW AND PRESENTATION.

2-2.1 General.

Preparation and review of cost estimates through project completion is the responsibility of an independent centralized Cost Engineering Office within the design agency. The Cost Engineering Office will provide independence and consistency with training, software, and cost estimating practices. In concert with this responsibility, the cost engineer must be accountable for the comprehensiveness, documentation, credibility and accuracy completeness, quality, accuracy and the reasonableness of the cost estimate. The project manager (PM) will disclose to the cost engineer the intended recipient(s) of the cost estimate and the reason the cost estimate is being produced.

2-2.2 Preparation.

Cost estimates may be prepared in-house or by contract. When it is necessary to contract services for the preparation of cost estimates, such services will be provided by competent firms experienced in cost engineering. Other specific needs, submittals, and requirements are to be provided to insure a complete understanding of the cost engineering requirements. These supplementary requirements are to be included as part of a comprehensive contract scope of work.

2-2.3 Review.

Cost estimates, whether prepared in-house or by contract, will be given an independent review by government cost engineers as prescribed by the cognizant agency review procedures. The cost estimate is to be reviewed for the purpose of confirming the validity of the assumptions and the logic used in estimating the cost of construction tasks. The review is to include a check of the quantities, unit prices, arithmetic, and include a comparison to any other available historical data. It is important that the reviewer develops and completes a review checklist to assure that important considerations have not been overlooked (see sample checklist provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05). The review checklist may be customized based on the nature of the work and the design stage. Cost estimates are not to be released until receiving review and approval.

2-2.4 Presentation to Management.

A cost estimate is not considered complete until management, as defined by the cognizant agency, has approved it. Refer to the cognizant agency for specific requirements. Because many cost estimates are developed to support a budget request or make a decision between competing alternatives, it is vital that management is presented with information on how the cost estimate was developed, including risks associated with the underlying assumptions, data, and methods. Therefore, the cost estimator presents management with enough detail to easily defend the cost estimate by showing how it is complete and high in quality. The information in a cost estimate presentation succinctly illustrates the main cost drivers and the final cost estimate, and is to match the information in the cost estimate documentation.

2-3 TEAM INVOLVEMENT.

Cost engineers are important members of the project delivery team (PDT). The cost engineer is expected to have a clear understanding of those responsibilities and areas where contributions can be made. It is imperative that the team concept be enhanced and supported by each member. As such, the cost engineer is encouraged to lead in cost issues and provide ideas for cost control and sharing measures. The cost engineering team will develop a cost estimating plan. The plan will state who is on the cost engineering team and the schedule for completion dates of the cost engineering products at each design stage.

2-4 PROGRAM SPECIFIC REQUIREMENTS.

In the MILCON and O&M programs, cost estimates are prepared throughout the planning, design, and construction phases of a construction project. These cost estimates may be categorized as follows: Programming & Budgetary, Current Working Estimate (CWE), and Independent Government Estimate (IGE).

2-4.1 Programming and Budgetary Estimates.

In the planning phase, the cost estimate is called a programming estimate and is prepared on a Department of Defense form, DD Form 1391. Develop this programming estimate based on preliminary construction scope or mission requirements. Refer to UFC 3-730-01 for criteria and standards for development and preparation of programming cost estimates for constructing military facilities.

2-4.2 Current Working Estimates.

Current working estimates for projects may be categorized as 15%, 35%, 50%, 65%, 95%, or 100% stages of design as examples. For Design-Bid-Build (DBB) projects the CWE’s are refined more during their respective phases, in order to match the increased definition of the design criteria and project requirements. CWE’s for Design-Build (DB) projects are based upon RFP performance and prescriptive specifications. A technical baseline document will be developed by the design team at the earliest possible design phase to define the project. The technical baseline document describes the acquisition strategy, the work breakdown structure, and how the project will perform its purpose.

2-4.3 Independent Government Estimate.

The last stage of development is the IGE. For DBB projects the IGE is based on the Ready to Advertise (RTA) set of the plans and specifications and contract amendments. The RTA set of plans and specification is typically considered the corrected final incorporating all back checked review comments. For DB projects the IGE is based upon the final RFP performance and prescriptive specifications and contract amendments. The IGE is the cost estimate that is provided for procurement.

2-4.4 Independent Cost Estimate.

An Independent Cost Estimate (ICE), is conducted by an organization independent of the cognizant design agency, it is based on the same construction scope used for the cost estimate. ICEs are used primarily to validate cost estimates and are reconciled with them. Because the team performing the ICE is independent, the ICE provides an unbiased test of whether the cost estimate is reasonable. The ICE is also used to identify risks related to budget shortfalls or excesses.

2-5 LIFE CYCLE COST (LCC) STUDY SUPPORT.

Quality management policy requires LCC studies to be performed to evaluate system alternatives. The alternative analyses are the responsibility of the design team. Cost engineering provides the cost estimating input for the LCC analyses. As preparation to such responsibility, the cost engineer is to be familiar with the LCC procedures.

2-6 COST ESTIMATE FORMAT STRUCTURE.

It is important that the format of the cost estimate be as consistent as possible. UNIFORMAT II (ASTM Standard E1557-09) has been established for this purpose: This is a hierarchical presentation of the scope of work. It provides a common, ordered hierarchy framework for summarizing information and for quantitative reporting to customers and management. The purpose of this format is to: (1) provide an organized manner of collecting project cost data in a standard format for cost reporting and cost tracking; (2) provide a checklist for categorizing costs; and (3) provide a basis to maintain historical cost data in a standard format.

2-7 WORK BREAKDOWN STRUCTURE (WBS).

2-7.1 Military Construction Program.

The MILCON process is formally structured to comply with the DOD’s Planning, Programming, Budgeting, and Execution (PPBE) process for resource allocation.

The common elements of the MILCON program are as follows:

- Planning and Programming: All effort of technical and functional activities associated with identifying the requirement, prioritizing, justification, and requesting funds for a project.
- Program Management: The business and administrative of planning, organizing, coordinating, tracking and controlling the overall program objectives as they apply to a specific program.
- Design and Construction: Develop plans, specifications, cost estimate, solicit bidders, execute the contract and construct the project. This UFC is focused on the design and construction component.
- Delivery: Provide final product to the owner/stakeholder.

2-7.2 Facility Construction WBS.

The goal of this work breakdown structure (WBS) is to establish a standardized classification of building elements and related sitework. These elements are major components to most facilities and perform a given function, regardless of the design specification, construction method, or materials used. Using the WBS ensures consistency in project management, data collection, and economic evaluation of projects over time and from project to project.

UNIFORMAT II (ASTM International E1557-09) provides a common framework for preparing cost estimates, developing models, and collecting cost data for Department of Defense (DOD) military construction projects. It is to be used for categorizing facility costs and associated supporting facility costs for conventional military construction projects. This WBS is comprised of a collection of six building related elemental system classifications, and a collection of one sitework elemental building classification system. Each system is organized in a hierarchical structure with multiple sub-elements. Detail items or assemblies can be entered at an appropriate level within the hierarchy. An example of the UNIFORMAT II WBS structure is shown to Level 4 below:

Level 1 – Major Group Elements
Example: A - SUBSTRUCTURE
    Level 2 – Group Elements
    Example: A10 - Foundations
        Level 3 – Individual Elements
        Example: A1010 – Standard Foundations
            Example Level 4 Elements from Appendix X1.1 of E1557-09
            Example: A101001 – Wall Foundations

Table A-1 in Appendix A lists the UNIFORMAT II elements to Level 3.

2-7.2.1 Measure.

A unit of measure is associated with each level of the WBS and must be followed in every cost estimate to facilitate the estimating review process. This will allow cost estimates to be compared to other similar project cost estimates.

2-7.2.2 Numbering Structure.

The complete hierarchical structure is defined in ASTM Standard E1557-09. An example is shown in Appendix A, Table A-1.

2-8 DEGREE OF DETAIL.

2-8.1 Construction Tasks.

Cost estimates within the scope of this manual will be prepared on the basis of calculated quantities and unit prices that are commensurate with the degree of detail of the design known or assumed. This is accomplished by separating construction into its incremental parts. These parts are commonly referred to as construction tasks and are the line-by-line listings of every cost estimate. Each task is then defined and priced as accurately as possible. Tasks are seldom spelled out in the contract documents, but are necessary for evaluating the requirements and developing their cost.

2-8.2 Analyzing Construction Tasks.

When analyzing construction tasks in a cost estimate, the cost engineer identifies the tasks that account for the major costs in the cost estimate. These tasks can be identified by applying the Pareto Principle (80/20 rule), which states that approximately 80% of the project cost is contained in 20% of the items. Because these significant items account for most of the project cost, they receive prime emphasis and effort in both preparation and review.

2-8.3 At the Most Detailed Level.

At the most detailed level; each task is usually related to and performed by a crew. The cost engineer develops or selects the task description by defining the type of effort or item to be constructed. Task descriptions are to be as complete and accurate as possible to lend credibility to the cost estimate and aid in later review and analysis. An example of a detailed manually prepared cost estimate is provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05. Whenever a significant amount of design assumptions are necessary such as in design-build process, the cost engineer leverages cost data from previous similarly designed projects or use parametric estimating models.

2-9 RELIABILITY.

GAO uses the term "reliable" to describe the standard in quality for cost estimating. A reliable cost estimate is defined as well documented, comprehensive, accurate, and credible.

Accuracy and completeness are critical factors in cost estimates. An accurate and complete cost estimate establishes accountability with the cost engineer and enables management to place greater confidence in the cost estimate. Given the probabilistic nature of cost estimating, a point estimate does not provide the best picture of the accuracy of the estimate. That requires accounting for the amount of variation inherent in the cost estimate. A given point estimate is one cost estimate in a range of cost estimates. A more complete understanding of accuracy, therefore, is provided by indicating where a given point estimate falls in a range of possible cost estimates.

2-10 ROUNDING FIGURES.

For preliminary or alternative cost estimates, when design details are limited, the cost estimate may be rounded based on the experience of the cost engineer, whereby the end cost is not significantly affected.

Rounding the total cost of military construction projects to the nearest thousand dollars for design estimates and Independent Government Estimates (IGE) is acceptable for reporting purposes.

2-11 SAFEGUARDING COST ESTIMATES.

Although not required by regulations, cost estimates based on less than completed design must be handled in a discretionary manner. Access to each cost estimate and its contents will be limited to those persons whose duties require knowledge of the cost estimate. Cost estimates prepared by A-E's will also be similarly handled. Architect-Engineer (A-E) contracts must provide a letter of transmittal that includes the following statement: "To the best of my knowledge the confidential nature of this cost estimate has been maintained." for each cost estimate submitted to the Government. This statement must be signed, dated, and maintained until the official markings have been removed. Any request by the public for information and pricing in the cost estimate will not be provided until coordination, verification of data, and approvals have been given by the commander or designated authority. Procedures for safeguarding the cost estimate are to be in accordance with the design agency's requirements.

2-12 SECURITY AND DISCLOSURE OF INDEPENDENT GOVERNMENT ESTIMATE.

2-12.1 Contents of the Independent Government Estimate.

The Independent Government Estimate (IGE) normally consists of a title page, signature page, and bid schedule. Supporting documents that are publicly available as parts of the solicitation (such as plans, specifications, and project descriptions) are not part of the IGE. IGEs for contract awards and contract modifications are treated the same.

2-12.2 Access to the Independent Government Estimate.

Access to the IGE and its contents will be limited to personnel whose duties require they have knowledge of the subject. When an A-E is responsible for preparing any such IGE, the A-E submittal includes a list of individual's names that have had access to the total amount of the IGE. Government personnel also sign the same or a similar list. A list similar to the "Sample Control Record for IGE", provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 is filed with the IGE.

2-12.3 Marking the Independent Government Estimate.

The IGE will be marked in accordance with DODINST 5200.48 and cognizant design agency requirement. The IGE will ensure that the protective marking "Controlled Unclassified Information" (CUI) is properly applied to pertinent documents, computer files, compact discs (CDs), printouts, and other documents prepared manually or electronically for incorporation into the IGE.

2-12.4 Disclosure Outside of the Government.

After contract award, ordinarily, only the title page, signature page, and bid schedule are disclosed outside the Government. The IGE back-up data is not released since it contains sensitive cost data (e.g., contractor quotes, crews and productivity) that are proprietary or might compromise cost estimates for future similar procurement.

2-12.5 Bid Protests and Litigation.

During bid protests and litigation, if appropriate and to the extent possible, Counsel should have the IGE and the IGE back-up data placed under a "protective order." There are valid reasons for not releasing the IGE back-up data supporting the IGE to the contractors. In the case of a bid protest, there is a possibility that the contract could be re-advertised or converted to a negotiated procurement. Release of the IGE back-up data would provide bidders with the detailed cost data that supports the IGE. If, however, the apparent low bidder protests the details of the IGE, the Command may provide the IGE and IGE back-up data, to the protestor only, upon receipt of complete details of the protestor's cost estimate. If the protest is not sustained and the proposal is re-advertised, bidders are entitled to have the same information as the protestor.

2-13 RELEASE OF INDEPENDENT GOVERNMENT ESTIMATES UNDER THE FREEDOM OF INFORMATION ACT (FOIA).

The IGE and IGE back-up data, prepared for construction contracts and modifications, are sensitive procurement information and in many cases are withheld under the FOIA.

2-13.1 Definitions.

- The IGE consists of a title page, signature page, and bid schedule.
- The IGE back-up data is the detailed cost data, which includes production and crew development methodology, labor, equipment and crew back-up files, subcontractor quotes and other data identified on agency approved cost estimating software as detail sheets.
- Fair market price determinations, under the Small Business Program, Federal Acquisition Regulations (FAR) 19.202-6, will be treated as the IGE for purposes of this guidance.
- Supporting documents that are publicly available as part of the solicitation, such as plans, specifications and project description, or that contains no

cost information, such as sketches, soil borings and material classifications, are not part of the IGE or back-up data.

2-13.2 Requests for Independent Government Estimates and Back-Up Data.

IGE's and IGE back-up data are intra-agency memoranda, which may be withheld under FOIA Exemption 5, "confidential commercial information" and "deliberative process" privileges. Proper use of Exemption 5, however, requires a showing that release of information will harm the Government's interests. Therefore, requests for IGE and back-up data will be reviewed on a case-by-case basis, based on the following guidance, to determine whether release will harm the interests of the Government. In reviewing requests, the FOIA Officer will seek the assistance of the cost engineer. If the FOIA Officer determines that release will harm the interests of the Government, the information will be withheld.

2-13.2.1 Sealed Bid Procurement.

When sealed bidding is used, neither the IGE nor the IGE back-up data is to be released prior to bid opening. See FAR 36.203(c), 36.204. It is well established that release of IGE's and back-up data before contract award would harm the interests of the Government. Refer to FAR 36.203, Federal Open Market Committee v. Merrill, 443 U.S. 340 (1979), Morrison-Knudson v. Department of the Army, 595 F. Supp. 352 (D.D.C. 1984), aff'd 762 F.2d 138 (D.C. Cir 1985).

2-13.2.2 Post Bid.

The IGE will normally be released when bids are opened. In some instances, however, the IGE will not be released at that time, such as when bids received are non-responsive and a re-procurement is envisioned.

2-13.2.3 Negotiated Procurement.

In negotiated procurement for construction under FAR Parts 15 and 36, the IGE will not be released prior to contract award, except that Government negotiators may disclose portions of the IGE in negotiating a fair and reasonable price, see FAR 36.203(c).

2-13.2.4 Back-Up Data.

The IGE back-up data will not be released. Release of IGE back-up data after contract award and before completion of a construction contract may also result in harm to the Government. The IGE back-up data is used to develop cost estimates for modifications and claims. Release of the backup data prior to contract completion provides the contractor with the details of the Government's position and would allow the contractor to develop a biased price proposal. This could harm the Government's ability to negotiate a fair and reasonable price for the modification or claim, putting the Government at a serious commercial disadvantage. Moreover, knowledge of the construction methods contemplated by the Government might reduce the contractor's incentive to discover less expensive methods. This could also reduce the contractor's incentive to locate and charge out materials at a lower cost, or to achieve project goals using less labor and equipment. See Quarles v. Department of the Navy, 983 F.2d 390, (D.C. Cir 1990). Taylor Woodrow International, Ltd. V. Department of the Navy, No. 88-429R, (W.D. Wash. Apr 6, 1989).

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CHAPTER 3 BASICS FOR PREPARATION OF COST ESTIMATES

3-1 GENERAL.

This chapter establishes uniform guidance to be used prior to cost estimate preparation. In the normal sequence of events toward the preparation of any cost estimate, it is of utmost importance to understand basic fundamental principles and responsibilities. Cost estimates consist of:

- Descriptions of work elements to be accomplished (tasks).
- A quantity of work required for each task.
- A cost for each task quantity.

A unit cost for each task is developed to increase the accuracy of the estimating procedure and to provide a reference comparison to historic experience. Lump sum cost estimating when used at the task level must be fully documented to show the intent and extent of the item.

3-2 PLANNING THE WORK.

The cost engineer must thoroughly understand the construction scope of work and the biddability, constructability, operability, environmental, sustainability (BCOES) aspects of the project being estimated. The cost engineer must review available resources including design analysis, drawings, and specifications. The cost engineer must also consider construction sequences, durations, and site conditions to determine total construction costs. A site visit is strongly recommended to enable the cost engineer to relate the physical characteristics of the project to the available design parameters and details. This is particularly important on projects with difficult site conditions, major maintenance and repair projects, and alteration/addition projects. The construction sequence must be developed as soon as possible and used to provide a checklist of construction requirements throughout the cost estimating process. The overall format of major cost elements in a cost estimate must be compatible with current standards, management needs, the anticipated bidding schedule, and the appropriate WBS.

3-3 QUANTITIES.

The quantity “take-off” is an important part of the cost estimate. It must be as accurate as possible, and be based on available engineering and design data.

- After the scope has been analyzed and broken down into the construction tasks, each task must be quantified prior to pricing. Equal emphasis is placed on both accurate quantity calculation and accurate pricing. Quantities are to be shown in standard units of measure and consistent with design units. Assistance for preparing “take-off's” may be provided by others within the organization in support of cost engineering or by A-E contracts; however, the responsibility for the accuracy of the quantities remains with the cost engineer.

- The detail to which the quantities are prepared for each task is dependent on the level of design detail. Quantity calculations beyond design details are often necessary to determine a reasonable price to complete the overall scope of work for the cost estimate. Project notes will be added at the appropriate level in the cost estimate to explain the basis for the quantity calculations, to clearly show contingencies, and to note quantities determined by cost engineering judgment that will be reconciled upon design refinement.
- For Design-Build contracts the cost engineer is provided a proof of concept (pilot project design, which demonstrates that a design concept is feasible) from the design team in which reasonable quantities and scope can be derived to establish the baseline cost estimate. The proof of concept addresses the RFP requirements so that the project delivery team can verify the scope can be built within budget.

3-4 TYPES OF COSTS.

Various types of cost elements must be evaluated in detail.

- Direct costs are those costs, which can be attributed to a single task of construction work. These costs are usually associated with a construction labor crew performing a task using specific equipment and materials for the task. Labor foreman cost is normally considered a direct cost. Subcontracted costs are considered as direct costs to the prime contractor in cost estimates.
- Indirect costs are those costs which cannot be attributed to a single task of construction work. These costs could include but are not limited to mobilization, demobilization, supervision, overhead, profit, and bond. Indirect costs are also referred to as distributed costs. When a percentage factor is used, an engineer’s cost estimate is developed to verify the adequacy of the percentage factor used. For example, thru the use of an estimated construction schedule, the superintendents, quality control manager, safety officer, and trailers monthly costs multiplied by the number of required months from the schedule is compared to the resultant of the percentage factor used for JOOH to verify if the percentage used is in the right order of magnitude.
- Cost estimates based on detailed design will be developed from separate direct cost pricing of labor, material, construction equipment, and supplies. Applicable indirect costs will be added to reflect the total construction cost. Other costs, including escalation, design contingencies, design-build design costs, building commissioning, sustainment, construction contingencies, construction supervision, inspections and overhead (SIOH), and Operation and Maintenance (O&M) Manuals, may be added to the cost estimate to determine the total project cost as required by program specific requirements. These costs are often applied as multipliers at various levels in the cost estimate and distributed across the

items within that level. In some cases, there may be specific tasks costs developed for such items. For Design/Construction Contingency and DB Design Costs a cost estimate is developed to verify the adequacy of the percentage factor used.

3-5 COST SOURCES.

Typically, there are various cost sources available to the cost engineer. In obtaining costs from any source, experience and ability to relate data in hand to a specific circumstance is important. The following discussion is provided on commonly used sources and source development.

3-5.1 Cost Book

The Cost Book is the common name for the Tri-Services construction direct costs database. It contains repetitive construction tasks with direct cost pricing (labor, equipment, material) based on a typical crew and production rate for new construction. Some Cost Book line items may include quotes for work that is fully provided and installed by subcontractor. Quotes for work fully priced by subcontractor must be clearly identified. Each office is encouraged to use this cost source and to refine the project database to more accurately reflect local costs at the project site (i.e., obtain quotes, adjust productivity, assess crew makeup).

3-5.2 Historical Data.

Historical costs from past similar work are excellent pricing sources when adequate details have been saved and adjustment to project specifics can be defined. Portions of other cost estimates having similar work can be retrieved and repriced to the current project rates. Automated historical databases are discussed in Appendix B. Historical data is consistently gathered, organized for ease of access, and analyzed for trends. MILCON historical data is utilized to develop the guidance unit costs provided in Chapter 2 of UFC 3-701-01.

3-5.3 Parametric Database.

A parametric database of predefined assemblies for buildings and sitework has been developed and is discussed in Appendix B.

3-5.4 Development of Specific Tasks.

When Cost Book items do not meet project needs, specific new cost tasks may need to be developed. Such development requires experience. Descriptions developed must adequately define the scope and material requirement for each task. Unit cost for each task is developed as a direct cost with separate costing for the labor, equipment, and material components. Notes, which explain key factors in the pricing and methodology, accompany the task development. Comparison with existing pricing guides is recommended.

- Labor unit cost - This cost is based on a defined crew from the Cost Book or on a newly developed crew, which performs the tasks at an assigned production rate. Hourly rates for each craft are applied to the crew labor to arrive at the hourly crew labor cost. The total crew labor cost/hour is divided by the expected production rate (units/hour) to derive the labor cost/unit.
- Equipment unit cost - This cost is derived similar to labor unit cost. Hourly equipment rates are obtained from the appropriate regional manual, entitled, Construction Equipment Ownership and Operating Expense Schedule (herein referenced as, Equipment Ownership Schedule), Engineer Pamphlet (EP) 1110-1-8 or developed according to the methodology as described in this pamphlet.
- Material unit cost - This cost is developed using vendor quotes, historical costs, commercial pricing sources, or component calculations. The price is to include delivery to the project site.
- Commercial unit cost books - These common sources are typically available through subscription or purchase. Basis of costs shown are typically explained along with adjustment methodology. Such publications are valuable for verification and appropriate for commercial type work item pricing.

3-6 COSTS AND PRICING.

The cost for each task is developed by summing the direct cost elements for materials, labor, and equipment. The indirect costs and other markups associated with each task or work item are identified and are considered separately for the specific project.

3-6.1 Minor Direct Costs.

The direct cost on construction tasks of minor overall cost significance and of a repetitive nature can normally be priced from any of those sources discussed above.

3-6.2 Historical Pricing.

When using historical pricing, adjustments must be made for project location, work methodology, quantity of work, and escalation to current price level, and other dissimilarities, which affect prices.

3-6.3 Lump Sum Items.

Use of lump sum items is discouraged. If lump sum items are used in the cost estimate, they must have backup cost data relating to their tasks and source of the data.

3-6.4 Detailed Backup of Cost.

As a general rule-of-thumb, it is highly recommended that when a task extended direct cost is 5 percent or more of the total direct cost, a detailed backup for the cost is prepared or vendor quotations obtained as pricing support to the cost estimate. Use of the Pareto Principle should be considered.

3-6.5 Predetermined Bid Items.

Applying a similar rule-of-thumb, in some instances, unit price bid items for IGEs may be based on suitable experienced bid prices or historical cost data, i.e., predetermined bid item does not exceed 5 percent or more of the estimated total cost a detailed backup for the cost is prepared as pricing support to the IGE. For cost estimates prepared during preliminary or planning phases, where design is limited or not available, predetermined unit prices adjusted to current pricing level may be used by the cost engineer. Use of predetermined prices are to consider any necessary adjustments in prime contractor's profit or distributed costs appropriate to the contract requirements. The cost engineer must use extreme care and sound judgment when using predetermined unit costs. The basis for the unit costs is to be well documented and included in the supporting data of the cost estimate. Where a bid item consists mostly of equipment and labor costs, with very little materials and supplies, it is advisable to develop the cost as indicated above, even though the item may fall under this rule-of-thumb.

3-7 COST ESTIMATE FORMAT AND SUPPORTING DOCUMENTATION.

Cost estimates are generally composed of contract costs and other allowable project costs authorized by directives or regulations. The overall format of the cost estimate must be in accordance with the appropriate WBS as described in Chapter 2. The cost engineer is to be aware of the documentation necessary to support the cost estimate submission requirements specified for each phase of project development. Support documentation such as project narrative, bid schedule, estimated construction schedule, backup data, and drawings and sketches are further discussed in Chapter 4.

3-8 MILITARY CONSTRUCTION PROGRAM SPECIFIC REQUIREMENTS.

In addition to costs described in this chapter, the cost estimate for Military Construction projects are to include other costs authorized by directive to be charged to construction as funded cost. These costs include installation costs or installed equipment in place to be furnished by the using service or other agency, and the cost of Government-Furnished Materials (GFM) or Government-Furnished Equipment (GFE) purchased with construction funds and furnished to the contractor without reimbursement.

3-9 UPDATING COST ESTIMATE.

At each project development milestone including solicitation amendments, the cost estimate must be updated with current costs so that it is always relevant and current. The continual updating of the cost estimate as the project matures not only results in a more accurate cost, but also gives opportunities to incorporate lessons learned. Future cost estimates can benefit from the new knowledge. For example, cost or schedule variances resulting from incorrect assumptions are thoroughly documented so as not to repeat those mistakes on future cost estimates. Finally, actual cost is collected and archived in the Historical Analysis Generator Second Generation (HAG/HII) historical database for use in supporting new cost estimates.

CHAPTER 4 COMPOSITION OF INDEPENDENT GOVERNMENT ESTIMATES

4-1 GENERAL.

Well-documented cost estimates are considered a best practice for high-quality cost estimates for several reasons.

- First, thorough documentation is essential for validating and defending a cost estimate. That is, a well-documented cost estimate can present a convincing argument of a cost estimate's validity and can help answer decision-makers' and oversight groups' probing questions.
- Second, documenting the cost estimate in detail, step by step, provides enough information so that someone unfamiliar with the program could easily recreate or update it.
- Third, good documentation helps with analyzing changes in program costs and contributes to the collection of cost and technical data that can be used to support future cost estimates.
- Finally, a well-documented cost estimate is essential, if an independent review or audit is performed, to ensure that it is valid and reliable. It also supports reconciling differences with an independent cost estimate, if performed, by improving understanding of the cost elements and their differences so that decision-makers can be better informed.

Documentation provides total recall of the cost estimate's detail so that it can be replicated by someone other than those who prepared it. It also serves as a reference to support future cost estimates. Documenting the cost estimate makes available a written justification showing how it was developed and aiding in updating it as key assumptions change and more information becomes available.

The IGE is the final approved cost estimate submitted to the Contracting Officer to support contract award. Each Agency may have its own requirements and procedures. The presentation format for this type of IGE generally is: Independent Government Estimate of Construction Cost, Basis of Estimate (BOE), IGE back-up data, and miscellaneous support data. Sample IGE sheets are provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05. Security and control of the IGE is described in Chapter 2.

4-2 INDEPENDENT GOVERNMENT ESTIMATE OF CONSTRUCTION COST.

The Independent Government Estimate (IGE) of Construction Cost is to be submitted as required by procurement regulations. It includes the protective cover page, title page, signature page, and bid schedule.

4-2.1 CUI Cover Page.

The IGE must include a CUI cover page per section 2-8.3.

4-2.2 Title Page.

The title page must include the name and location of the project, the office responsible for the project design, the cost engineer responsible for preparation of the IGE, and the submittal date.

4-2.3 Signature Page.

The signature page contains the names and signatures of those individuals responsible for the preparation, review, submittal, and approval of the IGE. It is necessary that the signature page contain the total amount of the estimated costs so that there will be no question as to the approved total amount. The number of amendments included in the IGE appears on the same page so that there will be no question whether the IGE accounts for all amendments.

4-2.4 Bid Schedule.

The bid schedule required by the solicitation documents must be completed as part of the IGE. As part of the design team, the cost engineer is involved in the development of the bid schedule. The format of the bid schedule must be anticipated and discussed as early in the planning process as possible. It is important that the bid schedule includes meaningful scopes of work elements structured to aid in evaluation and historical data collection. When the bid schedule is finalized for procurement, it must show unit prices, quantities, extension of unit prices, lump sum items, and total costs. Rounding off is not permitted on the bid schedule between the unit price and extension. Refer to Price Schedule (https://www.wbdg.org/ffc/navy-navfac/project-information-form-specifications-cover-sheet/price-schedule) for the minimum bid schedule items.

4-3 BASIS OF ESTIMATE (BOE).

Two important criteria are to be kept in mind when generating high-quality cost estimate documentation. First, document the cost estimating process, data sources, and methods. Second, present the results of the estimating process in a format that makes it easy to prepare reports and briefings to upper management and stakeholders.

Cost estimators document the steps used to develop the cost estimate. As a best practice, the cost estimate documentation addresses how the cost estimate satisfies the guidance used to govern the creation, maintenance, structure, and status of the cost estimate. It contains discussions, considerations, and the developed construction plan.

4-3.1 Cover Page and Table of Contents.

This page denotes the project name, date, milestone, names of the cost estimators and the organization they belong to.

4-3.2 Executive Summary.

This section provides at the minimum the following information:

- Summarizes clearly and concisely the cost estimate results, with enough information about cost drivers and high-risk areas for management to make informed decisions
- Identifies critical ground rules and assumptions
- Identifies data sources and methods used to develop major WBS cost elements and reasons for each approach
- Discusses independent cost estimate (ICE), if performed, results and differences and explains whether the point estimate can be considered reasonable
- Discusses the results of a sensitivity analysis, the level of uncertainty associated with the point estimate, and any contingency recommendations

4-3.3 Cost Estimate Purpose.

This section provides the cost estimates purpose, need, and submittal. If the cost estimate needed to be revised, note and identify the purpose of the revision.

4-3.4 Construction Scope and Assumptions.

The construction scope description provides detail to give a clear understanding of the scope of work. The construction scope description defines the assumptions made during the preparation of the cost estimate. It describes the project requirements that must be performed in sufficient detail to give a clear understanding of the scope of work. It also describes project details including length, width, height and shape of primary features, special problems that will be encountered in performing the work, site conditions affecting the work, reasons for selection of major plant and equipment, method and time for mobilization and demobilization of equipment, and the reasons for unusually high or low unit prices. Each cost estimate will include a statement, which relates both the development of design, as appropriate, and date of effective pricing.

The construction scope description defines the assumptions made during the preparation of the cost estimate. Assumptions represent a set of judgments about past, present or future conditions postulated as true in the absence of positive proof. It is important that assumptions developed by the cost estimator are based on input from the technical team.

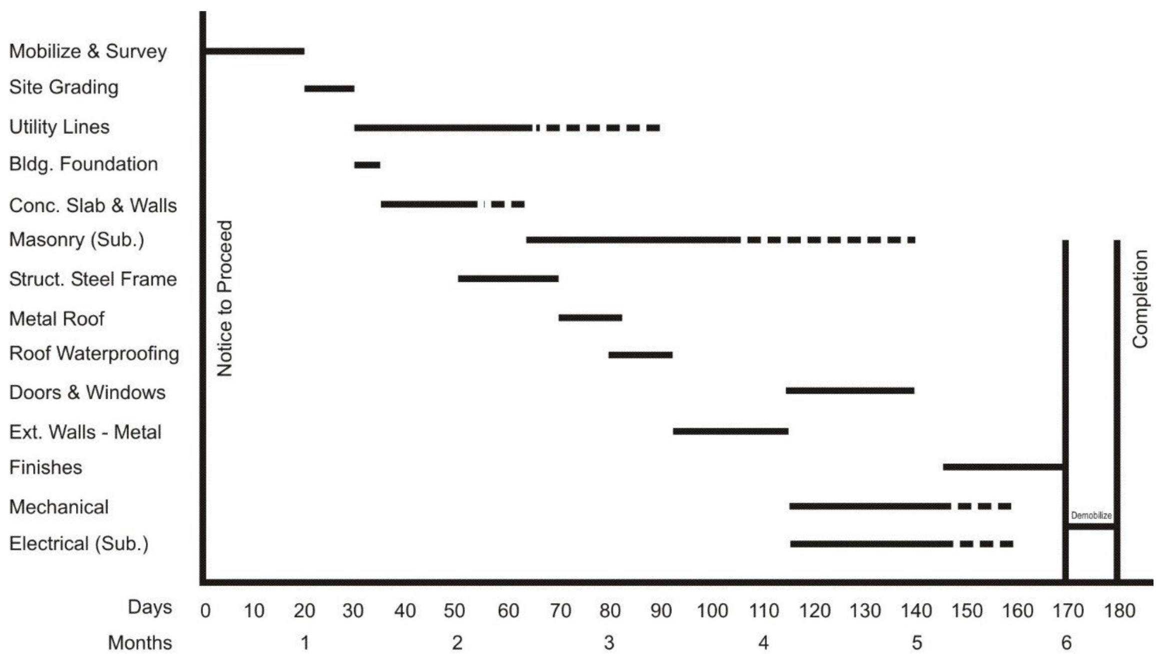
Other factors to be considered in the construction scope description include:

- Construction schedule, use of overtime, construction windows, phasing, acquisition plan and subcontracting.
- Project related details including site access, borrow areas, construction methodology, unusual conditions (soil, water or weather), unique techniques of construction, equipment/labor availability and distance traveled, environmental concerns, contingencies by feature or sub feature, if appropriate, and effective dates and sources for labor, equipment and material pricing.

4-3.5 Estimated Construction Schedule.

The cost engineer prepares a construction schedule to support the cost estimate that is consistent with the schedule for completion of the project. It may be in the form of a bar chart or network analysis system (see Figure 4-1 for an example). It must identify the sequence and duration of the tasks upon which the cost estimate is developed. The schedule considers holidays, non-workdays, and weather days as supplied in the specifications. The schedule must be prepared in sufficient detail to adequately develop the required labor, equipment, crew sizes, and production rates required for each of the identified construction tasks. In addition, it will support the development of the duration of the job office overhead. The construction schedule is reviewed by the project delivery team.

Figure 4-1 Construction Schedule Example



4-3.6 Sensitivity Analysis.

- Describe the effect of changing key cost drivers and assumptions independently
- Identify the major cost drivers that to be closely monitored

4-3.7 Risk and Uncertainty Analysis.

- Discuss sources of risk and uncertainty, including critical assumptions, associated with the cost estimate as developed by the CSRA
- Document the effect of uncertainty associated with the point estimate is quantified with probability distributions, and the resulting S-curve; the

method for quantifying uncertainty is discussed and backed up by supporting data

- Discuss risk distributions and correlation between WBS elements
- Describe the basis for contingency and how it was calculated.

4-3.8 Equipment and Materials Utilization.

On those projects involving considerable heavy construction equipment, it is necessary to sufficiently plan the equipment usage against the construction work schedule to identify the actual number of cranes, dozers, and allow for proper mobilization to assure that demand for the equipment is not over or understated. Equipment references are to be provided which indicate the region and date of the equipment library used for pricing the equipment. Materials, which require long lead-time and can become critical to the construction schedule are to be noted, planned, and adequately considered.

4-3.9 Labor Discussion and Utilization.

The cost estimate clearly states the sources for the various labor classifications and rates and include tabulation by crafts of the various composite wage rates used. When extensive overtime beyond the normal workday is used in the cost estimate, an explanation is to be included.

4-4 INDEPENDENT GOVERNMENT ESTIMATE BACKUP DATA.

This part of the IGE consists of the support and backup documentation. The various categories of support documentation contained in this part are:

- Cost estimate summary sheets. The automated or manually prepared summary sheets for direct, indirect and owner costs are used to summarize cost components for each bid item and by the appropriate Work Breakdown Structure. Distribution of overhead and profit is shown on this sheet.
- Mobilization, preparatory work, and demobilization. These costs are to be itemized and costed separately. These costs may be combined at summary level with overhead if these costs are not paid as a separate bid item.
- Profit computation sheet. When profit is included, the weighted guidelines will be used to compute the profit and will be part of the cost estimate backup.
- Overhead costs. The itemization and calculations of overhead costs, both job site and home office, are to be accomplished in accordance with Chapter 10.
- Bond costs. Bond costs are to be calculated in accordance with Chapter 12. Distribution is made to bid items similar to or as part of overhead costs distribution.

- Automated detail sheets. The completed direct costs are to be organized in the proper sequence by the appropriate Work Breakdown Structure for each bid item.
- Production rates. The automated or manually prepared details are used to express production rate analysis of crews. See Chapter 6 for further discussion.
- Crew, labor, equipment rates. These automated or manually prepared details are used to express the crew composition, and associated rates for labor and equipment costs. The information contained on these sheets provides the backup support for the task unit labor and equipment costs shown.
- Quantity computations. The quantity takeoff computations for the tasks estimated, are organized by task for the bid items and kept as backup. The takeoff references the drawing and clearly explain the computation.
- Quotations. Quotations are to be collected and compiled by task or bid item into an organized reference. When quotations were not obtained for significant material and supply items, the basis for the cost used is fully described. Quotations are considered proprietary information and kept confidential to protect the information entrusted to the cost engineer.

Projects outside continental United States (OCONUS) are to include International Balance of Payment (IBOP) analysis under normal or revised procedures. Cost estimates will not include the IBOP statement but the documentation will be retained at the cognizant design agency office. The projects will be evaluated for IBOP impact in accordance with DODI 7060.2, Federal Acquisition Regulation (FAR) 25-300 and Defense Federal Acquisition Regulation Supplement (DFARS) 225.75. Countries exempt from IBOP analysis are listed in DFARS 225.872-1.

4-5 MISCELLANEOUS SUPPORT DATA.

Include other information pertinent to the cost estimate such as drawings, sketches, and a listing of similar projects that may be relevant for comparison, which were used as the basis of the cost estimate. Drawings may include a project map showing the location of the work with respect to principal cities, roads, railways, and waterways; a site map showing the location of the work, borrow, quarry, and spoil areas, and existing work access roads; any existing facilities usable by the contractor; a general plan and elevation, or profile of the work with typical sections; and a construction layout.

Supporting documents that are publicly available as parts of the solicitation, such as plans, specifications and project description, or that contain no cost information, such as sketches, soil boring and material classifications, are not part of the IGE or back-up.

4-6 REQUIREMENTS FOR REVISION TO INDEPENDENT GOVERNMENT ESTIMATE.

The IGE may be changed or revised as a result of errors, differing conditions or additional information. Approval authority for revision to the IGE remains the responsibility of the Contracting Officer or authorized original IGE-approving official. Each office assures that appropriate justification is attached to the revised IGE. Any revision to the IGE must be clearly indicated, dated, justified, and approved. A copy of each IGE that has been approved is included in a file along with the details and circumstances reflecting the revisions.

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CHAPTER 5 LABOR

5-1 GENERAL.

5-1.1 Direct Labor Costs.

Direct labor costs are defined as base wages plus labor cost additives including payroll taxes, fringe benefits, travel, and overtime allowances paid by the contractor for personnel who perform a specific construction task. In addition to the actual workers, there are generally working crew foremen who receive an hourly wage and are considered part of the direct labor costs.

5-1.2 Indirect Labor Costs.

Indirect labor costs are wages and labor cost additives paid to contractor personnel whose effort cannot be attributed to a specific construction task. Personnel such as superintendents, engineers, clerks, and site cleanup laborers are usually included as indirect labor costs (overhead).

5-2 CREWS.

Direct labor cost requirements are broken into tasks of work. Since each task is usually performed by a labor crew including equipment, the crew must be defined, costed, and a production rate established for the task. Crews may vary in size and mix of skills. The number and size of each crew are to be based on such considerations as having sufficient workers to perform a task within the construction schedule and the limitation of workspace. Once the crews have been developed, the task labor costs can be determined based on the production rate of the crew and the labor wage rates.

5-3 WAGE RATES.

A wage rate must be developed for each labor craft, which will represent the total hourly cost rate to the construction contractor. This total rate will include the base wage rate plus labor overtime, payroll taxes and insurance, fringe benefits, and travel or subsistence costs as further described in this chapter. The composite wage rate for each craft will be used for development of the cost estimate. The computation will be prepared on the “Wage Rate Calculations” for provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 or similar local forms, or cognizant design agency approved cost estimating software.

Wage rates are generally well defined. The Davis-Bacon Act, PL 74-403, requires a contractor performing construction in the United States for the Government to pay not less than the prevailing rates set by the Department of Labor. Information on prevailing rates can be found at sam.gov. A schedule of minimum rates is included in the project specifications and is normally kept on file for each location by each local Office of Counsel. The cost engineer consults with the Contracting Officer on any questions regarding determination coverage, specific definitions, or concerns. Where labor is in short supply for certain crafts in the area, or the work is in a remote area, or it is well known that rates higher than the set rate scale will be paid, these higher wage rates are used instead of the minimum wage since this would be required of the contractor in order to attract labor to the job. The wage rate is adjusted to include travel time or night differential where these are a customary requirement.

For projects in locations not contiguous to the United States and its territories the wage rates are to reflect the prevailing wages being paid for construction labor in the host nation. These are to be fully burdened wage rates, including fringes, insurance and taxes.

5-3.1 Long Duration Projects.

For a long duration project, where future wage rates (i.e., Union Agreements) are known and used, care must be taken to avoid duplication by not applying an escalation rate to such costs.

5-4 OVERTIME AND SHIFT DIFFERENTIAL.

The cost engineer is to carefully consider the available working time in the construction schedule for each task accomplishment in a normal time period. The efficiency of both the second and third shifts are to be adjusted to recognize that production will not be as high as the day shift for most types of construction operations. A three-shift operation is normally avoided due to lower labor efficiency and the requirement to include equipment maintenance.

5-4.1 Overtime.

Overtime is to be included in the labor cost computation when work in excess of regular time is required by the construction schedule or is the custom of labor in the local vicinity. Overtime labor cost is normally calculated as a percentage of the base wage rate. It is usually based on time and one-half, but may be double time depending on the existing labor agreements. Tax and insurance costs are applied to overtime, but fringe benefits and travel and subsistence costs are not. Figure 5-1 shows an example of overtime calculation for 40 hours regular time, plus 8 hours overtime at time and one half:

Figure 5-1 Overtime Calculation

OVERTIME CALCULATION EXAMPLE	
48 hours at Straight Time	= 48.00 hours
8 hours at ½ Time	= 4.0 hours paid
Equivalent Straight Time	=52.00 hours
(52 hours paid/48 hours worked = 1.0833) - 1 x 100% = 8.33%	
Note: Refer to the Related Material on WBDG.org for example estimate sheets for method of application	

5-4.2 Shift Operations.

Many construction projects utilize multiple shift operations. When estimating direct labor costs for multiple shift operations, the cost engineer estimates the number of hours to be worked (include shift differential work loss) and the number of hours to be paid for each shift based upon the construction schedule. Differential shift premiums may need to be added to the hourly rate.

5-4.3 Tabulation of Overtime Percentages.

A tabulation of overtime percentages for most conditions is provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05. The percentage also includes an allowance for the direct work loss of multiple shift or shift differential, where applicable.

5-5 TAXES AND INSURANCE.

5-5.1 Rates.

Rates for taxes and insurance are to be verified prior to computation.

5-5.2 Workman's Compensation.

Workman's compensation and employer's liability insurance costs applicable for the state in which the work is performed are to be included in the composite wage rate. Insurance rates may be obtained from the state if the state law provides a monopoly or from insurance companies providing this type insurance. The project compensation rate is based on the classification of the major construction work and applies to every craft employed by the contractor.

5-5.3 Unemployment Compensation Taxes.

Unemployment compensation taxes are composed of both state and Federal taxes. Unemployment compensation tax will vary with each state while the Federal unemployment tax will be constant for every project. Insurance rates can be obtained from the state unemployment office, commercial publications, or the Bureau of Labor Statistics.

5-5.4 Social Security Tax Rates.

The social security tax rates and the income ceilings on which social security taxes must be paid vary from year to year. Therefore, the cost engineer must verify the rate to be used in the cost estimate. Current and future rates can be obtained from the Social Security Administration.

5-5.5 Total Percentage of Taxes and Insurance.

The total percentage of the above taxes and insurance is summed and then applied to the basic hourly wage rate plus overtime for the various crafts. Figure 5-2 illustrates the method for deriving the total tax and insurance percentage. Since rates are subject to change and in some cases vary by region, the calculations shown are presented as an example only. Actual values must be determined by the cost engineer for the specific project.

Figure 5-2 Total Taxes and Insurance Percentage

TOTAL TAXES AND INSURANCE PERCENTAGE	
Workman's compensation and employer/s liability (varies with state and contractor)	7.60%
State unemployment compensation (varies with each state)	3.20%
Federal unemployment compensation	0.80%
Social Security & Medicaid	7.65%
Total taxes and insurance	19.25%
Note: Foreman and overhead labor rates must also include these applicable costs. Refer to the Related Material on WBDG.org for example estimate sheets for method of application	

5-6 FRINGE BENEFITS AND TRAVEL/SUBSISTENCE.

5-6.1 Fringe Benefits.

Fringe benefits may include health and welfare, pension, apprentice training, depending on the craft and the location of the work. These summed costs are usually expressed as an hourly cost with the possible exception of vacation, which may be easily converted to an hourly cost. The type of fringe and the amount for the various crafts can usually be found with the Davis-Bacon Act wage determination in the specifications. Non-union contractors pay comparable fringe benefits directly to their employees.

Figure 5-3 illustrates the calculations for fringe benefits. Since the values change and vary by region and union agreement, the calculations shown are presented as an example only. Actual values must be determined by the cost engineer.

Figure 5-3 Fringe Benefits

FRINGE BENEFITS EXAMPLE	
Health and Welfare	$0.70/hr
Pension	$0.75/hr
Apprentice Training (N/A in this case)	$0.00/hr
Total Fringe Benefits	$1.45/hr

5-6.2 Travel and Subsistence.

Travel and subsistence (per diem) costs are normally expressed as a daily or weekly cost. Travel and subsistence may be converted to an hourly cost and excluded from an overtime premium unless travel and subsistence are part of an increased hourly wage. See example estimates provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 for methodology.

Some fringe benefits and travel/subsistence are subject to payroll taxes. For example, vacation benefits are taxable and added to the basic wage rate.

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CHAPTER 6 LABOR PRODUCTIVITY

6-1 GENERAL.

Estimating labor productivity is subject to many diverse and unpredictable factors. There is no substitution for the knowledge and experience of the cost engineer when estimating labor productivity. For some types of work, the task productivity of crew members such as equipment operators, helpers, or oilers is determined by the productivity of the equipment. For some labor based crews, the task productivity of craftsman such as carpenters, steel workers, and masons may be based on average experience in the Cost Book, tempered with the experience of the cost engineer, historical records, or other appropriate reference manuals.

6-1 PRODUCTIVITY ADJUSTMENT CONSIDERATIONS.

6-1.1 Labor Effort.

The labor effort needed to perform a particular task varies with many factors, such as the relative experience, capability and morale of the workers, the size and complexity of the job, site specific security requirements, the climatic and topographic conditions, the degree of mechanization, the quality of job supervision, amount of similar task repetition, and the existing labor-management agreements and trade practices. The effort from these labor efficiency factors and work practices that exist in the project locality must be considered in each productivity assignment.

6-1.2 Complexity of the Variable.

The complexity of the variables affecting productivity makes it difficult to estimate a production rate. Therefore, production rates are based on averaging past production rates for the same or similar work. The cost engineer must incorporate particular job factors and conditions to adjust historical data to the project being estimated. Other sources for production rates include reference manuals, field office reports, construction logbooks, and observation of ongoing construction.

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CHAPTER 7 CONSTRUCTION EQUIPMENT AND PLANT

7-1 GENERAL.

Construction plant and equipment refers to the tools, instruments, machinery, and other mechanical implements required in the performance of construction work. Construction plant is defined as concrete batch plants, aggregate processing plants, conveying systems, and any other processing plants which are erected in place at the job site and are essentially stationary or fixed in place. Equipment is defined as items, which are portable or mobile, ranging from small hand tools through tractors, cranes, and trucks. For estimating purposes, plant and equipment are grouped together as equipment costs.

7-2 SELECTION OF EQUIPMENT.

An important consideration in the preparation of a cost estimate is the selection of the proper equipment to perform the required tasks. The cost engineer is to carefully consider number, size, and function of equipment to arrive at optimum equipment usage. Some factors to consider during the selection process are: conformance to specification requirements; job progress schedule (production rate); magnitude of the job; type of materials; availability of space; mobility and availability of equipment; suitability of equipment for other uses; equipment capabilities; number of shifts; distances material must be moved; steepness and direction of grades; weather conditions; hauling restrictions; standby time; and mobilization and demobilization costs.

The cost engineer preparing the cost estimate must be familiar with construction equipment and job-site conditions. The selected equipment conforms to contract requirements and be suitable for the materials to be handled and conditions that will exist on the project.

7-3 ESTIMATING METHODOLOGY.

The "crew concept" discussed in Chapter 5 for cost estimates requiring detailed estimating of labor, materials, and equipment is to also be considered in costing equipment. For each significant work task, workers and equipment are expressed in the hourly cost and expected production rate. Where a major piece of equipment serves more than one crew, the total equipment time is prorated between both crews.

7-4 PRODUCTION RATE.

After determining the type of equipment to be employed, the cost engineer selects the specific equipment size which has a production rate suited to the efficient and economical performance of the work. The size and number of units required will be influenced by equipment production rate, job size, availability of space for equipment operations, the project construction schedule for the various work tasks, number of shifts to be worked, and the availability of equipment operators. Emphasis must be placed on the importance of establishing a reasonable production rate. Production may be based on actual performance data, commercial manufacturer tables or rates from Micro Computer-Aided Cost Engineering System 2nd Generation

(MCACES/MII)/historical equipment models and assemblies, adjusted for project conditions.

7-5 MOBILIZATION AND DEMOBILIZATION.

Mobilization costs for equipment include the cost of loading at the contractor's yard, transportation cost from the yard to the construction site, including permits, unloading at the site, necessary assembly and testing, and standby costs during mobilization and demobilization. Trucks for the project capable of highway movement are usually driven to the site and are often used to transport minor items. Labor, equipment, and supply costs required to mobilize the equipment are to be included in the mobilization cost. When the equipment location is unknown, the mobilization and demobilization distance should be based on a circular area around the project site, which will include a reasonable number of qualified bidders. Demobilization costs are based on that portion of the equipment that would be expected to be returned to the contractor's storage yard and may be expressed as a percentage of mobilization costs. Labor, equipment, and supply costs required for cleaning/prepping the equipment so that it is in the same condition as it was when it arrived at the site is to be included in the demobilization cost. Transportation rates should be obtained periodically from qualified firms normally engaged in that type work.

Mobilization and demobilization costs for plant are based on the delivered cost of the item, plus erection, taxes, and dismantling costs minus salvage value at the end of the project. Maintenance and repair are operating costs that are distributed throughout work accomplishment.

7-6 EQUIPMENT OWNERSHIP AND OPERATING EXPENSE COST RATES.

The EP 1110-1-8 Construction Equipment Ownership and Operating Expense (includes 12 volumes) determines the hourly rates for equipment ownership and operating expense by region. These regional rates are incorporated into the Cost Book and are to be used in the preparation of cost estimates for owned equipment. These volumes have been developed for different geographic regions in the United States, and the appropriate volume is to be used based upon project location. Rented and leased equipment is also discussed in the EP and is appropriate for inclusion in the cost estimate at competitive rates if judgment determines this to be a reasonable approach.

When the cost engineer develops costs for the actual equipment being used at a job site exceeding 40 hours per week, the rates must be adjusted as described by EP 1110-1-8.

7-7 PLANT COST.

In cases of highly specialized plant, 100 percent write-off of the total value of the plant may be justified for a particular project. For less highly specialized plant, some salvage may be anticipated, depending on storage cost, resale value, and probability of sale or reuse in the immediate future. The total project charge including operation, maintenance, and repair are distributed in proportion to the time and item the plant is used on the various contract items. Cost of plant required for the production of concrete, aggregates, ice or heat for cooling or heating of concrete, etc., is to be included in the cost estimate as part of the cost of these materials or supplies manufactured or produced at the site.

7-8 SMALL TOOLS.

The cost of small power and hand tools and miscellaneous non-capitalized equipment and supplies are estimated as a percentage of the labor cost. The allowance must be determined by the cost engineer in each case, based upon experience for the type of work involved. Unit prices based on historical data already include a small tools allowance. The small tool cost will be considered as part of equipment cost. Such allowance is typically 2 percent of direct labor cost. The cost engineer must ensure that this cost is not duplicated in the overhead rate percentages. The crews in the Cost Book do not contain a small tools allowance.

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CHAPTER 8 MATERIALS AND SUPPLIES

8-1 GENERAL.

Materials and supplies are defined below, and for the purpose of cost estimating, both can be considered materials unless they need to be separated because of different tax rates.

8-1.1 Materials.

Those items which are physically incorporated into and become part of the permanent structure.

8-1.2 Supplies.

Those items which are used in construction but do not become physically incorporated into the project such as concrete forms.

8-2 SOURCES OF PRICING DATA.

8-2.1 General.

Prices for materials and supplies may be obtained from pricing services, the Cost Book, catalogs, quotations, and historical data records. Each office should review the source of the pricing contained in these publications and assess the reasonableness prior to use. Standard unit prices from these sources are considered satisfactory only after an applicability determination has been made. Care is to be taken when using this type of cost data to make proper allowances for quantity discounts, escalation, and other factors affecting contractor cost.

8-2.2 Quotes from Manufacturers and Suppliers.

Quotes are to be obtained for significant materials and installed equipment and for specialized or not readily available items. Use the Pareto Principle to determine the number of quotes required. Quotations may be received either in writing, electronically, or by telephone. It is preferable to obtain quotes for each project to ensure that the cost is current and that the item meets specifications. If possible, more than one quote is to be obtained to be reasonably sure the prices are competitive. The cost engineer should attempt to determine and ensure that contractor discounts are considered in the cost estimate. Quotes are kept proprietary to preserve the confidentiality entrusted. A sample telephone quotation data sheet similar to that provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 is utilized for recording quoted information. The cost engineer is to also take into consideration FAR Subpart 25.2 Buy American Act-Construction Materials and FAR Subpart 6.1 Full and Open Competition for the materials specified.

8-3 WASTE ALLOWANCE.

Waste and loss considerations may be included in material unit price computations. This methodology when computing material costs results in a quantity takeoff of work placement, which is not altered to reflect material losses. However, the alternative methodology of increasing the measured quantity by waste and loss quantity is acceptable if the excess quantity will not be used for any other purpose. The preferred methodology used by the cost engineer is not to charge labor on the excess quantity. In either case, a note statement is required in the cost estimate explaining the methodology used.

8-4 FORWARD PRICING.

Sometimes quotes are requested in advance of the expected purchase date. However, suppliers are reluctant to guarantee future prices and often will only quote current prices. It may therefore be necessary to adjust current prices to reflect the cost expected at the actual purchase date. This cost adjustment, if required, is not to be included as a contingency, but clearly and separately defined in each cost estimate. Adjust current pricing to future pricing using program specific escalation factors. Computations of adjustments are to be clear and maintained as cost estimate backup support. The cost engineer is to ensure that this cost is not duplicated in the escalation to midpoint of construction percentages.

8-5 FREIGHT.

The cost engineer checks the basis for the price quotes to determine if they include delivery. If they do not include delivery, freight costs to the project site must be determined and included. The supplier can usually furnish an approximate delivery cost. For delivery charge, Free/Freight on Board (FOB) refers to the point to which the seller will deliver goods without additional charge to the buyer.

8-5.1 FOB Factory or Warehouse.

If the materials or supplies are FOB factory or warehouse, freight costs to the construction site are to be added to the cost of the materials or supplies.

8-5.2 Unloading and Transporting the Materials or Supplies.

If the cost of materials or supplies includes partial delivery, FOB to the nearest rail station, the cost of unloading and transporting the materials or supplies is to be included in the cost estimate.

8-5.3 Large Quantity in Bulk.

If the materials or supplies are a large quantity in bulk, which would require extensive equipment for unloading and hauling, it may be desirable to prepare a labor and equipment cost estimate for the material handling and delivery.

8-6 HANDLING AND STORAGE.

The contractor is usually required to off-load, handle and stockpile, or warehouse materials on site. These costs are to be included in the cost estimate. An item of electronic equipment requiring special low-humidity storage might have this special cost added to the direct cost of the equipment. For common items, such as construction materials or equipment needing secure storage, the cost for the security fencing, temporary building and material handling are considered as an indirect cost and be included in the job-site overhead cost.

8-7 TAXES.

When applicable, state and local taxes (i.e., sales, excise) are to be added to the materials or supplies cost. In some states, material incorporated into Federal construction is exempt, but supplies are not. Care is to be taken, therefore, that the sales tax rate is applied as required. The cost engineer is to verify the tax rates and the applicability of these rates for the project location. Sales tax is considered a direct cost of the materials and supplies.

8-8 MATERIALS OR SUPPLIES MANUFACTURED OR PRODUCED AT THE SITE.

If it is likely the contractor will manufacture or produce materials or supplies at the project site, a separate cost estimate component (i.e., batch plant) is to be developed for this work. This cost estimate includes a detailed equipment, labor, materials, and supplies estimate, and concludes with a unit cost of material or supply delivered to the stockpile, storage yard, or other end point.

8-9 GOVERNMENT-FURNISHED MATERIALS (GFM) OR EQUIPMENT (GFE).

On some projects, the Government may provide some of the project materials. Government-furnished materials and equipment are to be estimated in the same manner as other materials, except that the purchase price is not included. The cost estimate includes an allowance for transporting, handling, storage from point of delivery and assembly, sales tax, and installation if applicable. There may be special costs associated with Government-furnished materials such as insurance to cover loss until final installation, special storage costs, or special security measures. Note that these materials and procurement costs are normally to be included as part of the total project cost.

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CHAPTER 9 SUBCONTRACTED WORK

9-1 GENERAL.

In construction, specialty work such as plumbing, heating, electrical, roofing, plastering, and tile work are usually more effectively performed by subcontract. With so many specialties being performed, subcontract work becomes a very significant portion of the total costs of construction. Since each cost estimate is prepared as practically and as realistically as possible, subcontract costs become a necessary consideration.

9-1.1 Parts of Work to be Subcontracted.

The cost engineer must first determine those parts of the work that will probably be subcontracted. When the work to be subcontracted has been determined, those items will be identified in the cost estimate. The appropriate subcontractor overhead and profit costs are to be applied to subcontractor direct cost items in addition to the appropriate prime contractor overhead and profit.

9-1.2 Cost of Subcontracted Work.

The cost of subcontracted work is the total cost to the prime contractor for the work performed. Subcontractor's costs include direct labor, materials and supplies, equipment, second tier subcontracts, mobilization and demobilization, transportation, set-up, and charges for overhead and profit. Particular attention is given to large items such as turbines, generators, and incinerators. The total subcontract cost is considered a direct cost to the prime contractor.

9-1.3 Construction Contractual Methods.

The cost engineer should be aware of the type of contractual method for which the solicitation is being issued. Limited competition contractual procurement methods may result in multiple compounded levels of subcontracted work, e.g., compounded subcontractors' markups passed on to the prime contractor. Some examples of limited contractual procurement methods are 8-A Sole Source RFP, MATOC sole source task order, POCA sole source task order, etc. The prime contractor is required per the contract to perform a minimum amount of work, but the remaining work may be performed by subcontractors. If possible, particular attention is to be given to the workload capacity and workforce capability of the prime contractor. If the prime contractor already is at full capacity in performing other work, or their own workforce resources are at maximum usage, then the prime contractor will likely subcontract to the maximum extent allowable. Also, the same scenario would occur for the subcontractors if they are at their maximum capacities.

9-2 USE OF QUOTATIONS.

Potential prime contractors are not to be utilized for quotes. The cost engineer may utilize quotes for the expected subcontracted work when reviewed and verified as reasonable. In lieu of a quotation, each task of the subcontract is priced as a direct cost with an appropriate rate of subcontractor's overhead and profit added.

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CHAPTER 10 OVERHEAD COSTS

10-1 GENERAL.

Overhead costs are those costs, which cannot be attributed to a single task of construction work. Costs, which can be applied to a particular item of work is to be considered a direct cost to that item and are not to be included in overhead costs. The overhead costs are customarily divided into two categories:

- General home office overhead (HOOH) commonly referred to as General and Administrative (G&A) costs.
- Job office overhead (JOOH) also referred to as General Conditions or Field Office Overhead (FOOH).

10-1.1 Duplication of Overhead Costs.

The cost engineer must be sure that overhead costs are not duplicated between the two categories (JOOH/HOOH). Because of the nature of overhead costs, it is not practical to discuss all overhead items. Specific considerations must be carefully evaluated for each project. The cost engineer must use considerable care and judgment in estimating overhead costs. Many indirect cost items are frequently described in the General Requirements Section (Construction Specification Institute (CSI) Division 01) of the contract specifications. If not related to a specific work task, these costs must be identified and appropriately assigned as overhead costs.

Beyond ensuring there is no duplication of costs, the General Requirements Section of the contract specifications can also impact specific adjustments to costs, such as number of project offices, utility requirements/coverage’s, contractor quality control matrices, allowances or restrictions against multiple roles for a single supervisory role, etc.

10-1.2 Previously Determined Overhead Rates.

The application of a previously determined overhead rate may be used for early design stages, but it is not an accurate or reliable method of forecasting costs. Overhead will vary from project to project and may even vary from month to month within any given project. Job overhead items for the prime contractor are estimated in detail for projects at final design requiring a cost estimate. Detailing of overhead costs for subcontract work is recommended when the impact of these costs is significant.

10-2 GENERAL HOME OFFICE OVERHEAD (G&A/HOOH).

Home office overhead expenses are those incurred by the contractor in the overall management of the business. Since they are not incurred for any one specific project, they must be apportioned to all the projects. Many expenses such as interest and entertainment are not allowable. Construction equipment depreciation is included in the EP 1110-1-8, Construction Equipment and Operating Expense Ownership Schedule cost rates and are not included in the G&A rate. An accurate percentage of G&A can only be determined by an audit. On major changes requiring an audit, it is important to request that the G&A rate be determined.

Of all the categories of costs, the contractor's G&A costs are the least definable. Each contractor organizes his company differently from any other. Each incurs costs differently from varying sources and manages operations of that home office by their own methodology. It is important to understand that home office costs are not standard and fixed. Even though the cost for a specific contractor varies from period to period, a rate is normally averaged as a computation of total home office costs over a sufficient period divided by the total volume of business during that specific period. This rate computation methodology allows distribution and projection to future project cost estimates. When more specific data is not available, the cost engineer may include empirical rates. Empirical G&A rates typically range from three percent for large contractors to ten percent for small contractors. Home office costs are typically included in the estimate of overhead as the product of an average experienced percentage rate times the expected contract amount. Typical categories of home office overhead are:

- Main office building, furniture, equipment.
- Management and office staff, salary and expense.
- Utilities.
- General communications and travel.
- Supplies.
- Corporate vehicles.
- General business insurance.
- Taxes.

10-3 JOB OFFICE OVERHEAD.

Job overhead costs are those costs at the project site, which occur specifically as a result of that particular project. Some examples of job overhead costs are:

- Job supervision and office personnel.
- Engineering and shop drawings/surveys.
- Site security.
- Temporary facilities, project office.
- Temporary material storage.
- Temporary utilities.
- Preparatory work and laboratory testing.
- Transportation vehicles.
- Supplies and maintenance facilities.

- Temporary protection and Occupational Safety and Health Administration (OSHA) requirements.
- Telephone and communications.
- Permits and licenses.
- Insurance (project coverage).
- Schedules & reports.
- Quality control.
- Cleanup.
- Taxes.
- Fuel.
- Support Equipment utilized for general use on site
- Operation and maintenance of temporary job-site facilities.
- Project specific travel
- Relocation of key personnel

10-3.1 Mobilization and Preparatory Work.

The costs of mobilization and preparatory work, including the setup and removal of construction facilities and equipment are part of overhead costs unless there is a specific bid item. For large projects, the cost for each part of this initial work is to be estimated on a labor, materials, and equipment basis. For smaller projects, these costs may be estimated based on experience.

10-4 DURATION OF OVERHEAD ITEMS.

After the overhead items have been listed, a cost must be determined for each. Each item is to be evaluated separately. Some items such as erection of the project office may occur only once in the project. The cost engineer utilizes the construction schedule (see paragraph 4-3.5) in estimating requirements based on duration. Costs reflective of each particular item during the scheduled period are to be applied.

10-5 SOURCES FOR PRICING.

The cost engineer must rely on judgment, historical data, and current labor market conditions to establish overhead costs. Sources for information can be obtained from current or past contractors bid data and audits. Some contractors will informally discuss and furnish information for overhead items and audit reports of previous similar projects. Other sources include previously negotiated modifications and review of organizational charts of construction firms for staffing and overhead costs evaluation. Overhead salaries are to include an allowance for payroll taxes and fringes such as Federal Insurance Contributions Act (FICA), health benefits, and vacation.

10-6 DISTRIBUTION OF OVERHEAD.

The prime contractor's overhead costs, which have been costed in an organized format, are to be summed and distributed proportionally to the Contract Line Item (CLIN) items. A proportional distribution is commonly made by percentage ratio of total direct costs to those direct costs in each item. When options, additive, or split-bid items are included, only those job office overhead costs, which relate directly to the work, are to be distributed to those items.

Job office overhead costs which the contractor will incur regardless of whether the item is optional, additive, or split is distributed to base bid schedule items only. Selective distribution ensures recoupment of costs if only the basic contract scope is awarded. Regardless of the method of distribution, the cost estimates are to clearly demonstrate the procedures and cost principles applied.

For modifications that extend the baseline contract duration, the estimated job office overhead requirements are to be itemized and costed to reflect the actual net change in cost of overhead, that is, costs before and after the modification work. As a refinement to distribution, the cost engineer may reasonably and justifiably reduce the prime job office overhead distribution on subcontract work items. The balance of the total prime job office overhead are then distributed as discussed above to the remaining prime items of work.

CHAPTER 11 PROFIT

11-1 GENERAL.

Profit is defined as a return on investment. It is what provides the contractor with an incentive to perform the work as efficiently as possible.

11-2 WEIGHTED GUIDELINES METHOD.

Profit and weighted guideline methods determining profit are discussed in the FAR and its supplements. There are various types of weighted guideline methods for determining profit according to DFARS 215.404-4. The proper weighted guideline method to use will depend on the type of contractual acquisition action and the supplemental regulations that apply to the contracting activity. Reference FAR Sub-part 15.404-4 concerning the use of profit when price is based on a negotiated firm fixed price construction contracts. The use of the weighted guideline method when price is negotiated will be per the cognizant design agency guidance. The determination of profit, as appropriate for each procurement action, may be determined and submitted on the sample worksheet identified as Figure 11-1 which applies to the weighted guidelines alternate structured approach DFARS 215.404-4 (b)(1)(C) “Alternate Structured Approach”. Explanation of the factors to be used in calculating profit, are described below, and provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05.

11-2.1 Weighted Guidelines Method.

The weighted guidelines method yields a reasonable profit value and are to be used to determine profit for contracts that include profit. This methodology is also be used wherever a detailed direct costing method is used for preparing cost estimates. A rate of profit may be used based on historical experience for early stage cost estimates prepared for programming, budgeting, reconnaissance, or concept design.

11-2.2 Weighted Guideline Factors for the Alternate Structured Approach.

Based on the circumstances of each procurement action, each of the factors listed in the “Guidelines for Weighted Factors Profit Determination” at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05. will be weighted from 0.03 to 0.12 as discussed in the following text. Statements in sufficient detail to explain the reasons for assigning the specific weights shall be included on the profit computation sheet. The value will then be obtained by multiplying the rate column by the weight column. The value column when totaled indicates the fair and reasonable profit percentage.

- Degree of Risk. Where the work involves no risk or the degree of risk is very small, the weighting is 0.03; as the degree of risk increases, the weighting is increased up to a maximum of 0.12. Lump sum items will have, generally, a higher weighted value than unit price items for which quantities are provided. Other things to consider include ; the nature of work; where the work is to be performed; the reasonableness of negotiated costs; the amount of labor included in the costs; and whether the negotiation occurs before or after the period of performance of work.

- Relative Difficulty of Work. If the work is difficult and complex, the weighting is 0.12 and is proportionately reduced to 0.03 on the simplest of jobs. This factor is tied in to some extent with the degree of risk. Some things to consider include technical nature of the work; by whom work is to be done; location of work; and time schedule.
- Size of the Job. Work not in excess of $100,000 will be weighted at 0.12. Work estimated between $100,000 and $5,000,000 will be proportionately weighted from 0.12 to 0.05. Work from $5,000,000 to $10,000,000 shall be weighted at 0.04 and work in excess of $10,000,000 at 0.03.
- Period of Performance. Jobs in excess of 24 months are to be weighted at 0.12. Jobs of lesser duration are to be proportionately weighted to a minimum of 0.03 for jobs not to exceed 30 days. No weight is given for modification cost estimates when additional performance time is not required.
- Contractor’s Investment. Jobs are to be weighted from 0.03 to 0.12 on the basis of below average, average to above average of contractor investment. Things to consider include amount of subcontracting; mobilization payment item; Government-furnished property; method of making progress payments; and front-end requirements of the job.
- Assistance by Government. Jobs are to be weighted from 0.12 to 0.03 on the basis of below average to above average. Things to consider include use of Government-owned property, equipment and facilities, and expediting assistance.
- Subcontracting. Jobs are to be weighted inversely proportional to the amount of subcontracting. Where 80 percent or more of the work is to be subcontracted, the weighting is to be 0.03 and such weighting proportionately increased to 0.12 where work is performed by the contractor's own forces.

11-2.3 Separate Profit Calculation.

A separate profit calculation is to be performed for the prime contractor and for each subcontractor. When the subcontractor assumes the risk and responsibility for portions of the work, the prime contractor's profit rate on that work is decreased. As a general rule, profit is applied as a percentage rate to the total of costs required by the contract or modification scope. For early design stage cost estimates, a rate of profit may be assumed based on past historical experience.

Figure 11-1 Profit Computation Sheet using the Alternate Structure Approach

PROFIT COMPUTATION SHEET

Project:	Estimated By:
Contract No:	Checked By:
Change Order No:	Date: XX/XX/XX

Profit Objective For: (Prime Contractor, Subcontractor)

Factor	Rate (%)		Weight (0.03-0.12)		Value
1. Degree of Risk		X		=	
2. Difficulty of Work		X		=	
3. Size of Job		X		=	
4. Period of Performance		X		=	
5. Contractor's Investment		X		=	
6. Assistance by Government		X		=	
7. Subcontracting		X		=	
		%	Profit Factor		%

COMMENTS (Reasons for Weights Assigned):

1.

2.

3.

4.

5.

6.

7.

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CHAPTER 12 SURETY BONDS

12-1 GENERAL.

Surety bonds are three-way agreements between a bidder or contractor (the principal), and a second party (the surety), to assure fulfillment of the principal's obligations to a third party (the obligee). If the principal obligations are not met, the bond assures payment to the extent stipulated of any loss sustained by the obligee.

In most Government construction contracts, these three parties are as follows:

Three Party	Under a General Contract	Under a Subcontract
The Principal	Contractor	Subcontractor
The Obligee	Government	Contractor
The Surety	Surety	Surety

12-2 PURPOSE OF BONDS.

The purpose of surety bonds varies with the type of bond.

12-2.1 Bid Bonds or Bid Guarantee.

Bid bonds or bid guarantee provides an assurance that the bidder will not withdraw his bid within the specified period for acceptance and will execute a written contract and furnish the required bonds if the bid is accepted.

12-2.2 Payment Bonds.

Payment bonds protect subcontractors, suppliers, and laborers against nonpayment by the prime contractor.

12-2.3 Performance Bonds.

Performance bonds ensure the contractor will complete the project as specified and for the agreed price. It does not shift responsibility for administering the contract to the surety. A performance bond provides a financial guaranty for the work and provides the contractor with a method of freeing his working capital and other assets, which might otherwise be tied up by other forms of surety such as certified checks, retainage, or deposits.

12-3 AMOUNT OF REQUIRED SURETY BONDS.

The amount included in the cost estimate is based on the contract requirements, the bond rules, premium rates, and, if known, the actual contractor bond cost. Performance and payment bonds are required for construction contracts of $150,000 or more (FAR 28.102-1). Payment bonds are required for construction contract values from $35,000 to $150,000 or some form of payment guarantee (FAR 28.101-1 and 28.101-2).

Performance bonds may not be required for construction contract values of less than $150,000. The cost of performance bonds, payment bonds, and other types of bonds determined to be appropriate by the cost engineer are allowable costs.

12-4 RULES GOVERNING THE APPLICATION OF BOND RATES.

Bonds are classified as Class A, Class B, or Class A-1, depending on the type of construction to be performed. If the contract is susceptible to two classifications, normally the higher rate is applicable. Bond rates tables are provide at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05.

12-4.1 Separate Contracts.

Separate contracts take the same classification as a general contract. Neither the classification nor the rate is changed by subdividing the work or by the Government's providing certain materials.

12-4.2 Subcontracts.

Subcontracts take the same classifications and rates as general contracts.

12-4.3 Non-Deviating States Exceeding 12 Months Stipulated Time.

For states in conformance (non-deviating) with the Surety Association of America (SAA) rates (Bond Rates Table) where the construction time exceeds the bond stipulated time of 12 months, add 1 percent of the bond premium for each month in excess of 12 months.

12-4.4 Non-Deviating States Exceeding 24 Months Stipulated Time.

For states in conformance (non-deviating) with the SAA rates (Bond Rates Table) where the construction time exceeds the bond stipulated time of 24 months, add 1 percent of the basic premium for each month in excess of 24 months.

12-4.5 Deviating States Exceeding Stipulated Time.

For states not conforming (deviating) with the SAA rates where the construction time exceeds the bond stipulated time of 12 months, add ½ percent of the basic premium for each month in excess of 12 months up to 24 months and 1 percent of the basic premium for each month in excess of 24 months.

12-4.6 Consent of the Surety Not Required.

If the consent of the surety is not required and given for changes or extras, first and renewal premiums for the additional cost thus caused are computed at manual rates from the date of the bond.

12-4.7 Consent of the Surety Required.

If the consent of the surety is required and given for changes or extras, premium for the additional cost thus caused is computed at manual rates from the date of such surety's cost.

12-5 COST OF PERFORMANCE AND PAYMENT BONDS.

Performance and payment bonds are normally obtained as a single package. The premium is the same as for the performance bond alone. Rates vary with the type of the contract work, the dollar value, and the length of the contract.

The development of costs for surety bonds is to be in accordance with the design agency requirements.

12-5.1 Coverage Limit of Performance Bonds.

The coverage limit of performance bonds is specified in each contract and is usually for the full amount of the contract price (bid amount). The premium is adjusted at the completion of the work for any modification changes in the contract price other than changes due to time bonuses or penalties. If the original contract price is increased through change order, the contractor must pay an additional premium. Conversely, if any part of the original work is deleted and the original price thereby reduced, the contractor will receive a refund from the surety.

12-5.2 SAA Issues Advisory Rates.

It should be noted the surety industry has become a state regulated industry. The SAA issues advisory rates, but these rates may or may not be accepted by the state involved. Therefore, actual rates charged by surety corporations may vary from state to state.

12-5.3 Types and Classes of Bonds.

Contract Bonds Rate Classifications tables provided on https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 shows the various types and classes of bonds.

12-5.4 Calculation of Bond Premium Cost.

Figure12-1 illustrates the calculation of bond premium cost. Since the rates are subject to change and may vary by state, the calculations are to be used as a sample only. The cost engineer is responsible for ensuring the rates used are accurate and current. This example assumes a canal excavation project in Tennessee to be accomplished at an estimated cost of $2.5 million, including profit, with a duration of 20 months. From the Contract Bond Rates Classification tables, excavation is found in Class B. Referring to the Class B rate schedule in the Bond Rates table, the premium for a performance-payment bond written in the full amount of the contract price (including bond) and by a non-deviating Surety Association Company would be calculated as follows:

Figure 12-1 Bond Premium Calculation

BOND PREMIUM CALCULATION					
Estimated Bond Amount x Rate = Premium					
First	$100,000	@	$25.00/M	=	$2,500
Next	$400,000	@	$15.00/M	=	$6,000
Next	$2,000,000	@	$10.00/M	=	$20,000
Anticipated Estimated Amount (inc. bond)					
	$2,500,000		$28,500		
(20 mos - 12 mos = 8 mos surcharge)					
Eight additional months @ 1%/Month					
(8 mos x 1% x $28,500)		=	$2,280		
TOTAL PREMIUM		=	$30,780		

CHAPTER 13 OTHER COSTS

13-1 GENERAL.

This chapter provides guidance regarding other costs not specifically identified in previous chapters, but costs that must be included in the preparation of detailed project cost estimates.

13-2 CONTRACTOR COMPETITION AND MARKET ANALYSIS.

Each IGE for procurement will reflect the fair and reasonable cost for performing the scope specified. Although contractor bids will reflect the anticipated competitiveness, the IGE must remain the "yardstick" against which cost reasonableness is judged.

During development of the design-stage, market competitiveness may be considered for funding and design alternatives. When competition is included in the cost estimate, it must be clearly defined and documented in the BOE.

13-3 OTHER PROJECT COSTS.

13-3.1 Design Costs

Design costs for Design Build projects may not be included in the cost estimate for all agencies. Refer to cognizant design agency guidance for clarity.

13-3.1.1 SIOH.

An allowance or cost calculation for construction management is normally included in each Budgetary estimate. Budgetary estimates must include SIOH, a factor expressed as a percentage applied to the total of the construction contract including construction contingency. The rate of SIOH and its application is further discussed in the specific program regulation. The current cognizant design agency's authorized SIOH percentage for the continental United States (CONUS) and outside the continental United States (OCONUS) must be used.

13-3.1.2 Other Project Costs.

In order for a total project cost estimate to be prepared, other project costs identified in project requirements and per cognizant design agency guidance need to be estimated. These costs, such as as-built drawing preparation, O&M manual preparation, need to be identified and included as determined by the PM and specific program requirements.

13-4 COST ESCALATION.

Cost estimates, when finalized, must reflect cost escalation due to inflation. This cost escalation must be identified as a separate element within the cost estimate. This allows the cost engineer the ability to easily adjust the cost estimate to reflect schedule changes. The usual method of applying cost escalation is to use the midpoint of construction as the end date of the escalation.

13-4.1 Military Programs.

The Selling Price Index (SPI) will be used for bringing cost estimates from a historical date to the current date. The forecasted SPI is provided by Table 4.2 of UFC 3-701-01. Refer to cognizant design agency guidance for clarity.

13-5 CONTINGENCIES.

Contingencies are used to cover unknowns, unforeseen uncertainties, and unanticipated conditions that are not possible to adequately evaluate from the data on hand at the time the cost estimate is prepared, but must be represented by a sufficient cost to cover the identified risks. Contingencies relate to a known and defined construction scope and are not a prediction of future construction scope or schedule changes. Contingency allocations are specifically related to the project uncertainties and are not to be reduced without appropriate supporting justification. Contingencies are normally separated into two elements - design contingencies and construction contingencies.

13-5.1 Design Contingencies.

Design contingencies are assigned to cover construction cost increases due to design incompleteness, detail changes, alternative design changes, and associated costing inaccuracy. Design contingencies are used to cover known costs that are not yet well-defined (or defined at all) in the design. Design contingencies will normally decrease, as design information becomes known. The magnitude of design contingency is determined by the level of technical complexity of the project for which the cost estimate is being prepared. Cost Engineers use experience and reliable data in order to make assumptions that will cover those costs until they are defined appropriately in the design documents.

13-5.2 Construction Contingencies.

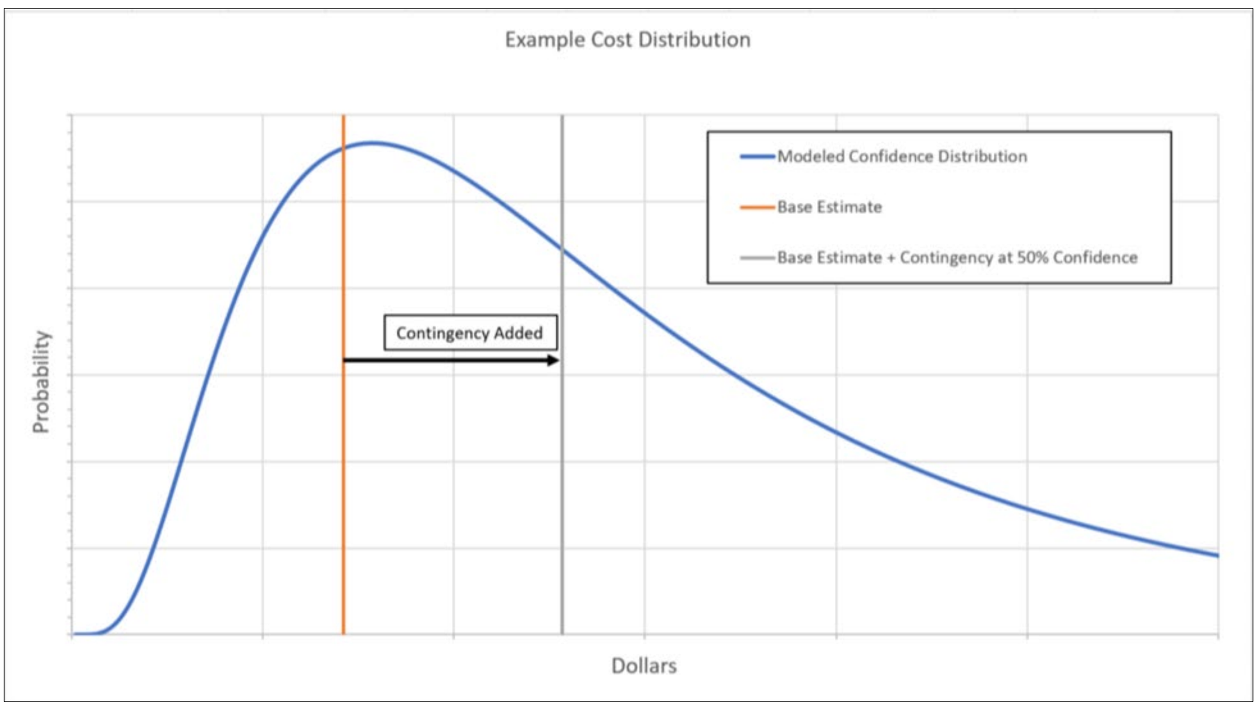
Construction contingencies are a reserve for construction cost increases due to adverse or unexpected conditions such as unforeseeable relocations; foundation conditions; utility lines in unknown locations; quantity overruns; or other unforeseen problems beyond interpretation at the time of or after contract award. Construction Contingency percentages for military projects may be applied in accordance with cognizant agency requirements.

CHAPTER 14 COST AND SCHEDULE RISK ANALYSIS

14-1 GENERAL.

Construction projects face uncertainties from design through construction that need to be addressed through risk management measures. Because the project scope definition is developed in an iterative fashion over time, the development of the associated cost and schedule for a project are based on iterative improvements in project scope definition. This iterative process drives the need for determining the appropriate contingency required at each cost and schedule estimate milestone for the uncertainties. The base estimate will reflect the anticipated value and the contingency will cover uncertainties for a total project cost and schedule or as defined by the cognizant agency procedures. The cost estimate can best be understood in the context of a range of possible cost (Figure 14-1). The contingency due to risks and unknowns will typically be highest at concept design and typically reduce over time as the scope matures and construction is completed. These considerations will minimize the likelihood that a project will experience funding-related issues. The iterative development of project scope definition gives rise to risks and opportunities that need to be managed.

Figure 14-1 Range of Cost



Cost and Schedule Risk Analysis (CSRA) is the process by which cost and schedule risks/opportunities are identified, documented, qualified, quantified and managed. Monte Carlo simulation is employed to determine the contingency needed to achieve any level of confidence. The output of the CSRA process includes a risk register and contingency models that provides a defensible contingency value.

The CSRA process was developed by the US Army Corps of Engineers in 2007 with the help of AACE and follows the best practices from range estimating techniques with adaptation to general DOD principles of cost estimating. Do not use "expected value" type modeling for construction risks.

The CSRA process provides many benefits, including:

- Communicating as a team regarding scope, status, cost, schedule and risk concerns
- Understanding the potential risks and opportunities that could impact the project
- Establishing contingencies supported by project team involvement and studies
- Defining and targeting high risk areas for management and risk reduction
- Realizing cost and schedule opportunities similar to the value engineering process
- Increasing the probability of successful completion of the project
- Understanding where the base estimate fall within possible ranges
- Informing decision makers by providing the context in which to consider a base estimate

The risk management process is incorporated as a risk management plan, (RMP) and included within the project management plan (PMP). The four main building blocks of the risk management process include:

- Risk Identification
- Risk Assessment
- Risk Response
- Risk Documentation

14-1.1 CSRA Stages.

CSRA is a dynamic, ongoing effort that can be useful at any given stage of project development and execution.

14-1.1.1 Budgeting.

The early stages of project development often focus on systemic risks. AACE Recommended Practice (RP) 10S-90 describes these types of risks as those that are artifacts of such things as an organization's project system, strategy, or culture. Systemic risk are often understood well by the project team and even by some of the project's stakeholders. Project specific risks must be considered at this level where available.

14-1.1.2 Design.

When the project team begins developing the project technical documents. Many if not most of the systemic risks will likely be mitigated or eliminated. At this stage systemic risks will typically give way to project-specific risks – those specific events, actions and other conditions associated with the project's scope (as per AACE RP 10S-90).

14-1.1.3 Construction.

The DOD Construction Agent (DCA) may choose to continue the use of the CSRA, developed in support of the IGE, as an in-house tool to assist the government's construction managers in tracking the project. This is not to be confused with the Contractor's own risk management tools. Any CSRA information developed in support of the IGE must not be disclosed to those without a need to know.

14-1.2 Terminology and Definitions.

It is helpful to consider the use of terminology in the context of the CSRA process. AACE RP 10S-90, Cost Engineering Terminology provides useful concepts for defining risks as used in this context:

- Allowance: A quantity of resources added to cost or schedule estimate to cover known but undefined requirements for specific items to be included in the cost or schedule.
- Confidence Interval: The probability that a specified range along the continuum of possible values will include the actual value of the quantity of resources being estimated.
- Confidence Level: The probability that the actual value of the quantity of resources being estimated is equal to or less than a specified point along the continuum of possible values.
- Contingency: A quantity of resources to be added to cost or schedule estimate to achieve a specified confidence level.
- Estimate: A prediction of the quantity of resources (material, labor, costs, time) required to achieve an agreed upon scope of work, at an agreed upon location, within an agreed upon period of performance. Note that cost and schedule are a type of estimate in this context.
- Risk: Any uncertain event that could affect a project objective or business goal such as cost, schedule or scope.
- Uncertainty: The total range of events that may arise and produce risks. These events are neither 0% nor 100% likely to occur. Risks may be favorable (opportunities) or unfavorable (threats). Considered collectively, Uncertainty = threats + opportunities.

14-2 RESPONSIBLITIES.

The CSRA requires the active participation of the project team. As members of the project team, the Cost Engineer and Risk Analyst play key roles in facilitating the process and in preparing the risk register, developing and running the risk models, and analyzing the results. However, the necessary familiarity with and detailed knowledge of the project resides with the PM and other project team members. In addition, the PM and other members project team also are in the best position not only to identify and qualitatively assess the risks, but they are also in a position to be able to provide potential risk mitigation measures.

14-2.1 Project Team.

The project team assists in identifying risk likelihood and their potential impacts to cost and schedule. The project team includes stakeholders that have knowledge of the project and critical responsibility for development and management of the total project. Project team members typically include representatives from but not limited to:

- Project and planning management
- Contracting and acquisition
- Real estate and relocations
- Environmental
- Technical design
- Cost estimators and schedulers
- Risk analyst
- Construction
- Operations
- Host installation public works personnel
- Sponsors
- Project End User

14-2.2 Project Manager (PM).

The PM is responsible for leading the project. Since CSRA is instrumental for successful project completion, the PM's engagement is critical in the following tasks:

- Developing a PMP that addresses risk management, the CSRA requirements and its execution.
- Supporting the CSRA process related to budgeting, scheduling, and team formulation to accomplish the CSRA.
- Participation in the identification of risk mitigation measures.

- Monitoring and managing recognized risk events that may impact successful execution of the budget and schedule.
- Evaluating the need for follow-on CSRAs.
- Validate that the CSRA results are appropriately captured in the project cost and schedule estimate.

14-2.3 Cost Engineer/Risk Analyst.

The experienced cost engineer or seasoned risk analyst will perform key roles in the CSRA process. One individual may be responsible for both functions or if multiple individuals are involved then effective coordination is required.

A cost engineer is typically assigned the role as the risk analyst and many times serves as the CSRA meeting facilitator to lead the project team through the CSRA process i.e., project team discussions to develop the initial risk register and establish the resulting CSRA conclusions. A confident facilitator, knowledgeable with the type of project work, is needed to actively engage and encourage communication amongst the project team.

The cost engineer/risk analyst is tasked to lead the CSRA and report the results. Typically, a risk analyst is responsible for developing and running the CSRA models to develop project contingencies. Additional responsibilities include:

- Sharing the contents, assumptions, and accepted risks of the base estimate.
- Updating the cost estimate as information is gathered from the project team.
- Sharing the contents and assumptions of the schedule.
- Updating the schedule as information is gathered from the project team.
- Record/document team comments and determinations in the risk register.
- Leading the market analysis to quantitatively bracket the variances with regards to cost and schedule.
- Facilitating the identification of risk events.
- Facilitating the qualitative assessment of risk levels.
- Create, run, document and summarize cost and schedule risk models.
- Collaborating with the PM the results of the CSRA.
- Incorporate the contingency results from CSRA model into the total project cost and schedule.

14-3 SUPPORTING DOCUMENTATION.

Applicable documents recommended for the CSRA process and deliverables include*:

- Current project scope
- Quality base cost estimate excluding contingency
- Quality Basis of Estimate
- Quality base schedule estimate correlating with the project scope and base cost estimate
- Agency specific guidance
- Risk presentation to educate the project team
- Risk checklist presenting typical risks considered
- Risk register
- Cost and schedule risk templates/models
- A table of recommended risk mitigation measures for the project
- Report of the process, outcome, and recommendations

14-3.1 Tri-Service CSRA Template.

The Tri-Service CSRA template is located at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 and is to be used for MILCONs that require a CSRA. The CSRA Template is to be used unless otherwise approved by the cognizant design agency. The template includes several tabs that are summarized below:

- Tab A-Quick Instructions: Provides instructions on how to use the template.
- Tab B-Meeting Agenda: Provides a sample agenda for the initial risk discussion.
- Tab C-Risk Checklist (MILCON): Provides a sample risk checklist for common risk events related to MILCON projects. The checklist is not all-inclusive and risks are to be added as necessary.
- Tab D-Project Data: Input project details and scope of work.
- Tab E-Cost & Schedule Summary: Input base cost and schedule estimate.
- Tab F-Meeting Attendance: Input list of attendees from initial risk discussion.
- Tab G-Assumptions: Provides a summary of the risk range assumption development for qualitatively analyzing the risks.

- Tab H-Risk Register-Model: List identified risks associated with the project. Provide qualitative and quantitative analysis and run the model.

- Tab I-Project Contingency: Provides a summary of the model contingency results for cost and schedule.

- Tab J-Sensitivity Chart: Provides a summary of the risks sensitivity analysis.

- Tab K-Dashboard Template: Provides a summary of the model contingency results and a table to itemize risks used in the model and identify suggested risk reduction measures.

14-4 CSRA PROCESS.

CSRA uses risk identification processes common in the industry. It is a formally documented process of the project team's efforts, considerations, and concerns. The CSRA process combines two powerful risk-management tools, a well-developed risk register and an integrated cost/schedule risk analysis model.

The CSRA identifies risks including but not limited to variances in the base estimate, then qualitatively assesses the risk. It then quantifies the risks related to the project cost and schedule. This is accomplished through collaborative meetings. The results are expressed in terms of cost and schedule contingency amounts, which are measured in both dollars and time. It also expresses the level of confidence in the ability to successfully execute the project.

CSRA is an ongoing and iterative process. Risks are to be considered from budgeting to construction, maintaining a broad view of risks and opportunities avoids leaving many of them unidentified and unmanaged. As the project evolves, new risks may be identified and previously identified risks may be accepted into the project scope and cost and schedule estimate, mitigated or retired. The CSRA must reflect the latest project scope and base estimate. CSRA could be continued through design, procurement and post award. The CSRA should be updated at each submittal.

The outcome of the CSRA includes:

- A risk register including current and historical known risks, team discussions regarding those risks, and recommended actions necessary to manage, eliminate, reduce or plan for known risk events and opportunities. This is best accomplished through the use of a risk breakdown structure that categorizes risks consistently.
- A well-documented, tailored project cost contingency at various confidence levels.
- A well-documented tailored project schedule contingency at various confidence levels.
- Common understanding of the project and the scope.

14-4.1 CSRA Determination.

The Monte Carlo CSRA is recommended for projects that are large, complex, of long duration, or critical funding constraints. Regulations, policy and guidance play a large role in establishing mandatory CSRAs. The PM must follow their agency requirements, but also consider whether other project milestones warrant a CSRA update based on scope, cost, schedule, and risk changes. This is a critical step in quality project management processes. The PM may directly consult leadership, but generally the regulations and intent are fairly clear.

14-4.2 Preparation.

The cost and schedule estimate based on the current project scope are prepared to support the CSRA process as the base estimate and base schedule. The total project scope must be reflected within the two products. During the early stages of the project, the base estimate may not be available at the beginning of the CSRA process, but the risk identification may be started and later quantified once cost and schedule estimate are available. Care is to be taken when design contingency is applied within the base estimate and if the CSRA includes risks focused on incomplete design scope to avoid overstating contingency. A best practice would be to include design contingency at the system level within the base estimate and model the variation with the CSRA.

The PM typically establishes the project team. The project team is comprised of experienced members and project stake holders with knowledge of the project scope and criteria, potential risks, opportunities, and unknowns.

In preparation for the initial risk discussions that prepare the first risk register (the document used to support the CSRA), it is recommended that the Risk Analyst distribute to the project team a list of potential risks that are commonly encountered for MILCON projects. A sample risk checklist is available as part of the CSRA template. The sample risk checklist is not intended to be exhaustive but serve to stimulate the team in the brainstorming of each project’s specific applicable risks. The project team is encouraged to examine lessons learned for inclusion in the risk checklist. After reviewing the checklist, the project team members will be better prepared to present their risk concerns at the brainstorming meeting where the risks are discussed and captured within the initial risk register.

14-4.3 Initial Risk Discussion.

The project team brainstorming session is the first step in developing the risk register that serves as the basis for the CSRA. In order to prepare the initial risk register supporting the CSRA, the following coordination steps are recommended.

14-4.3.1 Project Team Coordination and Assembly.

The PM coordinates the brainstorming session with the project team. This is the first meeting where the project team attempts to collectively capture the total project risks and place them into the risk register.

14-4.3.2 CSRA Presentation.

It is recommended that the designated facilitator begin with a CSRA presentation in order to explain the process and expected outcomes with the project team. A confident facilitator, knowledgeable with the type of work, is needed to actively engage and encourage discussion and communication among the project team members.

14-4.4 Project Scope and Cost Presentation.

Next, it is highly recommended that the PM or technical design lead and the lead cost engineer for the project present the project scope and related cost and schedule. The presentation includes the major construction features and assumptions in the design, base estimate, and schedule. Oftentimes it is discovered that the base estimate and assumptions do not match current understood scoping and construction elements. As a rule, well-defined scope is the critical element that then establishes the current cost and schedule estimate. Less defined scoping documents will generally lead to the development of more severe risks and higher contingency values. As scope is improved and more confident designs are developed, contingencies normally decrease. Risk analysis cannot overcome significant omissions or errors in scope of the project. If something significant is missing, the CSRA model may not provide an adequate contingency. It is also recommended that the risk analyst discuss the parameters related to likelihood of occurrence, cost impact ranges, and schedule impact ranges to better aide in risk identification.

14-4.5 Brainstorming Session.

The brainstorming session is the opportunity for the project team to qualitatively define the risk concerns, as well as potential opportunities. It is highly recommended that the brainstorming session include the major project team members because the dialogue between the members typically results in scope clarification or change, findings of new risks, and possible revision of the cost and schedule estimate. The potential variances to the base estimate that are identified in the brainstorming session are the basis for further study and modeling in the analysis. This stage is considered the qualitative stage that lacks the studies to establish cost and schedule impacts or variances. This period is more speculative, pre-study.

To guide the project team through the discussions, refer to the risk checklist for ideas. As previously mentioned, this list is not intended to be exhaustive. Each project team member is provided an opportunity to address their concerns. As concerns are discussed, the facilitator or risk analyst begins developing the initial risk register that supports the CSRA, capturing the project teams concerns and discussions. Like a value engineering study, any concern is valid, considered, and captured within the risk register—even lower risks, because they serve as record of discussion. This session can result in revised cost and schedule estimate.

Generally, the project team must address the key risks listed below:

- Potential scope growth

- Acquisition strategy
- Construction elements
- Design quantities
- Special fabrication and equipment
- Market/bidding conditions
- Escalation
- Cost estimate assumptions
- Schedule estimate assumptions
- External Risk
- Assumed Funding Strategy (MILCON, O&M, Other Appropriations)
- Design Confidence
- Project Management Plan (Pre & Post Design)
- Potential for unknown-unknown risks (risks unforeseen by the team that have an unknown likelihood of occurrence)
- Change management approach of the agency. Managing customer requested changes beyond the scope.
- Potential mitigation efforts for identified risks

14-4.6 Completing the Initial Risk Register.

A well-developed risk register captures the identified risks along with a qualitative risk assessment (in a range from “low risk” to “high risk”) that combines their probability of occurrence and their range of impact on project cost and schedule. It serves to document the risks considered throughout the design development (and potentially beyond), including mitigation measures.

Within the model, the risk register (Tab H) will serve as the basis for the CSRA model. When referring to the risk register, the project team focuses on the following fields:

- REF – Risk ID (typically numerical)
- Risk Type – Technical, External, etc. (drop down list)
- Risk/Opportunity – Event (simple clear title)
- Risk Event Description (clearly written specific concerns)
- PDT Discussion on Impact and Likelihood (decision justifying chosen risk levels)
- Project Cost: Likelihood, Impact, and Risk Level as a result.
- Project Schedule: Likelihood, Impact, and Risk Level as a result.
- Responsibility/POC

- Suggested Risk Reduction Measures

The project team attempts to capture concerns for project features, even if the risk level is considered low. The register serves as an archive of discussions and there is potential that those low-level risks may become higher following market studies, improved information being made available, or through time during the risk management and risk mitigation processes.

Within the risk register, the project team's concerns and discussions must be adequately and clearly captured because the logic presented in those discussions must support the "likelihood" and "impact" decisions reflected within the risk register. While this product is the initial risk register, it has already captured the project team's greater concerns. The project team can begin using this data to prepare for project risk management. The cost estimator/risk analyst is to send out a copy of the initial risk register to the project team to make sure their comments are adequately captured from the brainstorming session.

14-4.7 Modeling and Output.

The next steps in the CSRA process are to review the base estimate and schedule, conduct market research, develop and run the models, and analyze the model output. These steps are detailed in subsequent sections.

14-5 COST AND SCHEDULE ESTIMATE INDEPENDENT REVIEW AND ADJUSTEMENT.

The CSRA can begin before the cost and schedule estimate have received an adequate review, whether it is by QC check, agency technical review, or by external agencies. This may be a reasonable approach if the PM is keenly interested in quantifying the potential impacts from the established risk events. However, if later reviews determine that sufficient changes in the cost and schedule estimate are needed, the base estimate and CSRA may have to be adjusted prior to finalization of the analysis.

Once the initial risk register is complete, the PM and cost engineer, responsible for the cost and schedule estimate, must consider whether the base estimate truly represent the most likely project scope. Often times, project team discussions will present scope changes or processes that may impact the current cost and schedule estimate. There could be a different construction approach. There could be items such as revised productivity or crew makeup. Important assumptions and quantities may not yet be confident.

Other project team members may choose to revise their portions of the featured costs and schedules that reside within their area of responsibility. The cost engineer is responsible for the costs and schedules. Other project team members are responsible for the cost and schedule estimate of their project areas/efforts, such as project management, contract acquisition, design studies, construction management, etc. The PM must confirm from the project team whether these areas must be further developed or improved to reflect the most likely base estimate that serve as the basis for the market studies and the CSRA product.

14-6 MARKET ANALYSIS.

Once the initial risk register is completed and the project team is confident that the cost and schedule reflect the base estimate conditions, the initial risk register is ready for the risk analyst to begin the market analysis. Risks qualitatively determined to be medium to high will be moved forward for quantitative analysis. This classification is made using a likelihood vs impact matrix. It is recommended to carefully review the qualitative assessment of each risk to ensure that it is accurately characterized as only the moderate and high risks will move forward for Monte Carlo analysis in the risk model. Any risks misclassified are to be corrected in the risk register.

The market analysis supports the quantitative portion of the CSRA, establishing estimate values or ranges in cost and schedule impacts. It is intended to validate the presumed risk levels within the initial risk register for both cost and schedule. The market analysis will help establish the “most optimistic” (or “low variance”), and the “worst case” (also referred to as the “high variance”). These two data points or values will be used within the risk model to evaluate the range of costs and schedule from the base estimate. A key concept is that potential variances from the base estimate and schedule are studied. Risks that can be tied directly to base estimate and schedule are defined as the “likely” value as zero and model low, and high variance accordingly. For risks that do not have a direct link to the base estimate, define the three values (low variance, likely, high variance) according to market analysis.

The study and quantification of risks may require project team interviews, historical data research, internet searches, etc. Issues may include items such as real estate fluctuations, land acquisition and easements, construction productivity concerns, fuel pricing, construction modifications, specialized equipment and material availability, local labor resources and rates, potential scope growth, bidding competition, effects resulting from the acquisition strategy, economic trends, etc.

14-7 FINALIZING THE RISK REGISTER.

This section describes the completion of the risk register for the current submittal. A logical flow must occur between risk events, concerns, discussions, and reasoning for the chosen likelihood and impact values that result in the risk level of low-moderate-high.

To finalize the risk register, market analysis may result in revising the risk register as needed. Refinement may reveal similar risk events that could be duplicates or double-counted as a risk impact. It may result in adding risk/opportunity events not previously captured. It may result in revising the “likelihood” and “impact” values to support a revised risk level that reflects the research findings. If the likelihood and impact values is revised, the project team concerns and discussions may have to be reevaluated to ensure that they logically support the revised risk register. The final risk register must reflect the correct final risk classification of low, medium, or high based on the revised “likelihood” and “impact”.

The market analysis will enable the risk analyst to complete the risk model fields:

- Cost Impacts
- Cost Variations (low variance, likely, and high variance)
- Schedule Impacts
- Schedule Variations (low, likeliest and high)
- Correlation of Risks to One Another
- Cost Impacts due to Schedule Variations

The model focuses on certain risk register categories and the market analysis values related to low, likeliest, and high. The entire risk register can be included in the model; however, it can be cumbersome when producing paper documents and reports. The key risk register fields required to be completed are:

- REF (Risk number)
- Risk Type
- Risk/Opportunity Event
- Risk Event Description
- Likelihood-Impact-Risk level (Cost and Schedule)
- Variance Distribution (Cost and Schedule)
- Risk Correlation to Other(s)
- Suggested Risk Reduction Measures
- Cost and Schedule Variances (Low, likeliest, high)

14-7.1 Cost Impacts and Distribution.

The market analysis will help establish the input probability distribution parameters (low, likeliest and high values). These parameters may be used within the risk model to determine the input probability distribution. The impacts can be indicated in dollars or percent.

14-7.2 Schedule Impacts and Distribution.

The market analysis will help establish the input probability distribution parameters (low, likeliest and high values). These parameters may be used within the risk model to determine the input probability distribution. The impacts can be indicated in months or percent. Additionally in investigating the schedule risks often these risks will imply an additional cost may be incurred due to the schedule risk. In the recommended standard template there is to be a separate group of columns to include/model any specific risks due to schedule. This technique allows the cost due to schedule risks to be modeled. These risks sum into the overall cost risk forecast in the template. In general, most schedule risks will have some cost risk such as but not limited to time related cost impacts such as extended Field Office Overhead, support crews, and special monitoring. Often this cost risk is below the threshold for modeling and is evaluated case by case.

14-7.3 Correlations.

Many times risk events have a correlation or relationship to one another. A positive correlation occurs when one risk goes higher and the other must also go higher. A negative or adverse correlation occurs when one risk increases and the other risk must decrease. To complete the risk register, note the assumed correlations and include in the model development. When preparing the model, it is highly recommended to review correlations before running the risk model because they may significantly alter the output. Many times assumed correlations are actually restatements of the same risk and are best combined into one variable.

14-7.4 Risk Register Quality Control Check.

Upon completion of the market analysis, the cost engineer/risk analyst completes the risk register, confident that the:

- Project team risk/opportunity events are adequately captured/conveyed
- Project team discussions support the "likelihood" and "impact" decisions especially after updating cost or schedule impacts from modeling because it could change your impact rating.
- Market analysis supports the risk level assigned
- Current cost and schedule estimate serve as the base estimate for the CSRA
- Correlations and event duplication are minimized and addressed
- Market analysis adequately defines the cost and schedule variations

14-8 COST AND SCHEDULE RISK MODEL DEVELOPMENT.

The integrated cost/schedule risk model is developed by the cost engineer or risk analyst experienced with the CSRA process. The model includes the key risk drivers and a Monte Carlo computer simulation tool is utilized to produce the probability distribution of likely cost and schedule variances. These then become the basis for developing contingencies required to provide a given level of confidence. Cost and schedule processes are separated since each requires a separate analysis - though the results of each may impact each other. On larger projects, the CSRA process may require additional members to study the initial risk register, evaluate the concerns captured within the brainstorming session(s), perform market analysis of those risk events, and validate whether the project team's risk level assignments are accurate.

14-8.1 Risk Model Template.

The risk model utilizes the risk register as its basis within the spreadsheet format. The cost engineer/risk analyst and the project team must determine the best modeling method that provides adequate model output for the project. The result is a customized model specifically related to the project. The final product must present contingencies in the desired format for the total project cost and schedule. For example, CSRAs can be performed on each contract (assuming several contracts), on assumed funding cycles, on each project feature, or on the total project. The use of the standard risk model template is recommended as it provides a common platform for development, review, analysis and future data collection efforts.

14-8.1.1 Establishing the Risk Events for Study.

The CSRA process relies on the Pareto Principle that in construction projects 20% of the risks will cause 80% of the impacts. This is akin to the “Few Risk Items” approach outlined in the current DOD Joint Cost Schedule Risk and Uncertainty Handbook. Practice has shown that risk events evaluated as having lower than a moderate level of risk have a negligible impact on CSRA results and are therefore not considered to be materially beneficial to the process.

It is recommended that moderate and high-risk events be further studied and included in the model. Large and complicated projects may have considerably more identified risks meeting the threshold for modeling. Identified risks are examined to make certain of their overall risk rating. Often events may be qualitatively assessed in error by the team and a small effort of further study could indicate it is overall a low risk (not modeled) or a moderate to high risk (included in the model). If the risk analysis later determines a risk was either not identified or was not qualitatively assessed correctly by the team it is added/noted in the risk register and the proper classification entered to ensure the model and the risk register match.

The risk register depicts only the risk events under study; however, the cost engineer/risk analyst documents identified risk events within the model, simply indicating that the risk is not modeled and is not assigned a variance distribution.

14-8.1.2 Incorporating Market Analysis into Model.

Once the determination of which risk events will be incorporated into the model has been completed, the market analysis findings can be added. Values are then input into the model to support the variance distribution. When assigning the distributions, the likeliest value must be a hard value with no equations or links to other data. Remember that the likeliest value is generally be zero indicating that the base estimate value is the likeliest value for this model. If the likeliest value is nonzero this can indicate that the base estimate may be deficient in the costing/duration of this variable. It is recommended to correct deficiencies in the base estimate prior to modeling the project.

14-8.1.3 Establishing Variance Distribution.

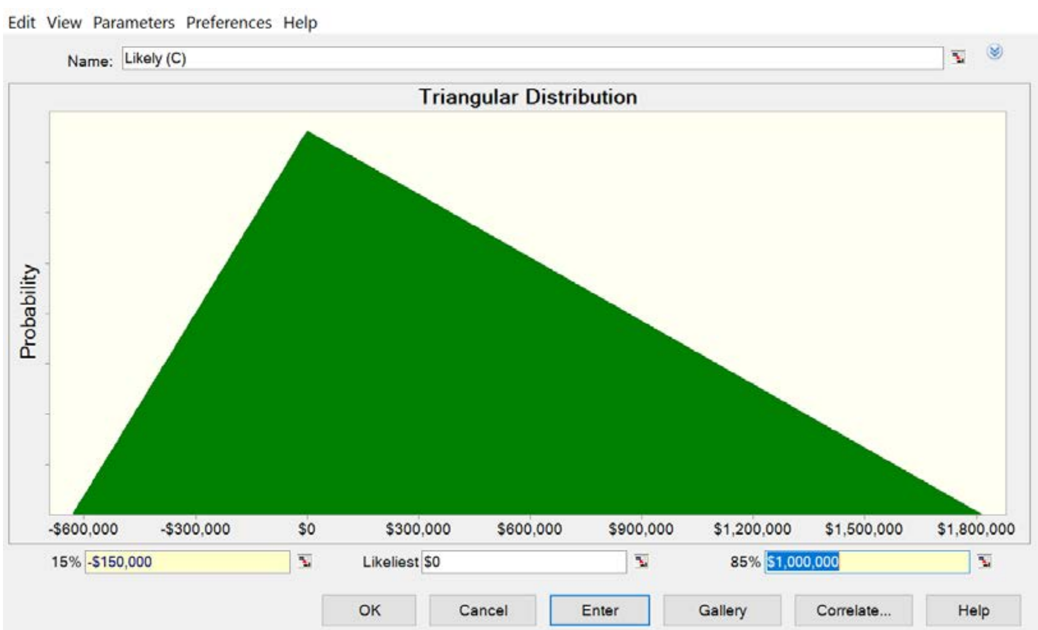
The variance distribution within the model must only address those risk events under study. The value in the base estimate establishes what is most likely to occur and the risk study is based on how the cost/duration within the estimate could vary. Most risks in the model will have zero for the likeliest value.

Within the model, the distribution gallery provides more than 20 diagrams or distribution choices that can represent the market analysis data related to low, likeliest and high value. The most commonly utilized distributions are the triangular and the uniform distributions. Other distributions may better address certain risks where better data exists and considered more appropriate. This is very rarely the case.

When modeling assumptions (risks) within the model, for each assumption (risk event), the cost engineer/risk analyst must properly name the risk event, enter the low, likeliest (usually zero), and high values and address any correlations, both positive and negative, between the respective risk events.

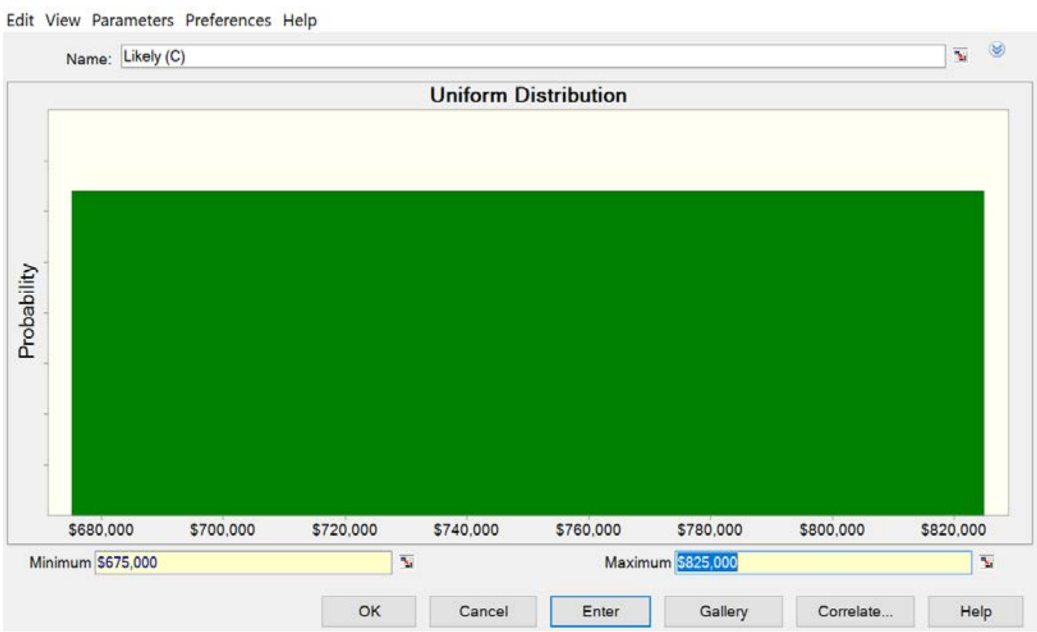
The triangular distribution (Figure 14-2) is commonly used for construction. The cost or schedule estimate generally will have likeliest value and the ranges of low and high values that are determined by market analysis. This distribution is recommended for the risk events that impact specific areas or details of the cost or schedule estimate. It is recommended to set the default parameters to low, likeliest (typically 0), and high value. It is also recommended and a GAO best practice that the low value be set to the 15th percentile and the high value be set at the 85th percentile when utilizing the triangular distribution. Lessons learned indicate that often the teams are too optimistic in the high value and underestimate the high value of the risk. There is research that shows that even the most experienced subject matter experts' opinion on the impact rarely if ever exceeds the 85th percentile.

Figure 14-2 Example of Triangular Distribution



The uniform distribution (Figure 14-3) is used when any value between the low and high value is equally likely to occur. In these instances, only two points are needed, the low and high value. A second variable of Probability of Occurrence could be added to the equation for events with discrete causal effect such as a storm or overtopping event. Caution must be exercised to use this approach to ensure the modeling is correct. Often a triangular distribution may be more appropriate.

Figure 14-3 Example of Uniform Distribution



14-8.1.4 Forecast.

The input risk distributions are used by the model to develop the forecast. The cost engineer/risk analyst needs to understand what the summation of the assumption represents. Simply summing the assumption cells and creating a forecast on a formula cell will yield the variance of the model. The creation of confidence tables and charts are not an automatic function but instead are created using the outputs of the forecast cell.

The cost engineer/risk analyst must set the model parameters related to desired reports, decision variables, defining the forecast, establishing precisions, etc. Once the model includes the risk events under study, distribution variances have been assigned, duplications and correlations have been addressed, and the base estimate captured, the cost engineer/risk analyst is ready for the initial model run.

14-8.1.5 Model Execution and Evaluation.

By this time, the cost engineer/risk analyst has a feel for the quality of the scope, base estimate, and market analysis. It will be of value when reviewing the initial output data. The cost engineer/risk analyst evaluates the initial reports, reviewing areas of potential conflict or inaccuracy. Even if the contingency values appear reasonable, a QC check must still be performed.

Generally, several iterations will be performed as the model is studied for logic, assumptions, and values. Through several iterations, the model is corrected and improved; however, care must be taken to ensure the model is not arbitrarily adjusted to present preferred results. Ultimately, the final product and report must reflect logic and pass the scrutiny of independent review.

14-8.1.6 Model Results Quality Control (QC).

A QC is required to validate reasonableness after the initial model/first trial has been run. Contingency calculations may seem too low or too high, based on the cost engineer/risk analyst's knowledge of the scope and cost and schedule estimate quality. If the contingency data falls significantly outside the anticipated range, there may be errors within the model, the base estimate, or market analysis. Within the sensitivity chart (Figure 14-5), the order of high-risk events may seem unlikely or out of expected order.

Common mistakes include:

- Poor project scoping. Risk analysis cannot overcome significant omissions or errors in scope of the project. If something significant is missing, the CSRA may not provide an adequate contingency.

- Base estimate is too optimistic or too conservative. A conservative base estimate could result in the outcome of negative contingency or an optimistic base estimate could result in the base estimate falling below zero percentage of occurrence.

- Double counting of risks - There may be similar risk events that are listed separately within the risk register, thereby measuring the risk twice. This is especially common on schedule risks since some activities may be on the same critical path and one risk event could help mitigate another.

- Omissions of risks- There may be critical risks absent from the modeling, especially external risks.

- Risk Mitigation measures assumed to be 100% effective prior to execution and or no consideration for second and third order effects of mitigation. The second and even third level effects of risk mitigation could be more severe than the original perceived risk.

The initial output may cause a change in the risk discussions on the risk register. The discussions are to be clear and explain the logic for the chosen likelihood and impact values.

Failure to update the project CWE with the correct risk percentage or amount to show the project's overall total cost correctly will have an impact on the fixed rate costs such as SIOH that grow linearly with the construction cost.

14-8.1.7 Risk Model Output.

There are numerous model outputs that are helpful in presenting data as well as supporting the CSRA report. While not all are portrayed in this document, the more common figures used to support the final report are presented in the following paragraphs. This data is obtained from the output after the risk simulation is run.

14-8.1.7.1 Sensitivity Chart.

The sensitivity chart (Figure 14-4 and Figure 14-5) ranks risk events by way of variability. It is similar to a tornado chart, but a tornado chart does not include any effects of modeling and simply shows the absolute value of the ranges of the modeled variables from highest to lowest. These charts can be very misleading as to the true contribution of contingency to the project. The risks with the largest ranges of cost or schedule typically show up at the top of the chart. This may or may not indicate their actual contribution to project contingency. High cost or time impacts with small ranges of variance can contribute substantially to the overall contingency but may not show up on the sensitivity chart. For example consider the following two risk events:

Risk 1. A risk with a low of -$4M(savings), a likely of $0, and a high of $4M (cost increase has a variance of $8M).

Risk 2. It is determined that most likely an event of $5M is missing from the base estimate, and it is added to the risk analysis with a low of $5M, a likely of $5M, and a high value of $6M.

From a sensitivity analysis point, Risk 1 has an $8M range and will show higher than Risk 2 ($1M range) on the sensitivity chart. Understanding and analysis of the model is required to determine the truly critical risk drivers that need to be addressed. It is recommended to compare the sensitivity results to a sorting of the risks based on the likely and high-risk values for comparison to identify additional critical risks beyond the sensitivity analysis. This is often referred to as a "Pareto ranking." Sensitivity analysis alone is not adequate for the ranking of risks in priority and the cost engineer/risk analyst must examine the risks, effects of modeling, and communicate the key risk drivers within the analysis.

Figure 14-4 Sensitivity Chart for Cost

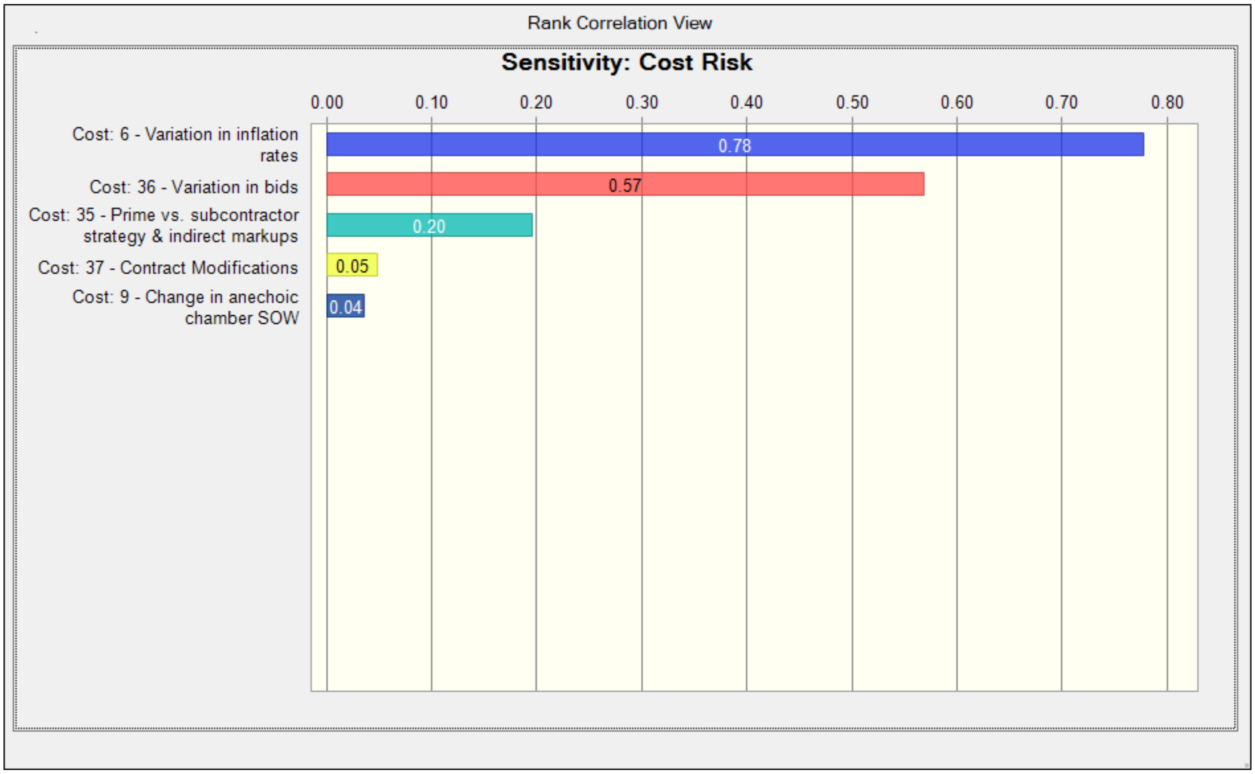
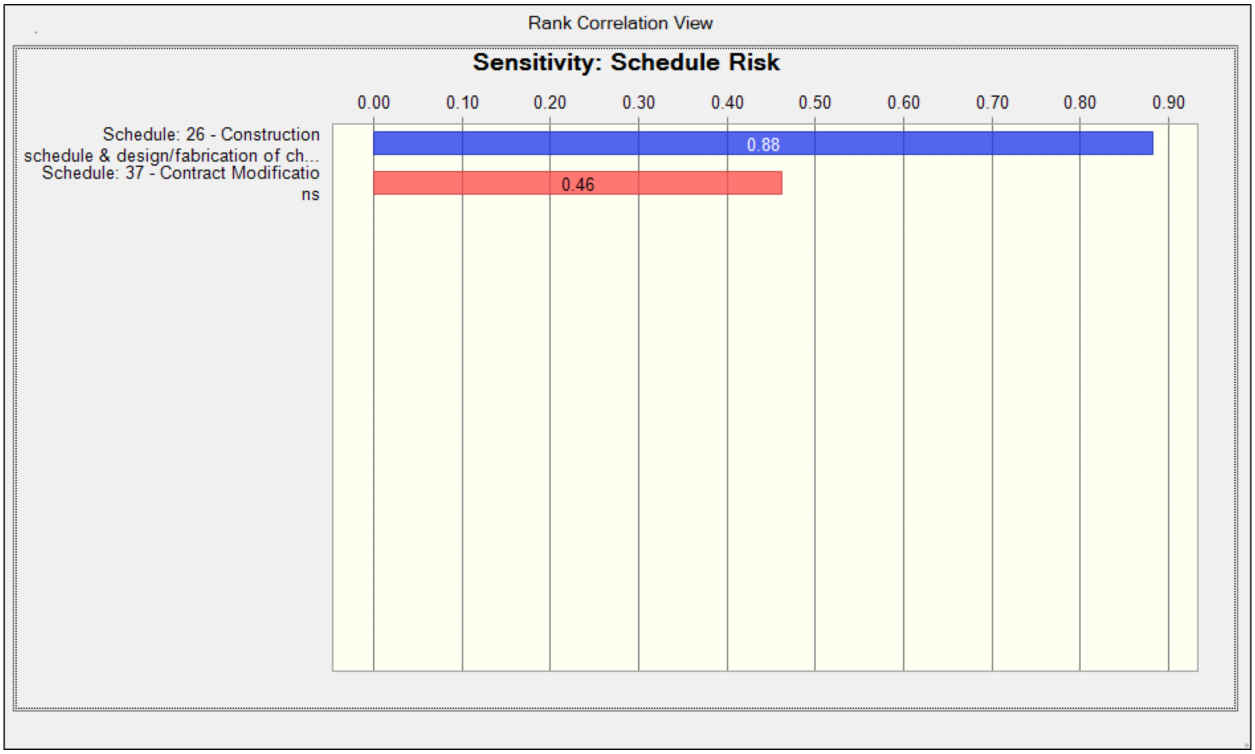


Figure 14-5 Sensitivity Chart for Schedule



14-8.1.7.2 Contingency Analysis.

A contingency analysis is measured against the base estimate and schedule in dollars and months. The model output creates tables and figures summarizing the cost and schedule values with associated confidence level for successful project execution. It can be presented in tabular form and graphically as a confidence curve. Each agency is left to decide what confidence level they will use. It is recommended that the project contingencies be presented with confidence levels and associated contingencies in 5-10 percent confidence increments from 0-100%. Events to consider in the confidence level chosen could be life safety, project complexity, national priority, project status, and likelihood of mitigating risks. In any case, the chosen value is justified within the CSRA and main reports.

Tables 14-1, 14-2 and 14-3, and Figures 14-6 and 14-7 are an example of the final CSRA outputs.

Table 14-1 Contingency Analysis Output for Cost

Base Estimate ->	$30,889,900	
Confidence Level	Contingency Value	Contingency
0%	-4,942,384	-16%
10%	617,798	2%
20%	1,853,394	6%
30%	2,780,091	9%
40%	3,706,788	12%
50%	**4,633,485**	**15%**
60%	5,560,182	18%
70%	6,486,879	21%
80%	7,722,475	25%
90%	9,266,970	30%
100%	15,444,950	50%

Figure 14-6 Cost Contingency Analysis

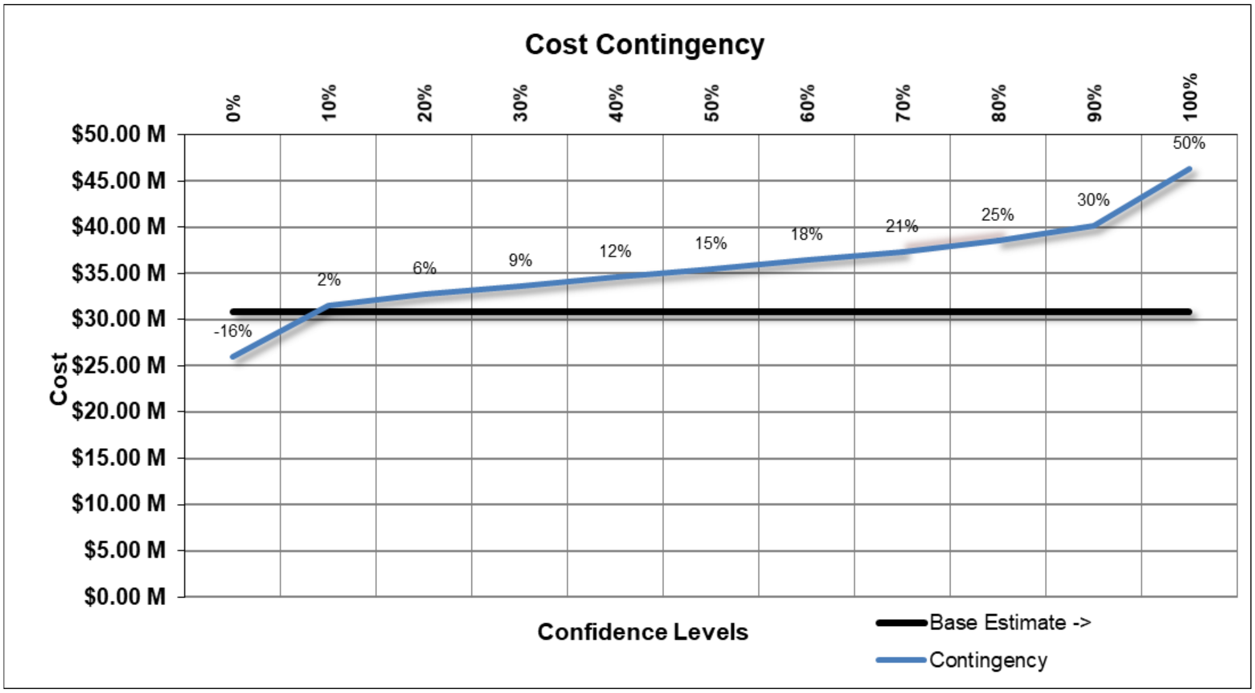


Table 14-2 Contingency Analysis Output for Schedule

Base Schedule Duration ->	53.0 Months	
Confidence Level	**Contingency Value**	**Contingency**
0%	0.5 Months	1%
10%	1.1 Months	2%
20%	1.6 Months	3%
30%	2.1 Months	4%
40%	2.6 Months	5%
50%	**2.6 Months**	**5%**
60%	3.2 Months	6%
70%	3.7 Months	7%
80%	4.2 Months	8%
90%	4.8 Months	9%
100%	6.9 Months	13%

Figure 14-7 Schedule Contingency Analysis

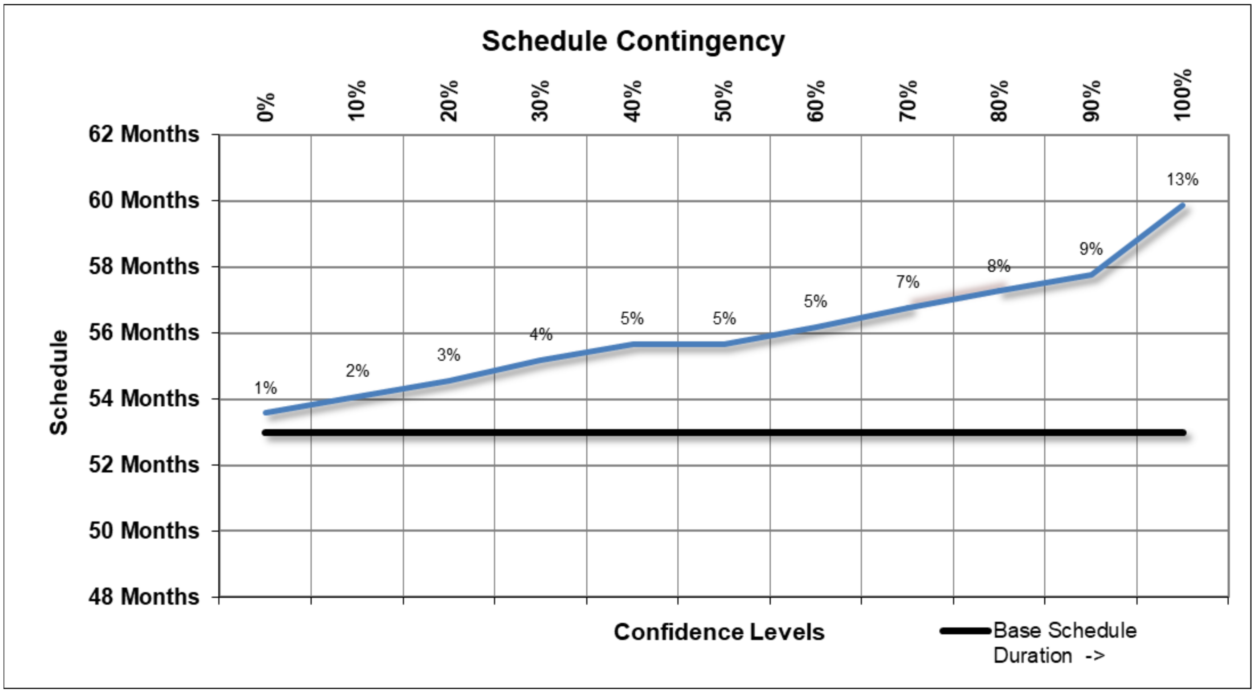


Table 14-3 Contingency Analysis Output for Cost and Schedule

Contingency on Base Estimate	50% Confidence Project Cost	
Base Estimate ->	$30,889,900	
Estimate Contingency ->	$4,633,485	15%
Base Estimate w/ Contingency (50% Confidence) ->	$35,523,385	

Contingency on Base Schedule	50% Confidence Project Schedule	
Base Schedule Start Date ->	October 1, 2021	
Base Schedule Finish Date ->	March 1, 2026	
Base Schedule Duration ->	53.0 Months	
Schedule Contingency Duration ->	2.6 Months	5%
Base Schedule w/ Contingency (50% Confidence) ->	55.6 Months	
Base Finish Date w/ Contingency (50% Confidence) ->	May 22, 2026	

14-9 CSRA DELIVERABLES.

Finally, the CSRA results are included within a report (A sample CSRA report is available on https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05). The CSRA report can be added to the cost report or it can remain a standalone report. The report is a result focused document and not include common methodology/process related discussion on CSRA. These deliverables are to be updated at each submittal as required by the inclusion of CSRA.

Include the following:

- Title page with project name, date, and author
- Executive Summary with the following points: project scope, key assumptions, major findings, observations and risk reduction recommendations.
- Tab K- Dashboard Template from CSRA model
- CSRA Model Excel file

CHAPTER 15 SENSITIVITY ANALYSIS

15-1 GENERAL.

As a best practice, a sensitivity analysis should be included in cost estimates because it examines the effects of changing cost estimate inputs, or parameters, and underlying assumptions. Sensitivity analysis involves recalculating the cost estimate with different quantitative values for selected inputs to compare the results with the original cost estimate. If a small change in the value of a factor yields a large change in the overall cost estimate, the results are considered sensitive to that factor.

Typically performed on high-cost and high-risk elements, sensitivity analysis examines how the cost estimate is affected by a change in a parameter or assumption. For example, it might evaluate how the point estimate varies with different assumptions about system reliability values, or how costs vary in response to system weight growth.

15-2 PROCESS STEPS.

For sensitivity analysis to reveal how the cost estimate is affected by a change in a single parameter or assumption, the cost estimator must examine the effect of changing one factor at a time while holding all others constant. This allows for an understanding of which factor most affects the cost estimate. By examining each factor independently, the cost estimator can evaluate the results to discover which parameters or assumptions most influence the cost estimate.

A valid sensitivity analysis typically has five steps:

1. Identify assumptions and parameters, including key cost drivers, as factors for sensitivity testing
2. Re-estimate the total cost of the program by varying one of these factors between two set amounts
3. Document the results
4. Repeat steps 2 and 3 until factors identified in step 1 have been tested independently
5. Evaluate the results to determine which factors affect the cost estimate most and document the results

15-3 IDENTIFY FACTORS.

The first step of a sensitivity analysis requires analysts to identify the factors to be varied. The sources of variation are to be well documented and traceable. Simply varying factors by a subjective plus or minus percentage is not useful and does not constitute a valid sensitivity analysis.

Uncertainty about the values of some, if not most, of the technical parameters is common early in a program’s design and development. Many assumptions made at the start of a program turn out to be inaccurate. Therefore, once the point estimate has been developed, it is important to determine how sensitive the total cost estimate is to changes in the factors. Some factors that are often varied in a sensitivity analysis are:

- Variations in specific material pricing
- Labor Rates of specific trade
- Escalation rates

In a sensitivity analysis, the cost estimator includes the factors that are most likely to change, such as an assumption that was made for lack of knowledge or one that is outside the project team's control.

Another method for identifying parameters is to examine artifacts from related analyses, such as cost and schedule risk analysis. One such artifact is a tornado chart, a special type of bar chart that shows which parameters have the greatest effect—positive or negative—on the overall point estimate.

Determining which parameters are key cost drivers can be done in several ways. One way to determine key cost drivers is to calculate the proportion of each cost element to the total cost. Those input variables affecting the highest proportion cost elements are varied in a sensitivity analysis. However, analysts may want to consider the parameters contributing to high-risk cost elements as well, even if they are not cost drivers, because these elements may become schedule drivers.

15-4 LIMITATIONS.

A sensitivity analysis reveals critical factors that most affect the cost estimate results and can sometimes yield surprises. Therefore, the value of sensitivity analysis to decision-makers lies in the additional information and understanding it brings.

However, sensitivity analysis does not yield a comprehensive sense of the overall possible range of the cost estimate. Rather, it examines only the effect of changing one factor at a time. In some cases, a sensitivity analysis can be conducted to examine the effect of multiple factors changing in relation to a specific scenario. But the risk of several factors varying simultaneously and the effect on the overall point estimate should be understood. Whether the analysis is performed on only one cost driver or several within a single scenario, sensitivity analysis tries to isolate the effects of changing one variable at a time, while risk and uncertainty analysis examines the effects of many variables changing at once.

CHAPTER 16 COMPETED PROCUREMENTS

16-1 GENERAL.

FAR 36.203 requires an IGE for contracts in excess of the Simplified Acquisition Threshold.

16-2 DIRECTIVES.

Those responsible for the preparation of IGEs for contracts should be thoroughly familiar with the requirements set forth in FAR, DFARS, their supplements, and per guidance of the cognizant design agency. The acronyms for the Federal Acquisition Regulations are listed in the Glossary.

16-3 SEALED BID ABSTRACTS.

A bid/proposal abstract are prepared on invitation for bid (IFB) procurements. The bid/proposal abstract is simply a table comparing each bidders/proposers pricing vs the IGE. An analysis is performed on the bid/proposal abstracts by the cost engineer.

16-4 PRICE ANALYSIS.

The cost engineer who prepared the IGE should be a member of the Price Evaluation Team (PET) for RFP's. A price analysis is to be developed by the PET on RFP competed procurements. The price analysis will compare the bottom line cost of each offer with the market average and IGE to provide the PET's evaluation of reasonableness. The PET notes in the price evaluation any unbalanced contract line item numbers (CLIN's) that may be considered detrimental to the government.

16-5 COST ANALYSIS.

The cost engineer who prepared the IGE should perform the cost analysis for RFP's. The cost analysis includes a technical reviewer who was part of the scoping team. A cost analysis is developed on non-competed procurements as well as on cost reimbursable procurements. For firm fixed price non-competed contracts, the cost analysis will compare individual aspects of the proposal to the IGE including labor, equipment, materials, and other markups and costs to evaluate reasonableness. For cost reimbursable projects, a cost realism analysis will determine the probable cost for each proposal given the proposal technical approach and the elemental costs of labor, material, equipment, and other markups and costs.

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CHAPTER 17 CONTRACT MODIFICATIONS AND OTHER NEGOTIATED PROCUREMENTS

17-1 GENERAL.

FAR Subpart 36.203 requires an IGE for modifications in excess of the Simplified Acquisition Threshold. IGEs are required for unilateral modifications. For contract modifications, the amount refers to the sum of the absolute value of increases and decreases. For example, if the SAT is $250,000 a modification containing an increase of $160,000 and decrease of $145,000 has an absolute value of $305,000, and therefore an IGE will be required.

17-2 DIRECTIVES.

Those responsible for the preparation of IGEs for contract modifications should be thoroughly familiar with the requirements set forth in FAR, DFARS, their supplements, and per guidance of the cognizant design agency. The acronyms for the Federal Acquisition Regulations are listed in the Glossary.

17-3 NEGOTIATED PROCUREMENTS AND CONTRACT MODIFICATIONS.

The cost engineer has several important tasks to perform prior to actually preparing the IGE. Some of the major activities to be considered in preparing the IGE are technical and cost analysis in addition to labor, material, equipment and construction techniques include:

17-3.1 Review of Available Documents.

Reviewing available documents and becoming thoroughly familiar with the scope and requirements of the changed work. This will perhaps entail a comparison, analysis, and discussions with the designer or field office to ensure common understanding of the scope of work. The cost engineer must assure that the proposed modification or procurement action is clearly defined with regard to specified work requirements, proposed measurement, and payment.

17-3.2 Determine Status of Construction.

Determining the status of construction and how the changed work will impact the construction schedule. This will require obtaining progress reports, schedules, and discussion with the field office responsible for the construction. For major or complex changes, a visit to the construction site is required.

17-3.3 Contractor’s Existing Methods, Capabilities and Rates.

The cost engineer must be fully aware of the contractor's existing methods, capabilities, and rates of accomplishment. The IGE is not to include arbitrarily methods and capabilities different from the method in which the contractor is performing the ongoing work. The cost engineer bases the change on existing contractor operations for similar work. When work is anticipated to be subcontracted, the IGE is prepared to include subcontractor costs.

17-3.4 Current Labor and Equipment Rates.

The cost engineer must obtain current labor and equipment rates for the work force and work actually ongoing. These rates are usually available from labor reports or from the contractor upon request. Suppliers for materials are not to be contacted for quotes. The price, which the contractor is expected to pay, is the basis for estimating material costs. A list of equipment on the job is to be obtained and equipment rates determined in accordance with EP 1110-1-8, Construction Equipment Ownership and Operating Expense Schedule for owned equipment. If rental equipment is being used onsite, contact the equipment supplier for current rental rates.

17-4 PREPARATION OF COST ESTIMATES FOR NEGOTIATION.

The cost estimate can be prepared after the information has been collected and analyzed, and the cost engineer decides upon the format to present the change. It is important to have a prior agreement and discussion as previously indicated with the contractor. Generally, successful negotiations depend on agreement in scope of work and accurate quantity take-off and a detailed cost estimate supported by accurate cost data for each element. General guidance for the calculation of direct costs is as follows:

17-4.1 Additional Work.

For additional work, items and format is priced similar to a new contract as performed by the known contractor. New work is to be priced at the rates anticipated to be in effect at the time the work will be performed.

17-4.2 Changed Work.

For changed work, a separate quantity takeoff for each item directly affected will be required for both before and after the change. Each item is to be priced at the rates, which would be in effect at the scheduled time of accomplishment. Typically, each item of changed original work is priced, and each comparable item of revised work is priced at the applicable rates. The net cost (or credit) would be obtained by subtracting the total of the original work from the total of the revised work. It is important that the cost engineer maintain a comparable scope of work for both cost estimates. When an item of work will be performed as originally specified, except for a revision in quantity, the net quantity may be estimated directly for that item.

17-4.3 Deleted Work.

For deleted work, the item and format is priced similar to a new procurement as performed by the current contractor. Current labor, equipment, and material rates at the time of the modification are to be used instead of rates used in the contractor's original bid/proposal or original IGE. In addition to the direct cost of the work, overhead, profit, and bond costs are included for credit on the deleted work.

17-4.4 Impact Related Costs.

Impact related costs, if applicable, are clearly described and included as a part of each cost estimate.

17-4.5 Detail of Cost Estimate.

The cost estimate for a modification is prepared in as much detail (inclusive of detailed notes) as required to clearly cost the change for negotiations. In many instances, even more detail is required to negotiate the lowest reasonable price. The cost estimate is, however, be modified to reflect a negotiated procurement in lieu of an advertised procurement. It includes a general summary sheet relating the major categories of cost of the modification, both for increases and for decreases. Revised construction drawings and specifications are included in the modification supporting documents. When the cost engineer prepares the cost estimate, the effort is to be the same as the contractor acting prudently under the given conditions. The results will generally provide an accurate cost estimate, which can be used as a firm basis for negotiation. The cost estimate does not rely on past generalized rates and settlements unless actually appropriate to the specific modification under consideration.

17-5 COST CONSIDERATIONS.

The cost estimate should be based on the data actually collected and experienced from the project. Time motion studies are important, and periodic field visits and log records can provide this data. Previous modifications can also provide valuable data. Valuable cost data is often available from past audit reports on other modifications. With the assistance of the auditor, many costs can be readily obtained and may be directly applicable to the present modification. The cost engineer must exercise judgment in the use of audit information from a specific report, which may not be released.

17-6 TIMELINESS OF PREPARATION.

Timeliness of the cost estimate for modification is as important as its accuracy. Procurement requirements stress the importance of settlement prior to commencing the work. Therefore, the cost engineer should immediately proceed to obtain the necessary data for the modification and notify the appropriate authorities of the earliest date that the cost estimate can be completed. It is generally understood that the larger and more complex the change, the longer the time requirement for the initial preparation of an accurate cost estimate.

17-7 IMPACT COSTS.

When a modification is initiated, the settlement of that modification includes not only the cost and time change of the work directly affected but also the cost and time impact on the unchanged work. The impact portion of a modification is very important to be estimated accurately. The scope of impact may be broad and susceptible to a large variety of situations. The following discussion will provide guidance and understanding of impact cost considerations.

17-7.1 Acceleration or Delay.

Generally, the greatest portion of impact costs results from acceleration or delays due to changes. When delays due to a change can be minimized, impact costs are reduced. Impact costs are normally determined on a case-by-case basis for each particular situation. The determinations have been based on interpretation of the Contract Clauses and on Board of Contract Appeals and court decisions.

17-7.2 Comparative Review.

Impact costs are generally presented by the contractor as part of the proposal. The existing construction schedule furnished by the contractor must be analyzed to determine the actual construction and the extent of the impact at the time of the change. The modification work must be superimposed upon the original schedule in such a position to determine and minimize the delay. The revised plan must then be thoroughly reviewed relative to the existing job plan. This comparative review indicates those areas, which have been affected by the modification.

17-7.3 Factual or Judgmental Costs.

Once the extent of impact has been determined, each cost claimed must be classified as either factual or judgmental. The factual costs are those which are fixed and established and can be determined directly from records. These include rental agreements, wage rate agreements, and purchase orders. Once the item has been determined valid as a factual impact, the item cost may be directly calculated. The amount of cost change is stated on the certified document or can be determined from the scheduled time change of the construction progress plan. Judgmental costs are those, which are dependent on variable factors such as performance, efficiency, or methodology and cannot be stated factually prior to actual accomplishment. These must be negotiated and based upon experienced judgments. In actual practice, most factual costs are based to varying degrees upon judgment.

17-7.4 Cost of Impact.

The cost estimate of impact is to be prepared for each activity affecting the change. In some cases, the impact items are typically so interrelated that it is often best to develop a detailed plan for accomplishing the remaining work. Each item in this plan would be estimated at the productivity and rate in effect at the time the work is to be accomplished. The same items of work under the original plan would also be estimated at the productivity and rate in effect at the originally scheduled time. The comparison of these two cost estimates yields the cost of impact. Impact costs determined to be valid must be estimated by the most accurate method available and included in the modification.

17-7.5 Impact Factors or Conditions.

The following impact factors or conditions play a recurring role in determining impact costs. Each modification must be evaluated separately and impact costs considered especially for the implications of the particular change. Impact costs are only included by detailed itemization and only after having been found to be valid.

17-7.5.1 Factual.

Impact costs considered factual include escalation of material and labor wage rates, and change in equipment rates.

17-7.5.2 Judgmental.

Impact costs considered judgmental include change of efficiency resulting from rescheduling; loss of labor efficiency resulting from longer work hours; loss of efficiency caused by disruption of the orderly existing processes and procedures; inefficiency from tearing out completed work and the associated lowering of morale; loss of efficiency during rescheduling of manpower; inefficiency incurred from re-submittal of shop drawings, and sample materials; additional costs resulting from inability to transfer manpower expertise to other work; and change in management for the revised work.

17-7.5.3 Factual Based on Judgmental.

Impact costs considered factual but are based on judgmental decisions including increase from extending the storage period for materials and equipment; increase from extending the contract for labor cost and subsistence; increase from a longer period of equipment rentals or use; increase from a longer period of utilizing overhead personnel, materials, and utilities; and increase from a longer period of providing overhead and project office services.

17-8 SUPPORT FOR THE NEGOTIATIONS.

Before participating as part of a negotiating team, the cost engineer must become thoroughly familiar with negotiating requirements and techniques. The expertise and support of the cost engineer can be very beneficial in major and complex changes.

17-8.1 Review for Allowability.

Many of the costs that are presented in the contractor's proposal breakdown must be reviewed for allowability. Of those costs found allowable, each item must further be reviewed for applicability for that portion relevant to the particular change. The auditor has primary responsibility for this determination and should advise the negotiation team accordingly. For those cases where the auditor is not directly involved, the negotiation team must base their decisions on regulatory guidance and the best expertise available. In accomplishing the review of the proposal, the cost engineer should remain constantly aware of the contractor's profit motivation. The Government must consider all reasonable costs anticipated to be incurred by the contractor.

17-8.2 Settlement of Disputed Work Items.

In some cases, portions of the cost estimate may be revealed only to the extent determined necessary by the negotiator to settle disputed items of work. The total of the IGE will not be released during negotiations. On occasion, important information has been revealed through negligence by allowing the IGE to lay open upon the negotiation table. During negotiations the IGE including backup support is considered CUI and protected accordingly.

17-8.3 Technical Evaluation.

A technical analysis, as performed by the technical team, is the evaluation of the contractor's proposal for scope differences from the IGE. The technical evaluation also may include questions asked during negotiations. This performed prior to negotiations will help expedite the negotiation process.

17-8.4 Teaming with Negotiator.

The cost engineer should be on the negotiation team. As a team member working with the negotiator, coordinate with the contractor to agree on scope of work and format prior to preparation of the IGE and submittal of the contractor's proposal. This discussion will assist both the Government and contractor in reaching a mutually accepted scope of work to eliminate unnecessary effort for both parties during negotiations.

17-8.5 Cost Analysis.

A cost analysis is the evaluation of the contractor's proposal for cost reasonableness which is typically determined after negotiations. The cost analysis must address the cost elements within the proposal, not just the bottom line cost. This is performed prior to award of the contract or modification.

17-8.6 Revision of the Independent Government Estimate.

Revision of the IGE may be necessary as a result of an error, changed conditions, or additional information. Approval authority for revisions to the IGE remains the responsibility of the Contracting Officer or authorized original IGE-approving official. When the IGE is changed during or subsequent to conferences or negotiations, the details of the basis for the revision or changes in price must be fully explained and documented in the price negotiation memorandum. A copy of each IGE that has been approved is included in the official modification file along with the details and circumstances causing the revisions.

CHAPTER 18 LITIGATION CONCERNING THE INDEPENDENT GOVERNMENT ESTIMATE

18-1 GENERAL.

There are two major situations in which the cost engineer may become involved in litigation concerning the IGE. These situations include:

- A bid protest when bids are opened;
- A proposed change order/modification is not accepted by a contractor and the contractor pursues the dispute.

The procedure to process the issues are the same for the many types of projects or contracts associated to military programs. When either of the above occurs, the cost engineer has a major role in reviewing the IGE and evaluating the Government's position.

18-1.1 Bid/Proposals.

During the bidding process, and upon receipt of bids/proposals, if bids/proposals are significantly higher than the IGE, the Contracting Officer should verify the reasonableness of the IGE. The cost engineer is a key resource for assisting the Contracting Officer in determining reasonableness. The allowed award percentage above the IGE must be in accordance with the design agency regulations.

18-1.2 Contract Modifications/Change Orders.

During the on-going construction, changes will occur; including over-runs of quantities, and disagreements may occur between the contractor and the Government. If a dispute does arise, it generally concerns a disagreement between what the government considers a fair and reasonable cost as compared to the proposal offered by the contractor. In the event, an agreement can’t be reached between the contractor and the Government, a dispute, or claim may result.

18-2 PREPARATION OF TECHNICAL AND COST ANALYSIS BY COST ENGINEER.

The cost engineer should prepare a technical and cost analysis evaluation for documentation of the contract file. Additional information concerning factors to be considered in the technical and cost analysis is presented in Chapter 17. Reference is made to FAR sub-part 15.404 for proposal evaluation.

18-3 REVIEW OF THE INDEPENDENT GOVERNMENT ESTIMATE.

18-3.1 Bid Protests.

If there is a bid protest concerning the reasonableness of the IGE, i.e., a bidder is claiming the IGE is too low, the cost engineer conducts a review of the IGE for missing scope, site conditions, quantities, market conditions, etc.

18-3.1.1 Independent Government Estimate Evaluation.

The cost engineer reviews the IGE to be sure that it does not contain mistakes. This evaluation must be completed as soon as possible to provide timely advice to the cognizant agency's staff to preclude delay in award. If the IGE is revised, and the revised IGE brings an offeror's price within the range of a fair and reasonable price, award will be made provided funds are available. The revised IGE requires the same approval authority as the original IGE.

18-3.1.2 Fair and Reasonable Determination.

When the IGE is reviewed and has been determined to be fair and reasonable for the intended scope of work, unless the protester withdraws the bid protest, the usual procedure will require a Contracting Officers Decision (COD) in the form of a (letter) memorandum of denial of the protest unless the protestor withdraws the bid protest.

18-3.1.3 Meetings.

Meetings may be held with the apparent low bidder or contractor prior to issuance of the COD memoranda to ensure that both the Government and the protestor have the opportunity to review the project and agree to the scope of work as specified by the plans and specifications. Meetings will also allow discussion whether there are unusual conditions or circumstances that may affect or complicate the work. If a meeting reveals an error or omission in the IGE, it may be revised as previously discussed.

18-3.1.4 Resolution Assistance.

The protest/dispute may take several months to resolve. The Government's position may be reviewed and evaluated at the appropriate agency office, as well as by the General Accounting Office, a court, or a board of contract appeals. During each of these reviews, questions will arise, and the cost engineer will be called on to support the IGE. The cost engineer(s) responsible for preparing the IGE are most familiar with the IGE, as such, should be prepared to assist counsel, contracting, and other staff to resolve the issue; and be prepared to testify in court and certify the validity of the IGE.

18-3.2 Contract Modifications/Change Orders.

The cost engineer may also be required to prepare cost estimates for major or complex changes; or design change orders for on-going construction projects; major or extensive quantity overrun bid items; or even assisting in evaluating claims occurring during construction whereby an IGE is required.

18-3.2.1 Independent Government Estimate Agreement.

Prior to the cost engineer finalizing the IGE, it is important to meet with the contractor to agree on the scope of work concerning change orders for on-going construction. The cost engineer will prepare the IGE as detailed in Chapter 17. On occasion, disputes arise between the Government and the contractor, primarily due to a very wide variance between the value of work estimated by the contractor and the IGE being on the low side. When a dispute arises, meetings are necessary in an attempt to resolve the difference in cost between the contractor and the Government. Even when the scope may be in general agreement, the cost may be in dispute. The Contracting Officer may issue a unilateral modification establishing the cost and the modification may result in litigation. The procedure upon encountering an impasse generally results in the Government issuing a COD, and the process is the same as previously discussed for a bid protest.

18-3.2.2 Independent Government Estimate Revision.

It is possible that not all of the facts of a claim, change, or major overrun of quantities have been provided or verified by the cost engineer. In those cases where the cost engineer was unable to meet with the contractor, and additional facts are discovered by other means, the cost engineer may revise the IGE as appropriate, provided an original IGE was prepared. The revised IGE requires the same approval authority as the original IGE. Upon revising the IGE and mutual agreement by the contractor and Government, a modification is processed.

18-3.2.3 Revision Documentation.

When the IGE is changed during or subsequent to conferences or negotiation, the basis for the revision or changes in price must be fully explained and documented in the price negotiation memorandum. Judgment in making this type of decision is to be based on the circumstances of a particular issue, not all-encompassing, and recommendations made to the Contracting Officer. For major differences in cost, disputes or claims not resolved, a revised IGE is recommended, supported by a technical and cost analysis of the dispute in litigation.

18-4 SECURITY AND DISCLOSURE OF INDEPENDENT GOVERNMENT ESTIMATES.

Security and disclosure of the revised IGE must be handled in the same manner as the original IGE. Procedures for handling the IGE are described in Chapter 2.

18-5 MISTAKE IN BIDS.

After the opening of bids, contracting officers examine bids for mistakes. In cases of apparent mistakes and in cases where the contracting officer has reason to believe that a mistake may have been made, the contracting officer requests from the bidder a verification of the bid, calling attention to the suspected mistake. Any clerical mistake, apparent on its face in the bid, i.e., obvious misplacement of a decimal point, may be corrected by the contracting officer before award, after first receiving verification of the bid intended.

18-5.1 Before Award in Sealed Bidding.

For other mistakes disclosed before award in sealed bidding, the bidder must provide clear and convincing evidence to establish both the existence of the mistake and the bid actually intended. The contracting officer must make a determination as to the circumstances to verify the mistake; to allow the bidder to withdraw the bid; or make a determination that the bid be neither withdrawn nor corrected. The cost engineer may be part of the team of specialists to provide an analysis and a recommendation to the contracting officer. For the cost engineer, the evaluation could be the verification of a quantity as related to a unit price bid item; or determination of a fair and reasonable cost for a service or product. The cost engineer may refer to FAR part 14 for the appropriate definitions, discussions and overview of the acquisition requirements pertaining to sealed bidding.

18-5.2 Before Award in Negotiated Procurement.

The process for determination of a mistake in bid when the solicitation of a project is contracted by negotiated procurement is similar to the procedure as for sealed bidding. Additional tools are available to the Government to amend a solicitation before award as compared to sealed bidding. Clarification may be used to communicate with an offeror for the sole purpose of eliminating minor irregularities, informalities, or apparent clerical mistakes in the proposal. In negotiated procurement, discussions mean any oral or written communications between the Government and an offeror that involves information essential to determine the acceptability of a proposal or provides the offeror an opportunity to revise or modify its proposal. When, either before or after receipt of proposals, the government changes, relaxes, increases, or otherwise modifies its requirements, the contracting officer issues a written amendment to the solicitation. In the event evaluation factors are selected to evaluate proposals, price or cost to the Government is included as an evaluation factor in every source selection. If a mistake in a proposal is suspected, the contracting officer advises the offeror or otherwise identifying the area of the proposal where the suspected mistake is and request verification. If the offeror verifies its proposal, award may be made. If an offeror alleges a mistake in its proposal, the contracting officer advises the offeror that it may withdraw the proposal or seek correction by submitting clear and convincing evidence and a determination is made by agency. The cost engineer may also be involved in providing support to the contracting officer if any mistake concerns scope, quantity or prices in the IGE. The cost engineer may refer to FAR part 15 for the appropriate definitions, discussions and overview of the acquisition requirements pertaining to negotiated procurement. In the event negotiations are conducted with offeror’s in the competitive field, the cost engineer should be a member of the negotiation team.

CHAPTER 19 STANDARD COST ESTIMATING FORMS

19-1 GENERAL.

This chapter contains a discussion of the standard cost estimating forms with a brief explanation of their use in presenting manually prepared cost estimates. A Basis of Estimate is to be provided for each cost estimate prepared using these forms. Refer to Chapter 4-3 for factors to be considered when preparing the BOE.

19-1.1 Completed Examples.

Completed examples of these forms are provided in this chapter. Cost estimates developed using these forms may be prepared in an electronic format or pencil format. For uniformity in form completion, the following general guidance is given:

Each original sheet is to be in reproducible quality.

- Once the cost estimate has been completed, checked, and approved, the desired number of copies is reproduced from the original.
- For Architect-Engineer prepared cost estimates, the original is included with the final submittal.
- Originals are normally retained by the cost engineering office preparing the cost estimate.
- A cover sheet is to be initialed by both the preparer and the reviewer.

19-2 FORMS.

Although no forms are mandatory for use in preparing early cost estimates, it is recommended that the cost engineer consider using forms expressing unit price and extended price in columns. The following standard cost estimating forms may be used in preparing detailed cost estimates for military projects. Sample forms for use in development of cost estimates are provided at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-740-05 and are discussed in paragraphs 19-2.1 through 19-2.5.

19-2.1 Cost Estimate Detail Summary Sheet.

Cost Estimate Detail Summary Sheet is used to summarize project costs, to relate the method of distribution of overhead and profit to the various bid items, and to determine the overall price for each bid item. For unit price bid items, calculations, results, and rounding may be shown on the line following the total bid item price calculation. Rounding of Lump Sum bid items may also be shown similarly. The total cost, or adjusted cost, is transferred to the bidding schedule.

19-2.2 Cost Estimate Analysis.

Cost Estimate Analysis is used to itemize and quantify work tasks and to calculate the direct cost for each task. The form follows, column by column, the format shown in the

Cost Book. It is also intended as the direct cost summary sheet for each bid item. Items of significant cost are related to other detailed backup sheets with analysis or quotations.

19-2.3 Cost Estimate Worksheet.

Cost Estimate Worksheet is used for miscellaneous cost items. Common uses include quantity takeoff, description and discussion pages, and price quotations.

19-2.4 Crew and Productivity Worksheet.

Crew and Productivity Worksheet is used to develop a crew analysis and task unit cost for labor and equipment. This is necessary for significant and unusual construction tasks. The "CREW REF NO" can be completed similar to the crew names described in the Cost Book.

19-2.5 Wage Rate Calculations.

Wage Rate Calculations, is used to calculate hourly cost for laborers.

APPENDIX A BEST PRACTICES

A-1 WORK BREAKDOWN STRUCTURE.

The information contained in this appendix is to aid in the presentation of cost estimates for military programs. The structure outlined in this appendix is described in Chapter 2.

A-1.1 Uniformat II.

Military Construction Uniformat II Structure, see Table A-1.

Table A-1 Uniformat II Structure

PRIMARY FACILITIES			
Section A	Substructure		
	A10	Foundation	
		A1010	Standard Foundations
		A1020	Special Foundations
		A1030	Slab On Grade
	A20	Basement Construction	
		A2010	Basement Excavation
		A2020	Basement Walls
Section B	Shell		
	B10	Superstructure	
		B1010	Floor Construction
		B1020	Roof Construction
	B20	Exterior Closure	
		B2010	Exterior Walls
		B2020	Exterior Windows
		B2030	Exterior Doors
	B30	Roofing	
		B3010	Roof Coverings
		B3020	Roof Openings
Section C	Interiors		
	C10	Interior Construction	
		C1010	Partitions
		C1020	Interior Doors
		C1030	Fittings
	C20	Stairs	
		C2010	Stair Construction
		C2020	Stair Finishes
	C30	Interior Finishes	
		C3010	Wall Finishes
		C3020	Floor Finishes
		C3030	Ceiling Finishes

Section D	Services		
	D10	Conveying	
		D1010	Elevators & Lifts
		D1020	Escalators and Moving Walks
		D1090	Other Conveying Systems
	D20	Plumbing	
		D2010	Plumbing Fixtures
		D2020	Domestic Water Distribution
		D2030	Sanitary Waste
		D2040	Rain Water Discharge
		D2090	Other Plumbing Systems
	D30	HVAC	
		D3010	Energy Supply
		D3020	Heat Generating Systems
		D3030	Cooling Generating Systems
		D3040	Distribution Systems
		D3050	Terminal and Package Units
		D3060	Controls & Instrumentation
		D3070	Systems Testing & Balancing
		D3090	Other HVAC Systems & Equipment
	D40	Fire Protection Services	
		D4010	Sprinklers
		D4020	Standpipes
		D4030	Fire Protection Specialties
		D4090	Other Fire Protection Systems
	D50 Electrical		
		D5010	Electrical Service & Distribution
		D5020	Lighting and Branch Wiring
		D5030	Communication & Security
		D5090	Other Electrical Systems
Section E	Equipment and Services		
	E10	Equipment	
		E1010	Commercial Equipment
		E1020	Institutional Equipment
		E1030	Vehicular Equipment
		E1090	Other Equipment
	E20	Furnishing	
		E2010	Fixed Furnishings
		E2020	Movable Furnishings

Section F	Special Construction & Demolition		
	F10	Special Construction	
		F1010	Special Structures
		F1020	Integrated Construction
		F1030	Special Construction Systems
		F1040	Special Facilities
		F1050	Special Controls and Instrumentation
	F20	Selective Building Demolition	
		F2010	Building Elements Demolition
		F2020	Hazardous Components Abatement
SUPPORTING FACILITIES			
Section G	Building Sitework		
	G10	Site Preparations	
		G1010	Site Clearing
		G1020	Site Demolition and Relocations
		G1030	Site Earthwork
		G1040	Hazardous Waste Remediation
	G20	Site Improvements	
		G2010	Roadways
		G2020	Parking Lots
		G2030	Pedestrian Paving
		G2040	Site Development
		G2050	Landscaping
	G30	Site Mechanical Utilities	
		G3010	Water Supply
		G3020	Sanitary Sewer
		G3030	Storm Sewer
		G3040	Heating Distribution
		G3050	Cooling Distribution
		G3060	Fuel Distribution
		G3090	Other Site Mechanical Utilities
	G40	Site Electrical Utilities	
		G4010	Electrical Distribution
		G4020	Site Lighting
		G4030	Site Communication & Security
		G4090	Other Site Electrical Utilities
	G90	Other Site Construction	
		G9010	Service and Pedestrian Tunnels
		G9090	Other Site Systems & Equipment

General Requirements *
Field Overhead *
Quality Control *
Design Build Fee *

Note: These item (*) are not part of the Uniformat II Structure, but are required in order to produce a complete cost estimate with markups.

APPENDIX B AUTOMATION

B-1 PURPOSE.

This appendix provides general information on using this automation and an overview of existing systems. Detailed guidance on the use of each system can be found in the appropriate system user manual for each software program. The appropriate policy guidance on the use of automation in developing cost estimates is provided in the specific Agency cost engineering regulations.

B-2 USE OF COST ENGINEERING AUTOMATED SYSTEMS.

The use of cost engineering automated systems enhances the efficiency, accuracy and credibility of project cost estimates. Automation assists in the standardization of cost estimating procedures and provides cost estimates that are easily reviewed, revised and adapted to new projects or situations. Standardization assists in collection and analysis of historical costs that can be used to develop budget estimates, for cost comparison purposes, for reporting and tracking of project cost data, and for the building of parametric models.

B-2.1 Software Updates and New Systems.

Automation continues to develop at a rapid pace. Minor upgrades may occur annually and major system changes can occur every two or three years. Major new systems may be fielded at any time. Cost engineers should insure that they are using the latest available version of the software.

B-2.2 Limitations on the Use of Automation.

Automation is just a tool and cannot take the place of professional cost engineering knowledge or judgment. The cost engineer should always be knowledgeable of the system's capabilities and limitations in relation to a project. The cost engineer must be especially careful using models and in adapting existing cost estimates to new projects to insure that there are neither duplications nor omissions in the cost estimate. Output is to be checked for reasonableness and assumptions and methodology verified and documented. The best cost automated system is not a replacement for good cost engineering judgment.

B-2.3 Automation Proponent.

The Tri-Service Committee on Cost Engineering is the proponent for all the major components of the Tri-Service Cost Engineering Systems (TRACES).

B-3 OVERVIEW OF TRI-SERVICE AUTOMATED COST ENGINEERING SYSTEMS (TRACES).

TRACES is the umbrella linking automated cost engineering systems and their associated databases. The entire system seeks to provide a user friendly cost engineering platform in a standard environment that will provide the cost engineer the tools to prepare, review, and maintain types of cost estimates.

TRACES includes the following major systems/modules: a detailed quantity take-off cost engineering system (MCACES/MII); a parametric systems for the preparation of less than fully detailed design cost estimates for military construction projects Parametric Cost Engineering System (PACES); a historical cost analysis generator (HAG/HII) to collect, store, and analyze historical cost data for facilities, and site work; a location cost factors system to adjust average historical facility cost to a specific project location (ACF) ; a dredge cost engineering system (CEDEP); a life-cycle cost (LCC) module (ECONPACK) for analysis of system design alternatives; a parametric system for preparation of Formerly Used Defense Sites (FUDS)/Cost to Complete (CTC) estimates (RACER); a scheduling software program (i.e., Microsoft Project, P2, Primavera); and risk analysis software (i.e., Oracle Crystal Ball).

B-3.1 Other Systems.

Other systems/modules which are specific to each Service's requirement include: PC-Cost, DD Form 1391 for Army users. EPG Electronic Project Generator to develop DD Form 1391 for NAVFAC users.

B-3.2 Micro Computer-Aided Cost Engineering System 2nd Generation (MCACES/MII).

MCACES/MII is a multi-user software program used for the preparation of detailed construction cost estimates for military, civil works, and HTRW programs. The system also includes a project database and supporting databases. The supporting databases include Cost Book, crews, assemblies, labor rates, equipment ownership schedule costs and models. Databases work in conjunction with each other to produce a detailed cost estimate. The databases are described in the MCACES/MII user's manual.

B-3.3 Parametric Cost Engineering System (PACES).

PACES is a parametric cost estimating system which is used primarily for development of programming or budgetary cost estimates in support of MILCON Program such as military facilities, family Housing, medical, and operation and maintenance projects. The PACES is a comprehensive program incorporating cost models for new construction, alteration, and renovation. The system uses a parametric methodology adjusting cost models for estimating project costs. The cost models are based on generic engineering solutions for building and site work projects, technologies, and processes. The generic engineering solutions were derived from historical project information, government laboratories, construction management agencies, vendors, contractors, and engineering analysis. PACES provides the capability to prepare cost estimates of military projects based on past designs on less than fully detailed design information. It uses the appropriate Work Breakdown Structure (WBS), a database of models and assemblies from historic projects, and a series of detailed linking algorithms used to develop a cost estimate. The cost estimate can then be transferred to

MCACES/MII for task-by-task analysis of the cost estimate. PACES is the Air Force's primary tool for preparing programming estimates.

B-3.4 Historical (Cost) Analysis Generator (HAG/HII).

HAG/HII is a stand-alone software/module which is used to collect and display historical cost data from awarded projects. HAG/HII uses the standard WBS structure to track historical bid costs by type, location, size and time, and has the capability of automatically normalizing and adjusting awarded costs. The HAG/HII system also provides a vehicle to retrieve selected statistical cost information from the historical cost database for use in the preparation of programming or budgetary estimates.

B-3.5 Area Cost Factor (ACF).

The ACF program calculates the area cost factor index for each specific location based on material, labor, and equipment index and matrix factors. At a given installation, the combination of local labor, material and equipment (LME) costs has the largest impact on total construction cost. Therefore, a comparison of the local LME project costs for typical military construction at different cities would give a comparison of relative construction costs. A market basket of 8 labor crafts, 18 materials and 4 pieces of construction equipment, and seven matrix factors for each location are used in the calculation of the ACF index.

B-3.6 Life Cycle Cost (LCC) Module.

The LCC module called ECONPACK is a stand-alone program designed primarily to conduct life-cycle cost (LCC) analyses among competing design alternatives for a given project providing a record of the results. The program comes with an extensive maintenance and repair (M&R) database tailored for Army buildings. The most prominent capabilities are: (a) to conduct LCC analyses in accordance with the provisions of statutes, regulations, and requirements; (b) to calculate the present worth of individual building or facility components; and (c) to compare M&R costs for building components in the M&R database.

B-3.7 Oracle Crystal Ball.

The Oracle Crystal Ball software program provides the capability to assess risk and uncertainty associated with any Military, Civil Works or HTRW project cost estimate, at any time during the project life cycle period. This process of "probability based" estimating can be used to revise cost and schedule estimates based on "confidence levels," and can assist in the evaluation of project contingency funds. The Oracle Crystal Ball software performs cost and schedule risk analyses on cost and schedule estimates using Monte Carlo simulation techniques as the basis of its calculations.

B-3.8 Other TRACES System/Module.

The need to integrate cost estimating tools with Agency specific program/project management systems has led to the development of several cost estimating tools and models. Some of these tools are stand-alone programs designed primarily for a specific requirement and for use by base/installation personnel.

B-3.8.1 PC-Cost.

PC-Cost is a comprehensive software package that allows the user to prepare and submit programming or budgetary cost estimates based on the Department of Defense Facilities Pricing Guide and Army specific HAG/HII data. PC-Cost also allows the user to create an cost estimate from an existing detailed or parametric cost estimate, download a DD Form 1391 cost estimate for revisions (for Army users of PAX System), or create a new DD Form 1391 estimate from a template. PC-Cost also provides a mechanism for a user interface access capability with MCACES/MII and PACES.

B-3.8.2 DD Form 1391 Estimate Generator.

The DD Form 1391 Estimate Generator is one of the modules within the Army's DD 1391 Processor. It is an interactive computer program which assists users in preparing the programming cost estimate shown on the DD Form 1391, Military Construction Project Data. (The DD Form 1391 is used by DOD agencies to justify the need of a military project and serves as a funding request for the Authorization and Appropriation of Military Construction funds by Congress.) The cost estimate generator of the DD Form 1391 Processor has capabilities for automatic computation of area cost factor adjustments, size factor adjustments, and automatic escalation computation. It uses the cost data from the DOD Facilities Pricing Guide and HAG/HII to generate costs of facilities.

B-3.8.3 Electronic Project Generator (EPG).

EPG, the Electronic Project Generator, is a web-based software system that supports the development, review, and approval of Navy MILCON and SRM projects. It is the paperless vehicle by which DD 1391 supported projects are entered into the NAVFAC planning, programming, and budgeting process.

B-4 OVERVIEW OF TRACES DATABASES AND FILES.

Databases and files used by the TRACES modules are as follows:

B-4.1 Cost Book Database.

The Cost Book database is a collection of common construction detail line item tasks used in developing project cost estimates for military, civil works, and HTRW programs. The Cost Book is organized in accordance with the Construction Specification Institute (CSI) numbering system. These material costs can be modified to reflect localized costs for other locations. Each task listed provides unit costs for labor, equipment, and materials. Localized Cost Books can be developed by modifying the key rates in the national Cost Book.

B-4.2 Models Database.

This database contains groupings of assemblies for a whole facility or sitework entity. Linkage between assemblies and assemblies to tasks are by WBS or as exists in a historic cost estimate. Linkage algorithms are provided to the cost engineer for project-specific cost estimate refinement. At the heart of the detail pricing is the Cost Book task costs. Using models can reduce the time for cost estimate preparation but relies heavily on past designs using default linkages.

B-4.3 Assemblies Database.

The Assemblies database stores common groupings of related work tasks, each representing a composite cost required to create a larger piece of a project rather than a single task. The individual cost items within each assembly are either extracted from the Cost Book or from the labor and equipment databases. The database is broken down according to the WBS. Each assembly includes parameter worksheets, requiring only that you input the parameters appropriate for your specific job. Using assemblies can greatly reduce the amount of data entry required to build a project.

B-4.4 Other Databases.

Other TRACES databases include the crews' database, labor rates database, and equipment rates database.

B-4.5 Work Breakdown Structure (WBS).

This data file provides a separate hierarchical work breakdown master structure for use as a template in formatting cost estimates for military projects.

B-4.6 Cost Escalation Index.

The cost escalation index provides a historic and projected cost index for cost escalation adjustment due to inflationary factors.

B-4.7 Area Cost Factor (ACF) Index.

The ACF index is used in adjusting estimated costs to a specific geographical area. The factors reflect the average surveyed difference for each location in direct costs between that location and the national average location.

B-4.8 Department of Defense Facilities Pricing Guide.

This guide is published yearly as an update to UFC 3-701-01. The guide provides unit cost factors intended for macro-level analysis and planning in tools such as the Sustainment Cost Factors which are generally not suitable for individual facilities or projects. The guide also provides unit cost data and related adjustment factors for selected DoD facility types and is intended for use in developing project-level cost estimates and preparing MILCON project documentation (DD Forms 1391 cost estimate).

B-4.9 Army Facilities Pricing Guide ($/SF).

This index is a listing of facility unit costs normalized to a geographical location factor of 1.00. Unit prices reflect costs forecast on the basis of an assumed midpoint of construction date. This guide is published via PAX Newsletter.

B-5 ASSIGNED AGENCY.

The Assigned Responsible Agency (ARA) for TRACES is the U.S. Army Engineering and Support Center, Automated Systems Branch, TRACES group, Huntsville, Alabama. The ARA serves as the focal point for support usage of these software programs by providing operation, maintenance, and "Hot-Line" telephone support.

APPENDIX C GLOSSARY

C-1 ACRONYMS.

ACF	Area Cost Factor
ACO	Administrative Contracting Officer
A-E	Architect-Engineer
AFARS	Army Federal Acquisition Regulation Supplement
AFCEC	Air Force Civil Engineer Center
AR	Army Regulation
ARA	Assigned Responsible Agency
ASA(CW)	Assistant Secretary of the Army (Civil Works)
ASTM	American Standards for Testing and Material
AT/FP	Anti-Terrorism/Force Protection
BIA	Bilateral Infrastructure Agreement
BOE	Basis of Estimate
CACES	Computer Aided Cost Engineering System
CD	Compact Disc
CE	Cost Engineer
CLIN	Contract Line Item Numbers
COD	Contracting Officers Decision
CONUS	Continental United States
CSI	Construction Specification Institute
CSRA	Cost and Schedule Risk Analysis
CTC	Cost to Complete
CUI	Controlled Unclassified Information
CWE	Current Working Estimate
DB	Design Build

DBB	Design Bid Build
DCA	DOD Construction Agent
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
DODINST	DOD Instruction
EP	Engineer Pamphlet
EPG	Electronic Project Generator
ER	Engineer Regulation
FAR	Federal Acquisition Regulations
FICA	Federal Insurance Contributions Act
FOB	Free/Freight on Board
FOIA	Freedom of Information Act
FOOH	Field Office Overhead
FUDS	Formerly Used Defense Sites
G&A	General and Administrative
GAO	Government Accountability Office
GFE	Government-Furnished Equipment
GFM	Government-Furnished Materials
HTRW	Hazardous, Toxic and Radioactive Waste
HAG/HII	Historical Analysis Generator Second Generation
HOOH	Home Office Overhead
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
ICE	Independent Cost Estimate
IFB	Invitation for Bid (Sealed Bidding)
IGE	Independent Government Estimate

JOOH	Job Office Overhead
LCC	Life Cycle Cost
MATOC	Multiple Award Task Order Contract
MCACES/MII	Micro Computer-Aided Cost Engineering System 2nd Generation
MILCON	Military Construction
NAVFAC	Naval Facilities Engineering Systems Command
O&M	Operations and Maintenance
OCONUS	Outside the Continental United States
OSHA	Occupational Safety and Health Administration
PACES	Parametric Cost Engineering System
PAX	Programming Administration Execution
PDT	Project Delivery Team
PET	Price Evaluation Team
PL	Public Law
PM	Project Manager
PMP	Project Management Plan
POC	Point of Contact
POCA	Performance Oriented Construction Activities
QC	Quality Control
RA	Risk Analyst
RFP	Request for Proposal
RMP	Risk Management Plan
RP	Recommended Practice
RTA	Ready to Advertise
SAA	Surety Association of America
SAT	Simplified Acquisition Threshold

SIOH	Supervision, Inspections and Overhead
SOFA	Status of Forces Agreements
SPI	Selling Price Index
TRACES	Tri-Service Cost Engineering Systems
UAI	USACE Acquisition Instruction
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
U.S.	United States
VE	Value Engineering
WBS	Work Breakdown Structure

APPENDIX D REFERENCES

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (NAVFAC)

Price Schedule
https://www.wbdg.org/ffc/navy-navfac/project-information-form-specifications-cover-sheet/price-schedule

PUBLIC LAW

PL No. 74-403 *Davis Bacon Act*

U.S. ARMY CORPS OF ENGINEERS

EP 1110-1-8 *Construction Equipment Ownership and Operating Expense Schedule*
https://www.publications.usace.army.mil/USACE-Publications/Engineer-Pamphlets/?udt_43545_param_page=2

U.S. DEPARTMENT OF DEFENSE

DoDINST 5200.48, *Controlled Unclassified Information (CUI)*
https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/520048p.PDF

U.S. GOVERNMENT ACCOUNTABILITY OFFICE

GAO-20-195G *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs*
https://www.gao.gov/products/GAO-20-195G

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 3-701-01 *DoD Facilities Pricing Guide*

UFC 3-730-01 *Programming Cost Estimates for Military Construction*

ASSOCIATION FOR THE ADVANCEMENT OF COST ENGINEERING INTERNATIONAL (AACE)

AACE International Recommended Practice No. 10S-90, *Cost Engineering Terminology*

ASTM INTERNATIONAL

E1557-09 *Standard Classification for Building Elements and Related Sitework – UNIFORMAT II*

UFC 3-810-01N
1 March 2016
Change 3, 1 December 2021

UNIFIED FACILITIES CRITERIA (UFC)

NAVY AND MARINE CORPS ENVIRONMENTAL ENGINEERING FOR FACILITY CONSTRUCTION

UFC 3-810-01N
1 March 2016
Change 3, 1 December 2021

UNIFIED FACILITIES CRITERIA (UFC)

NAVY AND MARINE CORPS
ENVIRONMENTAL ENGINEERING FOR FACILITY CONSTRUCTION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	7/1/2017	• Added paragraph 1.5 Safety. • Minor revisions to paragraphs 1-4, 2-4.1, 2-5, 2-5.3, 2-6.3, 2-6.3.1, 2-12, 2-17, 3-1, 3-2.5 and Appendix A, B-6 and C-1. • Added requirements for final drawings and specifications to be attached to Design Build RFP. See paragraphs 3-2.1 and 3-2.2. • Added requirements and best practices as they relate to Beryllium. See paragraphs 2-6.3, Section 2-7, 2-15.1.1, 3-1, 3-1.6, 3-2.3, 3-2.4.1, Section 3-2.7, and Appendix B-4.
2	7/1/2021	• Added reference to EM 385-1-1 in paragraph 2-3 Design Criteria. • Minor revisions to paragraphs 2-6.3, 3-2.4.1, 3-2.5, 3-2.5.1, 3-2.5.2, 3-2.6, 3-2.6.1, 3-2.6.2, and Appendix A. • Minor revisions to the titles of paragraphs 3-2.5 and 3-2.6 in the Table of Contents. • Added additional certified professionals that meet the requirements to prepare final drawings and specifications for paint in industrial and commercial facilities. See paragraph 3-2.6.
3	12/1/2021	• Added reference to DoD Environmental Laboratory Accreditation Program in paragraph 2-17.2.

This UFC supersedes UFC 3-800-10N, Final Draft dated July 2006.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 3-810-01N, *Navy and Marine Corps Environmental Engineering for Facility Construction*

Superseding: UFC 3-800-10N, Final Draft, *Environmental Engineering for Facility Construction.*

Description: This UFC provides specific criteria on environmental engineering design topics as they relate to project development of demolition, renovation and site development projects. In these situations, it is primarily intended to address hazardous waste management. It is organized into technical requirements and design deliverables. Requirements for design deliverables beyond or in more detail of what is already required by a Core UFC or by FC 1-300-09N and are provided for NAVFAC-only.

Reasons for Document:

- Provide criteria for meeting \1\ DoDI 6055.01 and applicable Occupational Safety and Health Act (OSHA) Standards/1/, U.S. Environmental Protection Agency (EPA) requirements, and other Federal, state, and local laws and regulations.
- Provide technical requirements for hazardous waste field investigation and design criteria in the development of reports, specifications, and drawings.
- Establish minimum technical requirements and deliverables, including environmental reports, specifications and drawings, in support of design activities.
- Define minimum requirements for specifications and contract drawings as they relate to hazardous materials.

Impact: By providing standardized criteria for the identification of hazardous materials during design it is expected that construction schedules and cost for change orders will be reduced by having adequate hazardous waste information included in the contract documents during the bidding process.

Unification Issues: Requirements in this FC conform to Navy instructions and manuals. These requirements include NAVY specific requirements that have not been unified. These Navy requirements may not work for Army and Air Force operations because of their organizational and operational differences.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Environmental Engineering combines the principles of engineering and science to protect the environment, preserve resources, and enhance public health. Congress has enacted various acts to improve or protect the natural environment, clean up polluted sites, and protect human health by providing requirements for drinking water, wastewater management, clean air, and various other issues that affect public health. This legislation establishes conditions requiring Federal agencies to implement projects in a manner that maintains or enhances the environment and public health.

1-2 PURPOSE AND SCOPE.

This document provides technical criteria and outlines technical requirements for the more typical aspects of the Environmental Engineering. It is not intended to cover all aspects of Environmental Engineering. It is primarily intended for building demolition and building renovation projects. It does introduce other topics such as cultural resources preservation, wetlands protection, and remediation of contaminated soil and groundwater. While topics such as contaminated soil and groundwater are introduced, this UFC is not intended to cover the remediation of all hazardous materials. Where remediation of specific hazardous materials not covered in this criteria is warranted, contact the appropriate Environmental Engineering media manager. Many of these topics are considered during the National Environmental Policy Act (NEPA) process. This UFC assumes that appropriate NEPA actions have been accomplished prior to committing resources to any proposed activity. Many facilities were constructed with materials that are now considered hazardous to worker safety and the environment. Removal and disposal of these materials requires a complex analysis of Federal, state, and local regulations to determine the appropriate methods for removing and disposing of these hazardous materials. Use this UFC to determine the minimum environmental engineering design requirements. State and local regulations may be more stringent. Where other state or local criteria regulatory requirements exist, comply with the more stringent requirements.

1-3 APPLICABILITY.

This UFC applies to all military service elements and contractors involved in the planning, design, and construction of Navy and Marine Corps facilities worldwide.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, \1\DoD Building Code (*General Building Requirements*)/1/. UFC 1-200-01 provides applicability of model building codes and unique government criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and other UFCs and Government criteria referenced therein.

1-5 SAFETY.

\1\All DoD facilities must comply with DoDI 6055.01 and applicable Occupational Safety and Health Administration (OSHA) safety and health standards./1/

1-6 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-7 GLOSSARY.

Appendix C contains acronyms and abbreviations used in this document.

CHAPTER 2 TECHNICAL REQUIREMENTS

Identification and compliance with all Federal, state and local environmental regulations requires comprehensive environmental investigations, analysis, design and engineering. A lack of these comprehensive environmental tasks and efforts leads to increased project schedules and costs, and potential Notices of Violations (NOV) and fines.

2-1 PERMITS.

Identify, assist or provide, as applicable, all permits, approvals and fees required for the design, construction and operation of the proposed project from Federal, state and local regulatory authorities or overseas equivalent. Comply with FC 1-300-09N for professional registration requirements. Licensure in the state where the project is located may be required to obtain permits and approvals. Coordinate with the Installation Environmental (EV) staff to obtain the project NEPA documentation, as applicable, for project specific requirements. For areas outside of the United States and its territories and possessions with host nation agreements, follow design approval procedure as directed in project scope and by the Government Project Manager. For areas outside of the United States and its territories and possessions without Host nation agreements, the Government will review and approve environmental plans.

2-2 REGULATORY NOTIFICATIONS.

Identify all regulatory notification requirements in accordance with Federal, state, and local regulations. Where the Navy needs to provide public notification, coordinate with the Government Project Manager and the Installation EV staff. Require the Contractor to provide copies of all regulatory notifications to the Government Project Manager and the Installation EV staff. Typically, regulatory notifications are provided for the following (this listing is not all inclusive): demolition, renovation, national pollutant discharge elimination system defined site work, or remediation of hazardous materials (such as asbestos, hazardous waste, and lead-based paint).

2-3 DESIGN CRITERIA.

Contact the Installation EV program staff for specific environmental requirements for the project location. Design projects in accordance with applicable requirements of the local regulatory agency with jurisdiction over the installation and the criteria in this UFC; whichever is more stringent.

Provide design in accordance with the following criteria precedence:

- Federal regulations required for installations in the United States, U.S. Territories, and U.S. Possessions governed by U.S. law

- Department of Defense Policies

- Department of the Navy Policies

- State and local regulations for the project location
- \2\EM 385-1-1 *Safety and Health Requirements*/2/
- Final Governing Standards (FGS) and Overseas Environmental Baseline Guidance Document (OEBGD)
- Protection of natural resources and minimization of potential environmental impacts

2-4 FIELD INVESTIGATION.

Comply with EM 385-1-1 and all safety and environmental regulations during field investigations, surveys, sampling, abatement and removal procedures, material management, and waste management. Take precautions to protect human health and the environment as required by Federal, state, and local regulations and DoD policy. Ensure that the contract documents include information and survey data sufficient to identify and quantify the materials listed in the following paragraphs.

Complete all field investigations (e.g., information gathering, surveys, sampling and testing), for the environmentally sensitive materials indicated below. Each Installation maintains record files pertaining to the environmental aspects of previously constructed projects. Contact the Installation EV program staff and obtain all existing surveys, test reports and drawings prior to beginning field investigations.

2-4.1 Safety.

Comply with \1\DoDI 6055.01 and the applicable Occupational Safety and Health (OSHA) Standards./1/ Verify that all preconstruction work performed and construction contract requirements, such as facility surveys, sampling, testing, and field investigations, comply with \1\ DoDI 6055.01 /1/ for respiratory protection, noise exposure, permit-required confined-space entry, personal protective equipment, protection of building occupants, and similar.

2-5 ASBESTOS-CONTAINING MATERIALS.

\1\These requirements apply to sites and projects where existing buildings or structures will be renovated, altered, repaired, or demolished as part of the scope of work. /1/Navy policy requires elimination of the asbestos hazard. Refer to OPNAV M-5090.1 Section Asbestos.

Do not remove installed RACM that are in good condition for the sole purpose of eliminating asbestos. Identify RACM that will not be disturbed or do not have the potential to be disturbed during the construction activities, and manage in place.

2-5.1 Conducting Field Investigations, Surveys and Sampling – Asbestos-Containing Materials.

Perform facility asbestos investigation, survey and sampling in accordance with 40 CFR 763 prior to any renovation, alteration, repair, or demolition project that will disturb building materials regardless of the age of the existing construction. For Federal requirements, refer to http://www2.epa.gov/asbestos/building-owners-and-managers#renovations. Data from previous asbestos surveys may be available from the Installation EV staff. Earlier surveys may not have included all suspect RACM that will be impacted by the project. This may include, but is not limited to, roofing materials, crawl-space soils, and confined utility chases. Provide personnel who are currently Environmental Protection Agency (EPA) accredited asbestos inspectors to perform ACM sampling.

2-5.2 Laboratory – Asbestos-Containing Materials.

Use laboratories that are fully equipped and proficient in conducting analyses of suspect RACM bulk samples in accordance with 40 CFR 763, are accredited by the National Institute of Standards and Technology/National Voluntary Laboratory Accreditation Program (NIST/NVLAP), and are a successful participant and maintain proficiency in the NIST/NVLAP sponsored quality assurance program for asbestos identification.

2-5.3 Control of Regulated Asbestos-Containing Materials.

Federal law defines demolition activities and renovation activities, and establishes different requirements for each one. Identify what requirements apply to the project, based on the National Emission Standards for Hazardous Air Pollutants (NESHAP) compliant survey, and\1\ include in the specifications. Before beginning any demolition or renovation activities, determine the potential for releasing asbestos. /1/ Identify the requirements for notification to the regulatory agency and include in the specifications.

2-6 PAINT.

2-6.1 Lead-Based Paint in Target Housing and Child-Occupied Facilities.

These requirements apply to projects involving the renovation, alteration, or repair of any target housing or child-occupied facility. Child-occupied facilities may include, but are not limited to, daycare centers, preschools, or kindergarten classrooms.

Federal regulations include specific requirements for any work in a child-occupied facility under EPA Title X and EPA RRP Rule. EPA Title X is not limited to residential units, and also applies to child-occupied facilities. Design and perform all phases of work relating to Lead-Based Paint in accordance with EPA Title X and EPA RRP Rule.

2-6.1.1 Conducting Field Investigations, Surveys, and Sampling – Lead-Based Paint in Target Housing and Child-Occupied Facilities.

Evaluate all surfaces impacted by the project for lead-based paint, including, but not limited to, painted surfaces (interior and exterior), dust, and soil. Perform all sampling and testing in accordance with EPA Title X and EPA RRP Rule. Sampling and testing will include x-ray fluorescence (XRF), bulk, wipe, water, and soil sampling as required by EPA Title X and EPA RRP Rule. Provide EPA accredited professionals to perform the lead-based paint field work, sampling, and risk assessment.

2-6.1.2 Laboratory – Lead-Based Paint in Target Housing and Child-Occupied Facilities.

Use laboratories that meet all the requirements of EPA Title X, EPA RRP Rule, and laboratories performing analysis for lead-based paint chip, air, water, soil, or wipe samples. Laboratories must be fully accredited by the EPA National Lead Laboratory Accreditation Program (NLLAP) and rated proficient in the EPA Environmental Lead Proficiency in Analytical Testing (ELPAT) Program. The EPA list of accredited laboratories is available on the following website: http://www2.epa.gov/lead/national-lead-laboratory-accreditation-program-nllap.

2-6.1.3 Removal of Lead-Based Paint in Target Housing and Child-Occupied Facilities.

Abatement is a lead-based paint hazard-reduction method that is designed to permanently eliminate lead-based paint or lead-based hazards. Permanent removal is defined as having a 20-year expected life. Require abatement to be performed by certified abatement workers who successfully completed an EPA accredited abatement worker course and who are supervised by an abatement supervisor certified under EPA or under a state program authorized by EPA. Abatement activities include:

- Removing lead-based paint and its dust.
- Permanently encapsulating or enclosing the lead-based paint.
- Replacing components with lead-based paint.
- Removing or permanently covering lead-contaminated soil.

Prior to clearing an area in which lead-based paint abatement has been performed, collect and analyze a representative clearance sample by a certified individual and an accredited laboratory, in accordance with the EPA RRP Rule. Require the Contractor to comply with the EPA RRP Rule in the specifications.

Residential lead-based paint may be disposed of in construction and demolition (C&D) landfills in accordance with 66 FR 53535 in addition to being disposed of in municipal solid waste landfills.

2-6.2 Lead-Based Paint in Commercial or Industrial Facilities.

In order to dispose of lead-based paint waste from industrial or commercial sources, take a representative sample of the waste material and require analysis using the toxicity characteristic leaching procedure (TCLP). Samples equal to or greater than 5.0 milligrams per liter (mg/L) TCLP are considered hazardous and need to be disposed of in an approved hazardous waste landfill. Samples less than 5.0 mg/L TCLP are considered nonhazardous and may be disposed of in a municipal solid waste landfill or a C&D landfill. Indicate final disposition of the waste material in accordance with the test results.

2-6.3 Paint – Lead, Cadmium, Chromium, and Other Hazardous Metals.

\2\ Refer to 2-6.1 Lead-Based Paint in Target Housing and Child-Occupied Facilities for any work being performed in target housing or child-occupied facilities/2/. Paints containing lead, cadmium and chromium are often found as protective coatings on structural steel, tanks, piping, metal building components, or exterior coatings on metal surfaces and are used in current operational processes in various facilities, such as aircraft maintenance hangars, ship maintenance and repair facilities, and similar types of facilities. Require control and management of dust and particulates containing lead, cadmium, chromium, and other hazardous metals generated from construction activities in accordance with \2\29 CFR 1926.62, 1910.1026, and 1910.1027 and OPNAVINST 5100.23G/2/, to avoid contaminated indoor air or contaminated dust on building surfaces.

Identify the potential factors that affect the thresholds and exposures to building occupants and construction workers in accordance with \1\DoDI 6055.01/1/ and state codes and laws. Require facility engineering controls, building occupant protection, construction activity requirements for worker protection, and any additional requirements for safe environmental conditions in the specifications.

2-6.3.1 Conducting Field Investigations, Surveys, and Sampling – Paint.

Monitor worker exposure in accordance with \1\DoDI 6055.01/1/. Use ASTM Standards and EPA or HUD Guidelines for air monitoring criteria. Evaluate anticipated waste materials as part of the field investigation and sampling. Refer to paragraph entitled “Control and Management of Solid and Hazardous Waste” for additional requirements.

2-6.3.2 Laboratory – Paint.

Use laboratories that are fully accredited by the EPA NLLAP and rated proficient in the National Institute for Occupational Safety and Health; EPA ELPAT to perform analysis for air samples. Refer to the paragraph entitled “Laboratory - Lead-Based Paint in Target Housing and Child-Occupied Facilities” for a link to the EPA website to verify the list of accredited laboratories.

2-7 BERYLLIUM.

\1\These requirements apply to sites and projects where any existing buildings or structures will be renovated, altered, repaired, or demolished. Beryllium can be found in the air and on surfaces where beryllium is used as either a pure metal, as beryllium oxide, as an alloy with copper, aluminum, magnesium, or nickel and in certain types of slags. Facilities that have the potential to contain beryllium include:

- Primary Beryllium Production,
- Processing Beryllium Metal/Alloys/Composites,
  - Foundries,
  - Furnace Shops,
  - Machine Shops,
  - Metal Fabricating Shops,
  - Welding Shops,
  - Dental Labs,
- Secondary smelting and refining work areas (recycling electronic and computer parts, metals),
- Abrasive Blasting Shops (slags).

If not properly controlled and managed, dust or particulates containing beryllium may be deposited on building surfaces. Facility types that may contain beryllium (dust and particulates) include areas such as aircraft maintenance hangars, ship maintenance and repair facilities, automotive repair facilities, dental labs and similar types of facilities.

2-7.2 Conducting Field Investigations and Surveys – Beryllium.

Perform a beryllium investigation and survey where beryllium is known to have been used or processed. Where beryllium has been used or processed, test all surfaces impacted by the project for beryllium dust. Perform all sampling and testing in accordance with applicable ASTM and industry standards.

When investigation and sampling are performed, there are hazards associated with the generation of dust. OSHA Standards cite action levels and exposure limits with regard to worker protection. Wherever employees are, or can reasonably be expected to be, exposed to airborne beryllium at levels above the time weighted standard permissible exposure limits or short-term exposure limit; monitor worker exposure and designate a competent person to perform the investigation and sampling in accordance with 29 CFR 1910.1024, 29 CFR 1915.1024 and 29 CFR 1926.1124.

2-7.3 Laboratory – Beryllium.

Use laboratories that are fully accredited by Industrial Hygiene Laboratory Accreditation Program.

2-7.4 Management – Beryllium.

Require control and management of beryllium during construction in accordance with 29 CFR 1910.1024, 29 CFR 1915.1024 and 29 CFR 1926.1124. Areas with beryllium dust may be cleaned by high-efficiency particulate air (HEPA) filter vacuuming in accordance with 29 CFR 1910.1024./1/

2-8 RADON.

2-8.1 Radon Mitigation.

Implement a radon mitigation system design in new or renovated, altered, or repaired occupied facilities as described in UFC 3-101-01. For any occupied building renovation, alteration, or repair, identify the levels of indoor radon. In addition, comply with ASTM E2121, Navy Radon Assessment and Mitigation Program – Guidance Document for Navy Family Housing, Navy Radon Assessment and Mitigation Program – Guidebook for Naval Shore Installations, and state specific documents from the EPA for additional information concerning radon zones, and level of risk (low, medium, high), whichever is more stringent.

2-8.2 Conducting Field Investigations, Surveys, and Sampling – Radon.

Use short-term testing detectors or long-term alpha tracking detectors to determine if radon is present at the project site. The short-term test is typically 90 days and the long-term test can be up to one year. Confirm with the Installation's EV staff that the radon detection devices and the sampling strategies and procedures comply with the Navy Radon Assessment and Mitigation Program (NAVRAMP). Obtain all existing radon test information from Installation EV staff.

2-9 POLYCHLORINATED BIPHENYLS.

Eliminate Polychlorinated Biphenyls (PCB) containing materials from all Navy equipment and all electrical distribution systems. Refer to OPNAV M-5090.1, Section, Polychlorinated Biphenyls.

2-9.1 Conducting Field Investigations, Surveys, and Sampling – Polychlorinated Biphenyls.

Obtain a current environmental survey from Installation EV staff that indicates the status of PCB in the building to be renovated, repaired, altered, or demolished. Provide an inspector who is familiar with the various uses of PCB. Based on the age of the facility and the extent of the project, determine the potential PCB sources. During the field survey, the inspector is to examine the potential PCB sources for labeling and manufacturer information. If there is no label that states “non-PCB”, contact the manufacturer for more information or assume the source contains PCB.

2-9.2 Management of Polychlorinated Biphenyls.

Manage and dispose of PCB in accordance with the Toxic Substance Control Act (TSCA) and with state and local requirements. Dispose of PCB materials at facilities meeting the requirements of incineration or in a chemical waste landfill as required by 40 CFR 761 Subpart D. Contractors are required to comply with all Navy-applicable PCB requirements while performing work onsite.

2-10 LOW-LEVEL RADIOACTIVE COMPONENTS.

Components that may contain low-level radioactive (LLR) material include thermostats, switches, smoke detectors, High Intensity Discharge (HID) lamps and exit signs. If there is no label or a warning on the label that states the contents of the source, assume it contains LLR material.

2-10.1 Conducting Field Investigations and Surveys – Low-Level Radioactive Components.

Obtain a current environmental survey from Installation EV staff that indicates the status of LLR components in the building to be altered, renovated, repaired, or demolished. Provide an inspector familiar with the various building components that could contain LLR material. Based on age of the facility and the extent of the project, determine potential sources. During the field survey, the inspector is to examine the potential sources for labeling. If there is no label that states the contents contain potential LLR material, contact the manufacturer for more information or assume the source contains LLR material.

2-11 ANIMAL DROPPINGS.

2-11.1 Conducting Field Investigations and Surveys – Animal Droppings.

Testing soil and air samples for Histoplasma is not likely to be useful because the fungus is thought to be common in the environment in certain areas, and positive or negative results in soil samples does not mean the soil is a source of infection or that the fungus is not there. Treat soils, buildings, or other areas with bat droppings or bird manure as containing the Histoplasma virus. Use best practice document DHHS 2005-109 when conducting surveys or preparing specification for building renovation, alteration, or demolition projects. Do not stir up dust by sweeping or vacuuming areas containing rodent droppings or nesting material as it may contain Hantavirus. Use Centers for Disease Control and Prevention (CDC) cleaning up after rodents for cleanup requirements. http://www.cdc.gov/rodents/index.html

2-12 MOLD AND SPORES.

These requirements apply to sites and projects where any existing building(s) or structure(s) will be renovated, altered, repaired, or demolished. \1\/1/ Design moisture barriers and retarders as defined in UFC 3-101-01. Additional requirements can be found in EPA 402-K-01-001.

2-12.1 Conducting Field Investigations, Surveys and Sampling – Molds and Spores.

During field investigations for hazardous constituents, areas with chronic moisture may be found and recognized as potentially containing harmful molds. Renovations, alterations, or repairs that involve unoccupied areas of a building often include significant water damage and fungal growth, which could pose a hazard to construction workers, the design team, and to occupants of other parts of the building. Complete the Microbial Assessment Survey and Report prior to the preparation of the project specifications. Provide a qualified microbial assessor that meets at least one of the following criteria to complete the survey:

- Bachelor's degree from an accredited university or college with a major in engineering, architecture, building construction, occupational health, microbiology, occupational safety, or a related natural or physical science. An additional 2 years' experience in conducting microbial investigations is required.

- Associates degree from an accredited university or college with a concentration in environmental, natural, or physical sciences. An additional 4 years' experience in conducting microbial investigations is required.

- Certification as an industrial hygienist as certified by the American Board of Industrial Hygienists, safety professional as certified by the Board of Certified Safety Professionals or engineer. An additional one year of experience in conducting microbial investigations is required.

- Certification by the American Council for Accredited Certification as a Council-Certified Indoor Environmental Consultant, Council-Certified Indoor Environmentalist, Council-Certified Mold Consultant, Council-Certified Microbial Investigator, Council-Certified Residential Mold Inspector, Council-Certified Mold Remediation Supervisor, or Council-Certified Mold Remediator.

Provide a microbial assessor familiar with signs of potential mold problems, including stains or discoloration of walls, ceilings, or carpets; swelling or sagging of building components; standing or dripping water; rot (wet or dry); and musty odors. Types of samples include air samples, bulk samples (chunks of carpet, wallboard, insulation, and similar), and water samples from drains and cooling pans. Collect samples using sterile materials and containers, and ship overnight for next day delivery in accordance with instructions provided by the laboratory. Use a laboratory with special expertise in mold analysis. Longer shipping time must be approved by the laboratory.

2-12.2 Laboratory – Molds and Spores.

Use laboratories that are fully accredited by the Environmental Microbiology Proficiency in Analytical Testing program of the American Industrial Hygiene Association to perform analyses for fungi (molds) or bacteria.

2-13 STORAGE TANKS.

These requirements apply to hazardous waste storage tanks regulated under 40 CFR 264 Subpart J and 40 CFR 265 Subpart J. UFC 3-460-01 covers the general environmental criteria and standards for storage tanks containing regulated substances subject to the provisions of the Resource Conservation and Recovery Act (RCRA) Part 280. Evaluate sites with known tanks, known soil, or groundwater contamination at the beginning of the design of facility renovations, repairs, demolition, and construction so appropriate precautions can be taken to protect workers and the environment prior to excavation.

2-13.1 Tank Installation.

Projects that include the installation of new storage tanks, including reinstalled tanks or replaced tanks, used to contain hazardous waste at treatment, storage, and disposal facilities are subject to Federal regulation and are to comply with the requirements set forth in 40 CFR 264 Subpart J and 40 CFR 265 Subpart J. Design storage tanks to meet Federal regulation for tank location, secondary containment, cathodic protection, leak-detection system, leak-detection testing, and similar.

2-13.2 Tank Removal.

These requirements apply to sites and projects where aboveground storage tanks (AST) or underground storage tanks (UST) are known to exist. Obtain copies of available reports, such as tank integrity assessment reports, groundwater sampling and testing, contaminated soil sampling and testing, and Closure Reports from the Installation EV staff. Coordinate with the Installation EV staff in order to determine the requirements to initiate a permanent closure process of the storage tank as applicable. Closure activities are regulated at the state level. Storage tanks and piping systems may be permanently closed by removing them from the ground, or by decontaminating and filling the empty tanks with an inert solid material, which is referred to as being “closed in-place”. Dispose of AST or UST following the hazardous waste requirements discussed in the paragraph entitled “Hazardous Waste”.

2-13.2.1 Conducting Field Investigations, Surveys, and Sampling – Storage Tanks.

Where the construction site contains tanks, a site inspection must be performed. Before performing field investigations and sampling, obtain all available information regarding AST and UST from the Installation EV staff. Develop a soil and groundwater sampling and testing plan. See paragraph entitled “Conducting Field Investigations, Surveys and Sampling – Contaminated Soil and Groundwater". Encompass all tank system components. Include information such as the age of the unit, corrosions-protection measures in place, and results of prior leak tests or inspections of the tank. See information required in the paragraph entitled "Report - Tanks".

2-13.2.2 Laboratory – Storage Tanks.

Use laboratories to analyze potentially contaminated soils, free product, or sludge that are fully equipped and proficient in conducting analysis in accordance with EPA SW-846, EPA 540/R-99/008, EPA-540-R-014-002, EPA-540-R-04-004, and certified by the National Environmental Laboratory Accreditation Conference (NELAC).

2-14 CONTAMINATED SOIL OR GROUNDWATER.

These requirements apply to sites and projects where contaminated soil or groundwater is known to exist. Evaluate sites with known soil or groundwater contamination during the planning phase and before initiating any facility design work. Obtain copies of available reports, such as groundwater sampling and testing, contaminated soil sampling and testing, and remediation reports, from the Installation EV staff. Coordinate with the Installation EV staff to identify permit conditions applicable to soil, restrictions on land development, and other requirements that must be considered for the project. Prepare specifications and construction documents that accurately convey existing site conditions as they pertain to soil and groundwater contamination. Manage and dispose of contaminated soils and groundwater in accordance with the requirements described in the paragraph entitled "Hazardous Waste".

2-14.1 Conducting Field Investigations, Surveys, and Sampling – Contaminated Soil or Groundwater.

When the construction site is known to contain contaminated soil or groundwater and no determination actions have been started, perform a site inspection. Before field investigation and sampling, obtain all available information regarding contaminated soil or groundwater from the Installation EV staff. Develop a soil and groundwater sampling and testing plan that contains, at a minimum, the procedure for collecting samples, the frequency of the sampling events, the test methods that will be employed, type of sampling design and sampling density, error Type, confidence level and procedure for handling samples. Follow EPA Soil Screening Guidance (SSG). The SSG presents a framework for developing risk-based, soil screening levels (SSL) for protection of human health. Screening levels are not national cleanup levels; instead, they are intended to streamline the evaluation and cleanup of site soils by helping site managers eliminate areas, pathways and chemicals of concern at National Priority List sites. See information required in the paragraph entitled "Report - Contaminated Soil or Groundwater".

2-14.2 Laboratory – Contaminated Soil or Groundwater.

Use laboratories that are fully equipped and proficient in conducting analysis in accordance with EPA SW-846, EPA 540/R-99-008, EPA-540-R-04-004, and certified by the NELAC to analyze potentially contaminated soils or groundwater.

2-15 CONTROL AND MANAGEMENT OF SOLID AND HAZARDOUS WASTE.

Disposal or ultimate disposition of waste materials is performed on all projects. Waste reduction in the form of recycling or reuse is encouraged. Require the Contractor to develop a waste management and reduction plan to be used during construction. Coordinate with the Installation EV staff and identify materials suitable for recycling or reuse, taking into account the Installation's recycling program. If disposal or ultimate disposition of hazardous or contaminated materials, soils, or groundwater are part of the project a waste characterization is required. Consult regional, state, and local regulations for more stringent threshold levels. To determine whether a waste fails the toxicity characteristic, perform a TCLP analysis on the waste. Note the TCLP analysis differs from total constituent laboratory analysis; TCLP analysis is only for disposal needs. However, total analysis may also be needed. Solid or nonhazardous waste accumulation requirements can be found, if regulated, within state-specific regulations and should follow industry standard.

2-15.1 Hazardous Waste Accumulation.

Require accumulation and storage of contaminated media and any debris according to applicable requirements while awaiting transportation and disposal. Require coordination with the Installation EV staff to determine what quantity may be stored on-site. Accumulate and manage any hazardous waste generated in accordance with 40 CFR 262, 40 CFR 264, and 40 CFR 265, Installation, state-specific and local requirements, whichever are more stringent.

2-15.1.1 Hazardous Waste.

Federal regulations define waste as hazardous when it exhibits a hazardous characteristic (such as ignitability, corrosivity, reactivity, or toxicity) as specified in 40 CFR 261, Subpart C, or when the waste contains a listed hazardous waste as identified in 40 CFR 261, Subpart D. RCRA requires that solid wastes be properly characterized at the point of generation. RCRA regulates "cradle to grave" control over hazardous wastes. Request recycling and reuse of waste classified as hazardous, in accordance with the requirements in 40 CFR 261.6.

Require treatment of hazardous wastes in accordance with 40 CFR 268. This section identifies treatment standards for hazardous waste that must be met before waste may be disposed (placed on the land). Follow the requirements of 40 CFR 262, 40 CFR 264, and 40 CFR 265 when accumulating hazardous waste onsite. Coordinate with the Installation EV staff for generator status of the Installation and applicability, including instances when an EPA identification (ID) number is required, accumulation requirements regarding quantities and time allowed, inspections, required documentation and labeling, reporting, training, and contingency planning. Table 2-1 identifies regulatory references that provide requirements for each of these. States may have more stringent requirements than Federal regulations provide. Determine state requirements for hazardous wastes prior to generation, characterization, classification, and disposal to determine the most stringent requirement.

Table 2-1 Regulatory References

	Conditionally Exempt Small Quantity Generators	**Small Quantity Generators**	**Large Quantify Generators**
Quantity Limits	≤100 kilogram (kg) per month ≤1 kg per month of acute hazardous waste ≤100 kg per month of acute spill residue or soil §§261.5(a) and (e)	>100 <1,000 kg per month §262.34(d)	≥1,000 kg per month >1 kg per month of acute hazardous waste >100 kg/month of acute spill residue or soil Part 262 and §261.5(e)
EPA ID Number	Not required	Required §262.12	Required §262.12
On-Site Accumulation Quantity	≤1,000 kg ≤1 kg acute ≤100 kg of acute spill residue or soil §§261.5(f)(2) and (g)(2)	≤6,000 kg §262.34(d)(1)	No limit
Accumulation Time Limits	None	≤180 days or ≤270 days (if greater than 200 miles) §§262.34(d)(2) and (3)	≤90 days §262.34(a)
Storage Requirements	None	Basic requirements with technical standards for tanks or containers §§262.34(d)(2) and (3)	Full compliance for management of tanks, containers, drip pads, or containment buildings §262.34(a)

	Conditionally Exempt Small Quantity Generators	Small Quantity Generators	Large Quantify Generators
Sent To:	State-approved or RCRA permitted/ interim status facility §§261.5(f)(3) and (g)(3)	RCRA permitted/interim status facility §262.20(b)	RCRA permitted/ interim status facility §262.20(b)
Manifest	Not required	Required §262.20	Required §262.20
Biennial Report	Not required	Not required	Required §262.41
Personnel Training	Not required	Basic training required §262.34(d)(5)(iii)	Required §262.34(a)(4)
Contingency Plan	Not required	Basic plan §262.34(d)(5)(i)	Full plan required §262.34(a)(4)
Emergency Procedures	Not required	Required §262.34(d)(5)(iv)	Full plan required §262.34(a)(4)
Department of Transportation (DOT) Transport Requirements	Yes (if required by DOT)	Yes §§262.30-262.33	Yes §§262.30-262.33

2-15.1.2 Universal Waste.

The regulations govern the collection and management of batteries, pesticides, mercury-containing equipment, and lamps, thus facilitating environmentally sound collection and proper recycling or treatment. Comply with the Federal universal waste regulations set forth in 40 CFR 273. States may modify the universal waste rule and add additional universal waste(s) in individual state regulations. Coordinate with the Installation EV staff and research the specific state for additional regulations that apply.

Universal waste may be accumulated for up to one year from the date when the waste is generated. In most cases, universal waste (such as, lamps and batteries) are “generated” when they are removed from service.

2-15.1.3 Beryllium.

\1\Comply with 29 CFR 1910.1024, 29 CFR 1915.1024 and 29 CFR 1926.1124./1/

2-15.1.4 Used Oil.

Comply with EPA required practices in 40 CFR 270, called "management standards," developed for used oil. These include proper labeling, proper and maintained containers, spill and leak prevention, and proper recordkeeping. Comply with additional, more stringent state requirements, if applicable. States may have additional more stringent requirements.

2-15.2 Conducting Field Investigations, Surveys, and Sampling– Solid and Hazardous Waste.

Require a waste characterization study (including solid and liquids) before disposing of potentially unknown hazardous or contaminated wastes. In order to determine if anticipated construction waste (solid or liquid) is within regulatory limits for disposal and ultimate disposition as a nonhazardous material, request the analysis of a representative sample of the waste stream in accordance with Federal regulations using the appropriate EPA analytical methods. Perform this sampling in accordance with RCRA procedures, state, and local regulations and with EPA and state guidelines for avoiding exposure to human health and the environment. Establish a health and safety program to be followed during the sample collection process, select the statistical method to be followed, and set a quality control procedure for the data collection in accordance with EPA 530-D-02-002. Collect a representative sample of the anticipated waste stream; it may be necessary to collect subsamples of various materials to collect an accurate heterogeneous waste stream sample. To accomplish the analysis of a heterogeneous waste stream, collect a composite sample that can be analyzed in accordance with Federal regulations, EPA protocols, and ASTM Standards. The representative composite sample should be prepared from samples of each of the different building material categories, and then mixed in proportion to the percentage by weight of the different components in the anticipated waste stream. Patch and repair sample locations with suitable materials. Consult a qualified laboratory for required sample quantities to obtain accurate analysis. Should other sampling methodologies be used, request coordination with onsite personnel before sample collection and analysis.

2-15.3 Laboratory – Solid and Hazardous Waste.

Use laboratories that are fully equipped and proficient in conducting analysis in accordance with EPA SW-846, EPA 540/R-99-008, EPA-540-R-04-004, and NELAC certified to perform analysis for potential hazardous waste.

2-16 OTHER ENVIRONMENTAL REQUIREMENTS.

2-16.1 National Environmental Policy Act.

NEPA and 40 CFR Parts 1500-1508, require Federal agencies to assess and consider the potential impacts to the environment by their proposed actions that occur within the United States. Executive Order (EO) 12114, requires similar assessment and consideration as NEPA, but applies to proposed actions occurring outside the United States. A NEPA analysis should be completed prior to beginning design. NEPA is prepared based on previous findings, anticipated building use and planned building locations. NEPA documentation addresses the requirements in Federal statute or EO that applies to the resources found within the project area.

Obtain the NEPA documentation prepared for the project from the Installation EV staff. The NEPA documentation identifies any sensitive resources that exist within or adjacent to the site and any mitigation or avoidance measures that are required. Comply with measures identified in the NEPA documentation and include them as contract requirements. If conditions change from what was analyzed in the NEPA document, such as a change in use, location on the site, the addition of or change in location of supporting facilities, or discovery of new information about the site, contact the Installation EV staff to determine if a modification to the NEPA document is required.

2-16.2 Cultural Resources.

Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires Federal agencies to consider the effects of actions they fund or approve on any district, site, building, structure, or object that is listed in or eligible for listing in the National Register of Historic Places (NRHP). The primary agency for enforcement of NHPA is the State Historic Preservation Officer (SHPO). Federal agencies must comply with Section 106 of the NHPA by adherence to the regulations found at 36 CFR 800. The Native American Graves Protection and Repatriation Act of 1990 (NAGPRA); 43 CFR 10 provides a process for Federal agencies and museums to return certain Native American cultural items -- human remains, funerary objects, sacred objects, or objects of cultural patrimony -- to lineal descendants and culturally affiliated Indian tribes. NAGPRA includes provisions for unclaimed and culturally unidentifiable Native American cultural items, intentional and inadvertent discovery of Native American cultural items on Federal and tribal lands, and penalties for noncompliance and illegal trafficking. NAGPRA outlines the treatment, repatriation, and disposition of such resources and ensures consultation with associated tribes or lineal descendants.

Obtain documentation from Installation EV staff regarding any known historic properties or the potential to discover historic properties within the project site and any mitigation required to avoid an adverse effect to historic properties. Comply with state and local preservation laws in addition to Section 106 of the National Historic Preservation Act (NHPA).

2-16.2.1 Archaeology.

Comply with the Archaeological Resource Protection Act of 1979; 16 U.S.C. 470aa-470mm. The Act defines regulations for excavating archaeological sites and requires that a permit be obtained from the Federal land manager when excavation or the removal of any archaeological resource occurs on public or Native American lands.

Obtain from Installation EV staff any measures, such as buffer areas, that were agreed upon during the Section 106 process. Include these measures and the necessary language to ensure protection of any archaeological resources, as contract requirements.

2-16.2.2 Architectural.

Obtain information on historic architectural resources from the Installation EV staff and include any mitigation measures as contract requirements. Refer to UFC 3-101-01 for projects involving historic architectural resources.

2-16.2.3 Inadvertent Discoveries.

These requirements apply to all projects that include ground disturbance. Include procedures for the Contractor to follow should an archaeological site be discovered during construction. If any previously unidentified prehistoric- or historic-period archaeological sites (for example, human skeletal remains or burials and artifacts) are discovered during construction activities, suspend all ground-disturbing activities and then notify the Installation EV staff and Contracting Officer. Consultation with SHPO, interested Native American tribes, and other interested parties should occur as appropriate regarding the site’s eligibility for listing in the NRHP, project impacts, necessary mitigation, and other treatment measures.

2-16.2.4 Tribal Consultation.

Obtain from the Installation EV staff any measures, such as buffer areas that were agreed upon during tribal consultation. Include these measures as contract requirements.

2-16.3 Air Quality.

These requirements apply to sites and projects with new or existing facilities and with new or existing stationary air emissions sources. Comply with Clean Air Act (CAA) requirements and state and local regulations. Coordinate with the Installation EV staff and provide the necessary information and require purchased equipment meets the necessary regulations. The National Ambient Air Quality Standards (NAAQS) include air quality standards that are implemented at the state level in the State Implementation Plan required under Section 110 of the CAA. Verify whether the project is located in an EPA nonattainment area for criteria pollutants and identify in the construction documents how this affects the project construction schedule and cost. Provide the

Installation EV staff with the information necessary for obtaining a new or updating the existing air permits.

Verify whether asphalt pavement plants in the project area have production limitations due to what is called “summer ozone season” and design accordingly. These limitations will affect the Contractor’s schedule and construction phasing.

Permanent equipment such as new boilers and emergency power generators must be added to the Installation’s air permit as required by applicable regulations. Coordinate with the Installation EV staff to determine conditions that require adding emission sources used during construction to the air permit, and require the Contractor to comply with these requirements.

2-16.4 Wetlands/Waters of the United States.

These requirements apply to project sites where there are wetlands and other waters of the United States (streams, rivers, and bays). The discharge of dredged or fill material into waters of the United States is regulated under Section 404 of the Clean Water Act. Comply with Section 404 of the Clean Water Act. Obtain documentation from the Installation EV staff to identify the location of wetlands or other waters of the United States on or adjacent to the project area. Avoid impacts to jurisdictional wetlands or waters of the United States to the maximum extent practicable or minimize impacts if they are unavoidable. Coordinate with the Project Manager to determine if alternative sites may be explored to minimize wetland impacts. Notify the Installation EV staff to determine if the NEPA documentation requires an amendment. If impacts to the jurisdictional wetlands or waters of the United States cannot be avoided, obtain all Federal and state permits before initiating any land-disturbance activities. Require the Contractor to comply with all wetland permit conditions. Coordinate with the Installation EV staff to determine suitable mitigation options.

2-16.5 Natural Resources.

Obtain documentation from the Installation EV staff to identify what natural resources are located on or within the project area.

2-16.5.1 Threatened and Endangered Species/Critical Habitat.

Require compliance with the Endangered Species Act and protect threatened and endangered species and the habitat upon which these species rely. Obtain the documentation from Installation EV staff, to include mitigation measures, as contract requirements, to protect threatened and endangered species and critical habitat that could be located on or in the vicinity of the project area. Implement and monitor mitigation measures. Provide implementation or monitoring reports, as necessary, to the Installation EV staff.

2-16.5.2 Migratory Bird Treaty Act.

Design in compliance with the Migratory Bird Treaty Act (MBTA) between the United States, Canada, Japan, Mexico, and Russia. The MBTA makes it unlawful to take, kill, or possess listed birds, unless permitted by regulation. Implement measures identified by the Installation EV staff to ensure compliance with MBTA requirements.

2-16.5.3 Essential Fish Habitat.

The Magnuson-Stevens Fishery Conservation and Management Act requires Federal agencies to consider impacts to essential fish habitat (EFH) from projects they authorize, fund, or undertake. EFH is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. These requirements apply to projects in or adjacent to EFH. In accordance with 50 CFR 600, Subpart J, Federal agencies must consider impacts to EFH from projects they authorize, fund, or undertake. Obtain the EFH assessment from the Installation EV staff and include the conservation recommendations made by the National Marine Fisheries Service as contract requirements.

2-16.5.4 Marine Mammal Protection Act.

The Marine Mammal Protection Act; 50 CFR 18 prohibits, with certain exceptions, the take of marine mammals in United States waters. These requirements apply to projects in or adjacent to the marine environment (oceans or seas). Obtain the documentation from Installation EV staff to determine what mitigation measures are required as contract requirements to protect marine mammals.

2-16.5.5 Bald and Golden Eagle Protection Act.

The Bald and Golden Eagle Protection Act; 50 CFR 22 requires the protection of the bald eagle and the golden eagle by prohibiting, except under certain specified conditions, the taking, possession, and commerce of bald and golden eagles. Obtain the documentation from Installation EV staff to determine if bald or golden eagles are located on or in the vicinity of the project area and include the mitigation measures as contract requirements to ensure their protection.

2-16.5.6 Stormwater Management and Erosion and Sediment Control.

Projects with land disturbance activities greater than one acre require coverage under the National Pollutant Discharge Elimination System (NPDES) permit program. Most states are authorized to implement the NPDES permitting program. Refer to the EPA website for the list of states authorized to implement this permitting program: http://water.epa.gov/polwaste/npdes/basics/State-and-Tribal-Program-Authorization-Status.cfm. Obtain the NPDES permit through EPA for all other states. Obtain from the Installation EV staff the regional permitting requirements and copies of all existing stormwater and erosion and sediment control permits that affect or encompass the project site. Identify all permit conditions that affect the design and include them in the specifications or on the drawings. Design stormwater management facilities and erosion and sediment controls in accordance with UFC 3-201-01.

2-17 CHLORDANE.

These requirements apply to sites and projects where existing building(s) or structure(s) will be renovated, altered, repaired, or demolished as part of the scope of work. \1\/1/ Specification preparation must comply with the applicable requirements of 40 CFR 260 – 40 CFR 270, Resource Conservation and Recovery Act.

2-17.1 Conducting Field Investigations, Surveys – Chlordane.

Prior to demolition of structures, it may be necessary to determine if chlordane was used to prevent termites. If adequate pesticide application records exist, it may be possible to confirm or rule out the use of chlordane or similar products. If adequate records do not exist, sample the soil around the foundation of a building scheduled for demolition. Chlordane was typically applied in a swath approximately 12-18 inches (300 to 450 mm) below the surface of the ground and approximately 12-18 inches (300 to 450 mm) away from the foundation. It may also have been injected through boreholes into the subsurface soil under concrete slab foundations. Sampling and analysis of the soil may be necessary along the foundation of suspect buildings.

2-17.2 Laboratory – Chlordane.

Laboratories performing analysis for chlordane in soil must be fully equipped and proficient in conducting analyses according to RCRA and SW-846, and accredited by \3\a recognized DoD Environmental Laboratory Accreditation Program /3/.

2-17.3 Control of Chlordane.

Chlordane is very stable and does not readily degrade or migrate in the environment. It is highly insoluble in water and if left undisturbed it will continue to serve its intended purpose for many years. Properly applied chlordane tends to only become a problem when disturbed, as in building demolition. Under RCRA regulations, as long as the soil remains undisturbed chlordane does not present a regulatory issue. It may even be acceptable to excavate chlordane contaminated soil to remove the foundation and place the soil back in the excavation site provided there is not subsequent disturbance or construction on the site. However, if the soil will be moved to another location or disturbed as part of new construction efforts, chlordane may present a hazardous waste disposal issue or costly environmental cleanup. It is very important that steps be taken prior to demolition to minimize the risk to the environment, site workers, or future users of the site.

CHAPTER 3 DELIVERABLES

This chapter identifies the expected level of detail and quality of all deliverables. The following information is critical to ensure contract documents are complete and biddable. Provide all deliverables in accordance with FC 1-300-09N and the following requirements.

3-1 FIELD INVESTIGATION REPORT.

Each Installation maintains record files pertaining to the environmental aspects of previously constructed projects. Utilize these resources and include applicable record files as an attachment to the required reports. Submit separate reports, including drawings, addressing each of the following environmentally sensitive materials:

- \1\Asbestos-Containing Materials/1/
- Paint - Lead-Based Paint in Target Housing and Child-Occupied Facilities
- Paint – Lead, Cadmium, Chromium, and other Hazardous Metals
- \1\Beryllium/1/
- Radon
- Polychlorinated Biphenyls
- Low-Level Radioactive Components
- Animal Droppings
- Molds and Spores
- Tanks
- Contaminated Soil or Groundwater
- Waste Characterization
- Chlordane

\1\When final drawings and specifications are not required for Design Build projects, provide field investigation reports in Part 6 of the Request for Proposal (RFP)/1/.

3-1.2 Drawings.

Provide scaled and dimensioned drawings, within the reports, showing existing site conditions and existing buildings or structures. Drawings must contain enough information to do quantity takeoffs for cost estimating purposes. Indicate project location and facility number. For buildings, provide drawings showing floor plans, and interior and exterior sections as applicable. Provide dimensions (e.g., building, rooms, halls) and room numbers to allow for easy alignment in the field. Include drawing notes indicating:

- type and location of the work associated with the project
- sample locations
- extents of environmentally sensitive materials
- condition, and form of environmentally sensitive materials
- extents of environmentally sensitive materials in poor condition requiring removal
- extents of environmentally sensitive materials in good condition that may remain if not disturbed
- components (e.g., mercury tubes, ballasts) containing environmentally sensitive materials; show locations and indicate the number of components to be removed
- access restrictions, utilities, and equipment that hinder access or egress (include dimensions for the restricted openings)
- components or environmentally sensitive materials to be removed or segregated prior to mass demolition

3-1.3 Report – Asbestos-Containing Materials.

Provide an asbestos report when asbestos field investigation work has occurred or when a prior asbestos report has been used to identify ACM and include the following information: a narrative summary of the work that identifies the project description, location, previous survey data, and additional ACM identified. List the areas, types, locations, and quantities of ACM and any contamination that will affect the project. Provide sample descriptions, results, locations, location maps, and photographic documentation. Obtain a copy of the Asbestos Survey Data Template located at http://www.wbdg.org/references/pa_dod_ntools.php. Include copies of the EPA asbestos inspector and the laboratory accreditation that performed the work.

3-1.4 Report – Lead Based Paint in Target Housing and Child-Occupied Facilities.

Provide a lead-based paint report and include a narrative summary of the work that identifies the project description, test results (including negative results), location, previous survey data, components with lead-based paint, and rationale for removal or abatement. Include all the requirements of EPA Title X and EPA RRP Rule. Include copies of all EPA lead accreditation certificates for the professionals that performed the sampling and analytical work, including the risk assessor, lead workers, samplers, and laboratory.

3-1.5 Report – Paint.

Provide a paint report and include a narrative summary of the work that identifies the project description, location, previous survey data, additional lead, cadmium or chromium paint identified, sample descriptions, results, locations, location maps, and photographic documentation. Include a description and full characterization of all waste streams (that is, hazardous, to include all waste codes, or nonhazardous). List the areas, types, and locations of paint and any contamination that will affect the project, including soil and dust. Include copies of all accreditation certificates, licenses, certificates, sampling plans, and analyses and test reports identified above.

3-1.6 Report – Beryllium.

\1\ Provide a beryllium report and include a narrative summary of the work that identifies project description, location and location of beryllium identified. Provide sample descriptions including test results, locations, location maps, and photographic documentation of each sample taken. List the areas and locations of any beryllium that will affect the project, including airborne particles and dust. Include copies of laboratory accreditation certificate, sampling plans, method of analyses and test reports./1/

3-1.7 Report – Radon.

Provide a radon report and include a narrative summary of the work that identifies the project description, location, and test results provided by onsite personnel. Provide research on potential radon in the area in the report. Briefly summarize precautions that need to be taken to address radon. Refer to EPA Radon Mitigation Standards (RMS) and radon-resistant new construction techniques.

3-1.8 Report – Polychlorinated Biphenyls.

Provide a PCB report and include a narrative summary of the work that identifies the project description, location, previous survey data, and additional PCB identified. List the areas, types, and location of PCB-containing lighting ballasts and all other PCB-containing equipment and any contamination that will affect the project. Summarize state or local laws that affect PCB removal and disposal and ultimate disposition for the project, such as project size, limitations on removal methods, and monitoring requirements. Include notification requirements, permit fees, licensing, or other specialized requirements.

3-1.9 Report –Low-Level Radioactive Components.

Provide a LLR components report and include a list of the areas surveyed, types of LLR components, location of LLR components, method of disposal and any additional information that may impact the project. Provide photographic documentation of LLR components.

3-1.10 Report – Animal Droppings.

Provide animal droppings report and include a narrative summary of the work that identifies the project description, location, and conditions found at the site. Provide photographic documentation of contaminated areas. Briefly summarize precautions that need to be taken to protect workers, building occupants, and the environment.

3-1.11 Report – Molds and Spores.

Provide a mold (microbial) assessment survey report and include a narrative summary of the work that identifies the project description, location, previous survey data, and additional mold identified. Determine the quantities, classification, and location of mold and any contamination that will impact the project. Briefly summarize precautions that need to be taken to protect workers, building occupants, and the environment. Provide copies of laboratory testing and classification reports and laboratory certifications.

3-1.12 Report – Tanks.

Provide a tank report and include the following information: contents of tank, size of tank, approximate location of tank, associated pipelines (including construction, size, and linear footage per diameter), existing soil conditions associated with tank, age of tank, and tank construction material. Document the quantity of remaining hazardous or toxic waste products in AST and UST. Coordinate with Installation EV staff to determine all requirements associated with removal, disposal, and ultimate disposition of the remaining product in a tank. Provide copies of laboratory certification and state or local accreditation certificates with the report. Include copies of all certificates of analyses or test reports with the report, including but not limited to NELAC certification under EPA program.

3-1.13 Report – Contaminated Soil or Groundwater.

Provide a contaminated soil or groundwater report and include the following information: type of hazardous constituents, approximate location of the contamination on the site, approximate depth of contamination, existing soil and site conditions, approximate quantities of contaminated soil or groundwater, and calculations with assumptions made in determining the estimated quantities. Include copies of all certificates of analyses or test reports with the report, including but not limited to NELAC certification under EPA program.

3-1.14 Report – Waste Characterization.

Provide a waste characterization report and include the following information: sample methodology, descriptions, results, locations, location maps, and photographic documentation. Specifically itemize anticipated waste materials to be generated during construction and provide the method of disposal and ultimate disposition for hazardous and nonhazardous wastes. Provide copies of laboratory certification and state and local accreditation certificates with the report. Include copies of all certificates of analyses or test reports with the report, including but not limited to NELAC certification under EPA program.

3-1.15 Report – Chlordane.

Provide a chlordane report when chlordane field investigation work has occurred or when a prior chlordane report has been used to identify contaminated soil and include the following information: a narrative summary of the work that identifies the project description, location, previous survey data, and additional contaminated areas identified. List the areas, types, locations, and quantities of contaminated soil that will affect the project. Provide sample descriptions, results, locations, location maps, and photographic documentation.

3-2 SPECIFICATIONS AND DRAWINGS.

3-2.1 Design Build Request for Proposal (Pre Award).

\1\Include final drawings and specifications for the control, removal, abatement, storage and disposal of:

- Asbestos-Containing Materials
- Paint - Lead-Based Paint in Target Housing and Child-Occupied Facilities
- Paint – Lead, Cadmium, Chromium, and other Hazardous Metals
- Polychlorinated Biphenyls
- Low-Level Radioactive Components
- Chlordane

For Design Build projects, provide field investigation reports in Part 6, specifications in Part 5 and drawings in Part 6 of the RFP./1/

3-2.2 Design Build Design Submittals (Post Award).

The Contractor's Designer of Record (DOR) is responsible for verifying all site information furnished in the Government issued Design Build RFP. The Contractor's DOR must verify existing site conditions and provide any additional field investigation needed to support the development of the final design and construction of the project. When the Contractor \1\conducts additional sampling, the Government furnished drawings and specifications provided in the RFP must be revised by the Contractor's DOR and used /1/ for final design and construction of the project.

3-2.3 Specifications.

Edit UFGS 01 57 19 to include paragraphs for asbestos, lead-based paint, \1\beryllium, /1/ polychlorinated biphenyls, or low-level radioactive components when those materials or components are part of the project. Specify disposal requirements based on project location. Review Federal, state and local disposal regulations before specifying disposal of any type of waste and comply with the most stringent requirement.

UFGS 01 57 19.01 20 is a regional supplement to UFGS 01 57 19 and contains state and local requirements applicable to the project for specific project locations. Review and edit UFGS 01 57 19.01 20 as applicable.

3-2.4 Asbestos-Containing Materials.

Provide an EPA accredited Asbestos Project Designer to prepare asbestos specifications and drawings.

3-2.4.1 Specifications for Asbestos-Containing Materials.

\1\Prepare specifications in accordance with the applicable requirements of 40 CFR 61.145, Subpart M, for any project that involves disturbance or removal of regulated asbestos-containing materials (RACM). Describe the applicable RACM control methods, notification requirements, and workers' minimum certification requirements. NESHAP classifies RACM into three categories: friable, Category I nonfriable, and Category II nonfriable. Identify the NESHAP categories that apply to the project. Identify which non-friable RACM have a potential to become friable during demolition and renovation activities and require those materials to be removed using friable control methods./1/

Edit the guide specification for asbestos removal using \2\UFGS 02 82 00/2/. Indicate the type and location of the asbestos and to provide a description and rationale for removal. Identify conditions that affect access or egress for workers and equipment, such as confined spaces, crawl spaces, or elevated working surfaces. Identify utility systems (HVAC, steam, electrical, and similar) required to be shut down during the project. Where the building is to remain partially occupied during construction, temporary utilities may be required. Where the building is to remain partially occupied by the Government during construction, specifically identify utility shutdowns to the project manager, in writing. Indicate work area isolation requirements. Indicate disposal and ultimate disposition requirements. Summarize conditions that affect asbestos removal and disposal or ultimate disposition for the project, such as project size, limitations on removal methods, and air monitoring requirements. Include notification requirements, permit fees, licensing, or other specialized requirements. Some jurisdictions may require third-party monitoring during the construction phase for asbestos abatement activities. Depending on the regulatory requirement, a separate contract to the third party (that is, a contact separate from the construction contract) may be required. Consult a local asbestos manager or regulatory expert. If replacement materials are required, coordinate with the architect.

3-2.4.2 Drawings for Asbestos.

Provide scaled and dimensioned drawings for floor plans or building sections showing all ACM. Provide building and room dimensions allowing easily established alignment in the field. If asbestos is present and will not be disturbed by the project, provide a drawing note indicating the type and location of the ACM with a note that the material is not to be disturbed by project work. For ACM impacted by the project, indicate location, condition, and form of all ACM to be removed, as well as the structures, utilities, and equipment that hinder access or egress. Provide dimensions for access or egress to crawl spaces, attics, chases, or restrictive areas that affect asbestos removal personnel or equipment. Identify rooms by name and number.

3-2.5 Lead-Based Paint \2\in Target Housing and Child-Occupied Facilities /2/.

Provide an EPA accredited Lead Paint Project Designer in accordance with EPA Title X and EPA RRP Rule to prepare the lead-based paint removal specifications \1\ and /1/ drawings.

3-2.5.1 Specifications for Lead-Based Paint \2\in Target Housing and Child-Occupied Facilities/2/.

Edit the guide specification for lead-based paint using \2\UFGS 02 83 00/2/. Indicate building components with lead-based paint that will be affected by the work. Identify conditions that affect access or egress for workers and equipment, such as confined spaces, crawl spaces, or elevated working surfaces. Identify utility systems (HVAC, steam, electrical, and similar) that may require shutdown during the project. Where the building is to remain partially occupied by the Government during construction, identify utility shutdowns to the Government's project manager, in writing. Indicate work area isolation requirements. Summarize state or local laws that affect child-occupied facilities and lead-based paint removal, containment, disposal, or ultimate disposition for the project, such as project size, limitations on removal methods, and air monitoring requirements. Include notification requirements, permit fees, licensing, final clearance criteria (dust wipes, soil sampling, and similar), disposal and ultimate disposition requirements, or other specialized requirements. Indicate disposal and ultimate disposition requirements. If replacement materials are required, coordinate with architect.

3-2.5.2 Drawings for Lead-Based Paint \2\in Target Housing and Child-Occupied Facilities/2/.

Information regarding paint as it pertains to child-occupied facilities may be detailed on the demolition drawings by adding notes indicating that lead-based paint abatement activities be conducted in accordance with the appropriate corresponding specification section and EPA Title X and EPA RRP Rule. Indicate existing lead-based paint affected by the project on the drawings using a chart or some other method to display the laboratory results of the lead analysis. For abatement drawings, provide scaled and dimensioned drawings and floor plans or building sections showing all items from which the hazardous paint will be removed, replaced, or encapsulated. Indicate all locations of hazardous paint to be removed, as well as structures, utilities, and equipment that hinder access or egress. Provide dimensions for access or egress to crawl spaces, attics, or restrictive areas that affect removal personnel or equipment.

3-2.6 Paint \2\in Commercial or Industrial Facilities/2/.

Provide \2\a certified industrial hygienist certified by the American Board of Industrial Hygiene, a certified safety professional certified by the Board of Certified Safety Professionals, or/2/ an EPA accredited, \2\or equivalent State certified/2/, Lead Project Designer to prepare lead, cadmium, and chromium specifications and drawings. \2\Refer to 3-2.5 Lead-Based Paint in Target Housing and Child-Occupied Facilities for any work being performed in target housing or child-occupied facilities./2/

3-2.6.1 Specifications for Paint \2\in Commercial or Industrial Facilities/2/.

Edit \2\UFGS 02 83 00/2/ to include requirements for the removal of paint containing lead cadmium, and chromium. Describe all the different scenarios that will be encountered in the project (that is, “tasks” per OSHA). Clearly identify all the areas with paint on the construction documents and outline the protocol for providing protection of workers and the environment during all construction activities \2\in accordance with DODI 6055.01, EM 385-1, and OPNAVINST 5100.23G/2/. Identify conditions that affect access or egress for workers and equipment, such as confined spaces, crawl spaces, or elevated working surfaces. Identify utility systems (HVAC, steam, electrical, and similar) that may require shutdown during the project. Where the building is to remain partially occupied by the Government during construction, identify utility shutdowns to the Government’s project manager, in writing. Indicate work area isolation requirements. Include state and local regulations, notification requirements, permit fees, licensing, or other specialized requirements. Identify the appropriate clearance level required for the Contractor to attain when finishing the construction activities that generate dust, fumes, or debris. Thoroughly research the clearance level for each type of construction project and the differences established based upon the nature of the project. Indicate disposal and ultimate disposition requirements and any special waste segregation requirements.

3-2.6.2 Drawings for Paint \2\in Commercial or Industrial Facilities/2/.

Information regarding paint as it pertains to demolition work may be detailed on the demolition drawings by adding notes indicating that specific requirements and demolition activities must be conducted in accordance with the appropriate corresponding specification section and title. Indicate on the drawings all existing paint determined from the field survey to contain detectable levels of lead, cadmium, and chromium using a chart or some other method to display the laboratory results of the lead analysis. For abatement drawings, provide scaled and dimensioned drawings and floor plans or building sections showing all items from which the hazardous paint (lead, cadmium, or chromium containing) will be removed (and hence abated). Examples of this include wood molding or steel structures that are to be salvaged and reused in the finished project but are coated with paints that contain the identified hazardous metal. Indicate all locations of hazardous paint to be removed, as well as structures, utilities, and equipment that hinder access or egress. Provide dimensions for access or egress to crawl spaces, attics, or restrictive areas that affect removal personnel or equipment.

3-2.7 Beryllium.

\1\Provide a Certified Industrial Hygienist to prepare beryllium specifications and drawings./1/

3-2.7.1 Specifications for Beryllium.

\1\Edit UFGS 01 57 19 to include requirements for beryllium abatement, containment, storage and disposal. Identify conditions that affect access or egress for workers and equipment, such as confined spaces, crawl spaces, or elevated working surfaces. Identify utility systems (HVAC, steam, electrical, and similar) required to be shut down during the project. Where the building is to remain partially occupied during construction, temporary utilities may be required. Where the building is to remain partially occupied by the Government during construction, specifically identify utility shutdowns to the project manager, in writing. Indicate work area isolation and disposal requirements. Summarize conditions that affect beryllium abatement and disposal for the project, such as project size, removal method, and air monitoring requirements. Include any specialized requirements that may be applicable. Outline the protocol for providing protection of workers and the environment during all construction activities in accordance with 29 CFR 1910.1024, 29 CFR 1915.1024 and 29 CFR 1926.1124./1/

3-2.7.2 Drawings for Beryllium.

\1\Clearly identify all areas where beryllium is present on the drawings and indicate beryllium work isolation zones. Provide scaled and dimensioned drawings and floor plans or building sections showing all areas from which the beryllium will be abated. Indicate all locations where beryllium particles and dust must be abated, as well as structures, utilities, and equipment that hinder access or egress. Provide dimensions for access or egress to crawl spaces, attics, or restrictive areas that affect removal personnel or equipment./1/

3-2.8 Radon.

3-2.8.1 Specifications for Radon.

Edit the guide specifications for radon mitigation using UFGS 31 21 13. A licensed professional mechanical consultant must handle specifications for radon remediation. Develop specifications in accordance with EPA RMS and radon-resistant new construction techniques.

3-2.9 Polychlorinated Biphenyls.

3-2.9.1 Specifications for Polychlorinated Biphenyls.

Edit the guide specification for PCB removal using UFGS 02 84 16 or UFGS 02 84 33. Indicate existence of PCB and detail equipment that contains PCB. Provide description of how PCB containing materials will be handled. Indicate the disposal and ultimate disposition requirements, which may include recycling.

3-2.9.2 Drawings for Polychlorinated Biphenyls.

Provide drawings that indicate the PCB-containing component to be removed, including locations and quantities. Indicate in the notes how the Contractor is to distinguish between PCB and PCB-free components. For light fixtures, provide exact number of lighting fixtures to be removed. Drawing notes or symbols allow the Contractor to do an accurate takeoff of the number of ballasts to be removed. As an alternative, if Electrical Demolition drawings are part of the same contract and they have sufficient detail to show all electrical fixtures, then the lamps and ballasts may be shown on these drawings. Clearly indicate in the notes the components to be removed prior to any additional demolition.

3-2.10 Low-Level Radioactive Components.

3-2.10.1 Specifications for Low-Level Radioactive Components.

Comply with OPNAV M-5090.1 Low-Level Radioactive Waste Disposal Program and contact Naval Sea Systems Command Detachment (NAVSEADET), Radiological Affairs Support Office (RASO) to determine the requirements applicable to the project. Edit UFGS 01 57 19 to include requirements for LLR component removal, containment, storage and disposal. If any LLR components are indicated in the Low-Level Radioactive Components Report, provide requirements for removal, containment, storage and disposal. Indicate disposal and ultimate disposition requirements, including information such as notification requirements, permit fees, licensing, or other specialized requirements.

3-2.10.2 Drawings for Low-Level Radioactive Components.

If LLR components are indicated in the Low-Level Radioactive Components Report, provide drawings that indicate the LLR components to be removed, including locations and quantities. Indicate disposal and ultimate disposition requirements. As an alternative, use Electrical and Fire Protection Demolition drawings; provide sufficient detail on these drawings to show all components. Clearly indicate in the notes the LLR components to be removed prior to facility demolition.

3-2.11 Mercury.

3-2.11.1 Specifications for Mercury.

Edit the guide specification for mercury removal using UFGS 02 84 16. If mercury tubes or the other items listed are present, indicate their existence. Provide a description and the methodology for removal, containment, and sampling. Summarize state or local laws that affect removal and disposal or ultimate disposition for the project, such as project size, limitations on removal methods, and monitoring requirements. Include notification requirements, permit fees, licensing, or other specialized requirements. Indicate disposal and ultimate disposition requirements. Investigate companies that recycle used mercury-containing devices and require recycling to the extent practical.

3-2.11.2 Drawings for Mercury.

Provide drawings that indicate the mercury tubes to be removed, including locations and quantities. As an alternative, use Electrical Demolition drawings that have sufficient detail to show all components. Clearly indicate in the notes the components to be removed before any additional demolition.

3-2.12 Animal Droppings.

3-2.12.1 Specifications for Animal Droppings.

Edit UFGS 01 57 19 to include requirements to for the removal of animal droppings. Identify conditions that affect access or egress for workers and equipment, such as confined spaces, crawl spaces, or elevated working surfaces. Identify utility systems (HVAC, steam, electrical, and similar), required to be shut down during the project. Where the building is to remain partially occupied during construction, temporary utilities may be required. Indicate work area isolation requirements. Include requirements for disposal, ultimate disposition, project size, and limitations on removal methods. A certified industrial hygienist must review the specifications.

3-2.12.2 Drawings for Animal Droppings.

If animal droppings are present, indicate their existence, location, and approximate quantity. Provide removal notes that describe equipment, precautions for removal personnel (such as using personal protection equipment), precautions for protecting occupants, and techniques for removal. Indicate disposal and ultimate disposition requirements.

3-2.13 Molds and Spores.

3-2.13.1 Specifications for Molds and Spores.

Edit the guide specification to address mold and spore remediation using UFGS 02 85 00.00 20. Identify conditions that affect access or egress for workers and equipment, such as confined spaces, crawl spaces, or elevated working surfaces. Identify utility systems (HVAC, steam, electrical, and similar) required to be shut down during the project. Where the building is to remain partially occupied during construction, temporary utilities may be required. Indicate work area isolation requirements. Indicate disposal and ultimate disposition requirements. Summarize state or local laws that affect removal and disposal or ultimate disposition for the project, such as project size, limitations on removal methods, and air monitoring requirements. A certified industrial hygienist must review the specifications.

3-2.13.2 Drawings for Molds and Spores.

Indicate the areas where mold is located and include a description or listing of all affected building components. Provide removal notes that describe equipment, precautions for removal personnel (such as using personal protection equipment), precautions for protecting occupants, and techniques for removal.

3-2.14 Tank Removal.

The drawings and specifications together must provide the Contractor with sufficient information to determine quantities of materials, material classification (hazardous, nonhazardous, and special waste), and regulatory testing requirements.

3-2.14.1 Specifications for Tank Removal.

Edit the guide specification for tank removal using UFGS 02 65 00. Several environmental issues must be addressed when removing and disposing of AST or UST. Determine the correct collection and disposal and ultimate disposition procedures for items, such as cleaning water, rinse water, and existing sludge or product in the tank. Require that the Construction Contractor certify that the removed tanks were rendered unusable before transportation to the disposal or ultimate disposition site. Incorporate any specific confirmatory soil samples to prove clean conditions. Include state and local environmental requirements relative to tank closure and removal in the specifications. Describe tanks, including their type, size, contents, and piping. Describe how much product will be left in the tank and who will be responsible for removing any existing product. Describe all required construction activities, such as gas-free tank, cleaning, removing fuel lines, draining fuel lines, and testing of cleaning residue, sludge, water and product for disposal and ultimate disposition purposes. A registered Professional Engineer or Professional Geologist must prepare the specification.

3-2.14.2 Drawings for Tank Removal.

Provide separate Tank Removal drawings or use civil drawings to indicate aboveground storage tanks (AST) or underground storage tanks (UST) that are to be removed or cleaned. Clearly indicate tank contents and the quantity of remaining product, water, or sludge in the notes. Provide an overview of the steps to cleaning and removing the tank. Indicate the disposal and ultimate disposition requirements for the product in the tank. Coordinate closely with Installation EV staff to determine if the tank product may be disposed of on Base; if so, clearly indicate on the drawings where the disposal and ultimate disposition facilities are located. Include photographs of the removed tank to show it has been rendered unusable, as contract requirements.

3-2.15 Contaminated Soil or Groundwater.

The drawings and specifications together must provide the Contractor with sufficient information to determine type and quantities of materials, disposal and ultimate disposition classification (hazardous, nonhazardous, special waste), and regulatory testing requirements.

3-2.15.1 Specifications for Contaminated Soil or Groundwater.

Edit the guide specification for contaminated soil or groundwater using UFGS 02 61 13, UFGS 02 61 23. Provide detailed requirements for worker protection, collecting groundwater, stockpiling contaminated soil, testing, and disposing of the wastes. For any new construction that requires dealing with contaminated soil or groundwater, clearly state all information pertaining to the existing conditions at the site. Comply with regulations regarding worker protection and additional requirements defined by EPA, the regulating authority for the site, or as applicable per EM 385-1-1. Indicate the existence of contaminated soil and groundwater and source of information. List all reports that contain existing analytical information on the existing site conditions. Describe which site controls will be used during construction (e.g. the use of organic vapor analytes or meters and equipment to test and monitor atmosphere), and all analytical requirements for testing and disposal and ultimate disposition of the contaminated material. Indicate the handling and disposal or ultimate disposition procedures.

3-2.15.2 Drawings for Contaminated Soil or Groundwater.

Provide separate drawings or use civil drawings that indicate the extent of known or suspected soil or groundwater contamination. Indicate the type and level of contamination.

3-2.16 Specifications for Waste.

Waste requirements are handled within various design specification sections. Refer to previous design specification requirements, see paragraph entitled “Control and Management of Solid and Hazardous Waste” and the applicable portions of this Chapter.

3-3 COST ESTIMATES.

Coordinate with the lead discipline to determine the extent of the work and develop cost estimates. Include estimated quantities, unit costs and total costs for each type of environmentally sensitive material, such as floor tile containing asbestos, insulation containing asbestos and lead-contaminated soil. Do not provide lump-sum quantities and costs. Provide unit pricing for each type of environmentally sensitive material encountered during field investigation or previously known to exist in UFGS 01 20 00.00 20.

CHAPTER 4 HANDLING AND STORAGE

Use the following information to assist in the preparation of the project specifications.

4-1 HANDLING AND STORAGE OF HAZARDOUS MATERIAL.

Properly store, manage, and maintain hazardous materials, such as fuels. Provide storage in accordance with Safety Data Sheets. Storage and handling of hazardous materials are regulated under 29 CFR, National Fire Protection Association and the American Petroleum Institute. Small flammable containers must be stored within a proper flammable storage cabinet. Fuel storage at quantities greater than 1,320 gallons require the preparation and implementation of a Spill Prevention, Control, and Countermeasures Plan, as described in 40 CFR 112. Certain hazardous materials may also be regulated under the Department of Homeland Security, Title 6 CFR 27.

4-2 HAZARDOUS MATERIAL TRANSPORTATION.

Hazardous material; 49 CFR 171.8, is a substance or material that the Secretary of Transportation has determined is capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and has designation as hazardous under the Federal Hazardous Materials Transportation Law; 49 U.S.C. 5103. The term includes hazardous substances, hazardous wastes, marine pollutants, elevated temperature materials, materials designated as hazardous in the Hazardous Materials Table 49 CFR 172.101, and materials that meet the defining criteria for hazard classes and divisions in 49 CFR 173.

4-2.1 Department of Transportation Requirements.

Requirements under 49 CFR 171-180 apply to all offsite shipments of hazardous materials. Provide a DOT-trained individual to verify that the requirements of 49 CFR 171-180 are met.

4-2.2 Shipping Name.

Material that exhibits one of the nine DOT hazard class characteristics (for example, explosives, gases, flammable liquids, flammable solids, oxidizing substances, toxics or poisons, radioactive materials, corrosive substances, or miscellaneous hazards) is regulated under DOT rules for the transportation of hazardous material. Provide a proper shipping name for each shipment of a suspected hazardous material using the Hazardous Materials Table in 49 CFR 172.101. DOT-trained personnel must make all determinations.

4-2.3 Packaging, Marking, and Labeling.

Mark the shipping name, hazard class, identification number, technical names (if applicable), EPA markings and waste code numbers, and consignee or consignor designations on packages for shipment 49 CFR 172.301. Once a waste is characterized, determine the appropriate label in accordance with the Hazardous Materials Table in 49 CFR 172.101.

4-2.4 Placards.

Provide DOT-trained personnel to determine the appropriate placards. Specific placard descriptions are found starting at 49 CFR 172.521. If a placard is required, it must be affixed on each side and each end of the vehicle.

4-2.5 Proper Container.

Use the appropriate United Nations (UN) approved container in accordance with 49 CFR 172.101, 49 CFR 172.102, and 49 CFR 173.

APPENDIX A REFERENCES

EXECUTIVE ORDER

EO 12114, *Environmental Effects Abroad of Major Federal Actions*

CODE OF FEDERAL REGULATIONS

6 CFR 27, *Chemical Facility Anti-Terrorism Standards*

29 CFR 1910, *Occupational Safety & Health Standards*

\1\29 CFR 1910.1024, *Beryllium*

\2\29 CFR 1910.1026, *Chromium (VI*)/2/

\2\29 CFR 1910.1027, *Cadmium*/2/

29 CFR 1915.1024, *Beryllium*

29 CFR 1926.1124, *Beryllium*/1/

\2\29 CFR 1926.62, *Lead*/2/

36 CFR 800, *Protection of Historic Properties*

40 CFR 61.145, SUBPART M, *National Emission Standard for Asbestos*

40 CFR 112, *Oil Pollution Prevention*

40 CFR 260, *Hazardous Waste Management System: General*

40 CFR 261, *Identification and Listing of Hazardous Waste*

40 CFR 261, SUBPART C, *Characteristics of Hazardous Waste*

40 CFR 261, SUBPART D, Lists of Hazardous Wastes

40 CFR 262, *Standards Applicable to Generators of Hazardous Waste*

40 CFR 264 Subpart J, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities*

40 CFR 264 Subpart J, *Tank Systems*

40 CFR 265, *Interim Status Standards For Owners And Operators Of Hazardous Waste Treatment, Storage, And Disposal Facilities*

40 CFR 265 Subpart J, *Tank Systems*

40 CFR 268, *Land Disposal Restrictions*

40 CFR 270, EPA Administered Permit Programs: *The Hazardous Waste Permit Program*

40 CFR 273, *Standards for Universal Waste Management*

40 CFR 745, *Lead Based Paint Poisoning Prevention in Certain Residential Structures*

40 CFR 761, *Polychlorinated Biphenyls (PCBs) Manufacturing Process, Distribution in Commerce, and Use Prohibitions*

40 CFR 763, *Asbestos Model Accreditation Plan*

40 CFR Parts 1500-1508, Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act

43 CFR 10, *Native American Graves Protection And Repatriation Regulations*

49 CFR 171-180, *Transportation*

50 CFR 18, *Marine Mammals*

50 CFR 22, *Eagle Permits*

50 CFR 600 Subpart J, *Essential Fish Habitat (EFH)*

\1\DEPARTMENT OF DEFENSE (DOD)

DoDI 6055.01, *DoD Safety and Occupational Health (SOH) Program,* *http://www.dtic.mil/whs/directives/corres/pdf/605501p.pdf*/1/

OTHER FEDERAL STANDARDS AND DOCUMENTS – GENERAL

16 U.S.C. 470aa-470mm, *Archaeological Resource Protection Act of 1979*

49 U.S.C. 5103, *General Regulatory Authority*

EPA Title X, *The Residential Lead Based Paint Hazard Reduction Act*

EPA RRP Rule, *Lead-Based Paint Renovation, Repair and Painting (RRP) Rule 2008* and associated amendments

EPA SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*

EPA 402-K-01-001, *Mold Remediation in Schools and Commercial Buildings*

EPA 530-D-02-002, *RCRA Waste Sampling Draft Technical Guidance*

EPA 540/R-99/008, *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*

EPA-540-R-014-002, *National Functional Guidelines for Superfund Organic Methods Data Review*

EPA-540-R-04-004, *Institutional Controls: A Citizen's Guide to Understanding Institutional Controls at Superfund, Brownfields, Federal Facilities, Underground Storage Tank, and Resource Conservation and Recovery Act Cleanups*

HUD Guidelines, Second Edition, *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing*

FEDERAL REGISTER

66 FR 53535, *Criteria for Classification of Solid Waste Disposal Facilities and Practices and Criteria for Municipal Solid Waste Landfills: Disposal of Residential Lead-Based Paint Waste;* October 23, 2001

INDUSTRY STANDARDS

ASTM E2121, *Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Building*

US ARMY CORPS OF ENGINEERS

EM 385-1-1, *Safety and Health Requirements*

DEPARTMENT OF THE NAVY

Navy Radon Assessment and Mitigation Program – Guidance Document for Navy Family Housing

Navy Radon Assessment and Mitigation Program – Guidebook for Naval Shore Installations

OPNAV M-5090.1, *Chief of Naval Operations Environmental Readiness Program Manual*

\2\OPNAVINST 5100.23G, *Navy Safety and Occupational Health Program Manual*/2/

NAVAL SEA SYSTEMS COMMAND DETACHMENT

Radiological Affairs Support Office

https://www.nko.navy.mil/group/raso/low-level-rad-waste

FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

FC 1-300-09N, Navy and Marine Corps Design Procedures

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, \1\DoD Building Code (*General Building Requirements)*/1/

UFC 3-101-01, *Architecture*

UFC 3-201-01, *Civil Engineering*

UFC 3-460-01, *Design Petroleum Fuel Facilities*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

http://www.wbdg.org/ccb/browse_cat.php?c=3

UFGS 01 22 00.00 20, *Price and Payment Procedures*

UFGS 01 57 19, *Temporary Environmental Controls*

UFGS 01 57 19.01 20, *Supplemental Temporary Environmental Controls*

UFGS 02 61 13, *Excavation and Handling of Contaminated Material*

UFGS 02 61 23, *Removal and Disposal of PCB Contaminated Soils*

UFGS 02 65 00, *Underground Storage Tank Removal*

\2\UFGS, *02 82 00 Asbestos Remediation*/2/

\2\UFGS *02 83 00 Lead Remediation*/2/

UFGS 02 84 16, *Handling of Lighting Ballasts and Lamps Containing PCBs and Mercury*

UFGS 02 84 33, *Removal and Disposal of Polychlorinated Biphenyls (PCBs)*

UFGS 02 85 00.00 20*, Mold Remediation*

UFGS 31 21 13, *Radon Mitigation*

APPENDIX B BEST PRACTICES

The best practices detailed herein apply to all sites and each project should be evaluated individually (if they are governed by regulation then they are a requirement and not a best practice). Neglecting to address the items listed below may result in unnecessary exposure to human health and the environment, changes in the project scope and be potentially subject the Government to regulatory notice of violations.

B-1 ASBESTOS.

RACM are commonly found in building materials and related products. Asbestos-containing products are available today and are often used in the form of tars, sealants, caulks, coatings, insulation, and roofing materials.

B-2 LEAD BASED PAINT IN TARGET HOUSING AND CHILD-OCCUPIED FACILITIES.

When dealing with target housing and child-occupied facilities, lead-based paint is defined by EPA and the U.S. Department of Housing and Urban Development (HUD) as any paint, varnish, shellac, or other coating that contains lead equal to or greater than 1.0 milligram per square centimeter (mg/cm^2) as measured by XRF analyzer or laboratory analysis, or 0.5 percent by weight as measured by laboratory analysis. This is not the OSHA definition of lead-containing paint.

A child-occupied facility is defined as a building, or portion of a building, constructed prior to 1978, visited regularly by the same child (6 years of age or younger) on at least two different days within any week (Sunday through Saturday period), provided that each day’s visit lasts at least 3 hours, the combined weekly visits last at least 6 hours, and the combined annual visits last at least 60 hours.

B-3 PAINT – LEAD, CADMIUM, CHROMIUM, AND OTHER HAZARDOUS METALS.

Many painted surfaces contain lead, cadmium, chromium, and other hazardous metals that may be regulated by the RCRA when these coated surfaces are disturbed by renovation, alteration, repair, or demolitions activities. These coatings are commonly found in buildings and steel structures, and on fuel piping and on every type of surface that can be painted or coated. Thresholds, exposures, and engineering controls for paint containing lead, cadmium, chromium, or other hazardous metals differ depending on a variety of factors including, but not limited to, whether or not these paints are used in operational processes, are painted surfaces of building components or exterior coatings, and are disturbed during construction activities. When investigation, sampling, renovation or demolition occurs, there are hazards associated with the generation of dust, debris, and fumes. The OSHA Standards cite requirements for work activities that can create an unsafe condition with regards to worker protection. These include, but are not limited to manual demolition, paint scraping, heat-gun applications, power tooling with dust collection, power tooling without dust collection, rivet busting, cleanup activities with dry abrasives, movement or removal of enclosures, abrasive blasting, welding, cutting, and burning on steel structures.

B-4 BERYLLIUM.

\1\Beryllium is a grey metal that is stronger than steel and lighter than aluminum. Its physical properties of great strength-to-weight, high melting point, excellent thermal stability and conductivity, reflectivity, and transparency to X-rays make it an essential material in industry. Workers in industries where beryllium is present may be exposed to beryllium by inhaling beryllium dust in the air or by dermal contact. Workers who come in contact with beryllium are at an increased risk of developing cancer; lung effects (CBD and acute beryllium disease); beryllium sensitization; skin sensitization; and skin, eye, and respiratory tract irritation.

B-4.1 Beryllium Uses and Products.

Beryllium is used in:

- Aerospace (aircraft braking systems, engines, satellites, space telescope),
- Automotive (anti- lock brake systems, ignitions),
- Ceramic manufacturing (rocket covers, semiconductor chips)
- Defense (components for nuclear weapons, missile parts, guidance systems, optical systems),
- Dental labs (alloys in crowns, bridges, and dental plates),
- Electronics (x- rays, computer parts, telecommunication parts, automotive parts),
- Energy (microwave devices, relays),
- Medicine (laser devices, electro-medical devices, X-ray windows),
- Nuclear energy (heat shields, reactors),
- Sporting goods (golf clubs, bicycles),
- Telecommunications (optical systems, wireless base stations)./1/

B-5 RADON.

Radon is a colorless, odorless, tasteless gas that is a byproduct of naturally decaying uranium. The amount of uranium beneath the earth’s surface varies greatly with geographic location and soil type. As the uranium decays below a building surface, it creates a radon gas that may penetrate through cracks and openings in the building’s foundation or basement. Buildings that have a tight shell have increased chances for radon being trapped within the structure.

B-6 POLYCHLORINATED BIPHENYLS.

Polychlorinated biphenyls\1\, commonly referred to as PCB or PCBs,/1/ are a group of toxic substances with chlorinated compounds that are either oily liquids or solids. PCB are typically colorless or light yellow. Some common PCB manufacturer product trade names are as follows: Apirolio, Aroclor, Asbestol, Bakola 131, Chlorextol, Clophen, Inerteen, Kanechlor, No-Flamol, Pyralene, Pyranol, Saf-T- Kuhl and Sovol. PCB were used for many years in electrical equipment as coolants and lubricants because they are good insulators that tend not to burn. The EPA banned the manufacturing of PCB in 1977 and regulated PCB as a toxic substance under the Toxic Substance Control Act (TSCA). Current PCB regulations can be found in 40 CFR 761.

Products manufactured prior to 1977 that may contain PCB include light ballasts, transformers, capacitors, heat transfer fluids, lubricants, hydraulic fluids, compressor oil, paints, plastics, asphalt roofing materials, paints, and caulk.

B-7 ANIMAL DROPPINGS.

B-7.1 Histoplasmosis.

Histoplasmosis is an infectious disease caused by inhaling the spores of a fungus called *Histoplasma capulatum*. The fungus is most associated with bird manure or bat droppings. The organism can be carried on the wings, feet, and beaks of birds and infected soil under roosting sites or manure accumulations inside or outside buildings. The fungus also grows in soils with high nitrogen content, especially those enriched with bird manure or bat droppings. Histoplasmosis is most commonly transmitted when the spores become airborne, often during cleanup or demolition projects. Areas with an increased number of infections are located in central and eastern states, along the valleys of the Ohio, Mississippi, and St. Lawrence Rivers and the Rio Grande.

B-7.2 Hantavirus.

Hantavirus is carried by rodents, especially mice and rats. The virus is found in their urine, droppings, and saliva. Potential sites where people may be exposed to the virus are outbuildings or sheds located in forests and fields that offer a suitable habitat for the virus’s rodent hosts. The virus is mainly transmitted to people when they breathe in air contaminated with the virus. When fresh rodent urine, droppings, or nesting materials are stirred up, tiny droplets containing the virus get into the air.

B-8 MOLDS AND SPORES.

Thousands of different types or species of fungi or "molds" are normally present in the environment, and many can grow within a building and cause occupants and workers discomfort or harm. Some fungi are toxic (that is, they secrete mycotoxins, which are harmful if inhaled or ingested), and many can cause allergic reactions of various types in susceptible people. Internal infections can also be caused by fungi, but are rare in people with normal immune systems. Fungi are commonly found in buildings that have flooding or long-term water damage from broken pipes, roof leaks, sewage backups, poor drainage, condensation, or inadequate HVAC system design. Because leaks can occur inside walls, in crawl spaces, in ventilation systems, or in enclosed ceiling areas, they may not be visible to the occupants.

B-9 STORAGE TANKS.

The majority of AST or UST contain petroleum products or other hazardous substances. Until the mid-1980s, most UST were made of bare steel that could corrode over time and allow the contents to leak into the surrounding soils and groundwater, causing harm to the environment and human health. Similar conditions are associated with AST.

B-10 CONTAMINATED SOIL OR GROUNDWATER.

There are instances where construction will occur on sites that are known to have contaminated soil or groundwater. The area could also be classified as a “past hazardous waste site” or “Installation Restoration” (IR) site. IR is a comprehensive program to identify, investigate, and clean up hazardous substances, pollutants, and contaminants at Installations. Sites include those contaminated by past defense activities that require clean up under the Comprehensive Environmental Response, Compensation, and Liability Act as amended by Superfund Amendments and Reauthorization Act, and certain corrective actions required by RCRA.

B-11 SOLID AND HAZARDOUS WASTE.

Solid waste is defined as a solid, liquid, semi-solid, or contained gaseous waste. A solid waste may be a hazardous waste or a nonhazardous waste.

B-11.1 Nonhazardous Waste.

Nonhazardous waste is solid waste that does not meet the RCRA or state criteria for hazardous waste. Nonhazardous wastes are regulated for disposal and may contain toxic chemicals or physically hazardous components. Some materials may be assumed nonhazardous because of the nature of the waste and the waste generation process. Examples include petroleum-contaminated soil and C&D debris.

Nonhazardous waste is a broad category that includes a range of materials with various management requirements. Nonhazardous wastes are generally regulated under state solid waste regulations. Some states call nonhazardous waste solid waste, special waste, industrial waste, or non-RCRA regulated waste. Review state solid waste regulations and determine state specific definitions. Nonhazardous waste classifications include waste that is excluded from, or does not meet, hazardous waste criteria, waste containing contaminants at concentrations less than hazardous waste thresholds (for example, ignitability, corrosivity, reactivity, or toxicity), or wastes that are prohibited from being disposed of at a subtitle D municipal solid waste landfill.

Nonhazardous waste may consist of contaminated environmental media, debris, or wastes. These wastes generally have less stringent storage, transport, and disposal requirements than hazardous wastes. Consider managing these wastes through waste minimization, reuse or recycling, and cost control.

B-11.2 Universal Waste.

Prior to demolition, facility should be cleared of any potential universal wastes, specifically fluorescent lamps and mercury containing electrical equipment such as thermostats or switches. EPA universal waste regulations streamline hazardous waste management standards for federally designated "universal wastes," which include:

- Batteries: “Battery” means a device consisting of one or more electrically connected electrochemical cells that are designed to receive, store, and deliver electric energy. An electrochemical cell is a system consisting of an anode, cathode, and an electrolyte, plus such connections (electrical and mechanical) as may be needed to allow the cell to deliver or receive electrical energy. The term battery also includes an intact, unbroken battery from which the electrolyte has been removed.
- Pesticides: “Pesticide” means any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, or intended for use as a plant regulator, defoliant, or desiccant, other than any article that:
    - Is a new animal drug under Federal Food, Drug and Cosmetic Act (FFDCA) section 201(w), or
    - Is an animal drug that has been determined by regulation of the Secretary of Health and Human Services not to be a new animal drug, or
    - Is an animal feed under FFDCA section 201(x) that bears or contains any substances described by the paragraphs above.
- Mercury-containing equipment: “Mercury-containing equipment” means a device or part of a device (including thermostats, but excluding batteries and lamps) that contains elemental mercury integral to its function.
- Lamps: A “lamp” is the bulb or tube portion of an electrical lighting device that may contain hazardous materials such as mercury or lead. Examples of common types of lamps containing hazardous materials include fluorescent, high-intensity discharge (HID), neon, mercury vapor, high-pressure sodium, and metal halide. Many lighting companies produce "low-level" mercury-containing lamps and claim they do not constitute a hazardous waste for disposal. In accordance with Federal law, the generator must prove that the lamps are nonhazardous if they choose to manage and dispose of them as such. Testing of the lamps may be

performed if it will result in a cost-saving solution. Otherwise, consider the lamps as hazardous, and properly manage and dispose them. The ultimate responsibility lies in the waste generator to determine the proper management and disposal of this waste.

B-11.3 Used Oil.

Used oil is any petroleum-based or synthetic fluid that has been used and is regulated under 40 CFR 279. During normal use, impurities such as dirt, metal scrapings, water, or chemicals may get mixed in with the oil, so that in time, the oil no longer performs well. Eventually, this used oil is replaced with virgin or re-refined oil to perform correctly. To meet EPA's definition of used oil, a substance must meet three criteria:

Origin: The first criterion for identifying used oil is based on the origin of the oil. Used oil must have been refined from crude oil or made from synthetic materials. Animal and vegetable oils are excluded from EPA's definition of used oil.

Use: The second criterion is based on whether and how the oil is used. Oils used as lubricants, hydraulic fluids, heat transfer fluids, buoyants, and for other similar purposes are considered used oil. Unused oil such as bottom clean-out waste from virgin fuel oil storage tanks or virgin fuel oil recovered from a spill, do not meet EPA's definition of used oil because these oils have never been "used." EPA's definition also excludes products used as cleaning agents or solely for their solvent properties, as well as certain petroleum-derived products like antifreeze and kerosene.

Contaminants: The third criterion is based on whether or not the oil is contaminated with either physical or chemical impurities during use. In other words, to meet EPA's definition, used oil must become contaminated as a result of being used. This aspect of EPA's definition includes residues and contaminants generated from handling, storing, and processing used oil. Physical contaminants could include metal shavings, sawdust, or dirt. Chemical contaminants could include solvents, halogens, or saltwater.

B-12 CULTURAL RESOURCES.

The term “cultural resources” includes archaeological sites, Native American and other traditional cultural resources, historic buildings and structures, significant objects, planned landscapes, and historic districts. The term “historic properties” is a technical term from the National Historic Preservation Act of 1966 (NHPA) to denote properties that have recognized public significance. The NHPA, 54 United States Code U.S.C. 300101 et seq., is one of the primary Federal statutes designed to protect cultural resources. The implementing regulation for NHPA is the Protection of Historic Properties; 36 CFR 800. Historic properties are defined in 36 CFR 800.16 as places listed in or eligible for listing in the National Register of Historic Places (NRHP). These properties may include districts, sites, buildings, structures, objects, and landscapes significant in American history, prehistory, architecture, archaeology, engineering, and culture. They include properties that belong to the prehistoric era as well as the historic era. Generally, properties must be at least 50 years of age to be eligible for the NRHP, unless they are proven to have exceptional importance. The NHPA also provides for consultation with Native American groups when a proposed project might affect cultural or traditional places or resources that have value to a Native American tribal group derived from the role the property plays in the community's historically rooted beliefs, customs, and practices.

B-12.1 Archaeology.

The Archaeological Resource Protection Act of 1979 recognizes that archaeological resources are an irreplaceable component of the heritage of the United States. Prehistoric archaeological resources are physical properties resulting from human activities that predate written records and generally are identified as isolated finds or sites. Prehistoric resources may include areas such as village sites, temporary camps, lithic scatters, roasting pits or hearths, milling features, petroglyphs, rock features, and burial sites. Historic archaeological site types, which result from human activities that occurred after European settlement, include town sites, homesteads, agricultural or ranching features, mining-related features, refuse concentrations, and features or artifacts associated with early military use of the land.

B-12.2 Architectural.

Historic architectural resources include fabricated, aboveground resources resulting from human activities that occurred after European settlement. These resources may include buildings such as houses, churches, barns, and lighthouses; early military buildings such as hangars, administration buildings, barracks, officers' quarters, warehouses, and guardhouses; and structures such as roads, bridges, and culverts.

B-13 CHLORDANE.

Chlordane was used extensively as an insecticide in the United States. It was sold from 1948 to 1988, both as a dust and an emulsified solution. The most common use of chlordane was for termite control. It was poured or injected around foundations to protect homes and buildings from termite damage. Its use was especially high in areas where termites caused structural damage, such as the southern U.S. Though banned for use on crops by 1978, its use for protection of buildings continued for another 10 years. In 1988, all commercial and domestic use of chlordane in the U.S. was banned by the EPA. Chlordane, heptachlor, and similar products can be expected to be found around the foundation of wooden (and possibly other) structures constructed prior to 1988. It is linked to various health effects on humans. Chlordane and similar products may still be in use in other countries.

B-14 REFERENCES.

DEPARTMENT OF HEALTH AND HUMAN SERVICES

DHHS 2005-109, *Histoplasmosis Protecting Workers at Risk*

CODE OF FEDERAL REGULATIONS

36 CFR 800, *Protection of Historic Properties*

40 CFR 279, *Standards for the Management of Used Oil*

40 CFR 761, *Polychlorinated Biphenyls (PCBs) Manufacturing Process, Distribution in Commerce, and Use Prohibitions*

APPENDIX C GLOSSARY

C-1 ACRONYMS

ACM	Asbestos-Containing Materials
AFCEC	Air Force Civil Engineer Center
AST	Aboveground Storage Tank
BIA	Bilateral Infrastructure Agreement
C&D	Construction and Demolition
CAA	Clean Air Act
CDC	Centers for Disease Control & Prevention
CFR	Code of Federal Regulations DHHS Department of Health and Human Services
DoD	United States Department of Defense
DOR	Designer of Record
EFH	Essential Fish Habitat
ELPAT	Environmental Lead Proficiency in Analytical Testing
EO	Executive Order
EPA	United States Environmental Protection Agency
EV	Environmental
FC	Facilities Criteria
FFDCA	Federal Food, Drug, and Cosmetics Act of 1938
FGS	Final Governing Standards
FR	Federal Register
HID	High Intensity Discharge
HUD	U.S. Department of Housing and Urban Development
ID	Identification

IR	Installation Restoration
kg	Kilogram
LLR	Low-Level Radioactive
MBTA	Migratory Bird Treaty Act
mg/cm^2	Milligrams per Square Centimeter
mg/L	Milligrams per Liter
NAAQC	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act of 1990
NIST/NVLAP	National Institute of Standards and Technology/National Voluntary Laboratory Accreditation Program
NAVRAMP	Navy Radon Assessment and Mitigation Program
NAVSEADET	Naval Sea Systems Command Detachment
NELAC	National Environmental Laboratory Accreditation Conference
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air
NHPA	National Historic Preservation Act of 1966
NLLAP	National Lead Laboratory Accreditation Program
NRHP	National Register of Historic Places
OSHA	Occupational Safety and Health Administration
\1\PCB or PCBs	Polychlorinated Biphenyls
/1/PPP	Pollution Prevention Plan
RACM	Regulated Asbestos-Containing Materials
RCRA	Resource Conservation and Recovery Act
RMS	Radon Mitigation Standards
RASO	Radiological Affairs Support Office

RFP	Request for Proposal
RRP	Renovation, Repair, and Painting
SHPO	State Historic Preservation Office
SOFA	Status of Forces Agreement
SSG	Soil Screening Guidance
SSL	Soil Screening Level
TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substance Control Act
UFC	Unified Facilities Criteria
UFGS	Unified Facility Guide Specifications
UN	United Nations
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
UST	Underground Storage Tank
XRF	X-Ray Fluorescence